Advances in agrarian genomics are writing a new page in the history book of science and technology. 'Redesigning Genomics – Reconstructing Societies' analyzes whether and how these advances could be also adding a new page to the work of making poverty history. It focuses on the local specific development of biotechnologies and genomics as a catalyst for development within the agrarian systems of peasants. It takes up the challenge to research whether and how these technologies might be sustainably developed (socially and technically) by local multi-stakeholder networks formed by peasants, peasants’ groups, civil society organizations, and researchers in the so-called Third World. These developmental dynamics are captured within the term Local Sustainable Biotechnological Developments, which can be defined as a type of development that is based in the reconstruction of biotechnologies mainly (though not exclusively) by and for local actors, and which strengthen peasant agrarian systems and which empowers peasants, civil society organizations and local researchers within biotechnological structures.
Redesigning Genomics –
Reconstructing Societies
Local Sustainable Biotechnological Developments

Daniel Puente-Rodríguez
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Redesigning Genomics – Reconstructing Societies
Local Sustainable Biotechnological Developments

ACADEMISCH PROEFSCHRIFT

ter verkrijging van de graad Doctor aan
de Vrije Universiteit Amsterdam,
op gezag van de rector magnificus
prof.dr. L.M. Bouter,
in het openbaar te verdedigen
ten overstaan van de promotiecommissie
van de faculteit der Aard- en Levenswetenschappen
op donderdag 17 juni 2010 om 9.45 uur
in het auditorium van de universiteit,
De Boelelaan 1105

door

Daniel Puente Rodríguez

geboren te Bilbao, Spanje
promotor: prof.dr. G.T.P. Ruivenkamp
copromotoren: dr.ir. J.P. Jongerden
              prof.dr. S.G. Hughes
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If I have seen farther it has been by standing on the shoulders of giants. This statement made by Robert K. Merton on science – creativity, transmission of knowledge, plagiarism, and the concept of progress – is certainly true for my work. There are a lot of giants in the exciting world of scientific literature who have inspired this research. However, now I would like to acknowledge the flesh and blood giants whose shoulders have been essential for conducting this PhD. Of course, the list is too long to be fully reproduced here, so my apologies to those not included.

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I am extremely thankful to the shoulders of some giants living in Andhra Pradesh (AP). Pakki Reddy warmly opened the door of the fascinating APNLBP network for me, and shared his knowledge and warm personality when this was required (shukriya). Among the researchers involved in this network I would like to thank especially Vimala Devi for showing me some technical aspects of a biotech redesign process at the DOR; and Sudhakar for his invaluable support at the Palem research station, and also for allowing me to share his family table. Amazing has been the cheerfulness that comes with the hard work delivered by the practitioners of the civil society organizations I visited. Amazing indeed was the work of the Grameena Mahila Mandal (working in the Nalgonda district of AP), a spectacular mix of human rights activism, women’s emancipation facilitation, sustainable agriculture, and biotechnological applications. Equally impressive for me was meeting the staff of the Society for Development of Drought Prone Area in Wanaparthy, from which I would like to thank especially Stephen Libera, and Bhaskar and Venkatekwa Rao for letting me see (on their motorcycles) part of the rural Mahaboobnagar district. Certainly I do appreciate the openness of peasants of the villages Venkaiahpally, Nallavelly, Nandhimallagadda, Tadipatri and Maltupally who shared with me their agrarian
knowledge and the new integrated biotech component. Finally, I would also like to thank Mahesh Kuman Edla for his translating work; he was not only translating words, but also cultures.

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To my children:

Yo creo que el Sol
tiene que estar celoso,
porque hay en la Tierra
tres niñ@s que le superan en brillo y gozo

la mayor se llama Lucía
su propio nombre lo indica
ella es, luz mía

el segundo es Aimar
y es un cielo mayor
que desde el que el Sol nos alumbra

e Irune la tercera
calienta más que el Sol
pues solo acaba de nacer y ya la queremos

Pues eso Sol
que salgas o no salgas
gracias a mis niñ@s
en nuestra casa siempre es primavera
casi verano

Marieke, met jou heeft liefde een volledige betekenis gekregen. Als ik op de schouders van een reus ben geweest, deze zijn de jouwe. Jouw steun door het hele Aio traject is van onschatbare waarde geweest. Ik kan me nog de lol herinneren die we hadden toen we de rollenspellen deden om de sollicitatiesgesprekken voor te bereiden. Aio zijn brengt een voortdurend ‘ups en downs’ gevoel met zich mee, maar dankzij jou zijn er geen moeilijke momenten geweest. Ik ben blij dat jij de constante factor van mijn leven bent. Te quiero.
### Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
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<tbody>
<tr>
<td>ABF</td>
<td>Agri Biotech Foundation</td>
</tr>
<tr>
<td>ACC</td>
<td>Andean Community Commission</td>
</tr>
<tr>
<td>AFSG</td>
<td>Agrotechnology and Food Sciences Group</td>
</tr>
<tr>
<td>AFLP</td>
<td>Amplified fragment length polymorphism</td>
</tr>
<tr>
<td>AGRUCO</td>
<td>Agroecología Universidad Cochabamba</td>
</tr>
<tr>
<td>ANT</td>
<td>Actor Network Theory</td>
</tr>
<tr>
<td>AP</td>
<td>Andhra Pradesh</td>
</tr>
<tr>
<td>APNLBP</td>
<td>Andhra Pradesh Netherlands Biotechnology Programme</td>
</tr>
<tr>
<td>APRA</td>
<td>Asociación de Productores Andinos San Isidro</td>
</tr>
<tr>
<td>APROTAC</td>
<td>Asociación de Productores Andinos 1ra. Candelaria</td>
</tr>
<tr>
<td>A.S.</td>
<td>Alexander Skirving</td>
</tr>
<tr>
<td>BHC</td>
<td>Benzene hexachloride</td>
</tr>
<tr>
<td>BP</td>
<td>British Petroleum</td>
</tr>
<tr>
<td>Bt</td>
<td>Bacillus thiuringiensis</td>
</tr>
<tr>
<td>BTU</td>
<td>Biotechnology Unit</td>
</tr>
<tr>
<td>BYSA</td>
<td>Biocombustibles de Yoro Sociedad Anónima</td>
</tr>
<tr>
<td>CAD</td>
<td>Centro de Apoyo al Desarrollo</td>
</tr>
<tr>
<td>CBD</td>
<td>Convention of Biological Diversity</td>
</tr>
<tr>
<td>CENDA</td>
<td>Centro de Comunicación y Desarrollo Andino</td>
</tr>
<tr>
<td>CEVER</td>
<td>Centro de Educación Vocacional Evangélico y Reformado ‘Dr. Ned van Steenwijk’</td>
</tr>
<tr>
<td>CGIAR</td>
<td>Consultative Group on International Agricultural Research</td>
</tr>
<tr>
<td>CIB</td>
<td>Central Insecticides Board</td>
</tr>
<tr>
<td>CIMMYT</td>
<td>International Maize and Wheat Improvement Centre</td>
</tr>
<tr>
<td>CIP</td>
<td>Centro Internacional de la Papa</td>
</tr>
<tr>
<td>COOPACYL</td>
<td>Cooperativa de Ahorro y Crédito Limitada</td>
</tr>
<tr>
<td>COOPENER</td>
<td>Community Cooperation with Developing Countries</td>
</tr>
<tr>
<td>CSO</td>
<td>Civil society organization</td>
</tr>
<tr>
<td>CUAM</td>
<td>Cuban Urban Agricultural Movement</td>
</tr>
<tr>
<td>DDT</td>
<td>Dichlorodiphenyltrichloroethane</td>
</tr>
<tr>
<td>DGIS</td>
<td>Directoraat-Generaal Internationale Samenwerking</td>
</tr>
<tr>
<td>DK</td>
<td>Denmark</td>
</tr>
<tr>
<td>DNA</td>
<td>Deoxyribonucleic acid</td>
</tr>
<tr>
<td>DOE</td>
<td>USA Department of Energy</td>
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<tr>
<td>DOI</td>
<td>Digital Object Identifier</td>
</tr>
<tr>
<td>DOR</td>
<td>Directorate of Oilseeds Research</td>
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<tr>
<td>EGTK</td>
<td>Ejército Guerrillero Tupac Katari</td>
</tr>
<tr>
<td>EMBRAPA</td>
<td>Empresa Brasileira de Pesquisa Agropecuaria</td>
</tr>
<tr>
<td>EPOR</td>
<td>Empirical Program of Relativism</td>
</tr>
<tr>
<td>ESRC</td>
<td>Economic and Social Research Council</td>
</tr>
<tr>
<td>EU</td>
<td>European Union</td>
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<tr>
<td>FACT</td>
<td>Fuels from Agriculture in Communal Technology</td>
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</table>
FAO  Food and Agriculture Organization of the United Nations
FHIA  Fundación Hondureña de Investigación Agrícola
FSPAU  Free Science Pan-African Union
FUNDER  Fundación para el Desarrollo Empresarial Rural
GCP  Generation Challenge Programme
GDP  Gross domestic product
GM  Genetic modification or genetic modified
GMM  Grameena Mahila Mandal
GMO  Genetic modified organism
GNP  Gross national product
Ha.  Hectare
HIVOS  Humanistisch Instituut voor Ontwikkelingsamenwerking
HPLC  High Performance Liquid Chromatography
IBTA  Instituto Boliviano de Tecnología Agropecuaria
IBU  Interactive bottom-up
IEEP  Institute for European Environmental Policy
ICT  Information and communication technologies
IMF  International Monetary Fund
IPR  Intellectual property rights
IRRI  International Rice Research Institute
ISSR  Inter-simple sequence repeat
JGI  Joint Genome Institute
Ltd.  Private company limited by shares
MAMUMCRAC  Mancomunidad de Municipios de la Cuenca del Río Aguán y Cuyamapa
MAS  Maker assisted selection
MDPL  Movimiento por el Desarme hacia la Paz y la Libertad
MIP  Major intrinsic protein
MITKA  Movimiento Indio Tupac Katari
MM  Molecular marker
MRTK  Movimiento Revolucionario Tupac Katari
NBS  Nucleotide-Binding Sides
NEIKER  Nekazal Ikergeta eta Garapenerako Euskal Erakundea
NGO  Non governmental Organization
NL  The Netherlands
NV  Naamloze vennootschap
Plc  Public limited company
PCR  Polymerase Chain Reaction
PhD  Latin expression – philosohie doctor – meaning ‘doctor of philosophy’
PPO  Pure plant oil
PRI  Plant Research International
PROINPA  Fundación para la Promoción e Investigación de Productos Andinos
QTLs  Quantitative trait loci
RAPD  Random amplification of polymorphic DNA
RFLP  Restriction fragment length polymorphism
RNA  Ribonucleic acid
R&D  Research and development
SCOT  Social Construction of Technology
Abbreviations

SDDPA  Society for Development of Drought Prone Area  
SE   Sweden  
SEPA  Semillas de Papa  
SHGW  Stichting Het Groene Woudt  
STRO  Social Trade Organization  
S&T  Science and technology  
Taq  Thermus aquaticus  
TRIPS  Trade-Related Aspects of Intellectual Property Rights  
UK  United Kingdom  
UN  United Nations  
UNDP  United Nations Development Programme  
US  United States of America  
USA  United States of America  
US$  Dollars of the United States of America  
WB  World Bank  
WDR  World Development Report  
WHO  World Health Organization  
WIPO  World Intellectual Property Organization  
WTO  World Trade Organization  
WUR  Wageningen University and Research Centre  
WWW  World Wide Web
1. Introduction: Genomics for development?

‘It is not true that the map of freedom will be complete with the erasure of the last invidious border when it remains for us to chart the attractors of thunder and delineate the arrhythmias of drought to reveal the molecular dialects of forest and savanna as rich as a thousand human tongues and to comprehend the deepest history of our passions ancient beyond mythology’s reach. So I declare that no corporation holds a monopoly on numbers no patent can encompass zero and one no nation has sovereignty over adenine and guanine no empire rules the quantum waves. And there must be room for all at the celebration of understanding’

‘It is interesting that many of the most dramatic scientific discoveries have moved human beings away from an exalted status: Copernicus's refutation of a geocentric universe, Darwin's prediction that humans arose from a "subhuman" ancestor, and the most recent data showing that humans have an average number of genes for a higher eukaryote’
(Bennetzen 2002)
1.1. Introduction

Advances in agrarian genomics are writing a new page in the history book of science and technology. This research analyzes whether and how these advances could be also adding a new page to the work on making poverty history. The focus of this research is on the local specific development of biotechnologies and genomics as a catalyst for development within the agrarian systems of peasants. It takes up the challenge to investigate whether and how these technologies might be sustainably developed (socially and technically) by local multi-stakeholder networks formed by peasants, peasants’ groups, civil society organizations, and researchers in the so-called Third World. These developmental dynamics are captured within the term Local Sustainable Biotechnological Developments, which can be defined as a type of development that is based in the reconstruction of biotechnologies mainly (though not exclusively) by and for local actors, and which strengthens peasant agrarian systems and which empowers peasants, civil society organizations and local researchers within biotechnological structures.

This research is conducted within a global context of rural poverty. It is estimated that around one billion people are still chronically undernourished, and that about one quarter of all children in developing countries are underweight and risk having a future blighted by the long term effects of undernourishment (United Nations 2008). The UN Millennium Development Goal Report 2008 expects another 100 million people to fall into this extreme poverty in the coming years (ibid.). Moreover, despite an increase in the urbanization of poverty, extreme poverty continues to be a primarily rural phenomenon. Of the world’s 1.2 billion extremely poor people, 75 percent live in rural areas and depend on agriculture for their survival (Anríquez and Stamoulis 2007). Some scholars and expert organizations have argued that science and technology can play an important role in developing further the agriculture in these regions (e.g. FAO 2003-04, Delmer 2005, Jefferson 2006, Fears 2007). This thesis looks at the extent to which (genomics) science and technology can be developed locally, with the aim of strengthening the agrarian systems of resource-poor farmers.

Poverty has, of course, been a constant feature of human history (at least since the Agricultural Era when poverty as a relative notion developed). Nevertheless, the issue of world poverty is specified in a changing global environment. Further to the worldwide phenomenon of urbanization, the industrially developed economies of the Northern hemisphere are in the midst of a substantial transformation that is moving them away from their dependency on heavy industry. Factory-like labour is being outsourced and relocated to various regions of the South as the advanced economies shift to an increasingly high-tech, knowledge-intensive mode of production. The two most important technologies involved in this are communication technologies, and biotechnologies (Castells 1996-2000, Kleinman 2005).

As an engine of economic growth, biotechnologies have different meanings for different parts of the world. For highly industrialized territories it can lead to reduced pollution, and the development of life saving drugs, and new crops and foods. In the South, however, as Kleinman (2005; p. 15) argues ‘the advantages of the new economy are less clear; disputes about ownership of biological material crucial to the economic revolution underway, dangerous working

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¹ ‘Biotechnology’ here refers to technologies ranging from traditional fermentation processes to the latest applications of genomics, and ‘genomics’ to a more limited subset of technologies within this. These terms are defined more precisely below.

² This concept is considered more comprehensively in Chapter 2.
conditions in firms owned by USA- or Europe-based multinationals, and growing disparities of wealth and access to new technologies cloud optimistic visions of a high-tech future’.

Genomics is a brainchild of these high-tech – and highly capitalized – economies. The path of development that agricultural biotechnologies has followed has, by and large, been dictated by agribusiness (Delmer 2005, Kleinman 2005, Jefferson 2006, Fears 2007). Beyond agribusiness, the prime beneficiaries of the current developments in biotechnology are generally large-scale farming systems, whose farm organization and orientation is consistent with this historical trend (Kleinman 2005). Commonly, the research questions guiding agro-genomics match the needs of and help to shape these large-scale commercial systems. While, the agrarian problems affecting traditional forms of agriculture on which peasants usually rely are not regularly transformed into relevant research questions. A situation is thus created in which decision-making on the development of technologies that can have a meaningful impact in peasant agrarian systems occurs outside of and excludes peasants’ territories and their agrarian needs. This type of technological development, which excludes peasants, is defined here as deterritorializing.

Assuming rather than further developing a critique of these historical trends the present work focuses on the social processes that might reverse this particular trajectory in the development of agricultural biotechnologies (and the nature and details of biotechnological innovation this implies). Specifically, we explore how certain social structures are enabling local biotechnological developments that employ genomic technologies to address some relevant (peasant) agrarian problems in specific (rural) territories in the developing world.

The study of the local specific development of biotechnologies attuned to local needs and capacities is approached through the central concept of ‘local sustainable biotechnological developments’. This central concept has two core elements: biotechnology and territory. From the perspective of biotechnology, it aims to inform wider debates around science and technology studies. Technologies are understood as a social structures (Sclove 1995); technological systems have politics (Winner 1985) and are generated by a co-construction process involving social and material elements (Mackenzie and Wajcman 1985, Bijker, Hughes and Pinch 1987, Feenberg 1999); and the way in which technologies are designed, developed and deployed is thus directly related to the actors involved in these processes, the choices they make and the social structures in which they interact. In addition to this, technologies add a specific element to the material dimension of socio-technological systems, which thus feed into the social structures these affect and transform. The focus here, therefore, is on the mutual shaping process that occurs between the social and material elements of biotechnologies.

From the perspective of territory, the central concept engages with debates around ‘alternative rural development’ (Friedmann 1992, Hettne 1995, Ploeg 2008) and ‘territoriality’, which concerns ‘power’ and ‘place’ (Sack 1986, Magnaghi 2005b). Like technology, therefore, territory here has an importantly social meaning. Combining these two core elements of the central concept, therefore, we can state that ‘local sustainable biotechnological development’ is situated at the intersection of territory and biotechnology, that it concerns the locality-specific exercise of power on biotechnological developments.

The concept local sustainable biotechnological developments owes much to the ‘tailor-made biotechnologies approach’. Tailor-made biotechnology emerges from specific experiences of local multi-stakeholder networks that are currently transforming biotechnology as an exogenous instrument into a catalyst for endogenous development. Some of these initiatives were organized within the ‘Tailor-Made Biotechnologies Network’ coordinated from the Critical Technology Construction unit at the Social Science Department of the Wageningen University.
and Research Centre (the Netherlands) under Professor Ruivenkamp, who has been elaborating on the concept of tailor-made biotechnology for a while (Ruivenkamp 1993, 2005a). It is within this framework that the present research has evolved, both theoretically and institutionally. Within this general field of tailor-made biotechnologies, the focus here is specifically on genomics technologies.

Empirical analyses in this research are conducted in the form of case studies. Three case studies are tested in the three interrelated analytic domains of ‘local sustainable biotechnological developments’: the territorial domain (concerning power and social dimensions), the technological (focussing on power and material dimensions) and reterritorialization (looking at the empowerment of territories) domains. By testing biotechnological developments at these three domains, this research aims to shed some light on the issues of how peasant territories can be included into the socio-technological structures of genomics, what (types of) social relations of empowerment appear in the local and sustainable development of genomics, and which new socio-technological structures emerge from the local specific development of biotechnologies. Thus, rather than developing genomics applications in ‘chic’ Northern or urban labs to send them later to peasant communities, this thesis argues that a territorialization of contemporary (genomic) biotechnologies is necessary, within (and with the consent of) the rural communities the biotechnologies are supposed to serve.

Concluding, this research contributes in two main ways. First, it adds to the debates around tailor-made biotechnologies further empirical analyses through the three case studies mentioned. Second, at the level of theory, it elaborates the concept of local sustainable biotechnological developments, which adds a territorial dimension to that approach, and which might be used as a research method by other social scientists to test whether and how the experiences on tailoring biotechnologies and genomics to the needs of peasants are indeed working as a catalyst for local sustainable developments.

1.2. Genomics for development? A deterritorializing approach

‘Local sustainable biotechnological developments’ might be perceived as a rather awkward term. It is employed here for want of anything better or more aesthetically pleasing. The succession of adjectives can be understood as comprising a concept of development with three components. Firstly, the adjective ‘local’ places sustainable biotechnological developments in a concrete place, a locality with all its natural and social specificities. The second adjective, ‘sustainable’ refers here to a desired outcome of the local biotechnological development. This research focuses on a ‘social sustainability’ rather than the more usually applied parameters related to environmental aspects (the idea of a social sustainability pursued through biotechnological developments is elaborated further in the final chapter, Conclusions). Thirdly, the subject matter of the concept is biotechnological development which in this research involves innovation in the field of genomics. These three elements of the central concept are directly related to the aforementioned analytic domains, and applied in the three case studies.

This section gives some background information on some of the issues involved and implied in the central concept (i.e. development, peasants, biotechnology and genomics). It introduces the potential of genomics knowledge and technology for the development of
agriculture. More specifically, it looks at how the current mainstream approach to the development of genomics can be characterized as deterritorializing from the perspective of peasant’s agrarian territories.

Genomics for what type of development?

At the very outset of its World Development Report 2008, the World Bank (2007) puts agriculture at the heart of future development, stating that ‘it is time to place agriculture afresh at the centre of the development agenda’. Given this, McMichael (2009) rightly wonders why, then, the last World Development Report (WDR) on agriculture was written a quarter of a century ago. He also criticizes the WDR trope in defining the poor and the way out of poverty:

‘An African woman bent under the sun, weeding sorghum in an arid field with a hoe, a child strapped on her back – a vivid image of rural poverty… But others, women and men, have pursued different options to escape poverty. Some smallholders join producer organizations and contract with exporters and supermarkets to sell the vegetables they produce under irrigation. Some work as laborers for larger farmers who meet the scale economies required to supply modern food markets. Still others, move into the rural nonfarm economy, starting small enterprises selling processed foods’. (World Bank 2007; p. 1)

Small-scale and subsistence agriculture is a normal practice all around the world, but it is misleading to present it as the initial stage to development. This could be even been characterized as neocolonial (Sachs 1992). Naturalizing the African woman as a baseline for a ‘development ladder’ is as misleading as the implication that agro-industrialization is inevitable, and desirable, at a time when low-carbon livelihoods are often more appropriate and possibly more just (McMichael 2009). The poverty trope informs, and legitimates, the development trajectory with which the Bank works (Da Costa and McMichael 2007), and through which it subdivides agriculture’s contributions into three distinct worlds: agriculture-based countries, transforming countries, and urbanized countries – a hierarchical order in which countries ‘follow evolutionary paths that can move them from one country type to another’ (World Bank 2007; p. 4). This developmental trajectory, upward from rural to transition to urbanized (type of societies) is mainly based on economic growth, and is not the way that development is here understood. Development is not understood here in terms economic growth which can be measured financially, because a conception of economic development that does not include social progress should be distrusted. Amartya Sen, winner of the Nobel Prize for economics, expresses this critique with development defined in terms of freedom, thus:

‘Development can be seen […] as a process of expanding the real freedoms that people enjoy. Focusing on human freedoms contrasts with narrower views of development, such as identifying development with the growth of gross national product, or with the rise in personal incomes, or with industrialization, or with technological advance, or with social modernization’ (Sen 2001; p. 3).

Rather than the possibility to be engaged in the ‘treadmill’ machinery of economic accumulation, development is considered here as a possibility open to all the dwellers of a territory to enjoy
material and social prosperity. Friedmann (1992; p. xi) argues that there should be economic growth, but not at the expense of the survival of the poorest. If social and economic development means anything at all, it must mean a clear improvement in the conditions of life and livelihood of ordinary people (Friedmann 1992). It should mean empowerment. There is no intrinsic reason moral or otherwise, he continues, why large numbers of people should be systematically excluded from development in this sense or, even worse, should become the unwitting victims of other people’s progress (ibid.). Since this research concentrates on biotechnologies and development, the focus of attention here is on the empowerment of the dwellers of peasant territories within biotechnological developments, and particularly on the empowerment processes of local multi-stakeholder networks. Moreover, because technology is one of the political arenas in which society is constructed, it follows that an empowerment within technological systems means social empowerment.

The understanding of development in this research is related to the alternative approaches to development (e.g. Nerfin 1977). Alternative, bottom-up and participatory approaches move away from the focus on a form of development which is based on economic parameters. The central idea of these approaches is that the emphasis should be placed on endogenous (from within, internal) rather than external forces of change. There is a variation on this by which where the centres of interest move from the urban areas to the rural areas. And as a whole this approach should be described as a development from below (Bunders 1990, Ploeg and Dijk 1995, Potter, Binns, Elliot et al. 2004). Finally, this approach is based on territoriality, and emphasizes the mobilization of mainly (though not exclusively) the locally available human and natural resources. Likewise, the concept of local sustainable biotechnological developments implies the integration of knowledge and specific technological applications of biotechnologies within local development. Furthermore it is increasingly suggested that development should meet the basic needs of the people (Potter, Binns, Elliot et al. 2004). Specifically, it is suggested, third world countries should try to reduce their involvement in processes of unequal exchange (Hettne 1995, Potter, Binns, Elliot et al. 2004, Magnaghi 2005b, Sachs 2005). At the same time, development needs to be ecologically sensitive; and it needs to stress more forcefully the (genuinely) democratic principles of public participation. It is within these alternative frameworks of a just model for economical growth that this thesis understands development; i.e. as the enhancement of a local society and its capacity for self-government, with different networks involved in the process and considering differentiated development styles - including within and through biotechnological developments.

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3 An emphasis on endogenous development has been constituted as one of the most important tendencies within the alternative approaches. Endogenous development has been defined as development based mainly, though not exclusively, on locally available resources, local knowledge, culture and leadership, with openness to integrating traditional as well as outside knowledge and practices. It includes mechanisms for local learning and experimenting, building local economies and retention of benefits in the local area (COMPAS 2007). For a more in-depth analysis on how endogenous rural development works, see Ploeg and Dijk (1995).

4 The idea being that the poor and disadvantaged should not have to degrade or pollute their environments in order to be able to survive. Or, as expressed in the often cited definition of sustainable development provided by the Brundtland Commission (WCED 1987), the aim is for development ‘that meets the needs of the present without compromising the ability of future generations to meet their own needs’.
Genomics for whom?: on peasants, resource-poor farmers and subsistence agriculture

The concept of subsistence agriculture is understood to refer to a type of farming in which all or most of the production is used to feed the household, with very little being sold. It is usually small-scale (with less than one hectare cultivated per year) and practiced by resource-poor farmers who may or may not be recognized as legally owning the (usually resource-poor) land they work. These farmers are resource-poor in terms of access to natural resources, credit, information and external inputs. The category of ‘resource-poor farmer’ is a little narrow for our purposes, however, as it does not encompass the multiplicity of real life roles that people play in rural life. That is, the people who populate subsistence agricultural systems are not necessarily resource-poor farmers – indeed they can be involved in other activities beyond farming such as employed in local town (for cash), combined with helping neighbours in the village on a seasonal basis (for goods), child rearing, etc. Therefore, the wider term ‘peasant’ is generally favoured here, especially as it historically refers to a social class and thus recognizes the socio-political dimension of the subject at hand in a way that the relatively neutral ‘subsistence farmer’ does not. It does however, have its problems.

Different conceptions of the peasantry, and its fate in modern capitalism, resonate with different interpretations of modernity and development (Bernstein 2003). Even when scholars agree in presenting peasant as a category to represent certain type of farmers, there does not exist a consensus about what the peasantry is. As is the case with other concepts, the conceptualization of the word ‘peasant’ can acquire different meanings when defined from different perspectives. For instance, we have the utopian world of Alexander Chayanov in his novel ‘The Journey of My Brother Alexei too the Land of Peasant Utopia’, in which the author seems to link his hopes of progress to the peasantry and their small holdings (Bernstein 2003). Against this, we have the pejorative concept of the uncivilized, of peasantry as a relic of the feudal past, with Hobsbawm (1994), for example, who believes that modern time starts with the ‘death of the peasantry’, which is caused by the ‘revolution of global society’. Between these two extremes there is an abundant literature on the topic ‘peasants’ (e.g. Bernstein 2003, Ploeg 2005, 2008, Jongerden 2008). Some of the conclusions that we could extract from these analyses are that: Firstly, peasants are not a uniform category. Secondly, this concept is being shaped and reshaped along history. Thirdly, it seems to be an agreement in that the main activity accomplished by peasants is farming. However, this is not the only activity they are engaging for their survival. Finally, most of these studies agree upon the importance of the globalization process for the evolution of peasants. For example, Henry Bernstein (2003) speaks about the global expansion of capitalism, and Jan Douwe van der Ploeg about Empire (Ploeg 2005, 2008). These globalization tendencies are seen as hostile for peasants. Certainly, we could argue that they seem to undermine peasant’s autonomy over their agrarian practices, and therefore, their autonomy in constructing their territories.

Van der Ploeg has defined the peasant condition in a rather comprehensive way (Ploeg 2005). He lays the emphasis on autonomy as a counterforce to the centralized control and appropriation which he believes is the main feature and mechanism for the development

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5 Of course even ‘resource-poor farmer’ and ‘subsistence farming’ are not value free concepts. For example, they carry connotations of impoverishment, of barely being able to survive – which may or may not be the case – and so needing help, thereby invoking models of international ‘aid’ in order to develop, i.e. join the market economy, etc.
produced by *empire*. Van der Ploeg argues that ‘central to the peasant condition is (1) the struggle for autonomy, survival and progress in a hostile context that is characterized by dependency relations, deprivation and marginalization. This struggle aims at (2) the creation and development of a self controlled resource base, that allows for (3) forms of co-production of human and living nature that (4) interact with the market, (5) enable survival and that (6) positively feed back into, and strengthen, the resource base, thus (7) improving the process of co-production and (8) enlarging the required autonomy. The same struggle often implies (9) an engagement in other additional activities in order to sustain this cycle (Ploeg 2005).

Van der Ploeg’s conceptualization of peasants is relevant to this thesis because an active role and an empowerment of peasants might be both the prerequisite for and the result of any significant further advance in local sustainable developments of biotechnology. The empowerment of peasants in the development of local specific biotechnologies reinforces the definition of peasants as a social category (group) aimed at increasing its own autonomy.

**A deterritorializing approach to genomics for development?**

Continuing the overview of the main terms employed in this thesis and the ideas they represent, this section attempts to deepen the definitions of biotechnologies and genomics. In so doing, it also presents the actual dominant path of biotechnology development as one of deterritorialization – a type of development which is developed from and for a supposedly abstract (non-territorial) understanding of territory, and which undermines peasant autonomy and thus the ability to develop local specific agrarian related biotechnologies.

**What is biotechnology and what is genomics?**

The United Nations Convention on Biological Diversity (CBD) held in Rio de Janeiro, Brazil (1992), defines biotechnology (Article 2) as ‘any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use’. Within this broad spectrum sense, even agriculture itself can be considered as biotechnology. Even since the societal transformation in the Neolithic from hunter-gatherer societies into agrarian forms, farmers have been selecting the most suitable varieties of plants according to their needs and wishes. Thus, they were transforming (also at the genetic level) the plants they used by planting them in different environments and by crossing plants with other varieties.

Assumed to be as old as human society and certainly traceable back to the advent of agriculture, other transformations accomplished in the habit of humans to deploy technology within our knowledge on biology have included the use of plants or their components for medical purposes. The process of controlled fermentation, for example, can be placed at the foundations of biotechnology, and now beer is brewed with the same basic method followed by the Mesopotamians. I.e. using malted grains (commonly barley or wheat) to convert starch from grains into sugar and then adding specific yeasts. Later, other cultures developed the process of lactic acid fermentation for the production and conservation of milky products.
More recently, this broad definition has been narrowed to refer only to recombinant DNA\(^6\) techniques. DNA recombination is the process by which pieces of DNA are cut from one organism and pasted into that of another organism. With the development of these techniques in the late 60s and early 70s came the recognition of their potential for genetic engineering or genetic manipulation. Co-discoverer with Francis Crick of the DNA structure, James Watson came to express recombinant DNA technology in biology in terms of computer word processing: as cut, past and copy DNA. Following the descriptive analysis of the working of DNA within the cell (phase 1), Watson describes the emergence of recombinant DNA as ‘phase 2 of the molecular biology’ revolution.

‘Molecular biology had come a long way in its first twenty years after the discovery of the double helix. We understood the basic machinery of life, and we even had a grasp on how genes are regulated. But all we had been doing so far was observing; we were molecular naturalists for whom the rain forest was the cell – all we could do was describe what was there, the time had come to become proactive. Enough observation; we were beckoned by the prospect of intervention, of manipulating living things. The advent of recombinant DNA technologies, and with them the ability to tailor DNA molecules, would make all this possible’ (Watson and Berry 2003; p.85)

DNA recombinant techniques have had a huge impact in society, opening a fierce pro-contra debate. This roaring debate has led some to argue that genetic modification technologies are biotechnology itself, while for others, these technologies are one important component of the techniques that are defined within a wider conceptualization of biotechnology. For others still, they represent the landmark in the differentiation between modern and traditional biotechnology.

‘Modern biotechnology can be defined as the use of cellular, molecular and genetic processes in production of goods and services. Its beginnings date back to the early 1970s when recombinant DNA technology was first developed. Unlike traditional biotechnology which includes fermentation and plant and animal hybridization – modern biotechnology involves a different set of technologies, including industrial use of recombinant DNA, cell fusion and tissue engineering amongst others’ (Zika, Papetryfon, Wolf et al. 2007; p. 5)

The complexity of the term ‘technology’ reaches the level of poetry when people deal with biotechnologies. No matter how lyrical and attractive it might appear to work with living matter, definitions of biotechnology (like almost every other definition) are far from innocent. Definitions are never innocuous, different groups will define biotechnology according to their interests. Taking an analytical approach, Bud (1991) argues that biotechnology is a ‘boundary object’. ‘Boundary objects are both adaptable to different viewpoints and robust enough to maintain identity across them’ (Star and Griesemer 1989; p. 387). The central meaning is suggested by the word itself and refers to the frontier between biology and technology or the interface between life and engineering. Throughout its history, this boundary has been mobile and contested (Bud 1991). Bud’s boundary object analysis might clarify why such a large set of definitions of biotechnology can be found. Definitions are not correct or incorrect, but they are more or less adequate to the aims at stake.

\(^6\) DNA (deoxyribonucleic acid) consists of two molecules joined in a double helix, held together by a string of four possible bases: guanine (G), adenine (A), thymine (T), and cytosine (C). This basis structure is the same for all organisms; the differences are in the length of the code and the order of the bases (Pilnick 2002).
The intention here is to gain a better understanding of biotechnological development, to which end the concept of local sustainable biotechnological developments is elaborated as an analytic tool with the three interrelated domains (territorial, technological and reterritorialization). From the (critical constructivist) approach to technology elaborated in this thesis (Chapter 2), we might argue that both the aforementioned broad definition of the CBD and this one given by the European Policy report of Zika et al. (2007) only address the second domain of analysis, i.e. the technological (material) domain. These definitions emphasize biotechnology as being a group of techniques, but fail to observe the social multiple aspects of (bio)technologies. And, they seem to visualize biotechnologies as disconnected from any type of territory. Biotechnologies seem to be designed in a global abstract space, applicable anywhere, anytime. It is against this that, following the arguments of e.g. Ruivenkamp (2003), and Kleinman (2005), this thesis proposes a definition of biotechnologies which integrates its social and material dimensions. In this framework, biotechnologies can be redefined as networks of social and material elements in which micro-organisms, plants, and their parts are used to develop new products. These networks evolve within concrete political, territorial and historical as well as scientific contexts; and through which therefore, humans (here specifically peasants, civil society practitioners, and local scientists) can influence specific innovations and the general direction of development.

Two main conclusions could be extracted from this definition. Firstly, a broad approach to biotechnologies is implied here, one in which genomics is considered as just one type – albeit very important – of biotechnology. The reason for this is that this research aims to be an intellectually normative effort to define trajectories by which biotechnologies in general (i.e. including but not limited to genomics) might strengthen already existent peasant agrarian systems, and it’s aimed also at researching trajectories for biotechnological research which may include farmers and civil society organizations within these systems. Therefore, although the focus here is on the technologies that we know as genomics, items like peasants’ knowledge and practices are also included in the total analysis of the technological systems. This is also justified insofar as a large set of technological practices has to be employed in order to be able to link the ‘high-tech’ genomics labs with peasant agrarian systems. It reflects indeed the contradictory and distant environments (territories) where genomics is usually developed and where rural-poor agriculture is practised. Thus, the deployment of genomics within development is not just a question of transfer, but one of link up socio-biotechnological networks with different technological capacities, methodologies and desires in a specific territory.

The second conclusion that can be drawn from the definition of biotechnologies presented here is that biotechnologies are political. This means that they reflect the nature of the relations that have brought them into being, and that biotechnological structures have also a sociological role and politicizing power in those societies in which they are able to evolve (Chapter 2.4).

**Genomics, narrowing the approach?**

‘The new discipline is born form a marriage of molecular and cell biology with classical genetics and is fostered by computational science’
(McKusick and Ruddle 1987)

The origin of the term ‘genomics’ is usually linked with the establishment of the journal by the same name. In the editorial of its first issue, Victor A. McKusick and Frank H. Ruddle sketch ‘a
new discipline, a new name, a new journal’ (McKusick and Ruddle 1987). The journal was thought to be an interdisciplinary forum and a common meeting ground for molecular biologists and biochemists, human and somatic cell geneticists, cytogeneticists, population and evolutionary biologists, genetic epidemiologists, clinical geneticists, theoretical biologists, and computational scientists, all interested in the biology and genetics of the human and other complex genomes (ibid.). In the words of Brenner (2000), genomics is a ‘reverse genetics’. The classical genetics goes from phenotype to genotype; whereas ‘the classical form of genetics relies on first finding a mutation by screening for phenotypic changes and then identifying the gene carrying the mutation’ (ibid.), in the case of genomics the move made is from genotype to phenotype.

As it is the case of other concepts such as genetics or technology, genomics is not about a thing, but an activity. It is ‘a new way of thinking about biology’ (Kuska 1998). McKusick and Ruddle (1987) specified the mapping and sequencing of genomes as the sorts of activities referred to by genomics. They argued that both sequence analysis and the revelation of its biological significance fit under the general banner of genomics as well. Many other commentators agreed on this dual-phase characterization (Powell, O'Malley, Müller-Wille et al. 2007). Structural genomics, or sequencing and mapping, inevitably leads to the much broader project of functional genomics, which attaches the knowledge of DNA sequences to information about functions. Generally speaking, genomics is defined just as the study of genomes. But within the framework of this thesis, which does not consider sciences activities as politically neutral, the definition of genomics should certainly include the functional use in concrete practices of the knowledge gained from the study of genomes.

Concluding the term ‘genomics’ here encompasses both the knowledge and the local specific application of the advances made within molecular biology in the study of genes and their functions. This understanding thus goes beyond more widely accepted neutral definitions like: ‘the study of genes and their functions’, or ‘the study of the genome’. Here, genomics refers also to the local specific application of this knowledge through molecular technologies, such as marker-assisted breeding or biodiversity studies with molecular markers. This research

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7 Molecular biology is an approach of biology to understand processes at the molecular level. Watson and Crick’s Nobel Prize-winning breakthrough in determining the structure of the DNA molecule can be regarded as the new discipline’s defining moment. Molecular biologists saw themselves as working in a multidisciplinary way and, therefore, in opposition to established disciplines such as biochemistry (Powell, O'Malley, Müller-Wille et al. 2007). Some of the technologies upon which molecular biology depend are X-ray crystallography, electrophoresis, paper chromatography, and sequencing (Kay 1993). Molecular biology has won a prominent place within the framework of biotechnologies; and molecular biology are found now at almost all research institutes dealing with biotechnologies, even in the developing world. One of the technologies emerging from within molecular biology, nucleic acid sequencing, became the basis for the technology that is the topic of my research, genomics.

8 Genomes are made up of a nucleic acid, either DNA or RNA (Ribonucleic acid), arranged in chromosomes. They contain vast amounts of information including the DNA or RNA sequence of individual genes, how genes are used and controlled and other factors that affect development (see www.genomicsnetwork.ac.uk)

9 The ‘genotype’ is the genetic constitution of a cell or an organism; the ‘phenotype’ is any observable characteristic of an organism (morphology, development, etc.)

10 Genome sequencing is the action of mapping the whole genome of an organism. DNA sequencing for instance, consists in finding out the order of the nucleotide bases – adenine, guanine, cytosine, and thymine – in a DNA fragment, or of the entire genome.

11 In 1996, McKusick and Rudle named their Genomics editorial: ‘Genomics: an established discipline, a commonly used name, a mature journal’ (McKusick and Ruddle 1996). The emphasis had shifted now from structural analyses to functional and comparative ones (Powell, O'Malley, Müller-Wille et al. 2007).

12 Source: www.epa.gov/comptox/glossary.html

focuses on the agrarian applications of genomics, which is why the term *agrarian genomics* (or *agro-genomics*) is sometimes utilized. Moreover, as explained, within the framework employed here, genomics should be considered as *one set of technologies within different existent biotechnologies*. Therefore, the term ‘biotechnology(ies)’ refers to a *wide set of technologies that includes genomics*, and the term ‘genomics’ refers to *this technological network formed by molecular biology applications, genome sequencing, and functional genomics*. Finally, since within the framework of this thesis technologies are not considered as just material (politically neutral) apparatuses, the term ‘genomics’ refers also to the *social dimensions involved in the practices of genomics activities*.

**Agro-genomics advances**

Developing the agrarian sector is acknowledged within academic and policy circles as an important step to improve the conditions of the rural poor, since most of this population depends on agriculture for its survival. Some scholars have argued that biotechnologies and genomics might play an important role in invigorating peasants agrarian systems (e.g. DeGregori 2001, Delmer 2005, Bruskiewich, Davenport, Hazekamp et al. 2006, Jefferson 2006, Louwaars, Thorn, Esquinas-Alcazar et al. 2006). Agriculture practices could be strengthened by the expansion of our understanding of the biological processes involved in plant development, such as growth, photosynthesis and reproduction, or the multiple interactions with pathogens and environmental conditions, and through the local application of this knowledge. This understanding and applications are being enlarged, among other things, because of genomics.

One such advance, for example, was the conclusion of the sequencing of the first plant genomes (Arabidopsis and rice) which has provided models for relating functions with genes. Mapping and sequencing genomes might eventually help to clarify gene function and expression and to functionalize this knowledge through linking the genetic elements of an organism with its phenotypic elements through molecular technologies, such as molecular markers.

The use of molecular marker technologies to help developing improved crop varieties (marker assisted selection) have been considered by some scholars as one of the main ways in which genomics knowledge could be used to improve rural livelihoods (e.g. Reece and Haribabu 2007). Molecular markers are identifiable DNA sequences found at specific locations of the genome, and transmitted through the standard laws of inheritance from one generation to the next. They can be identified by DNA assays, in contrast to morphological markers, based on visible traits, and biochemical markers, based on protein produced by genes (FAO 2003). The presence of a particular marker in a plant might indicate the presence of the particular trait associated with this marker. In addition, molecular markers can be detected at almost any stage of development of new varieties (Peleman and Voort 2003). Consequently, within the context of the plant breeding activity of crossing two plants with different traits to get one line with the combined desirable characteristics, with molecular markers we might detect, at an early stage, which offspring have the desired traits. In this way, the breeder might not need to wait until the plants grow, and fully express their phenotypes, so the offspring that lack these traits can be discarded. As a result, the use of molecular markers can sometimes reduce the time and space required for traditional plant breeding by consecutive crossing (Mohan, Nair, Bhagwat et al.

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14 There are several types of techniques to identify markers such as microsatellites, AFLP, RFLP, etc.
1997, Young 1999, Dekkers and Hospital 2002, Fears 2007). There seem to be general agreement that this is the main benefit of incorporating maker assisted selection (MAS) into a traditional plant breeding programme.\(^{15}\)

The value of molecular markers for plant breeding is further enhanced because genes tend to occur in the same order within the genomes of different but related species. So, once a molecular marker associated with a trait has been found at a concrete location of the genome of one plant, it may well serve to locate the marker associated with that trait within the genome of related plants – e.g. plants from the same family (Bennetzen 2002, Reece and Haribabu 2007, Yano and Tuberosa 2009). This is relevant from the perspective of this research as many of the molecular markers that have been developed for global economically relevant crops – most of them by large multinationals and major public institutions – might be used for the so-called ‘minor’ or ‘orphan’ crops, crops that play a key role in resource-poor farmers’ systems but which have not attracted significant research investments (Heller 1996, Naylor, Falcon, Goodman et al. 2004, Reece and Haribabu 2007). For instance, the development of markers in maize and other cereals such as wheat has helped to develop the technologies that can be applied in pearl millet, finger millet and foxtail millet (Reece and Haribabu 2007; p. 463). Moreover, MAS are starting to develop major crops with new, desired characteristics. For example, rice lines with different resistance genes have been commercially introduced in Indonesia, and are being produced by several national programs at the International Rice Research Institute (IRRI) of the Consultative Group on International Agricultural Research (CGIAR)\(^{16}\) (Naylor, Falcon, Goodman et al. 2004, Fears 2007). Strong national programmes, such as those in China, are effectively using MAS in certain cases, e.g. for the improvement of quality traits in rice, and fibre strength in cotton (Naylor, Falcon, Goodman et al. 2004). Babu and co-workers (2004) list case studies of MAS in which for instance, some resistance against a nematode has been introduced into soybean, and against bacterial blight and blast into rice, or cases in which MAS has been used for drought stress tolerance in maize.

The advances achieved on the agrarian applications of genomics involve promises to improve the practice of agriculture in developing countries indeed. But (bio)technological developments usually involve ambivalent dynamics. For example, the further understanding of plant processes (growth, reproduction, resistance to abiotic and biotic stresses, etc.) and about the linkage between genes and molecular markers with crop traits can, on the one hand, make plant breeding a more predictable and quicker process (Babu, Nair, Prasanna et al. 2004, Delmer 2005, Fears 2007). But, on the other hand, linking genes and molecular markers is an expensive and complex activity (Reece and Haribabu 2007) which can make plant breeding a more complicated and expensive process (Babu, Nair, Prasanna et al. 2004).

There are some other bottlenecks and possible side effects or negative outcomes concerning the introduction of molecular markers knowledge and technologies into plant breeding programmes. One type of complication involves the transmission of theoretical

\(^{15}\) Reece and Haribabu (2007; pp. 462-463) give other possible benefits of MAS. For example, they argue that MAS may be particularly useful when screening the resistance of a plant to pest or diseases at the phenotypic level is nearly impossible – e.g. because the impossibility of reproduction and analyzing the conditions in which the pest attack the plant or because the crop variety which is resistant and the pest or the disease affecting the crop are geographically remote.

\(^{16}\) The Consultative Group on International Agricultural Research is an alliance of countries, international and regional organizations, and private foundations supporting fifteen international agricultural centres, which work with national agricultural research systems and civil society organizations, including the private sector. The alliance aims to mobilizes agricultural science in order to reduce poverty (www.cgiar.org)
knowledge into practical application. An example of this is that as most of the traits of agronomic importance are complex, regulated by several genes, and might depend as well on environmental factors, they are not easily utilized for the development of new crop varieties. Babu et al. (2004; p. 611) argue that unlike the case of simply inherited traits that are controlled by one or a few major genes, improvement of polygenic traits through MAS is a complex endeavour. Moreover, they say that ‘there is a wider appreciation that simply demonstrating that a complex trait can be dissected into QTLs\(^{17}\) and mapped to approximate genomic locations using DNA markers would not serve the ultimate goal of trait improvement’ (ibid; p. 616).

One possible side effect of introducing MAS into plant breeding relates to the issue of ecology and sustainability, namely the loss of genetic diversity and of knowledge associated with the practice of plant breeding. The challenge here seems to be then to integrate the power of molecular markers for selection in plant breeding programs without losing the knowledge we have of the phenotypic diversity of plants. Thus Koebner and Summers (2003; p. 63) argued:

‘Overall, it will remain vital that ‘laboratory-based breeding’ should remain the servant of the field breeder and not its master – because if large-scale MAS deployment results in a ‘magic bullet’ approach to breeding in which major breeding targets are resolved by a single gene approach, then the holistic advances that have been achieved by the phenotypic selection of minor genes will be lost and the varieties that emerge might become vulnerable to future shifts in production systems/climate/end use and so on. Our thesis is that the breeding paradigm that has served the industry well over many decades will be touched, but not overturned by genomics driven MAS.’

Technologies, and therefore also genomics involve the promises for improving the practice of agriculture, at the same time, they also involve constrictions and unexpected or even undesirable outcomes. Another area of concern is the effects associated with the financing of the research. Genomics is an expensive business and has been developed mainly in expensive labs in the industrially developed parts of the Northern Hemisphere and primarily oriented towards commercial and industrial agriculture (Delmer 2005, Fears 2007). While there have been relatively few advances made in crop development and dealing with the agrarian problems associated with resource-poor farming and peasant agricultural systems. In this context, it is argued that genomics knowledge and technologies can be transferred from the North to the South and in this way strength peasant agrarian systems (e.g. Delmer 2005, Bruskiewich, Davenport, Hazekamp et al. 2006, Louwaars, Thorn, Esquinas-Alcazar et al. 2006). The idea, however, that Technologies can be just transferred from one context to another disregards completely the complex social and material interactions (co-construction) that constitute territories and technologies. As a result, applications of MAS and other biotechnologies may be practically useless for those on the ‘poverty line’. It is this type of socio-political difficulties (such as access to money, knowledge, and skills) which is the main focus here – motivating the examples of local sustainable biotechnological developments researched in the three case studies. This thesis researches the co-construction dynamics that emerge from experiences in which some genomics technologies are developed for or from within specific societies.

\(^{17}\) Though not necessarily genes themselves, quantitative trait loci (QTLs) are stretches of DNA that are closely linked to the genes that underlie the trait in question.
A deterritorializing approach for developing agro-genomics within development?

Deleuze and Guattari in their work ‘Anti-oedipus: Capitalism and schizophrenia’ (2005) use the concept of deterritorialization to designate the appropriation from the labour force of specific means of production. For instance, a series of enclosures acts throughout the eighteenth and nineteenth centuries deprived English peasants of land. Nowadays, deterritorialization is also related to the power relations embodied in the process of globalization, as the worldwide extension of capitalism. Alberto Magnaghi (2005b; p. 72) argues that the currently dominant ideology of globalization focuses on the material resources of territories through just a ‘few capital-intensive strongly innovative sectors: biotechnology, space technology, advanced chemistry, etc.’ and continues thus:

‘The development strategies and leading sectors are thus decided by production networks and the dominant governments in the world system, while the local systems inevitably adapt to the pre-established development patterns ranking the individual local economic systems in the overall hierarchy of the global system’ (ibid.; p. 72)

‘Territoriality’ is defined here in the context of biotechnological developments as the local specific control exercised on these types of developments by peasants, civil society organizations, and local researchers in the so-called Third and Fourth Worlds. It is suggested that the decision-making capacity for agro-genomics is located far away from peasant territories. This is the reason why the currently standard path of development is regarded as deterritorializing, i.e. from the perspective of peasants’ territories.

Through the process of deterritorialization – within the logic of the global capitalism – it is said that territories are reduced to quantitive functional variables (distances, material resources, etc.) which can be measured (Hettne 1995, Magnaghi 2005b). In this way, territories are reduced to localities without social specificities, and dwellers reduced just to consumers. Technologies are argued (Magnaghi 2005b) to be implemented in such a way as to decouple the territory form its social specificities given by its dwellers (i.e. the producers of territoriality). Magnaghi argues that ‘the territory gradually liberated also through technological developments, was represented and used as a purely technical support for economic activities, which were localized according to an entirely economic and technological rationale, increasingly independent of relations with place and environmental, cultural and identifying features’ (ibid.; p. 8).

Ruivenkamp (2005a) gives an example of this with his explanation of how the agro-industrial biotech approach is characterized by ‘freeing’ crops of their relationship with their surroundings while at the same time making them ‘dependent’ on the inputs of external agricultural research and business.

Agrarian genomics is mainly developed by few actors in few places (i.e. a small group of large corporations and a few research institutes in a handful of countries) and is focusing on few crops with an economic relevance within global markets (EASAC 2004, Naylor, Falcon, Goodman et al. 2004, Fears 2007). This characterizes the developmental path in the South as deterritorializing insofar as the labour force of its scientists and peasants is implicitly excluded from the genomics means of production, in Deleuze and Guattari’s terms. Moreover, and in Magnaghi’s terms, the implementation of agrarian technologies, in this case of agrarian genomics, not only escapes the territorial character of agriculture in peasant territories, i.e. the
aggregation of nature, society, and technology, but also reduces territories to localities with just an economic function. With the commercial ethos of agrarian genomics, peasants and local scientists being situated outside the places where the decisions around genomics are taken are then reduced to mere consumers of these agrarian technologies, naturally on the condition that they have the means to afford and adapt them.

On the contrary, this present work starts from the territory, with locally-based multi-stakeholder networks aimed at attuning biotechnology developments to local needs and capacities. These networks gain power in the management (of the local development, application, and administration) of biotechnologies which have the potential to strengthen the local agrarian systems. Employing the concept of ‘local sustainable biotechnological developments’, this thesis focuses on two main elements: technology and territoriality (power and locality). It examines the ways which local actors (i.e. peasants, civil society organizations, and researchers) can gain control on biotechnological developments.

Taking the perspective of these peasant agrarian systems (territories), an overview of the actual mainstream development of genomics suggests that the path of development that genomics technologies have been following can be characterized as deterritorializing. The argument can be expressed logically in the following way:

- Genomics is governed by researchers in private and public labs in the industrially developed parts of the world; from which it follows that
- Peasants, civil society organizations, and researchers (and their territories) from the third world are excluded from the decision-making processes of technology development; because of which
- A transfer of technology is proposed (becomes necessary) in order to use genomics for development

On the governance of genomics and the exclusion of peasants and their territories

New opportunities have been opened by the systematic production of knowledge in biodiversity and crop resources through genomics (Fears 2007), however, the logical follow up to this, of implementing these potentialities and converting them into concrete products or crops for subsistence agriculture is not a self-evident step. For example, most efforts in genomics are focussing on crops that are relevant for global markets, and in temperate climates, with the upshot that ‘minor’ tropical corps are not yet targeted for genome sequencing (EASAC 2004, Naylor, Falcon, Goodman et al. 2004, Fears 2007). Genomics research into minor crops has traditionally been marginalized by main stream sciences, but many crops that are neglected at the global level are staples for peasants at the regional level (e.g. Andean roots and tubers), or are important for local agrarian systems in other ways, such as source of income, as food supply in certain periods (e.g. indigenous fruit trees), living fences or medical purposes (e.g. *Jatropha curcas*\(^{18}\)), etc. Locally used species and varieties are also important for agricultural diversity (Heller 1996, Naylor, Falcon, Goodman et al. 2004).

In this context, the report on ‘genomics and crop plant science in Europe’ (EASAC 2004) argued that while sequencing technology continues to develop rapidly and costs to decrease significantly, the complete analysis of a large genome still requires major financial resources and technical limitations may also restrict progress. Therefore, it is unrealistic to use current

\(^{18}\) See Chapter 5.
technologies to just sequence the larger genomes of globally relevant crops, and the current goal should be to progress draft sequences for gene-rich genomics regions of genomes. Genetic markers are becoming available in a range of crops (ibid.). But again, for ‘minor’ crops like cowpea, common bean, the millets, or cassava which are relevant for peasants in several regions of the world we still have low and insufficient numbers of molecular libraries and markers. By way of example, as Delmer (2005; p. 15739) observes in her review of MAS applications in agriculture in the developing world, within the U.S. Department of Agriculture’s National Research Initiative there is now a program for Coordinated Agricultural Projects that has sponsored conferences on translational genomics and intends to fund integrated projects aimed at engaging applied plant scientists to better use the tools of genomics for crop improvement – but this is just for mainstream crops such as cotton, soybean, and barley. As for the interests of private multinationals, these do not extend much beyond cotton, maize, canola and soybean (Fears 2007).

One other point related to the neglect of ‘minor’ crop research is that when crops that are relevant for the rural poor are targeted through genomics, it is sometimes done with other intentions than the final aim of alleviating poverty (see Box 1.1).

**Box 1.1. Placing socially relevant crops at the core of the research agenda?**

There are impressive sequencing capacities within consortia (also within the public sector) currently producing large amounts of sequences for several model plants and crops. Raven and colleagues (2006; p. 468) have argued recently that ‘although the costs of sequencing are falling, sequencing eukaryotic genomes still requires a minimum commitment of US$5 to 10 million. For those who can raise such funds, the resulting information will provide an invaluable resource, underpinning research and technology development in their chosen organism and related species for decades to come’. In this article authors appealed for the use of these technological capacities to the targeting of crops which have a generally more relevant social importance, such as those that are the most important for peasant agrarian systems.

Cassava (*Manihot esculenta* Crantz) is one such important crop. It grows throughout tropical Africa, Asia and the Americas, and it feeds an estimated 600 million people each day (ibid.). Realizing the full genetic potential of cassava to meet the needs of resource-poor farmers requires among other things both conventional breeding and molecular technologies. Sequencing its 770-Mb genome would enhance both approaches (ibid.). For instance, agronomically important qualities could be introduced into varieties preferred by peasants by traditional breeding, genetic modification, or marker assisted selection. A positive decision in this direction could place socially-relevant crops like cassava into the mainstream plant science research (ibid.), and might, to some extent, open the decision-making process of plant genomics to peasants, and researchers of the so-called third and fourth worlds.

Recently, the challenge to sequencing cassava has been taken up by the Joint Genome Institute (JGI), which is one of three DOE Bioenergy Research Centres (which are pursuing basic research underlying a range of high-risk, high-return biological solutions for bioenergy applications) of the USA Department of Energy (DOE). These Bioenergy Research Centres are considered a relevant institution within the USA ‘National Plant Genome Initiative: 2009-2013’. The rationale of the project recognizes the importance that cassava has for feeding 600 million people worldwide, but the project is organized around other social priorities; i.e. the use of crops for the production of biofuels. It claims that the

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19 [www.jgi.doe.gov](http://www.jgi.doe.gov).
information it yields will enable the improvement to a wide range of crops ‘important for the USA’s biofuel supply’.\footnote{www.jgi.doe.gov/sequencing/why/51283.html, accessed 5 March 2009. The JGI has been also leading the sequencing of sorghum and soy, which are crops with similar social characteristics as cassava.}

Therefore, from the specific social relations organized around this new sequencing project of such a relevant crop, it follows that the primary application of the cassava genome information might be for the energetic purposes of North America rather than for poverty alleviation. Moreover and most provably, this means that \textit{scientific and technological structures in the South} are required for the implementation of the valuable information that this project will produce for enhancing for instance, the nutrient characteristics of the crop.

Another type of problem is related to lines of communication and application – the accessibility of new developments to those generally outside the orbit of the high tech labs, business boardrooms, and government departments. When genomics knowledge has been generated, there is a lack of public funds to support the efforts aimed at identifying and implementing connections between this upstream research and downstream applications for developing countries (Delmer 2005). One of the obstacles for transforming this knowledge into products is that of access to the knowledge and technologies. For example, due to the relatively high costs of marker assisted selection (Naylor, Falcon, Goodman et al. 2004, Reece and Haribabu 2007), it would seem mandatory that well founded research institutes allow free use of existing knowledge and technologies to multi-stakeholder networks within the poorest countries. This is now recognized within academic circles with an implicit agreement that some genomics activities, such as genome sequencing and comparing, should be conducted increasingly within this public domain precisely in order to avoid the problem of \textit{inaccessibility} to knowledge and technologies (Sulston and Ferry 2002, Delmer 2005, Hughes 2006, Fears 2007), especially when it comes to the use of theoretical and practical products for the purposes of addressing the agrarian problems of peasants.

As one of the institutions that might play a role in the deployment of functional genomics and marker assisted breeding within the agrarian systems of the poor, some attention has been given to the Generation Challenge Programme (GCP)\footnote{The GCP is a research and capacity building network which uses plant genetic diversity, advanced genomics science, and comparative biology to develop technologies that could enable plant breeders in developing countries to produce better varieties for resource-poor farmers in drought prone areas (www.generationcp.org).}\footnote{Source: www.cgiar.org/who/index.html, accessed 12 March 2009.} launched by the Consultative Group on International Agricultural Research (CGIAR) (e.g. Vroom 2009). The mostly public founded CGIAR spent a total US$560 million in 2007.\footnote{Source: www.cgiar.org/who/index.html, accessed 12 March 2009.} Over the period 2005-07 the GCP has expended US$14,057,317.\footnote{Source: www.generationcp.org/UserFiles/File/gcp-intro_dec2007.ppt#278,4,Finances, accessed 27 March 2009.} Nevertheless, it seems that the GCP is under-funded if it is to capitalize effectively on the advances in molecular biology (Hughes 2006, Fears 2007).

There are indeed some genomics developments which could improve the performance of agriculture in developing countries, but whose transformation into concrete applications seems to be a difficult task due to the lack of socio-technological structures in these countries which might facilitate that work.

\footnote{S. Hughes, personal communication, 12 March 2009.}
Economic exclusion

The knowledge produced with genomics technologies on living matters has greatly co-evolved together with economics, as it has been perceived as a newly financial opportunity. I.e., the transformation of the understanding of how genes are expressed and which role proteins play within that expression into (economically) useful organisms (Goujon 2001, Sulston and Ferry 2002). A rigorous measurement of the investments in agro-genomics is difficult because the explosion of the investment in this field is a relatively recent development (Fears 2007). Moreover, plant genomics, for instance, is just one part of the total plant agricultural research and development. Indeed genomics and other fundamental research might not be counted together with other applied sciences in calculating investments (ibid.); or, the other way around, many applications of genomics knowledge, such as MAS, might not appear in the figures which measure investments in pure genome analysis. Also, investments in microbial genomics might be not counted within plant genomics budgets, whilst the application of its outcomes could be relevant for agriculture. Nevertheless, we know that huge sums of money are involved and that the general trend of investment and expenditure in the genomics arena is continuing to rise rapidly, in the public as well as private sector.

Unsurprisingly, industrialized countries are making some heavy gross public investments in this sector. For instance, the member states of the European Union has placed at $1.3 billion the 2004-2009 benchmark expected expenditure for genome sequencing, functional genomics, or bioinformatics (EASAC 2004). While the USA National Plant Genome Initiative was estimated to have invested something like the same amount as the EU over the period 2003-2008 (NSTC 2003). In Japan, the RIKEN plant science and plant genomics centres invested $80 million (Fears 2007), while the Canadian Crop Genomics Initiative $70 million into plant genomics in canola, wheat, soybean, and corn (ibid.), and the Australian Centre for Plant Functional Genomics is investing $56.6 million over five years (part-contributed by grain companies), and its focus plant responses to abiotic stresses (drought and salt) in wheat, barley and other grain crops.26

Some of the larger developing countries have not only indicated their intentions to enlarge their public expenditure in agrarian R&D in recent years, but also specified targets. For instance, Fears (2007) reported that South Africa was committed to increasing its total public expenditure on R&D by a quarter, from a level of 0.8 per cent of GDP to more than 1 per cent, with plant biotechnology designated as a priority. Nigeria planned to create an endowment fund for science and technology worth up to $5 billion, enabling $500 million to be spent annually on research, with agricultural biotechnology as one priority area (ibid.). Public sector R&D budgets for China were not differentiated in terms of plant science/genomics, but its total R&D spending was expected to quadruple between 2005 and 2020, with genomics/proteomics a stated priority (ibid.). Vietnam would spend more than $60 million over the following 15 years on agricultural biotechnology including genetic modified (GM) crops and part of this investment would be used to train scientist (ibid.). India was spending around 0.1 per cent of its gross national product and 15 per cent of its total R&D expenditure on agricultural research and plant biology (Raghuram 2002). Mexico had recently allocated $250 million to agricultural R&D, focusing on alliance building between national research centres and producers (Fears 2007).

Much of the third world, however, is getting left badly behind in the new biotech race. China and India account for some 40 per cent of all expenditure made by the developing countries in this sector (Fears 2007). In this context, the power of private business – mostly

Western based international companies – motivated by financial rather than ethical drives, is extending considerably.

Whereas the public sector seems to have the leading voice on genomics basic research, the capitalization of this research is in the hands of the private sector. Private R&D investment expenditure is concentrated primarily in crop-protection chemicals (herbicides and pesticides) and genetic modification (crops and tools) for internationally tradable crops (cotton, maize and soybean) in countries with large scale, commercialized agricultural production systems (Spielman 2007). Private investment in agricultural research is increasing worldwide and is significantly larger than that of the public sector (Byerlee and Fischer 2002, Chataway 2005, Fears 2007, Spielman 2007, Vriend and Schenkelaars 2008). The major life science companies invested some $3.477 billion in 2002 (Spielman 2007). Only a small share of this private R&D investment is directed at third world countries (Fears 2007). Because of the high transaction cost in getting the technology to resource-poor farmers and the low profit margins (if any) that can be obtained from this social group (Pingali and Traxler 2002, Broers and Bunders 2005), the incentives for the private sector to invest in more marginal, subsistence oriented production systems are, at best, limited. Peasants, simply do not have the economic capacities required to become a significant target for industry, which needs revenues to match (i.e. surpass) the massive investments placed in upstream R&D.

In order to understand the magnitude of the private sector in agricultural research today, one only needs to compare its annual research budget to that of the public sector targeted to the developing country agriculture. One of the largest companies in this field, Monsanto expended more than US$780 million during 2007.27 Some 50 per cent more than the total annual budget for the same year of the largest international public-sector supplier of agricultural technologies for the third world, the CGIAR, whose investment amounted to US$506 million.28

This is far from being a comprehensive, authoritative survey of the field. These figures are not necessarily the latest, they are clearly not exhaustive, and their accuracy is challenged by factors such as the difficulty to access private sector information, or of isolate genomics investments from the rest of the investments in agrarian R&D (as mentioned). Nevertheless, they do give reasonable impression, sketching an overview of the concentration dynamics on the investments around genomics. No matter how difficult it may be to trace genomics investments both direct and those of its multiple spill-over activities, genomics is clearly a first world oriented business. Public and private sectors are increasingly interwoven in those countries. Although the basic research financed by the public sector of the industrially developed world is substantial, the investments of the private sector both in basic genomics and its capitalization are more dynamic than those of the public sector (Fears 2007, Hope 2008). One of the consequences that this trend provokes is that policy makers, and researchers of publicly funded institutes do not necessarily have control on the genomics R&D agenda, especially in poor countries.

Moreover, since science and technology are cumulative endeavours, then the effect on the subsequent knowledge and capacities of these inputs differentials might well be exponential, the gap between industrially developed and developing countries concerning science and (genomics) technologies even further extended by the actual differences in the amount of funds invested

27 The company concentrates the vast majority of its R&D efforts on new biotech traits, elite germplasm, breeding, new variety and hybrid development, and genomics research. Other R&D projects support the company’s current products, including improved formulations of Roundup herbicide. The annual R&D budget is targeted at roughly 10 per cent of sales (see: www.monsanto.com/investors/corporate_profile.asp, accessed 2 September 2008).

Genomics for Development?

(Pardey and Beintema 2001, CGIAR Science Council 2005, Pardey, Alston and Piggott 2006). However, this is not only a question of economic resources, but also, and increasingly, one of divergences in the R&D agendas between rich and poor (see Box 1.1). Pardey and co-workers show how the research agendas of rich countries are now shifting:

‘In particular, they are no longer interested in simple productivity enhancement. Dietary patterns and other priorities change as incomes increase. Food-security concerns are still pervasive among poor people, predominantly in poor countries. In rich countries we see a declining emphasis on enhancing the production of staple foods and an increasing emphasis on enhancing certain attributes of food (such as growing demand for processed and so-called functional foods) [...]’. Farmers in rich countries are demanding high-tech inputs that often are or not relevant or unaffordable for subsistence agriculture’ (Pardey, Alston and Piggott 2006; p. 2).

In other words, not only the concentration of investments in commercial agriculture, but also this divergence in the R&D agendas between rich and poor might jeopardize the capacity of poor regions of the world to apply the agrarian genomics technologies and knowledge that are now being globally produced.

Summarizing, genomics R&D is concentrated in the industrially developed countries of the world. Within the public sector agrarian R&D has become increasingly concentrated in few countries. Within the private sector there is a further concentration of investments within a small number of large multinationals. While basic genome research outputs are generally freely accessible (if one have the technologies and the know-how to do it), the technologies that allow for the capitalization of this knowledge are increasingly inaccessible. And as it has been suggested, the national agrarian research systems of the poorer countries and of international organizations (e.g. CGIAR) might be underfunded and therefore insufficient to apply locally globally produced genomics knowledge and technologies (Hughes 2006).

These concentration dynamics of genomics R&D decision-making, and the exclusion of peasants’ crops and problems as a target of the developments made in agro-genomics all contribute to making agro-genomics mainstream development a deterritorializing process (i.e. of peasant agrarian systems situated in the third and fourth worlds). Local networks that could implement these technological tools to strengthen their agrarian systems are, likewise excluded. In this context, it is not strange that when scholars speak about the idea of ‘genomics for development’ they mean a straightforward transfer of genomics to developing countries.

Transfer of technology as a remedial approach

Agro-genomics is developed by a relatively small number of researchers focussing on a relatively low number of crops that are relevant for global markets, which implies that peasants and their crops (their agrarian systems) are usually excluded from the decision-making processes of agrarian genomics. Thus it follows that the claims made by some policy makers and researchers on the potency of genomics technologies for addressing peasants’ needs are mainly based on the transfer of technology approach (Delmer 2005, Bruskiewich, Davenport, Hazekamp et al. 2006, Louwaars, Thorn, Esquinas-Alcazar et al. 2006). In the context of a technology transfer approach there are some relevant social aspects concerning technology that should be considered. Firstly, as mentioned above, technologies are systems formed by social and technical elements (Bijker, Hughes and Pinch 1987, Ihde 1990, Sclove 1995, Feenberg 1999). Therefore, a technology that
has been developed within a concrete social context can hardly be transferable to a different place, especially if that place is not characterized by an equal or similar social context sufficient to receive the technology. There is no technology that does not belong to a social system. Moreover, the adaptation of a transferred technology should fit within existing practices. Therefore, for instance, a Polymerase Chain Reaction (PCR) machine – an apparatus widely used for genomics applications – is of no use if transferred to a lab where nobody knows how it works, how to repair it, or if the lab does not have the economic resources necessary to pay the expensive polymerase enzyme required for making the reactions. Moreover, the adaptation of a transferred technology should fit within existing practices. Therefore, for instance, a Polymerase Chain Reaction (PCR) machine – an apparatus widely used for genomics applications – is of no use if transferred to a lab where nobody knows how it works, how to repair it, or if the lab does not have the economic resources necessary to pay the expensive polymerase enzyme required for making the reactions. Therefore, as mentioned, local multi-stakeholder networks are indeed essential in order to access and adapt (territorialize) global genomics knowledge and technologies.

Commonly, peasants have little or no access at all either to decision-making in designing research agendas or to the agrarian genomics applications. This is also true for civil society organizations. For example, a recent review of partnerships in crop biotechnologies in Africa including the applications of molecular markers observed that the partnerships of most of the projects studied had originated outside of national agricultural systems and were not clearly linked to national developmental goals (Ayele, Chataway and Wield 2006). Projects are usually financed by donors – bilateral, multilateral and a few private sector donor organizations, such as the Rockefeller Foundation (based in New York, USA) and Syngenta Foundation (Basel, Switzerland), in partnership efforts that tend to be science-driven and not always linked to users demands:

‘although project initiation methodology invariably refers to a participatory approach and commitments to capacity building and pro-poor agendas, some of the projects we studied tend to start with given solutions (influenced by personal, professional and commercial interest) and considerations of need assessment and delivery systems to end users often become an ex-post exercise’ (Ayele, Chataway and Wield 2006; p. 621).

Ayele and colleagues stress also that donors are inclined to select countries with some existing capacity in agro-biotechnologies (ibid.), leading to the tendency to exclude countries or regions with a weak scientific structures – a specification that correlate with the countries and regions that might most need support. Rich countries are increasingly focussing on technologies which require ever more complex capacities in terms of technical matters, informatics-knowledge, and intellectual property rights. This again means that technologies might be increasingly inaccessible for poor regions (Pardey, Alston and Piggott 2006, Deibel 2009), in spite of the actual efforts around the transfer of technologies.

In addition to this, even when science and technology are consciously transferred to resource-poor farmers’ fields, they are not always directly translated into concrete applications within these agrarian systems. This can be caused by, for instance, the lack of the social capacities (at the different localities) that are needed to understand and to engage with the technological developments. For example, concerns have been raised with the linear model of the CGIAR system in which technologies and knowledge are developed in one or other of its research centres fully dedicated to agricultural matters and passed down the line to national and then local research institutes and extension systems, eventually to be delivered into farmers’ fields (Hall, Yoganand, Crouch et al. 2004, Chataway 2005). These concerns are based on the

29 The problems related with the use of the PCR machine in labs with low technical and economic capacities are further elaborated in Chapter 4.
fact that this linear model can only work on the premise that the local research institutes and stations do indeed exist and that they have the capacities to adopt and adapt the knowledge and technologies that are sent to them; the opposite is usually the case.

Technological developments do not always have the expected results for which they are designed. For instance, Pardey et al. (1996) showed that research conducted in rice and wheat aimed at strengthening resource-poor farmers agrarian systems have had other important beneficiaries: ‘The U.S. investments in international agricultural research on wheat and rice were made primarily for humanitarian reasons, and they have been extremely effective at reducing poverty and hunger in developing countries. But they have also yielded direct economic benefits for the United States that far outweigh the U.S.’s investments. CIMMYT’s breeding achievements have generated U.S. benefits as high as 190 times the total U.S. contribution to CIMMYT’s wheat improvement budgets, while IRRI’s work in rice has realized U.S. returns of as much as 17 times the U.S. investment in rice research through the CGIAR’ (ibid.; p. 16).

Another actual example of the unexpected consequences which transferring some biotechnologies might have refers to their effects on the existing local agricultural and ecological systems. An example of this is provided by Delmer in her survey of the links between global advances in plant sciences and their application in developing countries. She states that ‘a recent example is the Roundup Ready soybean, which has been a huge success for the farmers of Argentina and Brazil but may be promoting a debatably dangerous trend toward monoculture and expansion of farming into valuable sites for biodiversity’ (Delmer 2005; p. 15742).

Clearly, the kind of simplistic understanding of a straightforward technology transfer in which technologies are first decoupled from their social character and then sent to a different context is likely to lead to a failure of even the best intentioned action in achieving its original purpose. Given the major problems linked to biotechnological development in developing countries, the need for the construction of new models becomes all the more acute. It is this need that the concept of ‘local sustainable biotechnological development’ seeks to meet, assuming the perspective of socially informed technology and emphasizing the territorial perspective of peasant agricultural systems.

There have been a number of theoretical studies concerning the strengths of genomics for small-scale agriculture (Delmer 2005, Bruskiewich, Davenport, Hazekamp et al. 2006, Louwaars, Thorn, Esquinas-Alcazar et al. 2006, Ruane and Robinon 2006). Nevertheless, some scholars (Delmer 2005, Fears 2007, Reece and Haribabu 2007) suggest that the weakest link between agro-genomics and peasants’ fields is the inadequacy or the lack of local social structures with the capacity to understand, access and transform the globally available knowledge and technologies into material (technological) applications attuned to the local needs. Few empirical studies have been conducted on the potentialities and constraints of the development of genomics emerging from concrete social realities. This thesis assesses the ongoing efforts of biotech networks to develop biotechnologies and genomics attuned to specific peasant agrarian systems.

30 The International Maize and Wheat Improvement Centre (CIMMYT – Centro Internacional de Mejoramiento de Maíz y Trigo) is a CGIAR centre.
31 The International Rice Institute (IRRI) is the CGIAR dedicated to rice.
1.3. Central academic issues

Turning to thesis structure, this section states the issues central to this research and its presentation, in terms of its scientific problem, the research aim and the formulation of questions of inquiry.

Scientific problem

In the context of an increasingly deterritorialized development of agrarian genomics from the perspective of peasants’ territories and their needs, the scientific problem of this thesis is to explore how multi-stakeholder networks formed mainly by peasants, civil society organizations, and scientists from the so-called developing world attempt to develop biotechnologies and genomics locally and sustainably – territorially.

Research aim

This thesis aims to go beyond the mere illustration of biotechnologies as systems formed by material and social elements, although this issue is theoretically and empirically examined. Here, the overarching goal is to explore the power dynamics engendered by multi-stakeholder networks to territorially develop biotechnologies in general and genomics in particular aimed at addressing some of the agrarian needs of peasants.

Furthermore, it intends to gain a better understanding of how a territorial development of biotechnologies might strengthen peasant agrarian systems – through the development of local specific biotechnologies – and empower peasants, civil society organizations and local researchers within biotechnological structures. Also, it is aimed at shedding some light on the material readjustments required for attuning biotechnologies to locality specific capacities and needs. This exploration is conducted at the three interrelated domains of local sustainable biotechnological developments, namely: the territorial (power and locality), the technological (power and technology’s material elements), and the domain of reterritorialization (empowerment). Empirical studies have been conducted in the form of three case studies. The case studies are aimed at supporting this conceptualization; i.e., the cases are, to a certain extent, illustrations of the guiding central concept of this thesis, local sustainable biotechnological developments.

Questions of inquiry

An initial literature analysis resulting in the previous background section (1.2) outlines a situation in which agro-genomics applications tend to ignore, or fail to fully meet the problems of peasants, and strengthens the assumption that local actors seem to be excluded from agro-
genomics research decision-making processes. This thesis argues that local sustainable biotechnological development might emerge as an alternative for this situation. In order to gain a better understanding of some of the strategies employed by local multi-stakeholder networks, both to solve peasant’s agrarian problems and to gain power in the genomics research decision-making process – i.e. to territorialize biotechnologies – the central research question addressed here is:

To what extent do local sustainable biotechnological developments appear to be a viable territorial alternative to the currently prevalent deterritorializing development of biotechnologies and of genomics for and within peasant agrarian systems?

In order to answer this central research question, four research sub-questions are formulated which are related to the three analytic domains of local sustainable biotechnological developments outlined and which will structure the research of the case studies. The first and the second research questions concern the first (territorial) and the second (technological) analytic domains respectively. The last two questions are related to the third analytic domain (reterritorialization).

I. What (social) power relations unfastened by local multi-stakeholder networks formed by peasants, civil society organizations, and researchers strengthen peasant agrarian systems through the development of local specific biotechnologies and empower these networks within genomics socio-technological structures?

II. What material redesign processes are conducting these networks to attune biotechnologies to local specific capacities and needs?

III. What new dynamics bring about local sustainable biotechnological developments within the historical trends of industrialization and biotechnologization of agriculture?

IV. Whether and how are the local sustainable biotechnological developments analyzed empowering the territories where they occur for future negotiations in biotechnological developments?
1.4. Research methods

‘Avoid any rigid set of procedures. Above all seek to develop and to use the sociological imagination. Avoid the fetishism of method and technique. Urge the rehabilitation of the unpretentious intellectual craftsman and try to become such a craftsman yourself. Let every person be her/his own methodologist; let every person be his/her own theorist; let theory and method again become part of the practice of the craft’ (Mills 1959).33

Technological developments are ambiguous processes. Technology embodies emancipatory as well as oppressive potentialities, depending on what kind of technology it is, which kind of individuals or social groups are involved in the development process, and the different meanings assigned by the final users. That is why, argues Schurman (2003), it is not difficult to imagine liberatory moments as more negative scenarios. The position of this thesis in relation to biotechnologies goes beyond empirical analysis of the ongoing co-evolution of technology and society at the micro-level, to further link up this co-construction with political dynamics at the micro, meso and macro levels. More specifically, this research concerns the politics of genomics and its possible territorialization within the reality of the rural poor in the so-called developing world. From this ontological position, the epistemological approach – i.e. to know how the politics of biotechnologies actually happens and how they ought to be reconstructed from a territorial perspective – takes the shape of case studies.

Some scholars have argued that the politicizing potency of biotechnologies in rural societies form a kind of prolongation of the colonial domination (Apffel-Marglin 1996). Given the realities of the globalized world, it seems as if the choices that peasant, peasants’ groups, local researchers and civil society organizations in the rural areas of the third and fourth worlds have consist of either just rejecting or being assimilated by these global tendencies. Nevertheless, there are other types of political dynamics operative within biotechnologies in development, and which are generated by multi-stakeholders networks formed by scientists, peasants, peasants’ groups, and civil society organizations working at the rural community level. Their attitude towards global biotechnological developments is neither one of rejection nor of passivity, but one aimed, rather, at reconstructing biotechnologies to fit local needs and capacities. This research focuses on these dynamics.

Based on these epistemological choices, this research explores three selected case studies at the three interrelated domains of local sustainable biotechnological developments:

- The territorial domain analyses the social strategies (power) to deploy genomics in a given agrarian system (local). In this domain the theoretical inspiration comes from Local Self-Sustainable Developments (Magnaghi 2005b), Another Development (Hettne 1995), Endogenous Developments (Ploeg, v.d. J.D.), Tailor-Made Biotechnologies (Ruivenkamp 2008a), and Territoriality (Sack 1986, Magnaghi 2005b).
- The technological domain employs the conceptual tools of Social Constructivism (e.g. Pinch and Bijker 1987, Bijker 1995b, Sclove 1995), Social Shaping of Technology

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32 This sentence has been adjusted in the interests of gendered-neutrality.
33 Quoted in John Gerring (2001; p. 3).
Genomics for Development?

(Mackenzie and Wajcman 1985), Actor-Network Theory (e.g. Callon 1986, Law 1986, Latour 1987), and Critical Theory of Technology (e.g. Feenberg 1999).

- **The domain of reterritorialization** elaborates on how local sustainable biotechnological developments influence or are influenced by historical and global trends in the development of biotechnologies, working with concepts such as ‘appropriation’ and ‘substitution’ (Goodman, Sorj and Wilkinson 1987), ‘control at a distance’ (Ruivenkamp 1989, 2005b), and ‘scientification’ (Ploeg 1987).

The relationship between the three domains and the different theories will be unfolded in the following chapter. Moreover, the thread of continuity through the different levels is that within all three domains it is assumed that the material and social dimensions of biotechnologies co-construct each other in the development process, and that this co-construction can be influenced by human agency. This basic assumption has guided an abstraction and generalization from the analysis of the case studies towards an understanding of the political and politicizing nature of biotechnology and genomics – as socio-technological systems. Each level of analysis includes the following cross cutting themes:

- Relationships between power and knowledge in the construction and reconstruction of biotechnologies in development.
- Contradictions and complementarities, and continuity and change within the historical process of industrialization and biotechnologization of agriculture.
- A search for alternative trajectories for the deployment of genomics within peasant agrarian systems.

**Qualitative technology research**

Qualitative methods (see Box 1.2) have been implemented to achieve the research aim of analyzing local specific developments of biotechnologies and genomics. Although some simple quantification has been introduced, this research is mainly a qualitative study. The reason why quantitative research has not been employed is not of an ideological nature, but it is related to the particular research problem and object of this research. The aim is to critically reflect on biotechnology development patterns that could strengthen both the agrarian daily activities of resource-poor farmers, and the position of peasants, peasants’ groups, civil society organizations, and local researchers in the decision-making processes of genomics socio-technological structures. These phenomena are difficult to measure numerically, and therefore a qualitative approach seems to be more adequate than a quantitative inquire. Moreover, a high degree of interdisciplinarity is required to address technological issues sociologically, as large set of variables of different nature have to be considered. Qualitative research seems also to be an appropriate approach because the interest here is to understand the social side of the biotechnological developments. The degree of expertise required to make strong statements

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34 Quantitative research uses numbers and statistical methods. It tends to be based on numerical measurements of specific aspects of phenomena; it abstracts from particular instances to seek general description or to test causal hypotheses; it seeks measurements and analyses that are easily replicable by other researchers (Grarry, Keohane and Verba 1994; p. 3).
concerning the material elements of the technological developments is far from the scope of this research – probably a quantitative approach could be effective in testing issues such as efficiency or environmental risks or ecological potentials of the technologies involved. Nevertheless, some technical discussions are also integrated within the analysis because at certain moments the material and social dimensions of technology are indissoluble, and therefore, an interpretation of both dimensions becomes unavoidable.

**Box 1.2. Qualitative research**

‘Qualitative research is an interdisciplinary, transdisciplinary, and sometimes counterdisciplinary field. It crosscuts the humanities and the social and physical sciences. Qualitative research is many things at the same time. It is multiparadigmatic in focus. Its practitioners are sensitive to the value of the multimethod approach. They are committed to the naturalistic perspective and to the interpretive understanding of human experience. At the same time, the field is inherently political and shaped by multiple ethical and political positions.

Qualitative research embraces two tensions at the same time. On the one hand, it is drawn to a broad, interpretative, postexperimental, postmodern, feminist, and critical sensibility. On the other hand, it is drawn to more narrowly defined positivist, postpositivist, humanistic, and naturalistic conceptions of human experience and its analysis. Further, these tensions can be combined in the same project, bringing both postmodern and naturalistic or both critical and humanistic perspectives to bear’; Denzin and Lincoln (2003a; p. 11) paraphrasing Nelson et al.’s (1992; p. 4) attempt to define cultural studies.

What in quantitative research is termed correlation or covariation, might be called pattern in qualitative research. Qualitative research gives higher priority to interpretation than to measurements (Stake 1995, Denzin and Lincoln 2003b). Erickson (1986) argues that, because of this priority, qualitative findings are not so much ‘findings’ as ‘assertions’ that the researcher comes to offer a personal interpretation of a certain phenomena. Interpretation can be easily associated with personal views. Stake argues that much of qualitative research is personalistic studies: ‘Impersonal issues applied to carefully observed human beings become personal issues’ (Stake 1995; p. 46). Due to the personal character of qualitative research, an effort for reflectivity is required. Alvesson and Sköldberg argue that a conscientious researcher must be reflexive, which means ‘interpreting one’s own interpretations, looking at one’s own perspectives from other perspectives, and turning a self-critical eye onto one’s own authority as interpreter and author’ (Alvesson and Sköldberg 2000; p. vii). Alvesson and Skölberg propose a multilayered, flexible structure of interpretation and reflection, which takes place at various stages of the research. The researcher moves back and forth between empirical material and various kinds of theories (in a kind of hermeneutic circle), letting the data generate larger reflection, letting the reflection generate the perception/use of more/different data, and so forth. They name this approach ‘reflexive interpretation’ (Alvesson and Sköldberg 2000; p. 247). When conducting the present research, an ongoing dialog has occurred between choices made at the theoretical level, the collection of data, the interpretation, and the work of writing. Of course, this personal reflective labour is supported and encouraged by the work of others who have got access to the different levels that compose the research. Finally, the validity of descriptions and of

35 In the present case, see Acknowledgements, or the sub-section on the ‘Validation of data: Triangulation’ near the end of this chapter.
interpretations is increased along with the reliability of the findings, through feedback in the form of critical review – including, as here, that from (part of) the population comprising the subject of the research.

It might be argued that the central element of this thesis is the interpretation rather than the representation of reality on the basis of the collected data. This is not a value-free choice. This implies that there is no such thing as unmediated data or facts. Facts in this case will be regarded as the result of interpretation. Moreover, since from the perspective afforded by this type of qualitative approach facts (and artefacts) are always context dependent. Therefore, one of the methods that is usually preferred within these parameters for the collection of data is that of case studies. This is also the case in this research.

**Case study as research method**

‘Since we can not accurately measure “degree of fascism”, we look to the most extreme cases of this phenomenon – Germany and Italy – to tell us about what fascism meant, or would have meant, in other places’ (Gerring 2001; p. 218)

The empirical analysis has been conducted in the form of case studies. A case study can be defined as a research unit. Stake (1995; p. 2) defines it as an integrated system with boundaries and working parts. It is purposive and even has a self. Stake (1995; p. 3) differentiates between two kind of cases. Firstly, there are intrinsic cases; cases which have their own intrinsic value, in which we are interested because we want/need to learn about them, those cases in particular. Secondly, there are instrumental cases, cases whose study offers opportunities for insight into a research question, a puzzlement, which we use in order to achieve a general understanding, to get insight into the question by studying a particular case. These are the type of cases that are employed for this research. The analysis of the cases selected here aims at obtaining a better understanding on the local specific development of genomics and the possible empowerment strategies linked to that process. Therefore, cases have been chosen on the basis that they might represent illustrations of the alternative local and sustainable development of biotechnologies in territories characterized by peasant agrarian systems.

A research conducted with case studies usually produces context dependent knowledge. Indeed, some scholars have argued that when studying human affairs there is only context dependent knowledge (Scott 1998, Flyvbjerg 2006). Since technology is also a human affair we might assume that for a truly understanding of a technological development, a case oriented approach is not only insightful, but it is probably necessary. This methodological choice has some consequences for the type of interpretations/conclusions we are to make. Flyvbjerg puts it in this way: ‘Social sciences has not succeed in producing general, context-independent theory and, thus, has in the final instance nothing else to offer than concrete, context-dependent knowledge. And the case study is especially well suited to produce this knowledge’ (Flyvbjerg 2006; p. 223). The question whether social science has or has not been able to produce context-independent theory is indeed an interesting one, but for the modest scope of this research it is enough to assume that case studies are instances of peasants’ problems related to biotechnology.

36 For a more in-depth study into case studies in the social science see: e.g. Ragin and Becker 1992.
specifically in the context of the local development of genomics (and other biotechnologies) and conceptual perspectives such as empowerment or territorialization. The research conclusions are based on the analysis of these cases.

In order to elaborate more general trends from these case-related (therefore context dependent) conclusions, a review of the most relevant literature in the field of ‘biotechnology in development’ has been also conducted. From this literature review, Section 1.2 (above) has sketched a situation in which genomics is mainly developed in a deterritorializing fashion (from the perspective of peasant agrarian systems). It is in the light of this that the conclusions have been formulated in general, global terms. However, given that these emerge from the case study research, they are presented as alternative trajectories to that mainstream deterritorializing developmental path of genomics. Each case constitutes a specific alternative trajectory that exemplifies the global conclusions drawn from the thesis as a whole.

Insofar as deterritorializing development is a disputed convention of contemporary innovation in genomics, these case studies and their territorial alternative trajectories could contribute to the possible emergence of a paradigm shift, as explicated by Thomas Khun. Insofar as the convention is asserted without dispute – or just assumed, unconsciously, as though there could be no other way forward – this work operates as a falsifier in the sense of Karl Popper. Recalling that Popper formulated his falsifiability principle for general truths with the example of the proposition ‘all swans are white’ – which can never be positively verified, but is disproved by the finding of just a single black swan – then, in a general context of a deterritorializing approach of genomics developments (white swans), this thesis presents the contrary possibility of local sustainable development. Each of the case studies is a black-swan illustrating alternative developmental trajectories for the local sustainable development of biotechnologies and genomics within peasant agrarian systems.

Case’s selection criteria

Case studies have been utilized to gain a further understanding of the research questions (above). Clarification of the deeper causes of the research problem, and the social and socio-technological relations operative and their consequences arising within the cases studied have been considered more important than the description of problem symptoms, or how frequently these types of local developments occur. Flyvbjerg argues that random samples emphasizing representativeness will seldom be able to produce this kind of insight, and states that it is more appropriate to select some few cases on the basis of their validity (Flyvbjerg 2006). He differentiates between two main types of selection procedures: random selection and information oriented selection. The former has the purpose of avoiding biases in the sample. In this type of selection, the sample’s size is decisive for generalization, needing to be representative so as to be able to generalize for the studied society or social group. The later has the purpose of maximizing the utility of information from small samples and single cases. The cases analyzed in this thesis have been chosen through the latter, on information oriented criteria. Cases are selected on the basis of expectations about their information content.

Statistically-based representations of local sustainable developments of biotechnologies and genomics for resource-poor farmers could probably be achieved with a statistics formula. However, the variables that interest us – technology, development, empowerment, territoriality –
inevitably take us into the terrain of subjectivity and interpretation. In other words, we move into a qualitative methodology – for which reason the positive decision to opt for an information oriented selection of cases.

Having opted for an information oriented selection the next decision to be made concerns the information approach: what type of information should the case studies seek to reveal? Flyvbjerg (2006; p. 230) classifies case studies within the information-oriented selection strategy as of four types, which get at four different types of cases, viz. extreme or deviant, maximum variation, critical, and paradigmatic (see Table 1.1).

<table>
<thead>
<tr>
<th>Type of cases</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Extreme/deviant cases</td>
<td>To obtain information on unusual cases, this can be especially problematic or especially good in a more closely defined sense.</td>
</tr>
<tr>
<td>2. Maximum variation cases</td>
<td>To obtain information about the significance of various circumstances for case process and outcome (e.g. three to four cases that are very different on one dimension: size, form of organization, location, and budget).</td>
</tr>
<tr>
<td>3. Critical cases</td>
<td>To achieve information that permits logical deductions of the type, “If this is (not) valid for this case, then I applies to all (no) cases.”</td>
</tr>
<tr>
<td>4. Paradigmatic cases</td>
<td>To develop a metaphor or establish a school for the domain that the case concerns.</td>
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</tbody>
</table>

Table 1.1. Types of selection and of cases and their purposes (Flyvbjerg 2006; p. 230)

The cases selected for this research were chosen for their capacity to illustrate territorial dynamics for the reconstruction of biotechnologies socio-technical structures within local development. These cases work as empirical bases from which emerges the conceptual framework of local sustainable biotechnological developments – and thus, of Flyvbjerg’s four types, their employment here most resembles paradigmatic cases. Paradigmatic cases highlight more general characteristics of the societies in question, or of the development at stake. In this respect, Kuhn has shown that scientific paradigms cannot be expressed as rules or theories (Kuhn 1970). However, as Flyvbjerg (2006; p. 232) explains, a paradigmatic case operates as a reference point and may function as a focus for the founding of schools of thought. Notwithstanding this paradigmatic function of the cases chosen, they can also be understood in other ways. Chosen, for example, because of their particularity within the assumed dominant deterritorializing development of agrarian genomics from the perspective of peasant systems, the cases are more like the type of deviant cases. And, if certain strategies in these cases have worked to empower peasants, then, some of the details of these strategies could be tested in other cases, or used to inform the organization of new biotechnological developments. This would classify them as critical cases. Indeed, Flyvbjerg argues that the various strategies of selection and types of cases are not necessarily mutually exclusive.

More specifically, the criteria used for the selection of the cases studies in this thesis have been as follows:
1. Coverage of a range of different territorial and cultural differences with the core context of peasant agrarian systems
2. Coverage of a cross-section of biotechnological developments emphasizing genomics applications
3. Coverage of a range of end-applications illustrating the different ways in which biotechnologies can provide agrarian services to peasant societies, with an emphasis on providing locally relevant applications
4. Focus on small-scale initiatives with clear local participation and leadership of peasants, peasants’ groups, civil society organizations, and local researchers

One of the key challenges in choosing cases has been that genomics is a relatively newcomer particularly in third world countries, which means that the projects selected are in a relatively early stage of implementation (especially in the second and third cases, Chapters 4 and 5). One consequence of this is that wider challenges and lessons are at the forefront of the developments. This was regarded as a positive feature for the research as the lessons learnt from the design phase and from the initial responses to these developments are important for an understanding of the mechanisms unfastened by the application of genomics in the context of pre-existing peasant agrarian practices and social frameworks. This is, after all, the basic dynamic which the territorialization of genomics in peasant agrarian systems faces. It might be helpful for policy makers and other actors taking part in biotechnological developments to gain knowledge on how these alternative ‘local sustainable biotechnological developments’ are – have been, can be – organized.

With these criteria in mind, a search of cases was conducted through the World Wide Web, literature research, and personal communication with persons who have some degree of expertise in the research topic. Three cases were selected, studied, and are fully analyzed.

Three cases

**Case 1** (Chapter 3): Territorializing the production of a Bacillus thuringiensis biopesticide within the context of peasant agriculture in Andhra Pradesh, India

This case explores the development of bio-pesticides for pest-management in the peasant agrarian systems of the semiarid districts of Mahaboobnagar and Nalgonda, in the state of Andhra Pradesh, India. In these territories, the main cultivated crop is castor (Ricinus communis L.). The castor semilooper (Achea janata) is one of this crop’s most serious pests causing heavy losses in the production of castor. The majority of chemical and bio-pesticides that are available within the territory to address this problem are not affordable and/or not suitable for peasant practices. This case study looks at how the human and natural resources of the territory are being mobilized to address castor semilooper through biotechnological means. Based on local strains of the soil bacteria Bt (Bacillus thuringiensis) effective against semilooper – strains studied with genomics

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37 During January and February of 2005, a round of semi-structured interviews was conducted within the Wageningen University and Research Centre with experts in the two fields of biotechnologies and of development. The aim was partly to gain a better understanding of issues concerning biotechnologies in development, and partly to explore this field and search for possible cases.
technologies –, multi-stakeholder networks formed by peasant groups and civil society organizations, public research institutes and agricultural extension systems have developed a process to produce a Bt spray to manage castor semilooper which is cost-effective and which requires technical capacities that can be reproduced on a small-scale at village level. Then, a decentralized system of production-units has been established in some villages to manufacture and distribute the Bt spray. Not only is the Bt spray produced here, but so also are other bio-pesticides and bio-fertilisers manufactured that are adapted to local needs and capacities.

This case focuses on the material redesigning process of production of Bt biopesticides production in the form of sprays. Bt sprays are normally produced by a liquid-state fermentation, but the network has developed a new production process, a solid-state fermentation. This redesigning makes production possible as outlined. The case shows that the social and material rearrangements around the Bt spray create a new understanding of the territory and of the development of biotechnologies. Biotechnologies are not longer developed somewhere else and ‘dumped’ in peasant territories, but are developed from the bottom-up. Moreover, peasants and civil society organizations are empowered in the development of appropriate pest-management technologies, and are therefore, also empowered within their own territory.

Case 2 (Chapter 4): The Wiphala Genomics: the territorialization of molecular markers in small-scale potato crop systems in the Bolivian Andes

The second case addresses the deployment of molecular markers (MMs) within the small-scale and highland potato crop systems of the departments of Cochabamba and Norte de Potosí in the Bolivian Andes. In these territories, the rich diversity of farmers’ potato varieties is essential for the survival of peasants’ households, as its usage is strategically vital in the high-diverse ecosystems of Andean Highlands. Moreover, potato diversity also has an important cultural meaning for the Quechua and Aymara populations that live in these territories. Unfortunately, this diversity is apparently decreasing.

This case outlines two contradictory understandings of potato diversity. On the one hand, potato biodiversity is understood as raw material. From this conception it follows that peasants’ varieties have no intrinsic value, value is added by breeders in breeding projects. On the other hand, biodiversity is understood as cultural material. From this conception it follows that potatoes are final entities created by peasants, and therefore they do have an intrinsic value. It is argued here that it is worth developing biotechnologies aimed at addressing the problems of local varieties. It is suggested that the deployment of markers within the cultural understanding of biodiversity (termed the ‘Wiphala Genomics’) has potentialities to address some agrarian constraints of peasants. Furthermore, certain participatory plant breeding networks are identified as appropriate social platforms for the deployment of MMs, platforms that are already shaping the Wiphala genomics.

This case also explores the material readjustments that MMs need to undergo if they are to be able to perform properly within Bolivian territories. Ultimately, the case reflects on how, when MMs are deployed within a raw material understanding of diversity, then for instance, the potato diversity tends to be extracted from the territory and appropriated by global networks to serve as basis for plant breeding outside the territory. Contrary to this, the territorially-based development of the Wiphala Genomics empowers Quechua and Aymara peasants within

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38 Participatory plant breeding could be defined as the development of new plant varieties through collaboration between farmers and formal plant breeders.
biotechnology systems, and strengthens the conservation and development of potato’s genetic variety and productive diversity. Therefore, by deploying MMs with a specific social and technical code, the developmental capacities of these Andean territories can be strengthened.

**Case 3 (Chapter 5): Biotechnologizing Jatropha for local sustainable developments in Yoro, Honduras**

Finally, against the background of an expanding bio-fuels regime within agriculture, the third case explores the ongoing efforts of local multi-stakeholder networks formed by peasant groups, NGOs, and research institutes in the department of Yoro, Honduras to give a new energy meaning to *Jatropha* that traditionally has been used for other purposes (e.g. as living fences for cattle, for the production of soap or for medical purposes.). Then, the structure that is constructed for the local and sustainable production and consumption of biofuel is analyzed.

This case also addresses the scientification and biotechnologization process (through genomics) that Jatropha is presently undergoing. With this purpose in mind, the case focuses on a globally oriented genomics network that is working with Jatropha. Coordinated from the Netherlands, this network is engaged in collaborations with local networks (including the Honduran) which might lead to an improvement of the local production of Jatropha. The case study focuses on the interaction between these two networks, that is on how the scientification and biotechnologization process that Jatropha is undergoing might strengthen the local development in Honduras.

**Some failures**

Some interesting cases have been discarded along the way on this research journey. This has happened, for instance when a case did not match the selection criteria, or else for reasons outside our direct control. Two cases are introduced here as in illustrations of these cases that failed to make the final selection.

Firstly, an example of a case that did not matched the required selection criteria was a project aimed at ‘bringing tomato genes back to the Andes’. This project was based on a ‘sustainable tomato production and breeding for marginal areas in the Andean highlands’ and attempted to ‘alleviate poverty’. Within the project there was one Bolivian research organization which had the required genomics capacities (i.e. the project met case selection criteria 2 and 3). Moreover, it was reported that conversations, and trainings had been initiated started with farmers, some of whom were resource-poor (criterion 1). The project was coordinated by a development oriented foundation with proven experience in participative plant breeding based at the Wageningen University and Research Centre (NL). The project appeared to be very promising.

Initial exploratory research, however, revealed that the possible genomics research within this case (for developing tomato seeds) was to be one conducted by Dutch seed companies, which were also considered as stake-holders. The most relevant publicly presented topic of this project was the capacitating of farmers (mostly medium-scale) to produce tomatoes in glasshouses. In other words, if somebody spoke in the project about technology, it was concerned with the transfer of glasshouse technology. Farmers would just buy the seeds (with the integrated
genomics knowledge) provided from the Netherlands. This project was then discarded as a possible case, because it didn’t meet criterion 4, which states that a local leadership should be exercised on the biotechnological development. In this project, peasants seemed to be just passive consumers of final biotech products (tomato seeds) which work with codes that had been written elsewhere by the agro-industry. Contrary to first appearances, this project was just reinforcing the idea of a deterritorializing biotechnology development. This swan was white.

Another case that was abandoned was a study of ‘the local specific production of bacteria based biofertilizers within the Cuban Urban Agriculture Movement’ (CUAM). The Urban Agriculture Movement is an agrarian set of practices linked to urban environments formed by multi-stakeholder networks in Cuba. It links urban farms, research institutes, farmers’ groups and trade unions, and local and national governmental organizations. The general objective of the CUAM is to increase food security in urban and semi-urban areas by ensuring a direct offer of fresh and healthy foods to the population. Apparently, the increase in food production is realized by combining practical knowledge of the population and recent scientific results combined with well-established collaborative and feedback relationships between producers and scientists. Within CUAM’s institutional context three new biofertilizers had been developed. The literature on this topic indicated that the applications of these products in the town-gardens has resulted in increased harvest levels and decreased production costs (Gómez, Sánchez, González et al. 2006). Because not all the strains of microbial species perform in the same way concerning for instance the fixation of nitrogen for different types of crops and of soils, scientists attached to one local research institute were collecting bacteria with biofertilizer properties from different regions and soils of the Caribbean island. Moreover, fermentation technologies had been developed for the different microbial species fixing nitrogen and producing microbiologically active substances. Apparently, semi-artsesian production units had been built to produce the biofertilizers in three municipalities (Nodals 2004). The result could thus be characterized as local specific biofertilizers.

Moreover, the technologies employed during the development of the products to find out the efficiency of the micro-organisms (to determine the production of vitamins, amino-acids and peptides of low molecular weight) were biochemistry techniques like the High Performance Liquid Chromatography (HPLC) or electrophoresis. In the initial stages to analyze the efficiency of the micro-organisms with these technologies, the studies where mainly conducted in collaboration with a Swedish university; now, they are conducted by Cuban research centres.

This case appeared to be an appropriate choice as HPLC was considered as one of the technologies which might fall within the spectrum of genomics related technologies (Criterion 2). Moreover, the local specific biofertilizers (Criterion 3) were supposedly oriented towards peasants’ systems (Criterion 1) and also seemed to have been territorially developed as local multi-stakeholder networks most likely self-managed the process (Criterion 4). Nevertheless, and

39 For more information about the CUAM see e.g. Altieri, Companioni, Cañizares et al. 1999, Murphy 1999, Premat 2005.
40 Nationwide urban agriculture efforts account for almost 60 per cent of all Cuban vegetable production (Bourque and Cañizares 2001)
41 Some scholars have restricted genomes and genomics to chromosomal DNA and the technologies of decoding it. Genomes and their gene activities are engaged in cellular and organism processes for which techniques like 2d electrophoresis and HPLC are appropriate analytical tools. Importantly, soil microbes function as consortia and the amendments seen in biofertilizers seek to bias and enhance these consortia. The effects of these consortia will be subject to analysis by Polymerase Chain Reaction or this other techniques (Steve Huges, personal communication, February 2007).
rather unfortunately, a decision to discard this promising case was made, due to the excessive bureaucratic procedures demanded by the Cuban state to conduct the field work.\(^{42}\)

**The collection of data**

The collection of data has followed a similar schema in each of the three cases. The preliminary phase consisted of the collection of case-related background information through a literature study, the Internet, and personal communications with key actors involved in, or with knowledge about the cases. Then, a research project proposal was written which presented the case background, research problem, main questions of inquiry, and a provisional timetable for contact with and/or research of individuals and organizations. This proposal also presented the possible hypotheses that were anticipated to emerge from the cases. The proposals were evaluated by the PhD project supervision team and sometimes by somebody within the organization coordinating the projects in the field.

After this preliminary phase the fieldwork was conducted. This consisted of personal interactions with key stakeholders and other informants of the networks involved in the three cases. These consisted of semi-structured interviews and discussion groups. Also, some personal observations were conducted in fields or labs, and in meetings within or between organizations. The researcher also gained access to a variety of internal documents from the different groups and organizations.

The field work for the first case study in Andhra Pradesh (India) was conducted during three weeks between October and November 2005. For this case, 32 semi-structured interviews and ten discussion groups were conducted (from which five with peasants, one with researchers, and four with civil society practitioners). During this period, the researcher also observed some practices performed by local networks: agrarian activities being carried out at that time, such as the harvest, the drying process and the sale of castor seeds, as well as the ongoing production of the Bt spray. For instance, the researcher spent one day in each of the three different production units (three days in total), to interview the local youth who work there, and gain a better understanding of the day-to-day realities of the production and distribution processes.

For the second case, on the deployment of molecular markers within the small-scale production systems of potatoes in the highlands of Bolivia, a total of 42 semi-structured interviews and three discussion groups (one with researchers, one with peasants, and one with civil society practitioners) were conducted. In addition to this, some days were spent making personal observations in a molecular biology lab, and planting potatoes (both in peasants’ fields and in the national potato germplasm bank of Bolivia). I was allowed to observe also a meeting of a local peasants’ trade union, another of researchers with peasants for the designing of participative potato breeding programs, one between researchers and a local NGO aimed at exploring the commercialization strategies for native potatoes, and a meeting between researchers and peasants for the establishment of a project to recover traditional constructions for the storage of potatoes (*pirhua*s\(^ {43}\)). The field work was conducted in ample three weeks between the months of October and November 2006.

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\(^{42}\) These procedures included initial permission from three separate ministerial offices, or a travel agenda which had to include the name of everybody (including peasants) with whom the researcher wanted to communicate.

\(^{43}\) A *pirhua* is a traditional Andean store construction made of adobe to protect potatoes and grain from rodents.
For the third case around Jatropha, a total of four discussion groups and 62 semi-structured interviews were conducted, from which 38 in Honduras and 24 in the Netherlands. The field work in Honduras was concentrated into a little over three weeks during the month of March 2008, while that in the Netherlands was conducted in a more extended way. Some interviews were made at the beginning of 2007, and the last recorded meeting was in late June 2008.

The final phase of the case studies was dedicated to data analysis prior to the composition of conference papers and scientific articles. Some key informants have had access to the investigation results for validation, in order to confirm descriptions and interpretations.

The validation of data: triangulation

Throughout the course of a case study, one wonders, do I have it right? Stake (1995) suggests that common sense works for us, telling us when to look again and where to ask for clarification, but common sense does not take us far enough. In our search both for accuracy and alternative explanations, we need discipline, we need protocols which do not depend on mere intuition and good intentions to ‘get it right’. In qualitative research, those protocols come under the name triangulation. Triangulation can be defined as the cross-checking of data from different sources to guarantee the accuracy of the collected information.

Borrowing from Norman K. Denzin’s book The Research Act (Denzin 1984), Stake (1995) details three protocols aimed at gaining reliability in the findings, and increasing credence in the interpretation.

Firstly, data source triangulation. The attempt is made to see if the phenomenon remains the same at other times, in other spaces, or as persons interact differently. In this respect, the present research has consulted different data sources to build up the different cases, including scientific literature, popular media (newspapers, magazines, etc.), websites, personal interviews, email communication, etc. Repetitions of information or explanation of a phenomenon by different sources – especially by respected reporters in different contexts and with variable overlaps of detail – suggests a certain level of acceptance and therefore, that it appears reasonable for these to be reported as an element that constructs our cases.

Secondly, investigator triangulation. Here, other researchers take a look at the same scene or phenomenon – at a case study. The most important activity for the ‘investigator triangulation’ carried during this research has been the continuous dialogue with the supervisory team of the PhD research project. In addition to this, there has also been a large group of people who have had also access, at different stages of the case analyses, to the collection and to the collected data, as well as to the results of the process of data interpretation. These people were chosen on the basis of their knowledge related to the case contexts, technologies, theoretical frameworks, etc. Their reactions have not only helped me to support, reject or reconstruct first interpretations, but also have provided additional data and theoretical perspectives to the case studies.

Thirdly, theoretical triangulation. This involves communication with co-observers, panellists, or reviewers from alternative theoretical viewpoints (Denzin 1989). This protocol is closely related to the second one, since, as Stake notes, no two investigators ever interpret things
entirely in the same way, whenever multiple investigators compare their data there is always some form of theory triangulation.

A protocol that might extend the classification of Denzin and Stake, and which has been used to validate the interpretations made in this research could be termed ‘discipline triangulation’. This would be defined as the review of one’s research by investigators from disciplines outside and unlike that of the researcher. The need for a triangulation with other disciplines, outside of sociology in this case, emerges primarily from the interdisciplinary character of this research. As a sociologist, I have been confronted with other fields, such as genomics technologies, plant breeding, or biology, of which my knowledge is limited. Therefore, certain assertions on matters that concern these other disciplines ought to be corroborated by experts in those fields. This has been done as appropriate and on an informal basis, e.g. via telephone, email, personal communications. A more formal trajectory of discipline triangulation has been also followed. This has followed the institutionalization of the interdisciplinarity of science and technology. For instance, one of the tutors of this research project is an expert in the technical side of biotechnological developments. He has had, of course, direct access to the evolution of this project, and has delivered commentary to some of the text produced within it. Moreover, all draft versions of the papers produced from all three case studies have been reviewed by a molecular biologist, or an expert of another discipline outside of the social sciences, but related to the case study from which analysis the texts emerged.

1.5. The structure of the thesis

Following this introduction, Chapter 2 unfolds the concept of local sustainable biotechnological developments. It introduces the concept’s theoretical frames of reference, and concretizes what have been the most relevant topics addressed in the three case studies at the three analytic domains. Then, Chapters 3, 4, and 5 present the empirical work of this research. Chapter 3 explores the redesigning of a Bt biopesticide within the context of peasant agriculture in Andhra Pradesh, India; Chapter 4 studies the deployment of molecular markers in small-scale potato crop systems in the Bolivian Andes; and Chapter 5 addresses the biotechnologization process that the fuel-crop *Jatropha curcas* is undergoing and its potential as a catalyst for local development in Yoro, Honduras. Finally, Chapter 6 is dedicated to the conclusions.

Labs and fields have been frequently perceived as disconnected, and their connection therefore as mandatory in order to meet the promises of genomics for peasant agriculture (EASAC 2004, Delmer 2005, Fears 2007, Reece and Haribabu 2007). The linkage proposed in the following chapters is what is termed here the territorialization of genomics. This linkage goes beyond a mere transfer of technology; it requires a reorganization of the social relations and of the material elements within agrarian genomics technological systems. These reorganizations should reorient genomics towards local specific needs and sustainable developments and ought to empower peasants, civil society organizations and local researchers within biotechnology socio-technological structures. The case studies presented in this thesis are examples of these reorganizations and developments. In short, to a certain extent, they are local sustainable biotechnological developments.
Chapter 2

2. Local Sustainable Biotechnological Developments

‘[… ] unexpected struggles over issues such as nuclear power, access to experimental treatment, and user participation in computer design remind us that the technological future is by no means predetermined. The very existence of these struggles suggests the possibility of a change in the form of technical rationality. They prefigure a general reconstruction of modernity in which technology gathers a world to itself rather than reducing its natural, human and social environment to mere resources. The goal would be to define a better way of life, a viable ideal of abundance, and a free and independent human type, not just to obtain more goods in the prevailing socioeconomic system. To the extent that technology is thus swept into the democratic movement of history, we can hope to inhabit a very different future from the one projected by essentialist critique. In that future technology is not a fate one must choose for or against, but a challenge to political and social creativity’
(Feenberg 1999; pp. 224-225)
2.1. Introduction

Local sustainable biotechnological developments is both a research method and an objective in itself. In this thesis, this concept is applied to a study of biotechnological developments aimed at strengthening peasant agrarian systems and the position of peasants and other local actors within biotechnological structures. Particularly, this investigation focuses on ways in which the position of peasants, civil society organizations, and researchers are strengthened within biotechnological developments, and how certain agrarian problems are addressed through the location-specific design of biotechnologies. The focus of this study is the agrarian applications of genomics – but genomics, as explained in the introduction, is placed within the wider context of biotechnology. As an objective, the central concept is proposed as an alternative approach to the conventional deterritorializing development of agrarian biotechnologies described (above 1.2). While a deterritorializing approach might be thought to be efficacious for some types of commercial and industrial agriculture, for the deployment of genomics within peasant agrarian systems, it is argued, a territorialization process is required. Advocate for the central concept need not, therefore, create a confrontation between non- and territorial developmental approaches. On the contrary, the aim is to create the space by which territorially based development may emerge as a corrective approach to the mainstream approach in the context of peasant agrarian systems.

The concept of local sustainable biotechnological development has two core elements, namely, territoriality and (bio)technology.

- Here, territoriality concerns ‘power’ and ‘locality’ (Sack 1986, Magnagni 2005b), and engages with debates around ‘alternative rural development’ (Friedmann 1992, Hettne 1995, Ploeg 2008) and ‘tailor-made biotechnologies’ (Ruivenkamp 2008a). This thesis focuses on certain territories, characterized as peasant agrarian systems, where biotechnologies are being reconstructed by the reorganization of certain social relations to meet local needs in line with local capacities. Territory, within the framework of this thesis is the place where agriculture and agrarian societies ‘happen’ and therefore, is one of the types of territories where technologies ought to be sustainably developed for the betterment of humankind. It is a place of convergence between nature, society and technology.

- From the perspective of (bio)technology, the central concept aims to inform wider debates around Science and Technology Studies. Technologies are understood as social structures (Sclove 1995), with technological systems as generated by a co-construction process between social and material elements (Mackenzie and Wajcman 1985, Bijker, Hughes and Pinch 1987, Feenberg 1999), and having politics (Winner 1985). Thus, (bio)technology is here understood as one of the social structures that reproduce societies. Technological

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46 The definition of ‘territory’ is not directly considered, but implied by such elements as social relations and structures, geography (e.g. reference to an eco-environment), geo-social features (e.g. local communities), agricultural character, etc.

47 Given that territory here is agrarian, the (defining) role of nature is manifest. However, the obvious natural dimension of territory is not a focus here. Although this is referred to, sometimes as vital – for example in the implications of the dry climate and semiarid landscape of the two districts of eastern Andhra Pradesh for biotechnology development described (Chapter 3) – practical issues and theoretical analysis related to local ecology and environment are generally backgrounded in this thesis.
social structures are systems formed by social and material elements. They are political and politicizing structures. The focus here, therefore, is on the mutual shaping process that occurs between the social and material elements of certain agrarian applications of genomics (to biopesticide, biodiversity, and crop development).

Situated at the interface between territory and biotechnology, the concept of local sustainable biotechnological developments concerns the exercise of power by local actors, from a specific place, on biotechnological developments. The concept is here defined as a type of development based on the reconstruction of biotechnologies mainly (though not exclusively) by and for local actors, and which strengthen peasant agrarian systems and which empowers peasants, civil society organizations and local researchers within the biotechnological structures. It is argued that a territorial approach to biotechnology development should consider, at least, three interrelated analytic domains, specifically:

1. The territorial domain concerns the social dimensions of power and locality for the development of biotechnologies. It involves the study of the social dynamics (power) engaged by multi-stakeholder networks to address the relevant agrarian problems of peasants in a given territory through biotechnology. It tests the horizontality (the, to a certain extent, non-hierarchical structuring) of the social relations between the different social groups involved in biotechnological developments by looking at whether and how (mainly) peasants, civil society organizations, and local researchers are included in them.

2. The technological domain analyzes power and the material dimensions of technology. It explores the material changes which are required for the local specific (territorial) development of biotechnologies. Actually, of course, the material level is interrelated with the social, the two co-construct each other within socio-technological structures – and considered here separately only for analytical reasons.

3. The reterritorialization domain focuses on the empowerment of territories concerning biotechnological developments. It studies the position and dynamics into which local sustainable biotechnological developments place the territories (where they occur) for future negotiations in developing biotechnologies. Therefore, it reflects on how the process of territorializing biotechnologies generates new socio-technological structures which strengthen peasant agrarian systems and the position of peasants, civil society organizations, and local researchers within biotechnological structures. It also reflects on the new dynamics that this type of development brings about within the historical context of an increasing industrialization and biotechnologization of agriculture.

These three domains, it should be noted, are not chronologically sequenced. It is true that there is a sense in which the territory is a given and reterritorialization the result of (bio)technological development, so chronology may be argued (with conditions, action, and effect). Nevertheless, these domains are presented and employed here as analytical realms of biotechnological development, not its consecutive phases. Processes of territorialization usually – or always – encompass a continuous process of reterritorialization, which most probably occurs contemporaneously. Moreover, the organization and reorganization of a territory can be prompted
just by social reorganizations of power or by socio-technological ones. To reiterate, these three domains are interrelated, and it is for analytical reasons that they are here considered apart and in this order.

The study of these three interrelated domains allows us to understand the social and material interactions of technology within a given territory (i.e. a peasant agrarian system), and the relations of these interactions with regard to the global dynamics affecting the development and deployment of biotechnologies. The three cases presented in the coming chapters are illustrations of these types of developments, and each is studied through the three analytic domains.

The following three sections of this chapter unfold the three interrelated analytic domains of local sustainable biotechnological developments. These sections (2.2, 2.3, and 2.4) elaborate the most important concepts of each analytic domain. In doing so, they place the concept within the relevant theoretical frameworks that have inspired and informed this approach. The three sections conclude by giving that what has been the focus of the domain in the analysis of the three case studies. The final section of this chapter (2.5) summarizes both the differences between a deterritorializing and a territorial approach to the development of biotechnologies in peasant agrarian systems, and the most relevant themes of the cases addressed through the three analytic domain concept of local sustainable biotechnological developments.

2.2. The territorial domain

Although the word ‘territory’ is most commonly used as a synonym for land, the larger part of the literature on the concept of territoriality is probably that contributed by biologists and deals with animal behaviour (Sack 1986). Writers who have used the straightforward meaning of this characteristic of some animals to describe human territoriality, have tended to do so arguing that territoriality in humans is part of an aggressive instinct shared with other territorial animals (ibid.; p.1). The understanding of territoriality presented in this thesis is quite different. Although territoriality is indeed understood as related to power and locality, it is not treated as an instinct, and neither is power seen as essentially aggressive. Territoriality is here approached from a more sociologic perspective. Categories like territory and territoriality have been increasingly utilized by geographers concerned with applying social theory within the discipline (Storey 2001). This leads to a definition of territory as a socially constructed locality (Sack 1986, Hettne 1995, Storey 2001, Segre 2003, Magnaghi 2005b). In this context, territoriality has been defined as ‘the attempt by an individual or group to affect, influence, or control people, phenomena, and relationships, by delimiting and asserting control over a geographic area’ (Sack 1986; p.19). This definition points out that territoriality refers to human control over area as a means of determining access to things and relationships. Territoriality is always socially constructed. In fact, according to Sack, territoriality does not exist unless there is an attempt by individuals or groups to affect the interactions of others (ibid.).

Socio-technological reorganizations of power are, at the same time, reorganizations of a territory – following the point on co-construction, in the sketch of the technological domain (2, above), and mitigating that the analytic purpose here separates the two.
Here, we are interested in the power dynamics exercised (by an individual or a group of persons to affect, influence, or control people, phenomena, and relationships) in a given territory in the process of biotechnology development. This local-specific or contextualized power exercised on people, phenomena and relationships concerning biotechnology development is in this thesis, the most relevant focus of the territorial domain of local sustainable biotechnological developments. Territory is here not just an item of geography, a spatial phenomenon in three or four dimensions, but is considered as the context in which social action acquires its specificity. And here we are interested in the social actions involved in the shaping and reshaping of biotechnologies.

Power is then a crucial analytic aspect of territoriality, and of its analytical deployment in the territorial domain. One of the philosophers who best has clarified the functioning of power is Michel Foucault. In his book Discipline and Punish (Foucault 1977) Foucault shows the multiple and complex actions by which power is exercised in, over, and transmitted through society. In this book he states that:

‘The study of this micro-physics [of power] presupposes that the power exercised on the body is conceived not as a property, but as a strategy, that its effects of domination are attributed not to ‘appropriation’, but to dispositions, manoeuvres, tactics, techniques, functioning; that one should decipher in it a network of relations, constantly in tension, in activity, rather than a privilege that one might posses; that one should take as its model a perpetual battle rather than a contract regulating a transaction or the conquest of a territory. In short this power is exercised rather that possessed; it is not the ‘privilege’, acquired or preserved, of the dominant class, but the overall effect of its strategic positions – an effect that is manifested and sometimes extended by the position of those who are dominated. Furthermore, this power is not exercised simply as an obligation or a prohibition on those who ‘do not have it’; it invests them, is transmitted by them and through them; it exerts pressure upon them, just as they themselves, in their struggle against it, resist the grip it has on them’. (Foucault 1977; pp. 26-27)

Following Foucault we might argue that the power involved in biotechnological development is not directly possessed by scientists working in the industrially developed parts of the globe, as it might appear at first sight. Decisions are indeed taken concerning the type of agriculture to which genomics is oriented, or type of actors who might be able to affect the developmental path of these technologies. For instance, by orienting genomics type of knowledge and technologies towards commercial agriculture, peasants and their agrarian systems are automatically excluded from the decision-making on genomics, as these systems (usually low-input, and/or of subsistence) do not usually use genomics based products-knowledge. Or, if they can and do use the products, they are integrated as passive receptors of ready-made technologies. However, as Foucault says, power in not possessed, but exercised through a certain organization of social relations. It follows, therefore, that the reorganization of social relations might transform power within biotechnological developments. A reorganization that is situated in the rural areas of peasant agrarian systems, and which primary issue is how local actors can take power through territorial strategies related to biotechnological developments.

A territorial strategy concerns dynamics of inclusion and exclusion (power) for the management of human and natural resources in a given locality (Magnaghi 2005b). Technologies play increasingly an important role in the management of resources and are themselves social activities (see Section 2.3). Here we are interested in the strategies of inclusion and exclusion from biotechnological (genomics) developments of certain social groups (i.e. peasants, peasants’
groups, civil society organizations, and local researchers) of specific peasant agrarian territories located in the developing world. The introductory chapter (Section 1.2) suggests that the mainstream agro-genomics developments can be defined as deterritorializing biotechnological developments from the perspective of peasant agrarian systems because: (1) genomics is controlled by researchers in private and public labs in the industrially developed parts of the world; from which it follows that (2) peasants, civil society organizations, and researchers from the third world (and peasant agrarian territories) are excluded from the decision-making processes of technology development; because of which (3) a transfer of technology approach is employed in which local actors are considered as merely passive receptors at the end of the technological pipeline. On the contrary, the territorial approach here presented aims to include within the socio-technological structures of genomics a larger set of social actors, namely the constructors of peasant agrarian systems. The goal of a territorial development is to improve the specific situation of a territory, and not to bring about 'development’ in terms of GNP (Hettne 1995, Magnaghi 2005b). As Hettne (1995; p. 200) argues that behind such abstractions there are concrete socio-economic ‘worlds’ with their own developmental problems and needs: an impoverished semiarid region, highlands, a forest, etc. Therefore, the goals of a ‘local sustainable biotechnological development’ should be defined within concrete territories and its impact in these territories should go beyond mere economic improvement.

Reflecting briefly on why the territorial analysis at the micro and meso levels of peasant societies is important for understanding biotechnological developments, it is necessary to consider how mainstream developments in agro-genomics tend to ignore them. The impression of and logic behind the conventional approach is essential aterritorial – once a certain technology is developed, it can be implemented anywhere. The reality, of course, is more complex than this. The real-life application of genomics technology requires and assumes many things. In the technological domain, for instance, the realization of advances may be prevented for a variety of reasons. Most labs in the third world are unable to apply some of the most sophisticated molecular marker techniques (e.g. AFLP\textsuperscript{49}) because of economic (e.g. reagent high prices), technical and knowledge constrictions, whereas in rich labs this is a routine activity (FAO 2003, Puente-Rodríguez 2009).

Friedman (1992; p. 40) argues that ‘we are interested in territoriality not because of some obscure spatial metaphysics but because people inhabit these spaces’, and it is these flesh-and-blood people who form peasant societies – based on agriculture for their survival – who ought to be empowered by the development of agrarian related biotechnologies, and therefore of genomics. Peasant societies do the best they can to develop agriculture in the places they inhabit. These agrarian activities, in which natural, social and technological elements interact, are one of the most important structural characteristics of the territories of peasants. Van der Ploeg (1992; p. 19) states that the different farming systems are linked with each other but contemporaneously containing nevertheless, their own identities, their own locality. Therefore, we could argue that biotechnological developments are actually finding many different territorialization pathways, through the different ways in which localities are organized and adapting the biotechnological developments within their multiple organizational frameworks.

Concluding, in this thesis, the territorial domain of local sustainable biotechnological developments explores this central question: What (social) power relations unfastened by local multi-stakeholder networks formed by peasants, civil society organizations, and researchers

\textsuperscript{49} Amplified fragment length polymorphism (AFLP) is one type of molecular markers based on the polymerase change reaction used for genomics research, DNA fingerprinting, marker assisted selection, or genetic manipulation.
strengthen peasant agrarian systems through the development of local specific biotechnologies and empower these networks within genomics socio-technological structures?

**A territorial approach to biotechnology development**

In order to systematize the study of this central question of the territorial domain – in the analysis of cases - the question is now converted into criteria for analyzing biotechnological developments. The two basic criteria employed here to test the territoriality of the biotechnological developments are: needs-orientation, and local specific power.

1. **Needs-oriented.** This criterion indicates that biotechnological developments ought to address relevant agrarian problems of peasant agrarian systems. All of us who has practiced agriculture (professionally or as a hobby) know that this is a difficult activity which is constrained by many biotic and abiotic (including social) factors. The needs of those who depend on agriculture for their survival are for sure more relevant that my own puzzling over some green worms which keep on devouring the broccoli I cultivate in my home-garden. For example, the worm semilooper (*Achea janata*) causes heavy losses of up to 20 percent of the total yield (Gaikwad and Bilapate 1992, DOR 2005b, Puente-Rodríguez 2007) of the most important crop – castor (*Ricinus communis*) – grown by resource-poor farmers in some areas of the Indian state of Andhra Pradesh (Chapter 3 of this thesis studies the development of a local biopesticide to address this problem). Groundnut rosette virus in sub-Saharan Africa was estimated to have caused 15 episodes since 1900, with losses valued at up to US$400 million per episode; and cassava mosaic disease in Uganda is thought to have caused an annual loss of US$70 million since 1900 (Fears 2007). These are to examples of relevant agrarian problems affecting the peasantry. As mentioned, the deterritorializing developments of agro-genomics have commonly excluded peasants’ crops and problems, yet, in the territorial approach presented here, peasants’ needs should be at the core of the research agenda and of the biotechnological development.

2. **Local specific power.** This criterion concerns the horizontal connectivity between and within networks in the development of biotechnologies. We have noted that the main characteristic of territority concerning biotechnologies is the local specific exercise of power on people, phenomena, and relationships. Genomics technologies as they are mainly developed today from a deterritorializing framework are insufficient by themselves and at a distance to strengthen peasant agrarian systems. There seems to be a consensus in the literature that the major problem is the lack of connectivity between researchers’ labs and peasant agrarian systems (Delmer 2005, Fears 2007, Reece and Haribabu 2007). The social relations organized within this deterritorializing genomics do not (cannot) bridge that gap. For the linking of labs to fields multi-stakeholder networks are required with a different set of social relations. This thesis examines three such multi-stakeholder networks and their efforts to territorialize biotechnologies within peasant agrarian systems. The territorial domain explores the power relations that emerge in such a process. More specifically, we try to understand how power can be locally exercised on biotechnological developments and how this local exercise of power empowers local networks within biotechnological developments.

These two criteria – that the territority of biotechnological developments are tested against here in the territorial domain during the analysis of the cases presented in this thesis – are not exclusive. One could think of other criteria – to which this research has given less attention –
for studying a territorial development of biotechnologies from the perspective of peasant agrarian systems, for example, knowledge/technology accessibility or sustainability.

- The ‘free accessibility to knowledge and technological capacities’ is here considered as a prior requirement if the multi-stakeholders networks in developing countries are to get access to the existent genomics technologies and knowledge. Available globally but originating from the industrialized world, genomics applications are framed within strict property systems. Although there are some very interesting initiatives concerning open source biology (e.g. Cambia\(^{50}\)), the structural power of ‘those who wish to preserve or strengthen proprietary exclusivity’ is significantly larger (Hope 2008; p. 322). An important principle of property rights for the development of genomics within development is that because the outputs of genomics are valuable for addressing some of the agrarian problems of peasants, these outputs (e.g. genome sequences or their functional characterization, technologies which facilitate the application of genomics knowledge) ought to be freely accessible, at least when they are used for strengthening resource-poor farmers’ agrarian systems.

The impact that intellectual property rights (IPR) issues have for the development of biotechnologies within peasant agrarian systems is not a central focus of research here. However, certain IPR issues have been elaborated when relevant to the analysis of case studies. A case in point is the third case study (Chapter 5) which explores the biotechnologization process of the Jatropha plant through genomics and which describes how the networks involved in potential local sustainable biotechnological developments are not able to employ a specific molecular marker technology because other networks that are involved in a commercial biotechnologization trajectory of the same plant – and which hold the patent on that marker technology – gained exclusive rights on the application of this technology with Jatropha.

- Another possible criterion for territorial development of biotechnologies in the context of peasant agriculture is ‘sustainability’. Agriculture is based on the management of the natural resources located in a territory, and these resources are limited. Therefore, for the sustainability of peasant agrarian territories, the human usage of biotechnologies should not lead to the degradation of (the natural resources of) the territories, not to a motionless situation, but it should be expected to lead to the enhancement of the territory. It should be a goal of genomics to facilitate the management of local natural resources, which should be sustainable and ought to facilitate the production of social wealth. For instance, the partial transformation of agriculture for the production of bio-fuels may enhance a given territory, insofar as it provides a territorial source of energy (as is argued here; see also Puente-Rodríguez 2009) – in which case it is far from intrinsically negative, as it is sometimes been claimed (e.g. GRAIN 2007a).

Research of the ecological sustainability of the biotechnological developments studied here is beyond the scope of this research. Nevertheless, ecological considerations are elaborated as appropriate from a socio-ecological perspective (e.g. Sosa 1990, Bookchin 1991, 2007). From this perspective, contemporary ecological challenges are regarded as not rooted only in natural factors, but also in social problems. Social ecology aims to conceptualize trajectories for the improvement of the human-nature relationship by challenging the hegemonic market philosophy based on growth and by integrating radical democratic principles in social relations. For example, the second case (Chapter 4) elaborates a framework in which there are contradictory understandings of potato biodiversity; i.e. biodiversity (in this case, the range of potato varieties) is regarded as raw material and as cultural material. This case study argues that the deployment of

\(^{50}\) Cambia is a non-profit organization aimed at producing open source conceptualizations and biotechnologies (\texttt{www.cambia.org}).
molecular marker technologies within the local-cultural understanding of biodiversity is more likely to satisfy a larger set of local actors, and also democratize biotechnological developments. Thus, the idea of sustainability assumed here is profoundly social.

The inclusion of the excluded

As described, the local specific exercise of power to affect, influence, or control people, phenomena and relationships in relation to biotechnological developments is the most important element of the territorial domain of local sustainable biotechnological developments. Therefore the territorial domain is concerned with human politics. This is not intended to mean the statecraft practiced by professional politicians (i.e. elected or selected people who manage and regulate social life). For the territorial approach presented here, politics means something more like ‘real’ participatory democracy, a communal ideal and method with directly accountable, open and accessible popular assemblies with an (relatively high) involvement of all in governance activities.51

It is in this context that local sustainable biotechnological development places the emphasis on the self-management of local resources (including technological developments and applications). However, given that isolationist self-managed development risks becoming parochial, sectarian, and xenophobic while globalization and the interconnectivity of societies and their politics, makes isolation increasingly impossible. Then, there is a need to extend the politics of direct democracy into the confederal association of local and global groups to foster a horizontal interdependence, rather than a hierarchical dependency. Here, politics means the engagement of multiple stakeholders in horizontal networks in the strengthening of peasant agrarian systems, and empowerment of peasants, peasant groups, civil society organizations, and local researchers within biotechnological systems. In other words, here we deal with the politics of technology (see below, Section 2.3). Local and globally oriented networks should collaborate, especially when the technologies at stake are highly sophisticated and have been developed in a different social environment (from the local peasant agrarian), as is the case with genomics. This is not to say that the multi-stakeholder networks presented in this thesis are ideal types, examples of perfectly democratic networks,52 or that the relations between networks are strictly horizontal. However, the dynamics they are engaged in do tend to include rather than exclude the social groups with which we are concerned.

The most important social group here is that of peasants. At the heart of democracy in the local and global networks of peasants are the peasants themselves. Characterized especially by lineage (family, clan, tribe) and proximity (as neighbours, shares of local resources, etc.) peasants societies tend to be rooted in deep traditions. These traditions may well be quite undemocratic, particularly opaque and rather inflexible. As an agent of change, development may well challenge the worldview of peasants and their traditional social relations, and informal networks; it will

51 By way of example, one might cite the Iberian libertarian movement during the social revolution of 1936 especially in the regions of Aragon and Catalonia. There, democracy was direct, and policies decided by directly democratic local assemblies. The administration of these policies was exercised by mandated comities or individuals who could easily be replaced if they failed to execute the mandate of the assemble (recognizing that the libertarian experiences of this period did also coexist with, for instance, patriarchy, and ideological purges).

52 Science and its networks, for instance, are commonly organized in hierarchical structures based on knowledge, experience, age, gender, and power – as are the scientific networks involved in the three case studies here.
most certainly have to work with them, and it oughts to respect them. As a social group, peasants may be suspicious of and reluctant to deal with new forms of biotechnology. On the other hand, they may also be very receptive and enthusiastic about anything that may make their lives a little easier.

Emphasizing the social rather than the anthropological, this thesis does not investigate the internal workings of the indigenous social groups and pre-existing peasant networks that constitute the fabric of territories in the three cases studied. Nevertheless, the totality of the lived experience and social relations of people – the peasantry – obviously represents a very important dimension in any (re)territorialization, including that of biotechnology. And the traditional working knowledge that peasant societies have of their environments, their ecologically honed farming practices, long-standing (bio)technological experience and sometimes ancient wisdom are very much a part of territorially based development.

In addition to peasants, there are other social groups constructing the territoriality of peasants agrarian systems and which are relevant for the territorialization of agro-genomics. One of them is the local scientific community. Local scientists are regularly supported by international developmental projects and often employed by the state; they are not infrequently posted from outside the territory, and generally based in the local town which operates as the socio-economic hub of the territory. However, the work of these scientists is usually dedicated to research aimed at strengthening the agrarian systems.

Due to the increasingly importance – both quantitatively and qualitatively – of molecular technologies, the academic composition of the type of networks that can be found in the field trying to develop the so-called ‘pro-poor’ agro-technologies is increasingly interdisciplinary (Pingali and Traxler 2002, Fears 2007, Reece and Haribabu 2007, Richards, Bruin-Hoekzema, Hughes et al. 2009). Laboratories of molecular biology are becoming more the norm rather than the exception, with agrarian genomics producing a huge amount of valuable data and technologies. Moreover, as Fears (2007; p. 16) argues, the complexity of dealing with the rapidly increasing outputs for example from crop plant genomics is likely to be further compounded by the rapidly increasing outputs from microbial genomics – this is the challenge of interactomics. Intra-connectivity among the members and groupings from local scientific communities therefore, needs to be operative, between those working with different species, between those working with model plants and those working with crops, and also between scientists from different disciplines. Within the territorial domain, this research looks at how local scientists access, manage, and deploy the pre-existing knowledge and technologies and how they transform (or territorialize) them to fit local needs and capacities.

It is commonplace for biotechnological projects in the third world to refer in their initiation and methodology to ‘participatory’ approaches and their commitment to ‘capacity building’ and ‘pro-poor’ agendas. Certainly, this type of language has become the rigueur in international funding circles and national policy development. However, as above mentioned, in their review on crop biotechnology partnerships (including the application of molecular markers) in Africa, Ayele, Chataway and Wield (2006; p. 621) report that some of the programmes they studied ‘tend to start with given solutions (influenced by personal, professional and commercial interests) and considerations of need assessment and delivery systems to end users often become an ex-post exercise. More successful initiatives start with user needs considered in conjunction with technological and product development with technological and product development with ongoing learning built into projects.’ Taken together with other analyses (e.g. Chataway 2005, Hall 2005) these facts show that the territorialization of genomics should occur there where it can address a relevant agrarian problem of peasants and ought to include a wider set of actors – at
least, peasants and local scientists, and also civil society organizations, which tend to act as mediators in peasant-scientist relationships.

Ranging widely from highly respected, organized and well-funded national foundations to fledging special interest groups of local activists, the number, range, and influence of civil society organizations (CSOs) have increased rapidly over the last couple of decades, leading to a ‘thickening of civil society’ (Fox 1996). These organizations tend to be especially active, in the developing world, where the weight and extent of state intervention had historically been limited, where indigenous movements have gained political representation (e.g. Bolivia, Chiapas-Mexico), or where decentralization of governance has created incentives for greater local participation. These organizations build the social capital of a territory, one that can identify broadly shared concerns among different groups, allowing them to focus on larger themes such as political participation and economic development (Janvry and Sadoulet 2004), or biotechnology development. The explosion of CSOs places strong demands for greater democratic participation on local governance and developments and for greater coordination between micro(local), meso and global policies and programs.

Some concerns however, have been expressed about the possible negative influence of the new powerful sector of CSOs – especially in the form of the so-called ‘non governmental organizations’ and agencies financed from the rich and industrially developed world. Attention is drawn, in particular, to their potential role as Trojan horses for the global expansion of capitalism, or neoliberalism, at the expense even of (real) development (Sachs 1992, Townsend, Porter and Mawdsley 2004). Notwithstanding the pertinence of some arguments elaborated by these criticisms, however, from the framework of this thesis the challenge is to gain a further understanding about how this ‘organizational revolution’ can be transformed into an instrument which facilitates the achievement of local gains, not only economic gains and gains in improved social services, but also political gains in the development of biotechnologies. Civil society organizations and intermediary research do indeed provide a critical link between peasants and scientists in initiating decentralized participatory biotechnological developments at locations that have been ‘left behind’ (Humphries, Gallardo, Jimenez et al. 2005, Puente-Rodriguez 2007, 2008b).

There are a multitude of networks working on agriculture development; all have different rules and are formed by different players which hopefully are appropriate to the issues and activities to which they are responding. Biotechnological developments have to be understood in this broader systemic sense if they are to be local and sustainable – as contributed by a territorial framework. It is stated, therefore, that within this embedded understanding of biotechnologies, the power and innovative capacities of the different actors producing and reproducing peasant agrarian systems should be integrated for the purpose of achieving a territorialization of biotechnologies. The biotechnological developments studied in the following chapters (the case studies) provide a close review of how peasants, peasants’ and other civil society organizations, and local scientists collectively develop biotechnologies aimed at both strengthening the agrarian systems of peasants by addressing relevant agricultural problems, and empowering these actors within biotechnological structures.
Territorial domain’s research focus

Thus, the territorial domain is the first analytic domain of local sustainable biotechnological developments. This section summarizes the focus of this domain in the analysis of the three cases presented in the following chapters. To recap, the territorial domain analyzes the local specific power exercised by multi-stakeholder networks on biotechnological developments to address relevant problems affecting peasant agrarian systems. The translation of this in the analysis of the three cases is described in the following paragraphs and represented schematically below (table 2.1):

The first case explores the development of biopesticides for and from within peasant agrarian systems in the semiarid districts of Mahaboobanagar and Nalgonda, in the state of Andhra Pradesh, India. In these territories, the main cultivated crop is castor (Ricinus communis), and the insect castor semilooper (Achea janata) is one of the most serious pests which causes heavy losses in castor production. The majority of chemical and bio-pesticides available within the territory are unaffordable and/or inappropriate for peasant needs. The territorial domain in this case thus analyzes how human and material resources of the territory are mobilized to address castor semilooper through biotechnological means. Based on local strains of the soil bacteria Bt (Bacillus thuringiensis) effective against semilooper, multi-stakeholder networks formed by peasant groups and civil society organizations, public research institutes and agricultural extension systems have developed a process to produce a Bt spray to manage castor semilooper which is cost-effective and which requires technical capacities that can be reproduced on a small-scale at village level. They have also developed a decentralized system of production-units (or bioresource centres) located in villages to manufacture and distribute the Bt spray. Not only the Bt spray is produced here, but also other biopesticides and bio-fertilizers that are adapted (territorialized) to local needs and capacities.

The second case addresses the development of molecular markers within the small-scale and highland potato crop systems of the departments of Cochabamba and Norte de Potosí in the Bolivian Andes. In these territories, the wealthy diversity of peasants’ varieties is essential for the survival of peasants’ households, as this diversity is used strategically to produce potatoes in the high-diverse ecosystems of Andean highlands. Moreover, potato diversity has also an important cultural meaning for Quechua and Aymara populations that live in these regions. Unfortunately, this diversity is decreasing. The territorial domain of this case reveals two contradictory understandings of potato diversity. One in which biodiversity is understood as raw material, and the other in which it is understood as a cultural material. According to the former, value is added by breeders in breeding projects (so peasants’ varieties only have instrumental value), while according to the latter potatoes are final entities constructed by peasants (and therefore they have an intrinsic value). Because biodiversity is decreasing and because of the importance that peasants’ varieties have both culturally and for the survival of peasant households, it is worth developing biotechnologies aimed at addressing the problems of these local varieties. In this case, it is argued that the deployment of markers in the cultural understanding of biodiversity (termed the Wiphala Genomics) has potentialities to address some agrarian constrains of resource-poor farmers (e.g. address biotic stresses suffered by local varieties). Furthermore, it is suggested that some participatory plant breeding networks which include local researchers and peasants’ groups and are concerned with local varieties are the appropriate social platforms for the deployment of molecular markers. These networks are already shaping the Wiphala genomics.
Local Sustainable Biotechnological Developments

The third case explores whether and how the biotechnologization process (through genomics) that the fuel-plant *Jatropha curcas* is undergoing might strengthen local sustainable developments. Specifically, it focuses on the ongoing efforts of the multi-stakeholder network Gota Verde – formed by peasants, peasant’s groups, local research institutes, and civil society organizations – to harness Jatropha as a complementary crop within the local small-scale production systems for the production of energy in the department of Yoro, Honduras. Honduras has a relatively large biodiversity of Jatropha as it is situated within the plant’s centre of origin. The case focuses also on the genomics research on Jatropha conducted by a Dutch research institute, and addresses the ways in which that research can assist local development in Honduras by establishing horizontal structures and relationships between global and local oriented networks. In this case, the territorial domain encompasses analysis of the strategies of local multi-stakeholder networks aimed at creating sustainable systems to produce and utilize Jatropha in the area.

<table>
<thead>
<tr>
<th>Cases</th>
<th>Territorial domain</th>
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| Case 1: Bt spray | - Small-scale production of castor in the semi-arid districts of Mahaboobnagar and Nalgonda in Andhra Pradesh, India.  
- Failure of existent pest-management technologies to address peasants’ problem with castor semilooper.  
- Multi-stakeholder networks are reorganizing human and natural resources to develop a Bt spray (biocidal).  
- A new technological social structure is emerging around the Bt spray which is characterized by an increasing involvement of multi-stakeholder platforms that include peasants, local villagers and civil society practitioners.  
- Bioresource centres are becoming places of encounter for territorializing biotechnologies. |
| Case 2: Molecular Markers (MMs) | - Potato peasants in the highlands of the departments of Cochabamba and Norte de Potosí, in the Bolivian Andes.  
- Loss of potato-biodiversity and unremitting problems with *Phytophthora infestans*.  
- Contradictory understandings of potato biodiversity in the Bolivian Andes (i.e. as raw material and as cultural material).  
- Participatory plant breeding platforms as appropriate social structures to deploy MMs  
- The Wiphala genomics. |
| Case 3: Jatropha | - Jatropha peasants in Yoro department, Honduras.  
- Local energy needs.  
- Local potential of Jatropha diversity.  
- Jatropha is undergoing a biotechnologization process (through genomics) that can either functionalize or develop the territory.  
- Structures are emerging for locally producing and utilizing Jatropha based biofuels.  
- Complementary production systems of food and fuel crops |

Table 2.1. Relevant issues of the cases addressed by the territorial domain
2.3. The technological domain

While the territorial domain deals with the social aspects (power and locality) of local sustainable biotechnological developments, the technological domain considers power and the material dimensions of these developments. In this thesis, technologies are considered as social structures because they function culturally and politically in a similar way to other social structures that form society. This section commences with a definition of social structures and elaborates on how technology works as a social structure. Then, the way in which the understanding of technology employed here corresponds to a critical constructivist approach to technology is explained, as characterized by: Firstly, its understanding of technologies as social structures indeed; secondly, it is based on empirical studies at the micro and meso levels to understand the co-construction dynamics between the material and the social elements that constitute technological structures; thirdly, it links the local dynamics with the more global political tendencies of biotechnology (at the macro level); fourthly, it is a normative approach aimed at the redesigning of biotechnologies, moving away from a deterritorializing development path towards local sustainable developments through the introduction of certain social issues (i.e. strengthening peasant agrarian systems and empowering peasant, civil society organizations, and local researchers within biotechnological systems) in their codes. The section finishes by introducing the focus of the technological domain for the analysis of the three cases studied within this research.

Technologies and social structures

Technology is here considered as a system formed by social and material elements (Mackenzie and Wajcman 1985, Bijker, Hughes and Pinch 1987, Feenberg 1999), and also, moreover, as one of the social structures that form societies (Sclove 1995). If technology is social, it follows that it also has politics (Winner 1985). Technologies reflect the social character of the territories where they have been developed or deployed. Therefore, they reflect the unequal distribution of social power that exits in and between societies. But technologies can also be reconstructed by inserting into their codes values such as justice or democracy (Feenberg 2008, Ruivenkamp, Hisano and Jongerden 2008). The act of technology reconstruction is a deliberate act of re-creation, applied at the level of knowledge systems and technical artefacts: ‘it takes place by changing the social relations from which the artefacts emerge, as well as by modifying the material content of the artefact’ (Ruivenkamp, Hisano and Jongerden 2008; p. 16). Not only is social action required in order to achieve a local sustainable development of biotechnologies, as described by the territorial domain, but also a material reconstruction of the apparatus itself (in order that its technological code reflect the character of its locality). The analysis implied by a technological domain also reflects a belief that other alternative (bio)technological developments are, in fact, feasible.

53 ‘The technical code is the rule under which technologies are realized in a social context with biases reflecting the unequal distribution of social power’ (Feenberg 2005a; p. 47).
Our daily activities are thoroughly intertwined with technologies. Nevertheless, when government, industry or the media consider technology, they usually address elements such as feasibility, financial cost-benefits relations, risk assessment, etc. These variables are incomplete, however, as they neglect the dynamics that occur with the deployment of technologies in society. They are incomplete because they fail to explain, for instance, the different strategic power relations that take place within the technological systems. Richard Sclove in ‘Democracy and Technology’, describes the omission of these important social issues in respect of technology as perplexing as ‘discovering a family that shared its home with a temperamental elephant, and yet never discussed – somehow did not even notice – the beast’s pervasive influence on every facet of their lives’ (Sclove 1995; p. 5).

A struggle for reflexivity becomes necessary in order to make visible that which appears to vanish in front of our eyes. Are technological systems so complex that we cannot understand them? Are we then not able to guide technological developments? The concept of social structure might help us understand this complexity. Employing the sociological definition of social structure proposed by Anthony Giddens (Box 2.1), the point is made that here technologies are one of the social structures that construct societies.

**Box 2.1. Giddens understanding of social structure**

Giddens defines structure as ‘rules and resources, recursively implicated in the reproduction of social systems. Structure exists only as memory traces, the organic basis of human knowledgeableability, and as instantiated in action (Giddens 1984; p. 377). By ‘social systems’ Giddens understands empirically observable, intertwining, and relatively bounded social practices that link persons across time and space. Social systems would encompass what most social scientists call ‘societies’. Structures shape people’s practices, but it is also people’s practices that constitute (and reproduce) structures.

Giddens seems to confirm the similarity of his concept of structure to the classical referential work of Lévi-Strauss. But he also attempts to distinguish himself from the French structuralist, in part by insisting that, because structures bind time and space they must be conceptualized as including not only rules but also resources. By adding resources to the understanding of structure, Giddens tries to distance his concept of structure from that of Lévi-Strauss because of the indifference of the later to questions of power, domination and social change (Sewell 1992). The dual conception of social structure, as it is defined by Giddens, transcends the classical sociological problem of agency and structure by making both elements mutually constitutive. Social structures are both cause and effect, both human products and architects of human actions and interactions.54

Understanding social structures as the rules and resources which reproduce societies, then the concept of social structure refers to the regularities and patterns underlying our behaviour and relationships. Moreover, the idea of social reproduction and social structure become very closely related to one another in sociological analysis. Our actions are influenced by the structural characteristics of the societies in which we move, and which we thereby recreate (and also, to some extent alter (Giddens 1989). Giddens formulates the duality of the concept social structure as ‘both the medium and the outcome of the practices which constitute social systems’ (Giddens 1981; p. 27). This dual notion breaks down the rigid quality attributed to the concept by the

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54 Giddens’ duality is not equally accepted by all social scientists, of course. An interesting book that works out the most relevant tensions unfastened by Giddens and his understanding of structure is this one of Clark and colleagues entitled ‘Anthony Giddens: consensus and controversy’ (Clark, Modgil and Modgil 1990).
Redesigning Genomics – Reconstructing Societies

metaphorical use of the word ‘structure’. In this sense, agency and structure are not opposed but presuppose each other.

Technology as social structure

Human activities and relationships (in which societies are based) originate from (and generate) many kinds of structures which exist at different levels, operate in different ways and are themselves based on widely varying types of resources.55 Commonly, items like religion, class, economy, family or law are described as social structures. It is possible to extend the analytic concept of social structure to technology because technology operates culturally and politically in a similar manner to the other ones (Sclove 1995). For instance, it is quite easy to understand that communication technologies play an important role in structuring contemporary social relations while also being themselves among the most visible of society’s products and resources. The same point can be made for other types of technology, like those of transport, and mobility – and those related to living organism, biotechnology.

Rules and resources

Technological structures are formed by the same two components as the other social structures, specifically rules or laws and resources. Technologies are constricted by rules originating in the social sphere (e.g. knowledge, beliefs, legal regulations, economics) as well as by physical laws (e.g. gravity, feasibility). But technologies also structure human behaviour in a deeply subconscious way which underline and inform our phenomenological experience through our daily adaptation to the already existent technologies. For example, in the way that our understanding of space-distance has been completely transformed by transportation technology. Technologies regulate (rule) social life, but they can also be restructured. Technologies can thus form the basis (resources) for new socio-technical systems or technological structures. For instance, the introduction of the telephone (its knowledgeable and technical elements) gradually displaced telegraph services but has more recently supported the development of the World Wide Web (Sclove 1995) and it has opening up possibilities for, among other things, fast planetary communication. Old technological structures are the resources for new technological structures. Moreover, possession of the knowledge of the rules and resources of a (technological) social structure enables the eventual rearrangement and extension of that same system or structure – in other words, to reproduce it with creativity. In this sense, agency becomes defined as the possession of the necessary skills to understand a given structure, not only in order to maintain it, and to transmit it and thus enable its continuance, but also to transform it.56

Although the existence of human agency on (technological) structures is undeniable, one other feature of social structures is their unpredictability. And so also technological structures, as

55 Structures are in continuous interaction and overlap with each other. The structures of capitalist society include both the social structure of commercial-industrial agriculture and this one of agrarian grassroots movements, or the production based on private property and profit as well as a mode style of labour organization based in workers solidarity.

56 Every single individual has agency; so he or she has the capacity to act creatively, feel desire, or interact with other persons. But at the same time this capacity is biased by the self assimilated unequal distribution of power between persons and groups. This fact has implications for collective struggles and resistances.
their functioning depends on so many factors as these technological structures are for instance, related to many other social structures. Taking an agrarian example, we could argue that, choosing one crop rather than another, or certain pestmanagement technology could mean the starvation of a family (or of a society), or its survival, or even its wealthy. Moreover, social structures change in the course of their history, so a succession of failures in the harvest of a crop might, for example, modifies the routines of planting or ploughing. This unpredictability means that even if we might want to consciously integrate values as justice and direct democracy within the code of certain technologies (e.g. strengthening the position of peasants within agro-genomics), this does not guarantee success, i.e. that the technological structure that emerges out the process will, in fact, be democratic or fair. This is due to one important aspect of technological-structures unpredictability, which is that there is a margin of flexibility about how the technologies will be finally used. The flexibility margin is not endless, and flexibility becomes rigidity as technologies and society adapt themselves to one another. For instance, western cultures, as we know them today, could not survive if communication technologies were turned off.

**Political-structural power**

_Technological structures are intimately related with other social structures_, in the same way that different technological systems are linked to each other and their context – For instance, a washing machine work in interaction with individuals (or families) and electricity networks. On its turn, the electricity network interacts and shapes other social structures (Hughes 1985, Winner 1985). Moreover, _technological structures are intimately interlinked with the political sphere_. The implementation of washing machines can be seen as a push within society towards an increasingly individualization by removing collective wash-places (see Sclove 1995; pp. 3-9). In his classic work, ‘Do artefacts have politics?’ Winner (1985) states that some technologies are consciously constructed with a political meaning, whilst others are inherently political. The former can be exemplified by the low-hanging overpasses on the bridges from New York City to Long Island that were consciously (low) designed and built so as to deny black people access to the recreation beaches of Long Island – since they were using the high busses of the public transportation system. As an illustration of the latter, the politically inherent technologies Winner states that opting for an electricity system driven by nuclear power, always and inevitably means to choosing a management and power system that is centralized to deal with the multiple dangers of nuclear technology. In one of the other way, technologies have politicizing consequences for society at large. Taking an agrarian example, the industrialization and biotechnologization of agriculture has meant, for instance and in some cases, the role of farmers changing from autonomous craftspeople to industrial workers who produce the crops determined by the market, with the seeds and inputs supplied by agribusiness companies (Goodman, Sorj and Wilkinson 1987, Ruivenkamp 1989, 2005b).

Technological structures – like all the other social structures – and their political dimensions have an immense impact on the lives of human beings. Technologies are even _structural for non-users_. They impact our lives even if we stay away from them. This ‘stay away’ might be based on a knowledge lack – on not knowing how to use technologies, or just not even knowing about their existence, or related to access prevention. The ‘stay away’ might also be a personal or collective choice according to moral or political beliefs. Regarding the former, farmers, for example, may be directly affected by the introduction of technologies – such as pesticides that lead to increased production but, thus drive down prices and also might increase
pest resistance levels – regardless of whether they are kept away from the pesticide, deliberately or otherwise, or even know about them. And regarding the latter, a person who is not user specifically desiring to keep biotechnologies at a distance still has to deal with the economic, political and social constructions that are organized around them. In fact, everyone is now made co-participant of the ecological dangers resulting from the pollution produced by the technological industrial system of production (although not every body has access to its potential benefits).

As in the case with the other social structures, technology has a strong cultural lading. Technological structures help us not only to understand the world we live in, but also, at the same time they are framing that same world. In fact, technologies act at the symbolic level, as items of culture. And as cultural symbols, technologies can function in many ways, at many levels, according to the context of employment and, of course the mode of interpretation. A different single technology or technological practice, therefore, may symbolize more than one thing, and even opposite things. For example, a farmer who uses crop varieties developed through recombinant DNA technologies might be called a modern farmer by some people in some contexts, or an environmental terrorist by others in another context. While a farmer using traditional varieties could be reprimanded with the status of recalcitrant farmer, or rewarded with that of organic farmer – with again different cultural connotations.

Finally, like other social structures, technological structures involve constrictions and produce potentialities. In this sense, they are influential but not determining. In the same way that as cultural symbols technologies are malleable, so also as social structures are they subject to influence. Therefore, the possibility to reject some technologies exists, and more interestingly from the framework of this thesis, social groups can change the developmental path of a concrete technology, to make it, for instance, more inclusive and democratic. It is this that, sociologically, enables technology to be reconstructed. Technologies (like other social structures) do not just appear, but are negotiated in social processes within the pre-existing social and technological systems; in fact they are contingent social products. It is during these processes that the developmental path of technologies is decided upon. In these negotiations there is an unequal distribution of power, which makes it difficult for some segments of the population to make decisions concerning processes which may become vital to their cultural and material environments, and which ultimately will affect society and nature themselves.

Reviewing how technological systems work as social structures, this discussion has looked at how technologies shape societies through their rules but are at the same time themselves socially shaped, and how they constitute the resources for creating new social structures or transforming those that already existent. In this sense, the common belief that technologies are morally or politically neutral should be discarded. Although, people or institutions may promote what they believe are technological neutral solutions, they are misguided, at best, because such solutions are never neutral. Technological developments always carry economic or political dimensions. There is a common view that we can not do otherwise than adapt our societies to the technological beat, i.e. that the pace and direction of change is immutable. There is another, contrary view, that technology can be changed, but only if we change society, i.e. that first we have to transform society and then we can start adapting technology to the new social reality. These views overlook the social constitution of technology, the definition of technology as a social structure, that technological developments are ongoing social processes embedded in the present social order and therefore, for good or bad, constraint and enforce social change. The type of change into which we aim to gain insights in this thesis is the sustainable and local specific development pursued through biotechnologies. The
consideration of technologies as social structures opens the door to an understanding of the socio-technological entanglement in which we live, and, therefore, to how local sustainable development might be consciously generated or strengthened through biotechnological developments.

A critical constructivist approach to (bio)technological developments

The basic understanding of technology as a social structure places this research within certain debates concerning technology. This section briefly sketches some of these and thereby elaborates further on the understanding of (bio)technologies employed here. Conceptions of technology, and the role that technologies play in society can be placed on a range between two poles of a spectrum. One of these poles understands technology as a determinant force on society. This position is maintained by technological determinism. The second pole presents technology as a neutral entity which can be fully shaped by society. This understanding is elaborated by social determinism.

At their most extreme, technological determinism schools hold that technical change produces social change, and that technical change is not caused by social factors. Technological determinism knows variants that regard society as positively determined by technical change, and other pessimistic variants which consider catastrophic the determinant influence caused by technology on society. Feenberg (1999) argues that some texts written by Marx are an example of the former. Some of Marx’s work can be understood as implying that technical change might first be limited to a technical (material) sphere but it soon involves a similar change in other spheres (Jordan 1971):

‘Technology discloses man’s mode of dealing with Nature, the process of production by which he sustains his life, and thereby also lays bare the mode of formation of his social relations’ (Marx, Capital Vol.I; p. 372, quoted in Jordan 1971; p. 201);
‘the windmill gives you society with the feudal lord; the steam-mill, society with the industrial capitalist’ (Marx 1847-1963).

Heilbroner (1994) argues that ‘the hand-mill (if we take this as referring to late medieval technology in general) required a work force composed of skilled or semiskilled craftsmen, who were free to practice their occupations at home or in a small atelier, at times and seasons that varied considerably. By way of contrast, the steam-mill – that is a representative technology of nineteenth century – required a work force composed of semiskilled or unskilled operatives who could work only at the factory site and only at [a] strict time schedule’. Moreover, Elster (1986) argues that some orthodox Marxists believe that the means of production changed faster than the relations of production, and this mismatch forms a source of continuous social conflicts. For them, technical change is not only the motor of capitalist progress, but also, by virtue of its tendency to replace labour by capital, the source of its destruction. According to this argument, the changes in the technical sphere (means of production) positively leads to changes in the social sphere (relations of production) which will destroy capitalism mode of production – Feenberg (1999) states that technical progress was believed to ground humanity’s advance towards freedom and happiness. This does not mean, however, that all writings of Marx are, or that Marxism in general represents a form of technological determinism. Among the several
interpretations of Marx’s writings, for instance, Mackenzie’s article (1984) ‘Marx and the Machine’ presents a nuanced reading of Marx on technology. Marxism at large is also populated by and influential for other currents of though on technology that are far from technological determinism, such as some constructivist (e.g. Mackenzie and Wajcman 1985) and critical approaches (e.g. Feenberg 1999).

A pessimistic variant of technological determinism is provided by essentialism (e.g. Heidegger 1977a, b, Ellul 1980, 1990). For essentialism, technology (often with a capital ‘T’) is not neutral, but has acquired an autonomous character. Human beings have lost control of Technology and become its prisoners. In this context Technology is immune to democratic control or humane reconstruction; it is a framework which constitutes the very structure of the modern world. In the words of Ellul:

‘Indeed, the human race is beginning confusedly to understand at last that it is living in a new and unfamiliar universe. The new order was meant to be a buffer between man and nature. Unfortunately, it has evolved autonomously in such a way that man has lost all contact with his natural framework and has to do only with the organized technical intermediary [...]. Enclosed within his artificial creation, man finds that there is “no exit”; that he cannot pierce the shell of technology to find again the ancient milieu to which he was adapted for hundreds of thousands of years’ (Ellul 1964; p. 428).

As in the case of Marx’s writings, it wouldn’t be fair to efface the works of Ellul and Heidegger from one’s memory because of their apparent technophobia and gloomy vision of the future. On the contrary, their thoughts are highly relevant because are based on sharp observations on technology. For instance, Ellul showed at an early stage, the importance that information technology would have for the connection of until then, separate technologies (Bos 2004; p. 16). Recently, it has become possible to see this connection role played by information technology in the development of genomics. In genomics, informatics and information technologies converge in such a way that the biological-genomic information and the digital information overlap to such an extent that they are almost inseparable.

At the other end of the spectrum of conceptions of technology and the role that technologies play in society we have social determinism or instrumentalism. Social determinism is the view that society shapes technology, and not vice versa. Within this framework, it is argued that social factors crucially influence the design of technology. Technologies don’t do anything by themselves, they are determined by the society in which they are developed. We can again distinguish two poles of social determinism. Firstly, a dystopic position that argues that humanity can be subjugated by technocrats through technology. Secondly, a utopic social determinism which says that technology can be deployed for the emancipation of humans. Both utopias and dystopias are briefly unfolded to understand their technological scenarios.

As an illustration of dystopic societies in which control exercised on humans is mediated by technological advances, we have the visionary works of George Orwell’s ‘Nineteen Eighty-Four’ and Aldous Huxley’s ‘Brave New World’. Actually, Orwell’s novel is mainly a critique of the betrayals by authoritarians of social revolutions – such as the anarchist revolution of Spain (1936) or the Russian revolution (1917), both betrayed by authoritarian communists (Goldman 1931-1970). But the book can also be read as an intellectual exercise to imagine how the future

\[57\] Or, in the words of McLuhan (1964), Technology has reduced us to the ‘sex organs of the machine world’. 

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could look like by the authoritarian use of the available information and communication technologies.  

The essential ambivalence – dangers and promises – associated with this instrumental use of technologies is made more explicit by Huxley in the foreword to his dystopic work ‘Brave New World’ (1972).  

‘it is only by means of the sciences of life that the quality of life can be radically changed. The sciences of matter can be applied in such a way that they will destroy life or make the living of it impossible complex and uncomfortable; but, unless used as instruments by the biologists and psychologists, they can do nothing to modify the natural forms and expressions of life itself. The release of atomic energy marks a great revolution in human history, but not (unless we blow ourselves to bits and so put an end to history) the final and most searching revolution’ (Huxley 1972; pp. 9-10).

So it is in our hands to choose the world we want to build by the way we use science and technology. Speaking about his dystopic work he argues that:

‘Indeed, unless we choose to decentralize and to use applied science, not as the end to which human beings are to be made the means, but as the means to producing a race of free individuals, we have only two alternatives to choose from: either a number of national, militarized totalitarianisms, having as their root the terror of the atomic bomb and as their consequence the destruction of civilization (or, if the warfare is limited, the perpetuation of militarism); or else one supra-national totalitarianism, called into existence by the social chaos resulting from rapid technological progress in general and the atom revolution in particular, and developing, under the need for efficiency and stability, into the welfare-tyranny of Utopia. You pay your money and you take your choice’ (ibid.).

One scholar who has worked on the utopian side of social determinism in which technology is used as a tool for achieving freedom is the anarchist and environmentalist Murray Bookchin (writing under the pseudonym Lewis Herber). In his essay ‘Towards a liberatory technology’ (Herber 1981), Bookchin defines his work on technology as a reaction to the dangerous pessimism of essentialists like Ellul and their beliefs about the ‘sinister own life of technology’ that can mechanize humans and even destroy them (Herber 1981; p. 10). For Bookchin, the danger of this gloomy understanding of technology is that it might lead us to forget that technology also has potentialities for freedom and also to a passivity which allows the destructive use of technology. Bookchin tries to gain a further understanding of the possible trajectories by which the existent technologies can be used and developed in an appropriate (i.e. liberatory for human beings and environmentally friendly) way. For him ‘the technique is the fundamental structure in which all living institutions of a dynamic social organism rest on’ (ibid. p. 11). As

58 For instance, in Orwell’s novel, Big Brother (1950-1983), The Party uses ‘telescreens’ to indoctrinate and control the inhabitants of Oceania – authoritarian state portrayed in ‘1984’. The telescreens are televisions with a security camera-like device used as source of propaganda and as control mechanism on people’s daily life. The device could at the same time send and receive images from the households to Big Brother. This technology allows the centralization of power on social life in Oceania.  

59 The book was first published in 1932 and the foreword was written in 1946. Huxley’s novel depicts a world characterized as a ‘paradise-engineering’ in which technology is introduced in all aspects of life (birth, social control, entertainment, and dead), and of which criticism only can originate in the savage’s human spirit.  

60 Dystopia might be thought to be more convenient in this case.
one illustration of how technology might be used to improve the welfare of human beings, Bookchin explains that the mechanization of cattle feeding in agriculture could lead to a system which might exempt farmers from their heavy tasks by ‘pushing some buttons and pulling a few switches.’ He then suggests that such mechanization can be applied independently of the social context:

‘it can be used to feed immense herds or just a few hundred head of cattle; the silos may contain natural feed or synthetic, harmonized nutrients; the feeder can be employed on relatively small farms with mixed livestock or on large beef-raising ranches, or on dairy farms of all sizes.’ In fact, for Herber, this mechanical system ‘can be placed in the service of the most abusive kind of commercial exploitation or the most sensitive applications of ecological principles’ (Herber 1981; p. 40).

Contrarily to Bookchin, we might take a different path of argumentation from this case. Whereas the mechanism might be flexible, like any other technology the flexibility is not unlimited: this technology is context dependent since the mechanization that he refers to requires, among other things, electricity. Therefore, we could argue that this type of mechanization is difficult or nearly impossible for farms that have not access to electricity. This is, for instance, the case of many of the agrarian systems of the peasant societies discussed in this thesis.

In fact, it is this social determinism approach based on the neutrality of technologies and which therefore states the social context independent applicability of a technology that is at the foundations of the technology transfer approach. From this perspective, genomic technologies can (and probably should) be developed in the industrially developed world and just transferred to countries with less genomics type of knowledge and technological capacities.

In contrast to the technological deterministic schools of thought, instrumentalism, or social determinism, seems to have lost the ‘respect’ for technology, insofar as it is engaged in discussing the use of different technologies (in plural and with small letter) with different social groups advocating their own social ideals. Both utopic and distopic approaches might appear to us as somewhat idealistic and naïve, precisely because of their belief in the neutrality and universality of technological developments. However, their fears and hopes, their optimism and pessimism are still present in several contemporary views around technology. For instance, concepts like ‘Orwellian’ or ‘Big Brother’ have been black boxed and are used for all kinds of dystopian and anti-technology movements. Moreover, as Fukuyama indicates, many of the technologies that Huxley envisioned, like in vitro fertilization, surrogate motherhood, psychotropic drugs, and genetic engineering for the manufacture of children, are already here or just over the horizon (Fukuyama 2002). While instrumentalism might be perceived as a challenge to technocracy and the blind faith in technological determinism, the idea that technology is intrinsically neutral and that technological systems can be modelled by us as we please is at least questionable. From a social determinist perspective we could argue that genomics technologies can be just transformed by social groups as one pleases. But technologies are not neutral entities, once a technology (i.e. its social and material components) is deployed within a society a mutual shaping process occurs which has an influence on both its material and social aspects.

Although it is rather logical to think that social and material elements of technological social structures are co-evolving, and that technology is also co-evolving with the other social structures, the dividing lines between sociological determinism and the critical constructivism approach presented next are difficult to trace. This is because within this critical constructivism also humans do have a manoeuvrering space for reconstructing technologies. Therefore, at some
point the analysis of ‘local sustainable biotechnological developments’ could sound as social determinism. However, within the understanding concerning technology of this central concept social and technical elements co-construct each other within a particular technological system. From this follows that technological social structures are nevertheless, as difficult to change as political or religious structures are.

Critical constructivism

The social movements of the 60’s created a context where the criticism that essentialism has against technology was incorporated into a more democratic framework (Feenberg 1999; p. 6). Within this trend we find scholars like Landgdon Winner (1985) or Don Ihde (1990); along with more radical thinkers who criticized the role of the scientific ideologies and technological determinism in the formation of modern hegemonies, including such as those who are representative of the Critical Theory. Such as Marcuse (1964), Habermans (1971) and Foucault (1977). Although the understanding of this form of domination is worked out in different ways by these three thinkers, all hold as central the argument that Western sciences and technologies form a program of control and domination over the population and nature. In the words of Marcuse,

‘the scientific method which led to the ever-more-effective domination of nature thus came to provide the pure concepts as well as the instrumentalities for the ever-more-effective domination of man by man through the domination of nature. […] Today, domination perpetuates and extends itself not only through technology but as technology, and the latter provides the great legitimization of the expanding political power, which absorbs all spheres of culture. In this universe, technology also provides the great rationalization of the unfreedom of man and demonstrates the “technical” impossibility of being autonomous, of determining one’s own life. For this unfreedom appears neither as irrational nor as political, but rather as submission to the technical apparatus which enlarges the comforts of life and increases the productivity of labour. Technological rationality thus protects rather than cancels the legitimacy of domination and the instrumentalist horizon of reason opens on a rationally totalitarian society’ (Marcuse 1964; pp. 158-159).

61 Critical Theory is the label used by the philosophers of the Frankfurt School. It was actually a camouflage to say Marxist theory (Wiggershaus 1995). However, they are interested in the liberatory principles of Marx rather than with their orthodox reading (ibid.; p. 5). In fact, the guiding principle of critical theory is an emancipatory interest in knowledge. Other important sources of inspiration for this school were Weber, Kant, Hegel and Freud. Moreover, Critical theorists develop a radical critique on the social establishment. They go beyond the, what we could call, ‘positive sociology’ defined by critical theory as just a kind of journalism with some more statistic data. In this context, the task of social science is to clarify the apparently given for granted social conditions by connecting them to a wider historical and socio-political context form which they emerged and within which they are re-shaped (ibid.).

62 Foucault’s philosophy is not usually placed within the critical theory school. Nevertheless, his analysis of the social construction of rationality and criticism of the domination of people by the scientific and technological knowledge is rather similar to that of Critical Theory. Moreover, Foucault himself recognized that his intellectual work might have been easier had he known of the existence of the Frankfurt School at an earlier stage (Foucault 1989; p. 349).
Marcuse believed that Western technology is pure ideology because it forces humans and nature to accomplish rational ends and takes us away from their liberating and growth potentials (from freedom to slavery). His work sometimes resembles the essentialism of Heidegger, however, Marcuse criticizes the idea that technological designs are governed by efficiency or scientific principles, claiming instead that this design is a socially determined technological project (Feenberg 2005b: p.103).

Foucault, in ‘Discipline and Punishment’ (1977), analyzes how the extension of scientific and technological knowledge is exercised by the extension of 'the technologies of the self'. For Foucault, the punishment exercised in the Middle Ages was a kind of spectacle, but economic changes and the enlargement of social struggles provoked the development of a more sophisticated control system supposed to control and shape human ‘souls’. The control is not exercised by individual persons, but by certain practices and relations (here, social structure). He presents architectural design (buildings) as technological materialization for the exercise of power. Foucault demonstrates that the similarities between prisons, military quarters, schools, hospitals, or factories are no coincidence. The domination is internalized by workers, students, prisoners, etc. in several and subtle forms, e.g. by realizing that one is, or could be, constantly controlled, or by the difference in size between the architectonical constructions and the persons gathered around them. From these place-technologies it is possible to exercise control and power over people. Therefore, scientific and technological knowledge shouldn’t be studied as neutral, but as means to deploy power and exercise control over people, processes, and developments. In this way the concept of disciplinary technologies might help us to further understand the way in which technology is political. Disciplinary technologies are those that have a moulding and influencing effect on the target population’s behaviour (Foucault 1977). This can be experienced by people during their internalization of domination forms in the schools, factories or prisons. The persons inhabiting these places develop disciplinary careers (Foucault 1977), controlled by the knowledge of medicine, psychology and criminology. In short, Foucault develops a political view of technology where technologies are far from neutral, which are embedded in networks that are socially contingent, and where means and ends are indissolubly co-creating reality. It is in this way that we understand technology here, and therefore also biotechnologies.

Towards a liberatory technology?

No matter how strong the hegemonic role played by science and technology in current societies might have appeared, critical thinkers nevertheless rejected the idea that there is a single path of progress based on a technical rationality. In so doing, they have opened a space for philosophical reflection on the social control of technological developments. It is in this space, which is cultivated here, in which control can be exercised by (local) actors in the production of (local specific) (bio)technologies that is essential to (local) sustainable (bio)technological developments. Marcuse’s one dimensional man and society appeared to leave however, little room to find a way out of the domination program of sciences and technology. But, he did see a possible way forward, the construction of the ‘new man’. He proposed the disclosure of the being

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63 In fact, Marcuse was a pupil of Heidegger until the professor showed his Nazi tendencies. For an in-depth analysis of their philosophical relationship, see Feenberg (2005b).
64 Speaking about his visit to a prison Foucault says: ‘But actually, at first sight you have the impression you are visiting more than just a factory, that you are visiting a machine, the inside of a machine’ (Lotringer 1996; p.113).
by a revolutionary change of basic practices; this might lead not only to the abolition of class society, but also to a new conception of science and technology in which the relation with nature will change. Nature will be then a subject rather than an object of rational instrumentality (raw material); in short, the new revolutionary human being could achieve the reconstruction of the technical base. For Marcuse there was no dimension of technology in which liberation might root itself (Feenberg 1999, 2005b). Also Habermas rejected the possibility that there might be technologies of freedom. As far as for this thesis is concerned, biotechnologies are not seen as intrinsically liberatory means, nor as oppressive. This does not mean that technologies, from the territorial approach here presented, are merely neutral instruments (that can be used positively or negatively). On the contrary, (bio)technologies are seen as one of the social structures or political arenas where societies are constructed. They are rules and resources that reproduce societies. This means that if even and when the territorial approach of local sustainable biotechnological developments comes to permeate policy and scientific circles, the action of consciously territorializing biotechnologies might not automatically generate efficient technologies for peasant agriculture, or the empowerment of peasants within biotechnological social structures.

Foucault also believes in radical change, which must be sought within the networks of relations that constitute social structures. Foucault argues that

‘the State consists in the codification of a whole number of power relations which render its functioning possible, and that Revolution is a different type of codification of the same relations. This implies that there are many different kinds of revolutions, roughly speaking as many kinds as there are possible subversive recodifications of power relations’ (Foucault 1980b; pp. 122-123).

We have said before that every territory has its own identity, its own locality. Therefore, paraphrasing Foucault, many different territorial path ways will emerge from the multiple recodifications of the power relations between genomics and the territories where they are deployed. Foucault’s analysis and those of critical theory help us in understanding that technologies can be political forms of domination, but that they are also socially contingent – i.e. the existent power relations can be transformed to reverse the domination tendencies of science and technology. Therefore technological systems can be re-codified and reconstructed to play different roles in different societies.

**Engaging the philosophy of technology with empirical research**

The contributions of critical theory to the conceptualization of technology are philosophical in nature and rather abstract. This approach is strengthened by more empirical analyses, such as offered by constructivism. Constructivism is aimed at understanding and deconstructing the mutual shaping process of technology and society. Under the umbrella of constructivism coexist a range of different tendencies, with several relevant currents of thought (see Box 2.2).

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**Box 2.2. Constructivism**

The reflections on technology accomplished by the above mentioned schools opened the doorway for the study of technology as a social environment. Constructivism carries out these endeavours. The origins of constructivism can be found in the work of for example, Bijker, Hughes and Pinch (1987), and Mackenzie and Wajcman (1985). These writers discarded most of the existing approaches to technology advocated by
historians, philosophers and economists. They extended the sociology of scientific knowledge into the realm of technology. The key argument of that sociological approach to science made within what is known as the ‘Strong Program’ of the Edinburgh School (e.g. Shapin 1975, Mackenzie 1981, Barnes and Edge 1982, Barnes, Bloor and Henry 1996) was that not only scientific processes but also scientific contents are influenced by social and psychological dynamics. Facts, therefore, whether in medicine, biology, or religion and mythology are social constructions. This epistemological relativism and the struggles for reflectivity within the Strong Program to understand how science construct the natural world flow into two different paths to understand the relationship between the natural and the social world.

On the one hand, it is necessary to push further the symmetry within the natural and the social world. These efforts are undertaken by Actor Network Theory (ANT) (e.g. Callon 1986, Latour 1987, Law 1987) that believes that nature and society are being ‘co-produced’ by science. It rejects a priori distinctions between subject and object, or nature and society. In the world of ANT every entity is a hybrid, and so are technologies. Technologies are not just objects that can be contrasted from the cultural world, but they gather both social and material elements in the form of networks. Within this ontology, life is formed by heterogeneous networks of persons, things, plants, natural phenomena, etc. – or ‘actants’ in Latour’s terminology.

On the other hand, the Empirical Program of Relativism (EPOR) extended the understanding of a social construction of nature within the ‘hard’ sciences. The core of the EPOR’s methodology is formed by the study of the interpretative flexibility of scientific facts and the closure of what is true within a fact. Closure occurs when the scientific community arrives at a consensus about a fact and its interpretative flexibility becomes neglected. This core methodology is integrated in the sociological study of technologies performed by the Social Construction of Technology (SCOT). If technologies are socially constructed, then it follows that their design is to a certain extent, a flexible process. Therefore, the final design could have been rather different. The shape of the final artefact is given by the relations and choices of relevant social groups which have different interests in and visions of a given artefact.

Constructivism – in all its multiple forms – has deconstructed several technological systems and produced a good number of fascinating pieces of writing concerning the development processes of different technologies (e.g. Cowan 1985, Hughes 1985, Callon 1986, Bijker 1995a). Brey (1997) argues that the greatest worth of constructivists’ technology studies lies in their detailed empirical analyses at the micro-level of the way in which technological development is a

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65 This epistemological relativism sounds, of course, as a blasphemy in the church of rationalism and positivism which maintain that scientific statements only can be accepted on the basis of facts. Some of them consider this form of relativism therefore as, relativistic indeed, post-modern and fashionable nonsense (e.g. Sokal and Bricmont 1998).

66 Strictly speaking, in ANT all actors (humans or non-humans) are actants, meaning entities made to act.

67 One of the criticism made of ANT is that the representation of nature is always mediated by others (Pickering 1992); especially natural scientists. This becomes problematic at the moment that the same experts play a double role in the analysis of a network, as research object and as authority source for other actors. This is a relevant issue for this thesis. While the position advocated here shares with ANT the view that non-human actors play an important role within a technological system, at the same time, we will use the knowledge of, for instance, agronomists to address the behaviour of plants, or of microbiologists when speaking about bacteria. This seems reasonable, since here natural science is not granted a monopoly in constructing the natural world. For example, Chapter 4 looks at the construction of two contradictory understandings of biodiversity in the Andes; one is mainly informed by natural scientists, but the other is mainly rooted in the understanding of biodiversity of peasants and civil society organizations, as well as by some scientists.

68 The Strong Program together with the EPOR form what in the sociology of science is known as the Sociology of Scientific Knowledge.

69 More in depth analyses of constructivism can be found in for instance e.g. Hagendijk 1996, van der Belt 2003, or Sismondo 2004.
contingent, heterogeneous process involving interpretation and social negotiation, and the way in which the resulting technology is socially shaped. This empirically based approach of constructivism can strengthen the philosophical perspectives of critical thinkers, and vice versa. Some researchers have argued that constructivism also has some limitations (e.g. Russell 1986, Winner 1993, Brey 1997, Sismondo 2004). These limitations might be overcome and therefore constructivism might be strengthened by applying the politically engaged approach to technology of critical theory. Two main limitations of constructivism are identified here.

Firstly, both SCOT and ANT focus on relevant groups of actors for the analysis of a particular technological design. Relevant social groups are groups of actors that share a common conceptual framework and interests, that try to push forward their own plan for shaping technologies. Although ANT has in some ways extended the sociological analysis to non-humans, people remain the research’s core subject matter. Among humans, scientists and engineers are the group most commonly chosen for analysis (Sismondo 2004). By focussing on relevant groups, it seems that constructivism loses insights on other ‘irrelevant’ actors. For example, those who might not have taken part in the design process, or perhaps even excluded from it. For instance, biotechnologies have been especially developed within the context of commercial and industrial agriculture, whilst there have been relatively few significant biotechnological developments within the context of subsistence agriculture. From a classical constructivist analysis of biotechnologies, peasants for instance, will probably never be considered a relevant group within biotechnological social structures, even though their agrarian systems are increasingly influenced by biotechnological developments (Ploeg 2008). In contrast, the critical constructivist approach here of local sustainable biotechnological developments actively highlights inclusion and exclusion dynamics. It focuses on the deep-seated political biases in technological choices, and power struggles by which biotechnological developments agendas might be set. From this perspective, it is as necessary as it is interesting to gain a better understanding of these exclusion dynamics and search for alternative inclusive trajectories. In this way, theory might support the efforts of a marginalized social group (peasants) to gain further power within territorial based biotechnological systems.

The limitation of constructivism concerning the attention given to relevant groups of actors is related also to the second concern noted here. Some scholars have argued that the place given by constructivists to relevant groups is related to their specific position within a technological system and it omits other historical processes (Russell 1986, Winner 1993, Brey 1997, Bos 2004, Sismondo 2004). From a more critical perspective, the argument goes, social groups should be placed within historical processes, social structures, and power relations (beyond their roles in a given technological system). In the analysis of local sustainable biotechnological developments, not only are social actors introduced from a political and historically embedded perspective, but also biotechnological systems also are considered within the context of historical trends. To this end, Section 2.4 gives some examples of critical studies concerning the historical political and politicizing potency of biotechnological systems in rural societies. These studies sketch historical trajectories in which specific technologies and actors are contextualized.\textsuperscript{70}

\textsuperscript{70} It would not be fair to mention these limitations without recognizing that there have been thinkers within the wide spectrum of constructivism who have understood these shortcomings and tried to address them. For instance, Bijker attempts to extend constructivism to broad political discussions about democracy (e.g. Bijker 1995b). He stresses the political implications of technology and the necessity of enlarging the set of relevant actors in the design of technologies. Also, gender studies conducted within constructivism extend the analysis of cases to more general
Just as critical theory provides a skeleton for constructivism to flesh out, so also is this philosophical approach to technology starting from conceptualizations of power, society and technology strengthened by the more empirical analyses of constructivists. As a result, the critical approach to technology might be reconstructed under a different light to better understand the relationship between technology and society, by specifying the characteristics of different types of technologies and their impacts within societies. For instance, technologies might have different codes which made them properly workable only within specific types of social relations. Or in the words of Winner (1985; p. 31) ‘certain kinds of technology do not allow such flexibility, and that to choose them is to choose a particular form of political life’. Indeed, if we want to know what type of society a particular technology embraces, then we have to research the particular social relations that produce and reproduce that technology. As Bos (2000; p. 59) points out, within a specific context, formally rationally designed systems acquire specific socio-political biases. Bos (ibid.) argues that:

‘Within a factory setting, efficiency is often defined against the “background assumption” of worker resistance to work (Feenberg 1991; p. 69). In order to counter this resistant attitude, factory machines are therefore designed to de-skill and discipline workers (Braverman 1974). The result is known as Fordism or Taylorism’

This example shows us how global tendencies or argumentations around the philosophy of technology or of society at large (e.g. Fordism) can be elaborated or corroborated by empirical dynamics at the micro level; with specific examples of real machines and the particular social relations involved during their development processes. An empirical analysis of specific socio-technological systems is required to properly understand the politics of that particular technology. That is why for this thesis three specific socio-technological systems have been chosen for analysis, i.e. the three case studies.

By focussing on how technological changes occur within a certain socio-technological system (as precisely as constructivism can deconstruct them), we can start to understand how technology related developments affect or will affect a given society. Then our empiricism can really begin to inform theory, and we can attempt to elaborate on the structural power of (bio)technology in society at large. This has been done by classic works in the critical analysis of biotechnology and its structural power on agrarian societies, which investigate the industrialization and biotechnologization process of agriculture (e.g. Goodman, Sörj and Wilkinson 1987, Ruivenkamp 1989, Kloppenburg 2004, Ruivenkamp 2005b). With critical studies informing the way we understand how technology is constructed enabling us to examine examples that then feed back into theory, we have arrived at a two-way flow: by studying certain technologies and their local dynamics, we are able both to understand the structural power of technology in societies at the micro level and also to discuss the effects of global tendencies on biotechnological developments and their structural power on concrete societies. Following the theory building of these opening two chapters, the empirical consideration of local sustainable biotechnological developments presented in this thesis starts from the research at three specific locations for the development of genomics technologies attuned to these locations; herewith it is aimed at gaining a better understanding on the politics of genomics.

social dynamics connecting case studies about the relationship between gender and technology to social structures and power relations (e.g. Cowan 1983, Cockburn 1985).

71 Alvesson and Sköldberg argue that critical theory is not primarily and empirically oriented approach and it could be even criticized because of this (Alvesson and Sköldberg 2000; p. 130).
However, this research on the socio technological relations at the micro level is not a descriptive commission. The reflective and normative character of critical philosophical thought ought to push the analysis beyond mere descriptive parameters of how the relationship between the social and the technological elements of a given socio-technological structure works, it should provide a guide towards change. Ruivenkamp argues that the utopian-realistic approach – as he refers to the critical theoretical approach – aims to realise social change (utopism) based on the concrete opportunities that the existing reality affords (realism) (Ruivenkamp 2008b; p. 52). Critical theory moves away from more empirical studies stranded in a fixed present and draws the attention to that what can be (Alvesson and Sköldberg 2000; p. 134), or what ought to be. In this context, showing that technology is socially contingent and that a co-construction process between technical and social elements occurs within a technological design is not enough (although this point is a very important historical progress in the sociological field of science and technology studies). It is also important to integrate certain normative arguments, those incorporating values such, as justice, or direct democracy into the political arena of (bio)technology development.

Within a critical-constructivist framework, the common vision of a linear development of technology from theory, to application becomes criticisable. Therefore, the general understanding that biotechnologies can be produced in rich regions and transferred to poor areas is, at least, questionable. In this context, we can consider Latour’s view that universal scientific knowledge is the product of the manipulation of local circumstances (Sismondo 2004; p. 67). According to this, it follows that a product that might be transported to other local circumstances (territory) is only deployable through a set of new manipulations that adapt it once again to those local circumstances, or that adapt the local circumstances to it. Similar (manipulative or adaptability) dynamics are addressed here when discussing, for instance, how molecular markers have to be adapted to the local conditions of Cochabamba in Bolivia, in order to be able to perform in the new social and technological environment (Chapter 4).

Moreover and most probably, both the outsider (bio)technological structure and the receiver territory where the technology is deployed will tend to adapt to one another. From this perspective, the development of a new technology is socially influenced at all levels and moments. That is, socially constructed. Nevertheless, technologies carry embedded within them all kind of social processes that have brought them into being. Or in Feenberg’s words, the technical code (Feenberg 1999, 2008). Many of these codes reflect specific social demands within the shaping process of the technologies. ‘Technical codes are durable, but they can be revised in response to changes in public opinion’ (Feenberg 2008; p. 23).

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**Box 2.3. Feenberg’s instrumentalization theory**

Feenberg’s instrumentalization theory is an analytical attempt to understand the essence of technology in its historical context rather than in a socially-aseptic space (Feenberg 1999; pp. 202-208). The instrumentalization theory is a two-level theory. The first analytical level consists of the de-contextualization of objects reducing them to their functional properties. However, Feenberg argues that no de-contextualization can be absolute (Feenberg 2005a; p. 57). At the second level, these elements are re-contextualized into concrete social, natural and technological conditions. Here the different elements are interlinked, instrumentalized and acquire a meaning (conscious or unconscious) in the usage. The social activity of recontextualization to develop a new technology forms, in Feenberg’s terminology the code of the technology. For Feenberg, it is the technical code what gives politics to technologies.

The two levels should not be understood as consecutive steps of the designing process because
Andrew Feenberg (see Box 2.3) applies social constructivist approaches to his fundamental framework of critical theory. Although his approach is sometimes too abstract and supported only by a few in-depth empirical cases, it is nevertheless a strong trial to link normative and political analysis of critical theory with more empirical approaches. From this framework it is possible to elaborate arguments on the hierarchical and oppressive values that technology sometimes promotes as elaborated by authors like Marcuse and Foucault – combined with a social constructivism that can show the feasibility (at the micro-level) of more democratic technological developments (and codes). This can be accomplished by extending the participation of social groups (including the excluded) and bringing technological developments under a more democratic control. Brey (1997) claims that Feenberg transcends the methodological symmetry between the material and the social elements of technological social structures by making evaluative and political claims. What we obtain from this convergence of approaches is, as Bram Bos has expressed it, ‘a politically aware version of constructivism’ (Bos 2000; p. 62).

The critical perspective of local sustainable biotechnological developments, which is aimed at highlighting the impacts that biotechnologies have in society and how they can be locally reconstructed might be strengthened then, by the study of case-based (micro-level) analyses. This would not be the case if technology had an internal logic (as claimed by essentialism), or if technologies were strictly neutral (social determinism). In these two cases, it would be enough to analyze that logic, or study the social decisions made during the technological development. In fact, if we assume the basic conviction that the politics of technologies can be only addressed when we look at the integration of a certain technology within a certain society, then the empirical research of these socio-technical systems becomes obligatory (Bos 2000). This is why, in order to gain a better understanding of the political character of biotechnologies and genomics within the normative disposition of this thesis – and its search for re-designing trajectories of biotechnology and genomics for strengthening peasant agrarian systems, and to empower local actors within technological systems – a case study analysis has been chosen.

This section has introduced the theoretical frame of reference of the technological domain for studying the development of local specific biotechnologies. Summarizing, the critical constructivist understanding of (bio)technologies within the territorial approach of local sustainable biotechnological developments can be characterized as follows:

- It employs an understanding of technologies as social structures
- It is based on empirical studies at the micro and meso levels concerning power and the material dimensions of technology

72 For instance, his case of the French Minitel network reappears through his work (Feenberg 1995, 1999, 2008).
- It connects power dynamics at the micro-level with more general political tendencies of biotechnologies at the macro-level. In this context, the (bio)technologization of territories can become an empowerment project (rather than a domination program)

- It is a normative approach aimed at redesigning biotechnologies towards a local sustainable development by the introduction into their codes of certain social issues (i.e. strengthening peasant agrarian systems and empowering peasants, civil society organizations, and local researchers within biotechnological systems)

**Technological domain’s research focus**

The critical constructivist understanding of (bio)technology in the territorial approach of local sustainable biotechnological developments is developed here through the second analytic domain, the technological. For each of the three cases the technological domain explores the co-construction of material and social elements at the micro and meso levels. Special attention is devoted to political dynamics of inclusion and exclusion as well as to the material changes that are required for the deployment of genomics within peasant agrarian systems. Moreover, the micro and meso level dynamics of the cases are considered in the light of a wider context in which the territorial developments are seen as illustrative alternatives to the deterritorializing approach as presented in the introductory chapter. A reflection on the structural power of biotechnologies in the societies is addressed within the third analytic domain; the domain of reterritorialization.

The technological domain focuses on an analysis of power and the material elements of a biotechnology development. As explained, the material level is interrelated with the social, the two are co-constructing each other within technological systems. Social action is required in order to achieve a local sustainable development of biotechnologies, as described by the territorial domain, and a material reconstruction of the apparatuses themselves is also required. The analysis implied by a technological domain also reflects a belief that other alternative (bio)technological developments are, in fact, feasible. The analysis of the three cases in the technological domain is described in the following paragraphs, and presented schematically bellow (Table 2.2).

In the first case, the technological domain focuses on the redesign of Bt biopesticides in the form of sprays. By way of introducing certain social demands within the technical code of Bt spray a redesign route develops which transforms the Bt spray production process. Bt sprays are usually produced by a liquid-state fermentation, but this is transformed here into a solid-state fermentation process. This enables the Bt biopesticide to be produced at village level within a decentralized system of production units (bioresource centres) dispersed through the territory. The redesigning process enable the production of a Bt biopesticide which is efficient in killing the pest, affordable for peasant economies, accessible at the village level, non toxic and doable within the territory. Within this technological domain, some attention is also given to the role played by genomics applications in accelerating the process to develop the Bt spray.

In the second case, some ways in which molecular markers could strengthen small-scale potato systems in the highlands of Bolivia are explored. This study also addresses technological difficulties experienced with hi-tech genomics development in the local labs. These include the material readjustments that molecular marker technologies have to undergo in order to be able to
perform properly in the Bolivian territories. For example, by the production of local products that is required for the performance of molecular markers but which are difficult to obtain at the locality (e.g. the polymerase, or ethanol).

Finally, in the third case, the technological domain addresses the biotechnologization process (through genomics) that Jatropha is undergoing within a globally oriented project conducted from the Netherlands. This study explores some of the tensions released by this process which could extend the control of external research institutions over local production systems, but which is nevertheless strengthening the developmental capacities of the small-scale local production systems of Jatropha in Yoro, Honduras.

<table>
<thead>
<tr>
<th>Cases</th>
<th>Technological domain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1: Bt spray</td>
<td>- Bt spray redesign process: from liquid to solid state fermentation.</td>
</tr>
<tr>
<td></td>
<td>- Social demands are introduced into the redesign process (i.e. affordable, accessible, sustainable, and feasible).</td>
</tr>
<tr>
<td></td>
<td>- Genomics accelerates the redesign process.</td>
</tr>
<tr>
<td>Case 2: Molecular Markers</td>
<td>- The potential of molecular markers for small-scale potato production systems in the Bolivian highlands (i.e. biodiversity study and marker assisted selection)</td>
</tr>
<tr>
<td></td>
<td>- Material readjustments are required for the deployment of molecular markers.</td>
</tr>
<tr>
<td>Case 3: Jatropha</td>
<td>- Biotechnologization through genomics of Jatropha within global and local networks for producing local specific biofuels.</td>
</tr>
</tbody>
</table>

**Table 2.2.** Relevant issues of the cases addressed by the technological domain

### 2.4. The reterritorialization domain

The reterritorialization domain is the third analytical domain of local sustainable biotechnological developments. Firstly, the **territorial domain** focuses on power and locality, the social dynamics engaged by local multi-stakeholder networks for addressing specific agrarian problems of peasants through biotechnology. Secondly, the **technological domain** studies power and technology’s material dimensions for developing local specific biotechnologies. Finally, the **reterritorialization domain** explores the empowerment of territories within biotechnological developments.

By way of territorializing biotechnologies certain changes have occurred at the social (territorial domain) and at the material (technological domain) levels. Biotechnologies have acquired new codes (e.g. inclusion of peasant needs) which require that biotechnologies have to be adapted to the society and social relations of a given territory. At the same time, agrarian societies have to adapt also to the new technologies. Therefore, new partnerships and identities appear, or old partnerships and identities are transformed – for example, NGOs can become...
Local Sustainable Biotechnological Developments

producers of biotechnologies (Puente-Rodríguez 2007) leading to new technological social structures. In an optimal situation, the new technological social structures reshape the territory in a way as to guarantee the sustainability of these structures and the sustainability of the society they help to create. In this context, the reterritorialization domain explores the consequences that the socio-technological changes occurring during the local sustainable biotechnological development have for future negotiations around biotechnologies in the territory. These changes ought to empower the territories within biotechnological developments. From the normative framework of this thesis, the reterritorialization should lead to or be the outcome of a local sustainable development; i.e. *a territory in which sustainable biotechnologies work for local development, and a territory which is empowered for future negotiations around biotechnologies.*

Moreover, the territorialization of biotechnologies and the empowerment process of territories (reterritorialization) occurring at the local level of the cases studied here, takes place within a global context and tendencies in which biotechnology is developed. The third analytic domain of reterritorialization consists of reflections on the structural power of biotechnologies. In this context, the deterritorializing approach of biotechnology development has commonly failed not only to represent the spaces in which peasants perform agriculture, i.e. their needs, but also their knowledge of the local biodiversity, microclimates, or even the different social agrarian practices which are specific to different territories. A deterritorializing and abstract development of biotechnologies not only occurs within the labs where biotechnologies are developed, but it has also consequences for the territorial farming activities of peasants. And given that technologies are not autonomous entities which follow their own logic or neutral things that can be applied everywhere without any regard at all to the local, even deterritorialized biotechnologies developed by agribusiness or research institutes in the industrially developed world have a practical need for specific sets of local capacities (knowledge, or technological). Therefore, new biotechnologies like genomics can be either parachuted into peasant territories or they can be locally reconstructed to fit local needs and capacities. It is this latter development path that forms the research interest here.

The deterritorializing development of biotechnologies occurs within the general framework of the historical process of industrialization and scientification of agriculture. This process leads agriculture to a ‘monotonization or homogenization’ (Ploeg 1992). Scot argues that this process leads to a simplification of agriculture which can be summarized as ‘the maximization of crop yield or profit’ through monocropping (Scott 1998; p. 263). Other authors have stressed the historical processes that the biotechnologization of agriculture brings about – such as appropriation (Goodman, Sorj and Wilkinson 1987), or scientification (Ploeg 1987). These processes (elaborated below) have usually been reported in the literature as negative tendencies for the local territories of peasants. Nevertheless, within local sustainable biotechnological developments their underlying *global and local relationships are reconstructed.* During the territorialization process of biotechnologies here studied, it is suggested that global forces collaborate with, rather than merely assimilate, local networks. In this context, historical processes of *appropriation,* or *scientification,* are challenged and to a certain extent reoriented towards local sustainable development. Importantly, the concept of local sustainable biotechnological developments is a normative one, holding that through the introduction of values such as justice or democracy into the process of biotechnology development, the new technologies can become a vehicle for sustainable local developments. The reterritorialization domain works as a reflective domain in these two areas, namely, the empowerment of territories within biotechnological developments, and the new dynamics that local sustainable
biotechnological developments bring about within the historical and global process of industrialization and biotechnologization of agriculture.

Biotechnology’s structural force on agrarian societies

The deployment of biotechnologies within agriculture has taken place within the historical process of industrialization and modernization; a social process, according to some critical thinkers, with political consequences and politicizing potentialities for local rural structures. One of the most interesting works produced within this critical perspective is the book ‘From Farming to Biotechnology’, written by Goodman, Sorj and Wilkinson (1987). This book shows how the transformation of agriculture has occurred through a successive capitalist industrial appropriation of rural labour and biological activities by external institutions (through machines, fertilizers, hybrid seeds, fine chemicals, biotechnologies, etc.) and a parallel development of industrial substitutes (substitution) for rural products. Capitalism needs these two processes for controlling agriculture, since agriculture confronts industrial capitalism with its natural constraints on production embedded in fixed time and space co-ordinates.

Appropriationism is constituted by the action of industrial capitals aimed at reducing the importance of nature in rural production, and specifically as a force beyond their direction and control. This was achieved initially by relaxing the spatial-temporal constraints via mechanization, and the transformation of natural processes into scientific knowledge and industrial property. Appropriation refers to the constant take-over of biological and social activities from farming practices by external institutions, especially by industry. For instance, the production of crop-seed used to be managed by farmers but is now more often performed by research organizations and thereafter appropriated by large agro-concerns. Or, soil fertility was traditionally managed by farmers (with strategies such as crop rotation, or fallow field systems), but now it is primarily organized with the use of artificial fertilizers supplied by agrochemical companies (Jongerden and Ruivenkamp 1996).

Substitutionism concerns the gradual process of reducing rural products to industrial inputs, and the replacement of rural products by industrial components. The tendency of substitution is to eliminate the rural product and therefore the rural base for agriculture. This process is illustrated by the paradigmatic development of the chemical industry and synthetic raw materials. Farm products are reduced to semi-manufactured industrial goods that are over time themselves replaced by synthetic industrial products. For example, butter (made from milk) has been substituted by margarine (made from vegetable oils), or sugarcane has been substituted by corn syrup (made from maize).

The historical processes of appropriationism and substitutionism shape, and are shaped by the fast developments in biotechnologies. The versatility of biotechnology, for example, accelerates both appropriation and substitution – which might be one of the main reasons why major transnationals, within the agrarian sector, aim to control biotechnology research and development. Goodman and his colleagues (1987) show how biotechnology, within the accumulation logic of large agro-industrial concerns, helps to break the direct relationship between agrarian products and consumption. Furthermore, when the biotechnologization of agriculture takes place in different regions of the world (as has been the case with the Green Revolution), it also shapes power relations within and around rural production. For instance, the
Local Sustainable Biotechnological Developments

process of substitution—shaped by biotechnology—has moved agriculture away from the use of ‘basic raw materials’ towards ‘new materials’ that meet the objectives of raw materials by a reformulation of other available materials, which might themselves be substitutes. For example, corn starch derived from genetically modified maize is processed into various sweeteners, especially high fructose corn syrups (used in foodstuff), and dextrose/glucose, e.g. for sorbitol (used for oral hygiene products, etc.)

Among other consequences, this is shifting supply from and weakening the market share of the traditional producers of raw materials, the third world. As Ruivenkamp (2005b) stresses, it is not only possible to interchange products or their components, but it is also possible to interchange producers from different sectors and world regions. In this way maize producers become competitors of sugarcane producers. Therefore, substituting sugar as a sweetener, and making producers of sugarcane and producers of corn interchangeable, supposedly contributed to the elimination of corn’s excess stocks in the USA, and to unemployment in the Philippines (Jongerden 2008).

Studying further the biotechnologization of agriculture, especially in third world regions, Ruivenkamp (e.g. 1989, 2005b) has built a theoretical framework around the concepts of appropriation and substitution. Ruivenkamp illustrates how agriculture has become increasingly a less autonomous sector. The agrarian sector has become a link in the chains of industrial production. This process occurs through the biotechnologization course which is directly related to the scientification process of agriculture. The scientification process of agriculture has been defined by van der Ploeg (1987) as the increasing prescription of farmers practices from the scientific domain. Van der Ploeg argues that this process, as a development model for agriculture, seems to be universally applied, without considering essential elements of local agriculture, such as time and territory. This process is not unidirectional, however. Science and agriculture are closely related with the construction of the territory (e.g. by peasants), and when science comes in contact with the local features of territories, then, the scientification process also have to adapt itself to the new context. There is, therefore, an experiential basis for local sustainable biotechnological developments.

Ruivenkamp shows how the scientification process of agriculture occurs through the industrial appropriation and relocation of farmers’ knowledge and practices to external research centres, and through the subsequent transformation of this appropriated knowledge into agrarian products (such as high-yielding and hybrids varieties, artificial fertilizers, agrarian pesticides and fermentation processes) by the same external research institutions. These institutions are able, through these (politicizing) products, to exercise control at a distance over certain agrarian activities that had previously been in farmers’ hands. Control at a distance, therefore, constitutes a new feature of the historical industrialization process of agriculture. The scientification of agriculture also feeds into the process of substitution. The appropriated knowledge of agrarian products and their different components facilitates the interchange of different (components and/or) products for the production of final goods.

While the industrialization of agriculture occurs through the processes of appropriation and substitution, the biotechnologization of agriculture increasingly takes place through control at a distance on agrarian production systems, and the interchangeability of producers (and even sectors), products and elements of these products. These analytical tools help us to understand how biotechnologies are developed within concrete socio-political contexts and have consequences for the contexts in which they evolve. Biotechnologies are political and politicizing structures not only because they are socially constructed, but also because they can restructure society. These analytical tools are relevant for defining the concept of local sustainable
Redesigning Genomics – Reconstructing Societies

biotechnological developments. In this thesis, genomics is studied within concrete territories and their specific social relations in which the technological applications have to be adapted to the social characteristics of the territory, and vice versa. Moreover, this process of contextualizing and territorializing biotechnologies is understood within global and historical biotechnological political trends.

Some of the authors referred to sketch a situation in which, through a deterritorializing production of science and biotechnologies, a standardization, homogenization or simplification (Ploeg 1992, Scott 1998) of agrarian systems (territories) occur. But this process is, of course, far from complete. Since agrarian systems are not just passive receptors of science and technology developments sent from cities and industry, and since technology is not a neutral route towards progress, then different reactions will and are emerging. Van der Ploeg (1992; p. 21) argues that ‘locality and heterogeneity are reconstituted, not as mere repetition of former expressions. They re-emerge as a repertoire of new, strategic responses to the now dominant tendencies and relations’ of standardization’. Following Van der Ploeg, we could argue that it may be this plurality within the different agrarian territories that will become the Achilles’ heel of the deterritorializing development of biotechnologies; at least in its current imperialistic form. A territorialization process seems unavoidable to be able to implement the potency of biotechnologies within resource-poor farmers’ agrarian systems, because it might also be impossible to do it in any other way. The socio-technological specificities of the different territories will inevitable adapt and transform the technologies that arrive there. The cases presented in this thesis are illustrations of how local strategies do and might reorient biotechnological developments towards local sustainable developments.

Reterritorialization domain’s research focus

Magnaghi (2005b; pp. 47-48) argues that where inhabitants have lost all decision-making powers over their own territory, many actions of economic development use local resources (environmental, territorial and human actions) for exogenous ends, burning them up in the competition of the world market, but without necessarily satisfying the needs of local inhabitants. Genomics is one of the technological means by which access to natural resources around peasant agrarian systems is gained. Therefore, the control (power) exercised by local actors on genomics technologies might guarantee the utilization of local resources in ways that consider local needs. This would be positive for the locality not only in a utilitarian way, but also from the territorial perspective. Following Sack (1986) we have defined territoriality as the local specific attempt by individuals or groups, to influence or control people, phenomena, and relationships. Therefore, how power is exercised, and how the excluded can be included in biotechnological developments is – within the normative framework of this thesis – considered relevant for its own shake.

As mentioned in the introduction of this chapter, every territorialization trajectory is at the same time a reterritorialization process. By way of territorializing biotechnologies a reterritorialization process occurs; territorialization and reterritorialization are two sides of the same coin. Here, they are different but nevertheless closely related features of the idea of a local specific development of biotechnologies, considered separately purely for analytical purposes. While the territorial domain concerns the social dynamics of a certain biotechnological development, the reterritorialization domain works as a reflective domain reviewing both the
territorial domain and its social dynamics, and the technological domain with its material changes; as well as considering the meaning that the local dynamics have within the global trends of biotechnological developments (e.g. appropriation and control at a distance).

The third analytic domain of local sustainable biotechnological developments explores how new technological social structures are emerging through the territorialization of biotechnologies. In some cases new identities have been acquired and social partnerships have been reorganized. Some material reorganizations have occurred by way of integrating social demands into the biotechnological developments, i.e. a technological redesign. This redesigning process of biotechnologies at the social and material dimensions thus produces new socio-technological structures, which are reconstructing the territories in which they evolve and at the same time reproduce. These changes at the local level have also consequences for the global trends in biotechnology developments. Ultimately, therefore, the domain of reterritorialization reflects on the possible reorientation of biotechnological trends from what is frequently a deterritorializing framework towards a territorial one. The principle reflections of the three cases in this domain are described in the following paragraphs, and summarized schematically below (Table 2.3).

The reterritorialization domain, in the first case (Chapter 3) suggests that the social and material rearrangements around the Bt spray in two districts of Andhra Pradesh, India, create a new technological code, both materially and socially. This process generates an understanding of the territory which makes possible the development of biotechnologies which are efficient, accessible, sustainable and feasible. New structures emerge where peasants, peasants’ organizations, local communities, civil society organizations and scientists meet to develop appropriate biotechnologies. These structures are materialized in the bioresource centres where the Bt spray and other biotechnology products are produced. Biotechnologies are no longer developed ‘at a distance’, but developed locally, from the bottom-up. Moreover, peasants and civil society organizations are empowered in the development of appropriate pest-management technologies, and therefore they are also empowered within their own territory.

In the second case study (Chapter 4), the reterritorialization domain reflects on how, when molecular markers are deployed within a raw material understanding of potato diversity, this diversity is extracted from the Bolivian highlands and appropriated by global networks to serve as a basis for plant breeding projects outside the territory. Contrary to this, Quechua and Aymara peasants, who inhabit these territories, are empowered within the development of the Wiphala genomics, as well as strengthened in their strategies for conserving and producing potato’s genetic variety and productive diversity. This issue is highlighted by applying the concept of *polypotency* (Sclove 1995) of technology, which maintains that technology is potent in many ways. By way of deploying molecular markers within a specific social and technical code in which power is exercised from within the locality (territorialization), the development capacities of these territories regarding biotechnological developments can be strengthened (reterritorialization).

In the last case study (Chapter 5), this analytic domain works as a reflective moment with regard both to how the biotechnologization process that Jatropha is undergoing might strengthen the small-scale production systems in Yoro (Honduras), and to the meaning that these dynamics acquire and produce within the global and historical trends of biotechnological developments.
Cases | Reterritorialization domain
--- | ---
Case 1: *Bt spray* | - Bioresource centres are seen both as socio-technological structures for developing biotechnologies locally and sustainably, and as a driving force for bottom-up development.  
- The social relations organized around the new Bt spray provoke a re-structuring of the territory in which peasant agrarian systems are strengthened, and peasants, villagers, civil society organizations, and researchers are empowered within biotechnological systems.  
- Global biotechnological developments are reoriented towards local sustainable development.

Case 2: *Molecular Markers* | - Molecular markers ought to be territorialized within a cultural understanding of biodiversity.  
- Molecular markers are reoriented towards local needs – from extractors to producers of potato diversity.  
- The polypotency of (bio)technology – global biotechnological developments are also polypotent.

Case 3: *Jatropha* | - Horizontal relationships between local and global networks for developing genomics.  
- The biotechnologization of Jatropha as a vehicle for local sustainable development.  
- Reconstructing biofuels and biotechnological regimes towards a development of local specific biofuels and biotechnologies.

Table 2.3. Relevant issues of the cases addressed by the reterritorialization domain

### 2.5. The way forward

‘Local sustainable biotechnological developments’ are defined in this thesis as the type of developments that strengthen the agrarian systems of peasants within a territory through the development of local specific biotechnologies, and which empowers peasants, peasants’ groups, local scientists, and civil society organizations within biotechnological systems. These developments are based in the reconstruction of biotechnologies mainly (though not exclusively) by and for the locality.

The territorial approach to the development of agro-genomics in particular and of biotechnologies in general is not regarded as opposed to what is termed the deterritorializing approach. Rather, it represents an alternative and corrective approach to this mainstream path of genomic technology development. It is not the objective of this research to look at whether a deterritorializing development of agrarian genomics might or might be not an appropriate approach for commercial agriculture (in developing or developed parts of the world). Here we are interested in the alternative territorial approach and in its relevance when biotechnological developments aim to strengthen peasant agrarian systems and to empower local actors within
biotechnological developments. It is entirely possible that the multiple social and environmental peculiarities of the different territories constructed around peasant systems (which are quite different from those ones in which genomics is developed) might make a territorialization process of the genomics technologies inevitable. Although it is not the intention here to present a bipolar situation (i.e. deterritorial versus territorial), these two understandings of whether and how biotechnologies should be deployed for strengthening peasants’ territories do represent different views of and have different consequences for the social, natural and technical dimensions that constitute any given territory. These differences are introduced schematically in Table 2.4.

<table>
<thead>
<tr>
<th>Deterritorializing biotechnological developments</th>
<th>Local sustainable biotechnological developments – a territorial approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Exclusion of local actors (e.g. peasants) from the development of biotechnologies.</td>
<td>- Inclusion of local actors (e.g. peasants and civil society organizations, and local researchers) in the development of biotechnologies.</td>
</tr>
<tr>
<td>- Transfer of technology.</td>
<td>- Redesign of technology.</td>
</tr>
<tr>
<td>- Abstract and functional understanding of the local.</td>
<td>- Territorial understanding of the local.</td>
</tr>
<tr>
<td>- Biotechnologies as neutral material entities.</td>
<td>-Biotechnology as a political entity, a social structure.</td>
</tr>
<tr>
<td>-Result:</td>
<td>-Result:</td>
</tr>
<tr>
<td>• further functionalization of localities (i.e. of peasant agrarian systems)</td>
<td>• reterritorialization or enhancement of the locality</td>
</tr>
<tr>
<td>• disempowerment</td>
<td>• empowerment</td>
</tr>
<tr>
<td>• abstract biotechnologies</td>
<td>• local specific biotechnologies</td>
</tr>
</tbody>
</table>

Table 2.4. Deterritorializing versus territorial approach to develop biotechnologies

The objective of the three-domain research method of local sustainable biotechnological developments is to find out dynamics by which biotechnologies might become a vehicle for local sustainable agrarian development, and by which a wider set of actors can be empowered within biotechnological systems. However, even if we find coincidences in the analysis of different cases on local sustainable biotechnological developments, these should not just be assumed as the model for designing agro-genomics research agendas. Scott (1998) argues that strong top-down social designs, planned by the state, usually fail because production processes depend on a large set of improvisations and informal practices that cannot be codified and which are specific to a local context. I would not like to make the same mistake and offer the approach presented in this thesis as a ‘one-size-fits-all’ model for redesigning biotechnologies. Different local contexts and different (bio)technologies require different redesigning strategies. However, the three analytic domains of local sustainable biotechnological developments could be applied to test the territoriality of the multitude of biotechnological developments within the diversity of peasants’ territories.

To conclude, Table 2.5 summarizes the main issues studied within the three analytic domains in the three cases and presented in the following chapters:
## Local Sustainable Biotechnological Developments

<table>
<thead>
<tr>
<th>Cases</th>
<th>Analytic domains</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Territorial domain</strong></td>
</tr>
<tr>
<td><strong>Case 1: Bt spray</strong></td>
<td>- Small-scale production of castor in the semi-arid districts of Mahaboobnagar and Nalgonda in Andhra Pradesh, India. - Failure of existing pest-management technologies to address peasants’ problem with castor semilooper. - Multi-stakeholder networks reorganizing human and natural resources for developing a Bt-spray (biopesticide). - A new technological social structure is emerging around the Bt spray which is characterized by an increasing involvement of multi-stakeholders platforms that are inclusive for peasants, local villagers and civil society practitioners. - Bioresource centres have become places of encounter for territorializing biotechnologies.</td>
</tr>
<tr>
<td><strong>Case 2: Molecular Markers</strong></td>
<td>- Potato peasants in the highlands of the departments of Cochabamba and Norte de Potosí, in the Bolivian Andes. - Loss of potato-biodiversity and unremitting problems with <em>Phytophthora infestans</em>. - Contradictory understandings of potato-biodiversity in the Bolivian Andes (i.e. as raw materials and as cultural materials. - Participatory plant breeding platforms as appropriate social structures to deploy MMs. - The Wiphala Genomics.</td>
</tr>
</tbody>
</table>
**Case 3: Jatropha**
- Jatropha peasants in Yoro department, Honduras
- Local energy needs
- Jatropha’s local diversity wealth
- Against this background *Jatropha curcas* is undergoing a biotechnologization process (through genomics) that can either functionalize or develop the territory
- Structures are emerging for locally producing and utilizing Jatropha based biofuels
- Complementary production systems of food and fuel crops

- Biotechnologization through genomics of Jatropha within global and local networks for production of local specific biofuels

- Horizontal relationship between local and global networks for developing genomics.
- The biotechnologization of Jatropha as a vehicle for local sustainable development.
- Reconstructing biofuels and biotechnological regimes towards a development of local specific biofuels and biotechnologies.

| Table 2.5. Issues addressed by the three domain concept of local sustainable biotechnological development in the analysis of case studies. |  |  |
Chapter 3

3. Territorializing the production of a *Bacillus thuringiensis* biopesticide within the context of peasant agriculture in Andhra Pradesh, India

'It is a kind of moral right or a matter of justice, that people should be able to influence the basic social circumstances of their lives'
(Sclove 1995)

'I like the Bt spray because we don’t get breathing problems and irritation as with the other pesticides. It is also cheap, easy to use, and it kills the worms'
(P Alivielamma)

73 An earlier version of this chapter has been published as: Daniel Puente Rodríguez (2007), ‘Redesigning the Production of the *Bacillus thuringiensis* Bio-pesticide within the Context of Subsistence Agriculture in Andhra Pradesh, India’; in the Asian Biotechnology and Development Review, Vol. 9 (3), pp. 55-81. Some of the major findings of this case were presented at the Innogen Annual Conference ‘Genomics for Development? The Life Sciences and Poverty Reduction’ held 5-6 September 2006, in London (UK). On the basis of the data collected for this case an opinion piece has been also published as: Daniel Puente-Rodríguez (2008a), ‘A Local Approach to Agri-Technology in India’. Science and Development Network. Available at: [http://www.scidev.net/en/opinions/a-local-approach-to-agri-technology-in-india.html](http://www.scidev.net/en/opinions/a-local-approach-to-agri-technology-in-india.html)

74 Mrs Alivielamma is a peasant in Venkayapalli village (in the Mahaboodnagar district of Andhra Pradesh). This statement was made during a discussion group in the village (31 October 2005)
3.1. Introduction

Alongside the efforts of private and public institutions to relate the development of biotechnologies to a relatively homogenous non-territorial framework aimed at developing global products to manage the multiple biotic stresses affecting agriculture, there are also initiatives by multi-stakeholder networks aimed at territorializing the development of pesticides. These two types of initiatives are characterized by the different technological choices that are made to manage biotic stresses, resulting in different techniques of pest management.

This chapter explores the ongoing experience of multi-stakeholder networks situated in the two dry-land districts of Mahaboobnagar and Nalgonda of Andhra Pradesh, India and coordinated by the Andhra Pradesh Netherlands Biotechnology Programme (APNLBP) in their attempt to redesign the production of biopesticides based on extracts of the soil bacterium Bacillus thuringiensis (Bt). The new Bt product is applied to control the semilooper (Achea janata) pest, which causes heavy losses to the most important crop grown in these regions, castor (Ricinus communis). The multi-stakeholder approach is intended to strengthen the development perspectives of small-scale agrarian systems in these dry-land districts. By relating technology development to the context of the village economy, it is claimed that a significantly different Bt biopesticide is emerging, one that is unlike the Bt-resistant plants and sprays delivered by multinationals.

The development of the new biotech product (the Bt spray) is examined here at the three proposed analytic domains of local sustainable biotechnological developments. Firstly, at the territorial domain the power strategies of the local multi-stakeholder networks – formed by peasants, civil society organizations, and public research institutes and extension services – to mobilize and enhance local resources (human and natural) for the design, development and deployment of the Bt spray are analyzed (Section 3.3). Secondly, the technological domain (section 3.4) explores the technological redesigning process that has been required for the production of a pest-management technique attuned to the needs of local small-scale castor production systems. This redesigning process refers to the shift from the production of Bt sprays usually produced by the multiplication of Bt spores through liquid-state fermentation to a solid-state fermentation process. The former production process requires high capital and technical resources that are difficult to access in rural India, whilst the later is a cost-effective, 'low-tech' production process reproducible on a small-scale at the village level. Within this domain also the role that genomics has played in accelerating and strengthening the redesigning process is discussed. Finally, Section 3.5 of this chapter looks at the reterritorialization domain reflecting on how the control over the development process of the Bt technology has been reorganized towards an increased involvement of multi-stakeholder platforms. Consequently, it is argued that

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75 Implemented by the Dutch Ministry of Foreign Affairs (see Box 3.1) through its development-cooperation agency (DGIS), the APNLBP was a special biotechnology programme aimed at improving the quality of life of resource-poor farmers in the predominantly dry districts of Mahaboobnagar and Nalgonda in Andhra Pradesh (recently reorganised as the Agri Biotech Foundation, ABF, the work this institution has now been expanded to other districts of the state - G. Pakki Reddy, personal communication, 29 October 2008. The APNLBP employed a methodology in which biotech projects were initiated based on local needs assessments and priority settings, and involving networks formed by farmers, CSO policy makers and scientists (see Figure 3.1). Financial support for the APNLBP/ABF has been provided by the Dutch Government, while the local Agricultural University of Hyderabad has provided land for an ABF campus (June 2 2007). See www.abfindia.org.

76 Biopesticides are substances created from living matters to control pests.
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the bottom-up biotechnological redesign and the space conquered for negotiations by (the empowerment of) peasants and civil society organizations are reinforcing each other in such a way that the political dimensions of the Bt spray are, to a certain extent, reshaping the social agrarian landscape (reterritorialization) of Andhra Pradesh.

By reflecting on the design, development and deployment of the Bt spray, this chapter attempts to illustrate how the act of territorializing biotechnologies is moved by the exercise of a local specific power within the concrete self-organizing social environment of a given territory. In these processes, certain social issues are incorporated into the technical side of the biotechnological development; this leads to new products which can address the needs of resource-poor farmers. Furthermore, it is the intention of this chapter to add empirical data to the debate in the social sciences about the possibilities for reorienting the development of biotechnologies from a non-territorial development – dominated by high-tech laboratories located mainly in urban areas – to a local sustainable development in which specific social issues can be introduced into the design of new biotechnologies and products by a wider set of social actors.

Before going into the analysis of the developmental dynamics of the Bt spray the chapter first explores the social relevance of Bt products in the State of Andhra Pradesh for both large-scale and small-scale farming systems.

3.2. Social relevance of the production and use of *Bacillus thuringiensis* based products for Andhra Pradesh agriculture

Andhra Pradesh is a large, relatively poor state situated mostly on low-lying land on India’s eastern seaboard (Map 3.1). Some 35 per cent of the population of India survive on less than a dollar a day but the per capita income of Andhra Pradesh is even lower than that of the country as a whole. India’s fifth largest federal state by population and fourth largest state by area, Andhra Pradesh (AP) can be broadly divided into three regions, namely Costa (Coastal Andhra), Telangana (west on the Deccan plateau) and Rayalasemina (southeast on the Deccan Plateau).

This study was conducted in the Mahaboobnagar district, the largest district in the Telangana Region and the second largest in AP, and in the Nalgonda district (Map 3.2). The rural population in these districts forms 90 per cent and 87 per cent respectively of the total population. Agriculture is rain-fed, but the districts are located in the semiarid region of India with water source problems due to recurring meteorological drought exacerbated by overexploitation of the meagre groundwater resources. Many other interrelated problems weigh on the lives and work of small-scale farmers in these areas in

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77 [www.worldbank.org/in](http://www.worldbank.org/in). The overwhelming majority (72 per cent) of the more than one billion inhabitants of India live in the countryside. Over 80 per cent of those are small-scale farmers and landless labourers who own a mere 35 per cent of the total 10 million hectares of cultivated land (Vimala Devi and Rao 2005b)
addition to drought, including low yields, extreme poverty – and pests.

The main crops cultivated in these districts are castor, red gram, sorghum and groundnut. Of these, castor\textsuperscript{78} is the most important, occupying 27 per cent of the cultivated area of Mahaboobnagar and 20 per cent in Nalgonda. Many insect pests constrain the cultivation of this crop, one of the most important being the semilooper, which causes heavy losses of up to 20 per cent of the total yield (Gaikwad and Bilapate 1992, DOR 2005b).

Castor semilooper and other pests had conventionally been fought with the massive use of chemical pesticides. Indeed, AP is one of the major consumers of agro chemicals in the country (Kolanu and Kumar 2007). However, there has been a significant decline in pesticide consumption in the state during the past decade, from an estimated 13.650 tonnes used in 1992-93 to 3.600 tonnes throughout the period 2003-04. Officials at the State Agricultural Department attribute this decrease to the adoption of integrated pest management practices, along with a growing awareness among peasants of the risks attached to agro chemicals (Reddy 2003).

In fact, the employment of pesticides for pest management is problematic in these territories for a variety of reasons. Firstly, most commercial products are unaffordable for small-scale farmers. Secondly, peasants have to deal with untrustworthy merchants. Unlicensed dealers and retailers sell pesticides without being aware or without informing about their toxicity, an uncontrolled marketing that has escalated pesticide misuse. In addition, ‘ghost companies’ visit villages from time to time to sell ‘pest-management’ products that can vary from out-of-date products, to plain water in pesticide packaging. Banned pesticides like DDT and BHC\textsuperscript{79} are still being sold on these regions. This could mean that the actual pesticide consumption is even higher than official figures suggest (Shetty 2004). Thirdly, the toxicity of the available chemical pesticides causes health problems to peasants. Peasants are often unable to read the pesticide’s instructions labels (either because they cannot read or do not understand the language on the labels) and do not have the necessary means for protection, such as masks and gloves, etc. Finally, the massive use of pesticides has degraded the fertility of the soils and caused problems for non-target organisms (Vimala Devi and Rao 2005a).

In addition to the application of chemical products,\textsuperscript{80} various other methods are used to manage the castor semilooper. For instance, hand picking and killing the (older) larvae of the

\textsuperscript{78} Castor is one of the major oilseed crops of India which accounts for 76 per cent of all world exports. Within India, Andhra Pradesh is the second larger castor-growing state in the country, with 0.39 million ha. of land producing 0.13 million tonnes annually (DOR 2003). Peasants here produce castor as a seasonal cash-crop. Castor produces oil, which is used for a number of industrial applications, e.g. lubricant and hydraulic fluids, dye, detergents, plastics, and paints. It has also other, traditional uses: medicinal for example (as a purgative), for lighting (as a fuel for lamps). Moreover, the toxicity of the oil ricin has been traditionally used as a powerful poison. It is the extreme toxicity of the oil that has gained international attention of late, with reports that Taliban fighters are experimenting with it (BBC 2006, NRC 2006), and work on vaccines already begun in the USA (Vitetta, Smallshaw, Coleman et al. 2006).

\textsuperscript{79} DDT (abbreviated from its full name dichlorodiphenyltrichloroethane) and BHC (benzene hexachloride) are synthetic pesticides.

\textsuperscript{80} Among those chemical products, Monocrotophos 0,05 per cent, quilalphos, 0,05 per cent, endosulfan 0,07 per cent and acephate 0,075 per cent are reported to be efficient against the semilooper (DOR 2003, 2005b), but they are also reported to be highly toxic for humans, harming villagers’ health, and for other organisms (Shetty 2004).
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semilooper is an effective traditional method practiced by some castor growers. Moreover, some efforts have also been made to control the pest by releasing parasitoid eggs of *Trichogramma chilonis*, and of *Telenomus proditor*. Nevertheless, this practice has not gained popularity among peasants because of the complex set of practices necessary for an appropriate usage (DOR 2005b). Other biological controls effective against semilooper include extracts from the neem seed and other neem formulations. Finally, the bacterium *Bacillus thuringiensis* (Bt) has been found to be effective against semilooper (Vimala Devi, Prasad and Rajeswari 1996). This chapter focuses on the development of a Bt-based biopesticide spray to control the castor semilooper.

The menu-card of *Bacillus thuringiensis* (Bt) as a biopesticide alternative

Bt is a soil bacterium. The insect pathogenic activity of Bt is a natural process occurring in the daily organic life of farmers’ fields. Bt has toxic effects on certain insects (in the Lepidoptera, Coleopteran and Dipteral families). However, Bt is considered safe for humans and other mammals (Kough 2003), as well as highly specific and therefore safe also for non-targeted insects (Federici 2005, Vimala Devi, Ravinder and Jaidev 2005). In short, current Bt-based developments could be the start of a long series of new and expected safer technologies to augment productivity and to bring about a more sustainable agriculture. Within Bt alone, there are already over 50 genes with known insecticidal properties (Krattiger 1997). Indeed, Bt is the only microbe that has been successfully commercially exploited for the management of insect pests. Bt based formulas have been used as an effective biopesticide in agriculture since the discovery of the mechanism of its toxicity (in the fifties) (Federici 2005, Kleinman 2005) and Bt products currently make up 95 per cent of the world market in microbial pest control agents (Vimala Devi and Rao 2005b).

Three main technological trajectories have been followed for the production of Bt-based products:

- recombinant DNA techniques
- biopesticide Bt spray (liquid-state fermentation)
- biopesticide Bt spray (solid-state fermentation)

Recently, researchers have begun the transference of certain genes from Bt to plants, in order to create crops that produce their own insect toxins.\(^8\) The development of this technology has provoked a fierce pro-anti debate. In spite of the great expectations of some researchers, sceptics expect insects to develop resistance Bt, especially when it is genetically transferred and it usage widespread and large-scale (Krimskey and Wrubel 1996, Jenkins 1998, Kleinman 2005). In addition, cross-pollination between genetically modified and non-modified crops may occur (Federici 2005). Many criticisms are based on the fact that large life-science corporations (joint business of agro-chemical and biotech companies) dominate the commercialization of Bt (Jenkins 1998, Federici 2005). For instance, only 17 per cent of all patents granted from 1986 to 1996 were issued to public institutions and universities (mostly from USA and Russia) (Krattiger

\(^8\) In 1995 the US Environmental Protection Agency approved the commercial release of the first transgenic crop containing a pesticide in the form of a Bt-potato to control the Colorado potato beetle. It was produced by Monsanto (Krimskey and Wrubel 1996, Kleinman 2005).
The major players in transgenic Bt plant technology are Monsanto, Novartis, AgrEvo (Bayer CropScience) and Mycogen with their own technologies, and Dekalb Genetics Corporation and Pioneer Hi-Bred International through strategic alliances (Krattiger 1997).

The production of Bt transgenic crops is increasing in India as a whole (James 2008), but resource-poor farmers are generally unable to use them because of their high prices (Qayum and Sakkhari 2005). The use of Bt-cotton seeds, for instance, implies increased investments in terms of purchasing seeds, fertilizers and pesticides. Peasants frequently need to take loans to be able to afford such costly inputs, and risk being left with crippling debts compounded by high interest rates in the case of disappointing harvests or crop failures. Moreover, most efforts, so far have been oriented to the development of Bt crops of major agrarian and commercial importance, bypassing relatively minor crops like castor.

The two major methodologies employed in addition to the DNA recombinant trajectory for the manufacture of the Bt bacteria in the form of a bio-pesticide are the solid-state fermentation and submerged (liquid-state) formulations. Formulation is a crucial link between production and application and dictates the efficiency and economic viability of the final product. Moreover, the maximal production of Bt toxin can be achieved only by paying careful attention to the interaction between fermentation conditions, media and the Bt isolates involved (Vimala Devi and Rao 2005b). Furthermore, the sustainability of the production process is related to the following factors:

- cost of raw materials
- strain efficiency
- required degree of automation
- continuous power supply
- sufficient supply of technical skills (Vimala Devi and Rao 2005b, El-Bendary 2006)

Of these, one of the principal expenses involved in Bt production is the cost of raw materials. In the conventional production process (industrial-scale, liquid-state fermentation), the cost of raw materials comprises between 30 and 40 per cent of the total costs, depending on the plant production capacity (El-Bendary 2006). Local production of this insecticide in resource-poor rural areas therefore requires the use of production media made from cheap, locally available resources. Although the efficiency of the commercial formulations for the agrarian contexts with

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82 AgrEvo and Rhône-Poulenc Agro merged in 2000 to form Aventis CropScience, which in 2002 was bought by Bayer creating Bayer CropScience (www.bayercropscience.com).
83 Some scholars have even claimed that farmers in the Warandal District in Andhra Pradesh have even been pushed to commit suicide because of the debts incurred through the purchase of the Mayco-Monsanto transgenic cotton seeds (Shiva and Jafri 1998, Stone 2002).
84 In India, Bt-based pesticides are being marketed by three companies: Delfin from M/s Margo Biocontrol Pvt. Ltd, Dipel from M/s Cheminova, and HALT form M/s Wockhardt Ltd (DOR 2005a). The total sales in 1999 were about 70 tonnes (Dr. Mc. Sharma, pers. Comm. Director, Biotech International, New Delhi).
85 Efficiency in this context means longer shelf life, ease of application and enhanced performance of Bt formulations (Brar, Verma, Tyagi et al. 2006).
86 The basic active agent of Bt, called delta endotoxin, is produced in the form of crystalline parasporal inclusions during the sporulation. This is a kind of latent state in which the bacteria nearly dry up, and by which the bacteria can survive in hard condition. During this stadium Bt produces specific proteins that as crystals (cry-proteins) stay at the spore (Bos 2004). According to Rowe, Margaritis and Dulmage (1987) and to WHO (1999), nine different toxins have been described in Bt strains, of which the delta endotoxin has received much attention in the production of bio-pesticides (El-Bendary 2006).
the required economic capacities has been proved, the liquid-state fermentation might not be economically feasible for resource-poor rural areas due to the relatively high costs of technicians and automation, with equipment including a deep-tank fermentor, and high speed cooling centrifuge as well as drying facilities, e.g. spray-dryer (El-Bendary 2006).

In India, Bt biopesticides are produced by the liquid-state fermentation, with companies usually importing the technical and biological materials and producing the final products in India (DOR 2005a). This commercial strategy has not succeeded in developing suitable technologies for small-scale agriculture because it requires:

- high capital investment
- a high level of automation
- high technical skills
- a continuous power supply (Vimala Devi and Rao 2005b)

Thus it is that solid-state fermentation emerges as a more feasible methodology for territories that lack the human and economic capacities to engage in liquid-state fermentation. Moreover, solid-state fermentation, unlike liquid-state fermentation, is not a water-intensive process, a crucial factor in drought-prone areas like those in Andhra Pradesh considered here. Concomitant advantages of the solid-state fermentation therefore are:

- Low methodology costs
- low capital investment requirements
- a low level of automation
- low technical skills requirements
- low usage of water (Vimala Devi and Rao 2005b, El-Bendary 2006)

Summarising, within the narrow context of an industrial and non-territorial development of Bt pesticide products for agriculture, no suitable pest-management technology has been developed attuned to the potentialities and constrains of peasants in the agriculture of these territories. It is quite apparent, therefore, that solid-state fermentation constitutes a potentially critical methodology for the production of efficient, locally-oriented biopesticides in developing countries. Nevertheless, little has been published on this subject (El-Bendary 2006).

This chapter is a report from the field on the employment of solid-state fermentation for producing local specific biopesticides. It explores the dynamics involved in the redesign by local networks of the production of a Bt biopesticide for the management of the castor semilooper, from a liquid-state fermentation to solid-state fermentation. The study is structured through the three analytic domains of ‘local sustainable biotechnological developments’ outlined. The following section examines the territorial domain (power and locality) of the process of redesigning the development of a Bt biopesticide.
3.3. A locality specific approach to the development of Bt biopesticides – The territorial domain

The development of the Bt spray examined here was initiated within the institutional framework of the Andhra Pradesh Netherlands Biotechnology Program (APNLBP). Created by the Dutch Ministry of Foreign Affairs through its development-cooperation agency (DGIS) (see Box 3.1) in 1996, the APNLBP was a special biotechnology program aimed at improving the quality of life of resource-poor farmers in Mahaboobnagar and Nalgonda. Its main work was to initiate and manage biotech projects based on local needs assessments and priority settings. In order to properly understand the APNLBP programme, we should know that the Dutch Ministry of Foreign Affairs decided at the outset to delegate responsibility for the management of its projects to a local steering committee. This committee was composed of members of peasants groups, public extension systems, civil society organizations, public research institutes, and policy makers (see Figure 3.1). The APNLBP initiated more than 70 projects in total, which were coordinated by the Biotechnology Unit (BTU), an autonomous body within the institutional public scientific agrarian system. The BTU was lead by a multidisciplinary team. Based on scientific analysis, BTU’s decisions were in principle recommendations that have to be validated by the steering committee which had a more holistic view over the regional reality because of the plurality of its members.

Box 3.1. The interactive bottom-up approach and the Dutch Special Programme on Biotechnology

In the late eighties, the Department of Biology and Society of the VU University of Amsterdam developed a participatory methodology aimed at reducing communication barriers between dominant players (e.g. researchers and industry) and non-dominant players (e.g. peasants and third world organizations) and at guiding the development of biotechnological innovations for small-scale agriculture. This was termed the ‘interactive bottom-up (IBU) approach’ (Bunders, Broerse and Stolp 1989, Bunders 1994, Broerse and Bunders 2000, 2005). At the same time, the Directorate-General for International Cooperation (DGIS) of the Netherlands, drew up a policy paper on biotechnology and development cooperation aimed at formulating a coherent special programme for the problem-oriented application of biotechnology for the benefit of the third world (Broerse and Wessels 1989). The Dutch Special Programme on Biotechnology officially started in January 1992. Four countries (Colombia, Kenya, Zimbabwe, and India) were selected on the basis of their interest shown in establishing biotechnology policy, the existence of local research capacity, the cooperative relationship with DGIS, and regional role of the country (DST/SO-Biotech 1994). The IBU approach was selected as the guiding methodology of the programmes (and projects) in the four countries. Following this approach, in India, the APNLBP was formed under this program.

87 DGIS searched for institutions and partners who were eager to experiment with an alternative approach to the traditional top-down. They proposed them the IBU approach (see Box 3.1).
88 The majority of these projects have been concluded. The APNLBP has been reorganized and is now lead by the Agri Biotech Foundation (ABF). ABF coordinates more than 15 projects, and apparently, follows the same organizational and methodological logic and conserve the same objectives as the APNLBP (Pakki Reddy, personal communication, 29 November 2008).
89 Actually, the Athena Institute for Research on Innovation and Communication in Health and Life Sciences, which operates within the Faculty of Earth and Life Sciences.
The IBU approach consists of a set of principles and guidelines. The principles lay the foundations of the approach and concern the following issues: the vision that biotechnological innovations can positively contribute to small-scale agriculture, and that small-scale farmers can play a prominent role in decision making, trust, mutual learning, building of coalitions, interdisciplinary approach, and integration of different types of knowledge. The guidelines provide phases and methods that can be flexibly applied according to the local circumstances. The IBU approach is divided into four phases. Firstly, the initiation and preparation phase in which the objectives are to establish (and train) a team of researchers/practitioners and to become familiar with the local circumstances. Secondly, the collection, exchange and integration of information phase, which involves the gathering of knowledge of relevant actors and available biotechnologies. Thirdly, the public priority setting and planning phase, in which participants are brought together in interactive workshops settings. This phase ought to be characterized by close interaction between participants and should produce a widely accepted plan of action. This plan of action is the input to the fourth phase, the project formulation and implementation phase, in which specific projects are formulated and implemented. Broerse and Bunders (2005; p. 43) argue that in all phases, interaction is essential, ‘exploring the options in close collaboration with all concerned’.

However, the implementation of an interactive and participatory approach by a formal institution became an intricate process,90 which led DGIS in 1997 to integrate the special programme into its regular activities. Not only did DGIS make its own interpretation of the IBU approach, but, most probably, so did each country. This chapter focuses on the interpretation (territorialization) of these participatory and interactive principles and strategies as evidenced in the foundations of the redesigning process of the Bt-spray.

One of the most interesting features of the APNLBP was that it followed the interactive bottom-up (IBU) approach (Box 3.1) for the development of biotechnologies. In order to formulate projects and programmes on the basis of local needs and priorities the first stages of APNLBP projects involved exploratory workshops with peasants, researchers, governmental and non-governmental organizations participating. These meetings were intended to lead to an understanding of the most important agrarian problems for peasants that could be addressed with a biotechnological approach. To this end, one of the important elements of these workshops was the presence of local civil society organizations, working as translators in the knowledge communication exchanges between formal researchers and peasants. These civil society organizations continue to be deeply rooted in the territories, able to mobilize the local labour force (peasants or technicians) and stimulate the use of local resources. When a relevant agrarian problem was identified at the initial workshops, research institutes with experience in that problem were located and contacted with a view to setting up a project. This type of interaction between all significant stakeholders seems to have been a constant in almost all the projects engineered by the APNLBP.

These exploratory workshops were the starting phase of the development of the new Bt spray. Naturally, the castor semilooper emerged as one of the major problems faced by peasants in Mahaboobnagar and Nalgonda, and researchers, civil society organizations and peasants exchanged their agrarian knowledge and experiences of the management of the insect pest.91 Peasants expressed the inappropriateness of, and problems caused by the commercial formulas. It was during these discussions that the search for a cost-effective, socio-technically accessible and

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90 For a more in depth analysis of the difficulties of this process see: Broerse and Bunders 1999, 2000.
91 To put the quality of this knowledge exchange in perspective, some communication problems were caused because some city-scientists were unfamiliar with the local rural-languages which forced them to hold some of the meetings in a different language than the language spoken by local peasants.
appropriate method for the production of Bt sprays was begun. Other methods were also explored (e.g. hand picking, and building structures to attract insect-hunting birds) and other projects initiated (e.g. genetically modified castor containing the genes of Bt that trigger the production of toxic substances\textsuperscript{92}).

During the redesigning process of the Bt spray (addressed in the next section) an apparently regular horizontal interaction emerged among the farming communities, civil society organizations and scientists. For instance, when they were collecting local isolates of Bt in peasants’ fields, testing the efficiency of the isolates against the local semilooper, and experimenting with the feasibility of the Bt spray production process at village level.\textsuperscript{94} As a result

\textsuperscript{92} APNLBP has also developed a transgenic castor to manage the castor semilooper, Bt-castor. Although the Bt-castor has already been developed in the lab, this project appears to be struggling, in my view primarily due to the absence of a deployment strategy for the Bt-crop for the resource-poor territories. There are also feasibility issues: where will the Bt-castor seeds be produced, what will be their price, and how will the Bt-castor deal with the negative image that some local stakeholders, CSO especially, have of transgenics?

\textsuperscript{93} This scheme was inspired by Bujs (2002).

\textsuperscript{94} The protocol for the production of the Bt-biopesticide is a novel one, and the network has started a patenting procedure. The protocol is reproduced by the bioresource centres (for free), but it is protected against companies that would like to utilize it to produce the biopesticide. Sixteen companies have already bought the technology (Vimala Devi, personal communication, 21 November 2008). The agreements with this companies prohibit their production

\begin{figure}
\centering
\includegraphics[width=\textwidth]{figure3.1.png}
\caption{The Bt spray Human Actor Network. The thickness of the arrows indicates the intensity and arrowheads the direction of the relationships.\textsuperscript{93} Acronyms: APNLBP – Andhra Pradesh Netherlands Biotechnology Program; DOR – Directorate of Oilseeds Research; CSO – Civil society organization; SDDPA – Society for Development of Drought Prone Area. GMM – Grameena Mahila Mandal.

During the redesigning process of the Bt spray (addressed in the next section) an apparently regular horizontal interaction emerged among the farming communities, civil society organizations and scientists. For instance, when they were collecting local isolates of Bt in peasants’ fields, testing the efficiency of the isolates against the local semilooper, and experimenting with the feasibility of the Bt spray production process at village level.\textsuperscript{94} As a result

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\end{figure}
of this cooperation, an opening is created for civil society organizations and peasants to gain some degree of control over the development process of new biotechnologies attuned to their territory. In this way, the huge distance that usually exists between the so-called producers and consumers of biotechnologies (Delmer 2005, Fears 2007, Reece and Haribabu 2007) is also addressed. Of course, the redesign process is not a perfectly even affair, and there are inevitably stages during the development of the Bt spray when the presence of a certain kind of actor is crucial, and the input and decision-making capacities of others is rather small. For instance, during the molecular characterization of the local Bt isolates in the search for the more powerful isolates, molecular biologists play a vital role, and other actors little or none.

Throughout the field trials that followed, scientists, civil society organizations and peasants continued to shared their knowledge as the network gained a further understanding of the management of castor semilooper with Bt under field conditions. Peasants are now able to decide the best time to spray, and detect whether semilooper larvae has died because of the Bt spray application (by checking the hardness of the dead larvae). Management of the semilooper has been achieved with only two sprays of Bt in fields where previously four or five sprays of chemicals like quinalphos had been required. In addition to the high toxicity of the local isolates for the pest, efficiency also seems to be high because the natural enemies of semilooper – like the insects *M. maculipennis* and *Euplectrus maternae* – survive the Bt spray, leading to natural suppression of the semilooper in the later part of the worm stage (Vimala Devi and Rao 2005b).

The scientists involved in this project recognize that making space for peasants in all the stages of biotechnology development is a crucial element of successful product (re)design. Not only does it facilitate understanding of the nuts and bolts of the technology on the part of the users, but also serves to ‘easily get the acceptance of the technology by farmers and therefore avoid the possible rejection of the technology in its later stages’. The collaboration between different kinds of knowledge and interested parties is perceived here, however, not (merely) as a means to secure the acceptance of certain biotechnologies, but as an end in itself. Therefore, at this stage we are confronted with an issue of a moral nature. To reformulate a statement made by Richard Sclove (1995) ‘Is it a kind of moral right or a matter of justice, that people should be able to influence the basic social circumstances of their lives?’ If our answer to this question is in the affirmative, this would seem to imply that peasants should have access to decision-making along relatively egalitarian and participatory lines in biotechnology product development in general, and in this particular case, in the development of pest-management products.

The ability of people to influence the basic social circumstances of their lives in this case is not only morally appropriate, but also more efficient. And this efficiency is not only related to cost ratios, time saved, ecological gains and human health unharmed in killing the castor semilooper, but also to the deployment strategy of the Bt product within the territory. A decentralized system of production units has been constructed in order to deal with the dispersion of villages in the two districts concerned, with micro-enterprises for the production of the Bt biopesticide established in some villages. These units are run by different local civil society and sale of the product in the two districts where the project is conducted, thus preventing competition from the companies with the production units run by the local civil society organizations.

95 The cost benefit ratio for the Bt spray treatment (2 sprays) was 3.10 while it was 1.62-1.80 in quinalphos – 5 sprays (ekalux EC 25) (Vimala Devi and Rao 2005b).

96 We do, of course, have to recognize the difficulty for lay persons in general, and poorly or uneducated peasants in particular in understanding biotechnological discussions. This acknowledgment also introduces problems related to local educational systems that are beyond the scope of this article.
organizations with technical support from the research institutes. They have also generated some employment for the local youth. In some cases, these units are integrated into what is called within the APNLBP a bioresource centre. In the labs of these centres other biopesticides apart from Bt (like *trichoderma* and *baculovirus*) are developed, and have also the facilities to manufacture other kinds of agrarian products like biofertilisers (e.g. vermiculture) and neem tree products. Moreover, from a total of six bioresource centres, only one is still financially and institutionally supported by the APNLBP program, the rest being already (economically and organizationally) autonomous units.

The bioresource centres appear to have some potential to become a catalyst for local sustainable rural development. In these centres, the heterogeneous set of social agents (researchers, peasants and civil society organizations) converges to coordinate the production of the new Bt biopesticide and other appropriate local (territory-specific) agrarian techniques. These centres operate as places where users and producers of biotechnologies come together to share knowledge and develop appropriate biotechnologies. With the bioresource centres located at village level, access of peasants to information about products (usage, risk, and quality) is facilitated, and they acquire a certain level of control over the units. Peasants can thus gain power within their biotechnology socio-technical systems. Future studies of these experiences will address the extent to which such control as is exercised or experienced by peasants can be defined as significant, and how far the new emerging biotech elites, in the social form of civil society organizations, are more effective in addressing some of the agrarian problems of peasants than the research stations in India (also situated in rural locations) have been so far.

The territorial approach in perspective

We could argue that the social dynamics unfastened for the development of the Bt spray are territorial insofar as they are needs driven (i.e. by the disastrous effects of castor semilooper and the failures in the conventional chemical pesticide solution), and because significant power in the biotechnological development is exercised from within the locality. This is illustrated in the bioresource centres where the dwellers and constructors of the territory exercise a local-specific control on the redesign and production of the Bt biopesticide. This section addresses the territorial dynamics of the local networks for redesigning the Bt spray viewed against the background of the broad Indian contexts of biotechnology development. The section introduces very briefly the main activities of the public and private sectors, and civil society organizations.

India has a very strong public-sector concerning agrarian science and research infrastructure. However, it seems that this system is organized around a centralized model of technology development and transfer that jeopardize its usefulness for resource-poor farmers. Some important elements of this situation are, for instance, the strong hierarchies and separation between research, extension and farmers. In general terms, this model has been described as a ‘hard science’ approach, i.e. one that gives relatively little importance to sociological considerations and tends to perpetuate the hierarchy of science and society and centralized top-down patterns of control that this implies (Rajeswari 1999, Clark, Yoganand and Hall 2002, Sualiman and Hall 2002). However, the work of the Bt network described would be unrealisable.

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97 The most basic control is in regard to product quality and price. If the product is too expensive or ineffective, peasants will simply not buy it.
without the structures and persons working in the Indian public sector (Fig. 3.1). Good examples of this invaluable public sector’s presence in the project include the Directorate of Oil Seed Research (DOR), which has developed the novel Bt multiplication methodology and conducted the molecular analysis; the research station at Palam (Mumbai), which is organizing a bioresource centre; and the new Agri Biotech Foundation located within the Acharya N.G. Ranga Agricultural University in Hyderabad, AP, which continues to play a coordination and assistance role.

Alongside the far-reaching Indian public sector, the biotech private sector is growing very rapidly (Damodaran 2004) throughout the country. There are special biotech plans for the different states which promise fiscal and infrastructure support to prospective entrepreneurs. In the case of AP, this has led to the creation of the Genomics Valley in Hyderabad (mainly oriented to pharmaco-genomics) where private companies predominate. These companies are first and foremost focusing on markets to reimburse their expensive investments in upstream R&D and since resource-poor farmers lack the economic means with which to pay for their highly priced products, have little incentive to develop agricultural products for village communities. Some companies have started programs aimed at developing the so-called pro-poor technologies, but it has usually been done as a public relations exercise to improve the agri-business image. In 1999, for example, the USA-based multinational Monsanto started the ‘Small Holder Programme’ in Andhra Pradesh aimed at providing a package of extension services98 for resource-poor farmers.99 However, Monsanto’s main interest was to clean up the company’s image, and that of GMOs. In this respect, Glover argues that:

‘Smallholders were implicated in this process, both as potential customers in their own right and as symbols of the anticipated benefits of GM technology. However, the specific form of the technology had already been strongly shaped by the judgements and evaluations of scientific experts, legal institutional frameworks and the expectations of shareholders and investors. Consequently, the needs and priorities of smallholders themselves were not at the heart of the Small Holder Programme. They were unable to influence Monsanto’s upstream research and development process. Instead, they were assumed to occupy passive roles as consumers and beneficiaries at the end of a pipeline of modern farming technology, rather than empowered shapers of the innovation processes which produced that technology’ (Glover 2007, 2008; p. 2).

Other scientists who have analyzed the APNLBP network (Clark, Yoganand and Hall 2002) have noted the absence of private companies in the program. This absence is understandable, in the initial phases of the program, not only just because the absence of private companies in these rural areas, but also because of the aforementioned peasant lack of the economic attractiveness required to become a target group for the private sector. However, some traces of private sector participation do emerge in phases close to concretization in the development of some products. For instance, due to the lack of genome sequencing infrastructures in the public research

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98 These services included inputs such as seeds, GM traits and crop protection products, technical advice, demonstrations and training, and easier access to microcredit and markets for farm produce. A key feature of some of the projects was the establishment of ‘Farmer Service Centres’ in villages – local offices where farmers could seek advice, borrow or hire farm equipment and obtain inputs such as seeds and fertilizers (Glover 2007).

99 The program was launched in several countries, comprising 21 projects in 13 countries by 2001 and reaching more than 320,000 small-scale farmers (Austin and Barrett 2001). Monsanto was directly involved in just a few of these projects, in Mexico, India, Indonesia, Kenya and South Africa. In India, the company claimed to be reaching 35,000 farmers in 415 villages in West Bengal, Madhya Pradesh, Rajasthan and Andhra Pradesh (Glover 2007).
institutes and universities involved in the Bt spray project, and because of the compulsory official registration of every pesticide by the Indian government, the services of some private companies\textsuperscript{100} are required to map the genome of the most powerful local Bt isolate found against the castor semilooper. Moreover, and in the reverse direction, because the redesigned Bt spray is highly efficient in managing the pest, some companies have approached the Bt network. Their motivation for this is not to support an effective approach to biotech development, but to buy the technology. If the number of bioresource centres grows quantitatively and qualitatively, we can expect agribusiness to become more involved for better or worse.

Going deeper into the Indian landscape, poverty is concentrated in the rural areas. This is also true for the state of AP, where due in part to the poor performance of the public sector in these rural areas, a breeding ground has been created for the growth of radical movements like Maoist guerrillas (including in the regions considered here). A multiplication of civil society organizations is filling the space that the government is unable to cover. In this context, developmental civil society organizations and intermediary research provide a critical link between peasants and scientists in initiating decentralized participatory biotechnological developments at ‘left behind’ locations (Humphries, Gallardo, Jimenez et al. 2005). Certain civil society organizations are essential to the opening of the door to the decision-making room in the development of biotechnologies to a wider sector of the population. The high level of trust between peasants and the civil society organizations involved in the project during the development of the Bt spray has been decisive. This is because the design phase of the pest-management techniques is a long-term process, and the return from the labour investments is uncertain.

**Obstacles to the sustainability of the Bt spray**

Although the focus of this chapter is on an analysis of the social and technological changes that occurred during the redesigning process of the new Bt product, and how these dynamics are contributing to a reconceptualization and reorganization of the local agrarian territories (reterritorializing), it is also recognized that the redesign is still an ongoing process. Therefore, some obstacles that might threaten the sustainability of the process have been identified.

In my view, the collaborative efforts and new partnerships between the pluriform set of actors involved in the redesigning process should be regarded and engaged in with a long term perspective. This would be advantageous firstly, because of the obvious benefits of inclusive dynamics for poverty alleviation. Secondly, it seems important to make an assessment of the performance of the Bt spray over a period of time, for instance to deal with any emergence of resistance by the castor semilooper to the local isolates used in the spray formula. Thirdly, once the production of the Bt biopesticide has been fully assumed by the local civil society organizations, some technical problems may appear for which the support of DOR scientists in Hyderabad will be required. Finally, it is important to monitor possible future health problems which are unexpected at this stage but might yet emerge from a massive use of the biopesticide in the region.

\textsuperscript{100}Bioserve (led by Bioserve USA) and Bangalore Genei (owned by the Indian chemical corporation ‘Sarman Group’).
In order to guarantee the sustainability of the decentralized Bt biopesticide production system in the form of the bioresource centres, a long-term collaboration between local producers and scientists will be vital. However, this long-term collaboration can be jeopardized within the Bt network by the lack of commitment to identification with and/or motivation in respect of the network on the part of the people involved. For instance, some scientists do not feel as if they belong to a network outside that of their research institute. For them the Bt spray is just another project, albeit one that requires a ‘peculiar’ methodology with more visits to the field than usual. Similarly, most of the staff members of civil society organizations working at the production units seem to develop a routine of laboratory labour to earn their salaries.\(^{101}\)

When discussing the centrality of claims for the immanence of radical changes attendant upon technological transformations, David Noble has noted that despite the promises of revolutionary changes, the old order tends to reproduce itself, ‘a change without change’ (Noble 1977: p. xxiii). These words are quite pessimistic and may deny or simply cease to observe real social change or human agency (especially insofar as the change is small, slow and incremental in nature, apparently evolutionary rather than revolutionary when viewed close up, in the short-term). Nevertheless, they do contain a certain degree of truth. So far as this case study is concerned, the hierarchical Indian social structure certainly continues to reproduce itself both by supporting the old elites, like scientist (some of them don’t feel as belonging to the Bt network, but to the one of their urban institutes), and also (potentially, at least) by creating new ones, for instance, the empowered civil society organizations that can create new clientelist relationships with peasants’ communities by acquiring the control of the new biotech production centres.

Another obstacle related to the available human resources is the difficulty in finding (young) researchers to occupy positions in the impoverished and isolated rural areas of the sub-continent. Unfortunately, this brain drain of village-to-city and India-to-abroad, is a mass phenomenon taking place at all levels of Indian society (Ghose and Ghosh 2003).

One last important issue concerning the sustainability of the Bt network is the financial support of the APNLBP by the Dutch ministry of foreign affairs which stopped in 2009. Further studies of this biotech network will be necessary in order to find out whether the closure of this unique economic financial source might become an obstacle to the different projects and therefore, for the Bt spray.\(^{102}\) Were this to be the case, it would certainly raise issues of responsibility around such (short- to medium-term) project development based on creating a dependence on external sources that are withdrawn before the projects become economically viable (even though they have become operational and are successful by other measures). It is to be hoped, however, that the economic dependence can be overcome (as it already has in large measure) by the territorial reorganization of the production of the biopesticide, and of other agrarian products. Through the decentralized system of bioresource centres, the individual units have managed to gain a localized productive and distributive autonomy. Failure, even – of units, the spray, its production and/or the network – may still lay the groundwork for future successes.

This section has analyzed the social aspects of the territorial approach for developing the Bt biopesticide. We have seen how one particular multi-stakeholder network can exercise a local-specific power over a biotechnological development and successfully redesign an efficient,

\(^{101}\) For instance, some of them do not know the price of the final product.

\(^{102}\) The APNLBP is one of the four country programme supported by the Dutch Ministry of Foreign Affairs. The other three country programmes have been operating in Colombia, Kenya, and Zimbabwe. In the last two of these countries, the economic support has stopped leading to the end of most local projects.
affordable and accessible product. The next section analyzes the technical aspects of this redesigning process.

3.4. The Bt spray redesign process – The technological domain

From the workshops conducted to assess the agrarian problems of peasants in Mahaboobnagar and Nalgonda, the castor semilooper emerged as one of the most important agrarian problems faced by peasants. Bt was chosen as the biological matter to be explored for controlling the plague. At that time, there was an agreement to develop a Bt biopesticide which, besides its efficiency in dealing with the semilooper, needed to incorporate the following social features:

- **Affordability**: the sale price of the final product has to be in range of the economic means of peasants. Therefore, a low cost of production was required.
- **Accessibility**: peasants had to be able to purchase the product whenever they thought the crops required it. Therefore, a decentralized system of production and distribution at the village level had to be constructed.
- **Sustainability**: the product had to be non-toxic for humans and other organism. Moreover, it had also to be socially sustainable, and based mainly (though not exclusively) on local human resources.
- **Feasibility**: the product had to be attuned to the socio-technical capacities available at the locality.

With these conditions in mind, the network was pushed to think beyond than the two technological trajectories for the production of Bt-based pesticides generally favoured, i.e. genetic modified crops, or Bt sprays based on a liquid-state fermentation. A reorganization of the production of Bt sprays was launched. This redesign process is described here, with particular attention given to the material changes occurring in the process. We will follow the Bt from the collection of Bt isolates on peasants’ fields, through the bacteria evaluation and characterization in the laboratories, the Bt multiplication employing a solid-state fermentation process within a decentralized system of production units, to final use against the semilooper in the small-scale castor production systems.

**The genomics link within the redesign process**

It was decided to embark on the isolation of local Bt strains rather than use of commercially available formulas, for two main reasons. Firstly, in India, there is a specific regulation system for the promotion of Bt for pest management which prescribes that final products have to be registered by the Central Insecticides Board (CIB), and the CIB guidelines permit only the registration of formulations that employ local isolates. Secondly, local isolates seem to have a better capacity to withstand environmental stresses and persist longer in the field (Vimala Devi and Rao 2005b).
In order to isolate local strains, researchers of the Directorate of Oilseeds Research (DOR) and peasants first collected samples of soil and dead larvae of castor semilooper from peasants’ fields. With funds made available through the support of APNLBP, the network was then able to isolate and analyze the Bt yielded from the samples, work undertaken by DOR microbiologists in Hyderabad (in India, a molecular analysis is mandatory when a large-scale usage of a pest-management product is expected). Next the genomic DNA from the isolates was analyzed (using the Polymerase Chain Reaction with three set of primers viz. ERIC, BOX, and REP) in order to identify which species and subspecies of Bt were present (some subspecies are more toxic against the semilooper than others). Researchers found out also what, of the already known, cry genes were there (cry gene profiling).

From the initial 256 soil samples collected, a total of 120 local isolates were identified for further analysis. They were compared with well known commercial isolates (Delfin from Margo Biocontrol Pvt. Ltd., Dipel from M/s Cheminova, and Halt from Wockhardt Ldt.), and with five strains purchased from the Ohio State University in the USA. From the five strains two Bt (subspecie kurstaki) strains were found to be effective against the local semilooper. Moreover, four of the local isolates were found to be also efficient against the semilooper The two from Ohio where used for the study in addition to the four local isolates yielded from peasants’ fields.

After that, scientists performed several bioassays in the lab, followed by various tests carried out on site, in the local fields, conducted in collaboration with the peasants. Two of the four local strains tested were found to be extremely effective in controlling the local semilooper under field conditions. Finally, the local isolate DOR-1 was chosen for further mass multiplication.

From liquid-state to solid-state fermentation

The mass production of Bt spores was redesigned by developing an alternative to the costly, water-intensive and technically demanding conventional technique of liquid-state fermentation (above, Section 3.2). Given the socially-oriented production criteria listed above, this alternative implied the multiplication of Bt by its fermentation in a solid medium in which local agricultural waste/by products were used, such as from the wheat and molasses crops. Since magnesium, manganese, iron, zinc and calcium ions are present abundantly in wheat bran, the employment of this would obviate the need to supplement these ingredients reducing (a small share of) the costs. In addition to this, DOR provides the production units with some chemicals to facilitate the fermentation process. It was thus decided to use wheat husks as the medium and, moreover, not to invest in large, expensive fermentors, but to use plastic basins for the multiplication of the Bt isolates. This would bring the cost of production down further, and not only because of the low costs of plastic basins but also because of their re-usable nature when compared to the easily fractured glassware fermentors (Vimala Devi and Rao 2005b; p. 113). Also, as the inoculation was to be carried out separately in the plastic basins, any mistakes would only lead to the loss of small amounts of the inoculated medium. In this production process risks would be spread out

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103 A primer is a strand of nucleic acid that serves as starting point for DNA replication. They are required because the enzymes that catalyze replication, DNA polymerases, can only add new nucleotides to an existing strand of DNA.

104 DOR-1 contains the cry genes: cry 1Ab, cry 1Ac, cry 2Ac, cry 2Ab, and cry 1.
over more units, as opposed to the submerged fermentation process, for instance, in which a single power outage might completely destroy the inoculation medium (ibid.). In respect of the problems caused by such failures in the electricity supply, an ingenious system has been constructed in some bioresource centres, formed by interconnected car batteries which stores power and then supplies it when needed.

In addition to the use of local agricultural wastes, and plastic basins (and back-up power contraption) a third innovation of the Bt networks was the covering of the inoculated medium within the plastic basins with a plastic sheeting, and kept in a room for around 65 hours. During this 65-hour period, technicians have to remove the plastic for aeration. Aeration is provided every eight hours (four times in total) after the second day, either in a laminar air-flow cabinet or in a chamber where the desired conditions of a laminar air-flow cabinet are simulated. This aeration system enables production to be decentralized and carried out in biotech units at the village level.

The downstream processing for obtaining the final product is carried out through a centrifugation process in which the medium is filtered with distilled water. The supernatant containing the beta exotoxin is discarded. The resulted pellet containing the spores and crystals of Bt is mixed with the carrier, shade dried in the plastic basins and then powdered with a kitchen coffee-mill. The final Bt product is mixed with water by peasants in their fields and sprayed on the castor.

Large-scale field trials conducted with the DOR Bt-1 formulation in the districts of Mahaboonagar and Nalgonda have shown that the castor semilooper can be managed with two sprays at 15-day interval, and that pest-management costs are reduced threefold when compared to the use of chemical insecticides (quinalphos). Around 150 grams of Bt powder are required per acre (0.4 hectares) to control semilooper, depending on the stage of the crop. The material costs for production of one kilogram of Bt powder are 32 Rupees (about 1 Euro – 2007).

**Some reflections on the redesigning process**

With the intention of introducing certain social requirements into the development of insecticide techniques, the local networks have developed a novel procedure for the production of a Bt spray. The shift from a liquid-state to solid-state fermentation has been enabled by both social and technical reorganizations. The local collection and collective multiplication of Bt isolates have occurred through a local revalidation of the formal and informal knowledge systems of peasants and of scientists, as well as by involving local labour force (young villagers) in carrying out the multiplication process in the different production units.

During this biotechnological development, new partnerships have been started between different kinds of social actors. Moreover, to develop biotechnologies in tune with the material and social situations of the small-scale production systems of the dry-land agriculture in the two districts, the local networks have mainly mobilized the available resources and therefore the existing biotechnologies. Both high and low technologies are used by these networks, separately in some projects (like vermiculture or recombinant DNA), and mixed in others, like the Bt spray redesign, in which genomic techniques, e.g. sequencing of the genome of Bt DOR-1 have been assembled with the low-tech solid-state fermentation.
Throughout this territorial approach aimed at developing location-appropriate (territorial) biopesticides, certain social demands have been introduced within the material development of a new biotechnology. These dynamics have facilitated not only the materialization of a new technique for pest-management, but also the emergence of a new socio-technical structure organized around the new Bt spray. The consequences that this socio-technical structure has for the empowerment of the territories where the structure is emerging are discussed in the following section.

3.5. The politics of the Bt spray – The reterritorialization domain

Through the redesigning process of the Bt spray, material changes have occurred which facilitate the production of the Bt spray at the local level and make it affordable and accessible for peasants. In order to accomplish these material changes was required a reorganization of the pluriform set of social relations involved in the development and use of agrarian technologies – i.e. a reorganization of power structures. Peasants, local researchers, civil society organizations, and villagers collaborate to territorialize the development of biotechnologies and they are now producing local specific biopesticides. They are empowered for biotechnology development. These creative social dynamics are characterized both by the promotion of horizontal relationships between a wide set of local actors (local specific power) for biotechnology development, and by the creation of a decentralized system of production units for developing biotechnologies. These dynamics are transforming or reproducing the local socio-technological structures. The production units, or bioresource centres, are an essential element in the territorialization process that the ‘local sustainable biotechnological development’ (i.e. the Bt spray redesigning process) has brought about. This section will first reflect on the sociological implications of the bioresource centres, and then go on to explore the implications that these (micro- and meso-level) developments have for the global debates around the structural potency of biotechnologies in rural contexts.

Bioresource centres and self-management

As it has been mentioned, the bioresource centres are located at the village level, they are run by local civil society organizations, are technically supported by public research institutes and they employ local youth labour. The centre labs are not only the site of Bt semilooper pesticide powder production, but also of other agrarian technologies (e.g. other biopesticides and biofertilizers). The reorganization of social relationships has facilitated the appearance of these centres. Three main features of the bioresource centres might be usefully summarized and emphasized here, as this decentralized system of biotech production units can become an agent of change for transforming the structures that deliver agro-biotech products to small-scale agriculture in Andhra Pradesh.

Firstly, the bioresource centres facilitate peasants’ access to biotechnological developments and their products. Due to their location and social organization, these centres
search for products relevant and efficient for the local agrarian systems, and then manufacture these products in such a way as to be affordable to the village communities. Therefore, the biotechnologies are locally developed and attuned to peasants’ needs. This empowerment of peasants (and other actors, such as civil society organizations) within biotechnologies’s socio-technological structures, at the same time strengthens the local agrarian systems. In Chapter 2, territoruality was defined as the local specific, individual or collective dynamics that enable access to, and control or influence over biotechnological developments. One might, therefore, argue that the bioresource centres are an illustration of the territorial character of the Bt spray redesigning process, as local power is exercised on the process.105

Secondly, the self-management strategies to produce biotechnologies are reuniting the dweller and the producer of the territory. Peasants, along with peasants groups, and civil society organizations and villagers are transforming their roles, from just users of agro-technologies to producer-users. In this way, inhabitants gain a new, enriched identity. This co-evolving relationship between dweller/producer and territory enacts a reproduction, a reterritorialization of human settlements, forging new knowledge and technologies, and revitalizing relationships between people and the land they work and live on. Moreover, practices of co-operation and participation are necessary for this type of redesigned biotechnological product development. The strong decentralization process and inclusive strategies of the Bt network thus facilitate the development of new forms of community. Participation here is then understood as the self-managed social production of the territory (territoriality).

Thirdly, there is the challenge of sustainability. In Chapter 2, social structure was defined as the laws and resources that reproduce society. The material and social elements that characterize the bioresource centres work as the basis for new material constructions (e.g. new products, or production units), and new social relations to produce agrarian technologies in particular and rural life in general. To find one of these production units in a village of Mahaboobnagar and Nalgonda is both extremely surprising and rather inspiring – and the more so in the context of rural and agrarian territories which have little or no industry or research capacities, and where is it easy to meet a dealer selling all types of pesticides (and who knows what masquerading as such). Section 3.3 of this chapter listed some challenges facing the long term sustainability of the bioresource centres and the Bt product. Long term horizontal co-operation between scientist and peasants (facilitated by civil society organizations) requires a desire for cooperation. Peasants generally seems to be open to new products, crops and crop management strategies (Chambers, Pacy and Thrupp 1989, Vásquez 2005), an observation that certainly seems to be born out in this case with the involvement in the redesigning network and uptake of its products. Whether researchers and funding agencies are willing to be territorialized within and orient their research questions and capacities to the rural poor districts of India remains an open question. The Bt spray multi-stakeholder network in eastern Andhra Pradesh might be a symptom of the need for such a territorialization.

105 An example of this local empowerment is the ad hoc experimentation by some peasants who are testing the utility of the Bt spray for other pests affecting their crops. A case in point is Mr. A Rami Reddy in the Venkaiiahpalli village (Mahaboobnagar district) who, in December 2005, decided to begin independently experimenting with the Bt-spray in a small cotton field.
Challenging local-global trends

The new socio-technological structure emerging with the Bt spray is transforming, to some extent, the organizational landscape for the development and deployment of biotechnologies in the two rural districts involved. It is disengaging, for instance, the local development of biotechnologies from the global process of the industrialization and biotechnologization of agriculture. In this context and in this chapter, we have witnessed the efforts of local networks to (self-)manage the political reorganization of the material and social resources to develop an appropriate Bt spray in the rural context of Andhra Pradesh through which the traditionally top-down, deterrorializing Indian model of biotechnological developments has been, in a way, reversed. What has emerged, or been constructed, is a much more bottom-up approach, where the whole set of actors is, up to a point, involved in the different phases of the biotechnological development. Furthermore, the redesigning process takes place by disconnecting the Bt production from the global industrial production chains to develop pesticides.

As a historical review shows (Section 3.2), the agro-industrial model has been unable to develop suitable pest-management techniques for peasants to manage castor semilooper in this region – but the territorial model of local sustainable biotechnological developments may, it seems, have succeeded. Some philosophers have analyzed the way in which the political and politicizing force involved in the development of biotechnologies within these historical processes of industrialization is creating new rural identities by shaping the social context in which the biotechnologies are deployed (Ruivenkamp 2003, Kloppenburg 2004). The industrialization process of agriculture (above Section 2.4) has been enabled by the deployment, among other factors, of three main political developments:

- There has been an *industrial appropriation* of some key farming activities, like crop and pest management by external institutions through the supply of industrial inputs (Goodman, Sorj and Wilkinson 1987).
- A *scientification of agricultural research* has taken place in which an increasing prescription of farming practices emanates from the scientific domain (Ploeg 1987).
- With the *biotechnologization* of agriculture, a *remote control* or control from a distance (Ruivenkamp 1989, 2005b) exercised by external institutions upon different farmers' activities has emerged.

These three developments are challenged by the strategies aimed at self-managing the production of the new Bt spray. For instance, the *industrial appropriation* of farming activities by external institutions is notably reversed by the *self-organized practices of local networks* to create their own pest-management technology by collective action to isolate, select, multiply and distribute Bt within the territory.

The *scientification* of agricultural research characterized by stimulating the development of modern agriculture within the global context of industrialization, and delocalized commodified knowledge is strikingly challenged by the *creation of horizontal structures* in which peasants, civil society organization practitioners, and formal scientists *share* their formal and informal

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106 At this stage, we could speak about the subpolitical (Beck 1997) character of the local networks because they mobilize resources and organize politics beyond the representative institutions of the political system of the Indian nation-state.
knowledge systems. Within these horizontal structures the interests and problems of peasants are not only included, but become central to the scientific research agenda. In addition, the scientification is remodelled towards local sustainable developments by the relative low technical requirements to produce the Bt spray. Sciences are still transforming agrarian societies, but the sciences are themselves also being transformed and brought down to earth, or applied to, for and by local needs and resources. In a word, the scientification process of agriculture is territorialized.

Finally, the biotechnologization process is implicitly opposed by the social dynamics enacted by the local networks in redesigning biopesticides with the aim of fighting a local pest in a manner suitable for a localized production and usage. Peasant communities are liberated, no longer controlled from a distance by the external industrial suppliers of pest-management products, and become empowered producers of an (externally uncontrollable) Bt spray which is territorially affordable, accessible, sustainable and feasible.

3.6. Conclusions

Is the redesigned Bt spray a new pest-management product? If we just look at the final product the answer will be probably no; as a Bt-based biopesticide spray is nothing very novel. But, if we analyze the social code attached to the redesigned product we appreciate the qualitative differences that make the new Bt spray a very different biopesticide and, indeed, a suitable alternative for peasant agriculture in Andhra Pradesh. The technologies involved merit this evaluation insofar as they are redesigned so as to facilitate their adequate functioning within the social and technical conditions of the territory. The concomitant social reorganization meanwhile involves engagement in new partnerships and embrace of new roles and power relations related to biotechnological developments.

In the territorial domain we have seen that a new technological social structure is emerging around the Bt spray, characterized by an involvement of multi-stakeholders platforms that are inclusive for peasants, local villagers and civil society practitioners. The benefits and responsibilities that the new technology realizes are redistributed within the territory where the biotechnological development has taken place. This especially occurs through the bioresource centres that work formally and informally as places of encounter for the different stakeholders and as sites for the exercise of local power to develop biotechnologies for and by the local actors. New identities are thereby shaped – like the civil society organizations that become producers of biotech products, and the social scientists who get involved in the coordination of biotechnology programmes –, identities that are contributing to a transformation of the traditional Indian structures of biotechnology development, and making biotechnology indeed a resource for local development.

In the technological domain, a biotechnological redesign has occurred aimed at harnessing the production of a biopesticide to the territorial circumstances, and which has been accomplished by introducing certain social requirements into the biotechnological redesign. This socio-technical rearrangement has developed a Bt spray which is efficient in killing the pest, affordable for peasant economies, accessible at the bioresource centres, non-toxic and can be produced with the available resources. Moreover, the network has taken advantage of some
genomics applications to accelerate the redesign process, by making a genetic selection of the most toxic Bt isolates.

Finally, in the third domain of analysis, the reterritorialization, we observe that the new Bt spray becomes a socio-technological structure which requires the reinforcement and time-extension of the new partnerships and roles developed by the different social networks to maintain the efficient production of the Bt spray within the territories. The new partnerships have to be maintained over time in order to address potential problems which might emerge at the level of the material (e.g. the emergence of semilooper resistance to the chosen local Bt strains selected, the appearance of mechanical difficulties at the production units, the supply of chemicals, etc.) or social (knowledge from the urban scientists might be required to repair technical problems in the Bioresource centres, or to set up new bioresource centres, etc.).

The reterritorialization domain has also suggested that some of the developments that the industrialization and biotechnologization processes of agriculture bring about are challenged by the local sustainable biotechnological development conducted by the Bt spray network. Traditionally, an external control on the development of pest-management techniques has been framed within the industrialization and biotechnologization processes of agriculture. This used to be generally assumed as unilinear, and encouraged peasants to become more integrated in markets and dependent on the use of external inputs, technologies and capital. It promotes a more uniform pattern of farming and of an increasingly de-territorialized development of pest-management technologies. As such, it has resulted in a weakening of the linkages of scientific to peasant knowledge systems, and of biotechnologies to local socio-natural ecologies. Therefore, it devalued the knowledge of peasants and the developmental potentiality of territory. While the tendency for the development of pest-management technologies was to look at innovation primarily as a process led by scientific research conducted mainly in centralized autonomous institutes of pure research within the public or private domain that essentially were sending pesticides to different territories, local sustainable biotechnological developments are based on collaborative networks that cut across the standardized distinctions between the pure and the applied, the public and the private, the academic and the popular, between the producers and consumers of biopesticides.

Concluding, we could label the redesigning process of the Bt spray as a ‘local sustainable biotechnological development’ as it facilitates the access of peasants to biotechnological developments and products, and as it promotes, by way of biotechnologies, a new understanding of the territory. During the reterritorialization process, certain social issues are introduced within the biotechnological redesign to produce appropriate biotechnologies. These dynamics are not only constitutive of biotechnology redesign, but also inherently reconceptualizing the territory, by making a larger set of social groups responsible for the sustainable reproduction and development of the territories themselves. The new biopesticide has acquired a political and politicizing character that encourages the reproduction of the social structures, roles and identities organized around it to guarantee the sustainability of the product and its associated rural development. Future studies will address whether these socio-biotechnological developments gain momentum and whether these dynamics indeed work as a catalyst for local sustainable development in Mahaboobnagar and Nalgonda.
Chapter 4

4. The Wiphala Genomics: the territorialization of molecular markers within small-scale potato crop systems in the Bolivian Andes

'[To the European] the whole scheme seems… laughable and ridiculous, and in the end he would probably conclude that it is merely foolish to crowd different plants together in this childish way so that they may choke one another. Yet if one looks at it more closely there seems a reason for everything. The plants are not growing at random, but have been planted at proper distances on hillocks of soil arranged in such a way that when rain falls it does not waterlog the plants, nor does it pour off the surface and wash away the fine soil…. The soil is always occupied and is neither dried up by the sun nor leached out by the rain, as it would be if it were left bare…. This is but one of many examples that might be given that should warn us to be very cautious and thorough before we pass judgment upon native agriculture. The whole method of farming and outlook of the farmer are so entirely new to us that we are strongly tempted to call it foolish from an instinctive conservatism' (Howard Jones)

We are intelligent, you white people think that we don’t know but we know a lot! I do speak three languages: Spanish, basic like this, and Aymara, and also Quechua. Sometimes I go to the town and they call me ‘coca-chewer Indian’, but I know a lot, I know how to predict the weather, and you must have a look to this irrigation system! (Rufino Terrazas)


108 Quoted in (Scott 1998; p. 275), from Paul Richards (1983).

109 Mr. Terrazas is an Aymara peasant of the high-mountain community Lakunakuni in the Ayllu Majasaya Mujlli, Cochabamba department, Bolivia. The irrigation system he was showing me consisted of a long (about 1 Km long) hose pipe connecting one of his potato fields with a water source higher than the field at the other side of the valley. The water falls by gravitational force. The end of the hose has a brainy device made from the tops of coke bottles and ballpoint pen tubes forming a sprinkler system for the potatoes.
4.1. Introduction

Biotechnology and genomics are considered to be very important for the enhancement of the management of genetic resources worldwide. Since these resources are especially located in the surroundings of resource-poor farmers (Brush 1992, Cleveland and Murray 1997, FAO 1997), it is expected that the development of genomics might increase the potentialities of agrarian systems of these people and their communities (Bruskiewich, Davenport, Hazekamp et al. 2006, Louwaars, Thorn, Esquinas-Alcazar et al. 2006). However, achieving this is easier said than done. Biotechnologies have been primarily developed in the context of commercial and industrial agriculture, while there have been relatively few significant biotechnological developments in the context of subsistence agriculture. Therefore, we may ask whether biotechnologies and genomics might be jeopardising their developmental potentialities – especially in genetic resource-rich areas – because these technologies have been developed away from and not oriented towards the social group that may need them most, peasants.

There have been a number of theoretical studies concerning the strengths of genomics for the management of genetic wealth in the context of small-scale agriculture (Delmer 2005, Bruskiewich, Davenport, Hazekamp et al. 2006, Louwaars, Thorn, Esquinas-Alcazar et al. 2006, Ruane and Sonnino 2006). Nevertheless, few empirical studies have been made on the deployment potentialities and constraints of genomics emerging from concrete social realities.

This chapter assesses the ongoing efforts of local biotech multi-stakeholder networks to develop (territorialize) biotechnologies and genomics that are appropriate to the needs of peasant and their potato systems in the Bolivian Andes. The empirical study in Bolivia was conducted in the highlands of the department of Cochabamba and Norte de Potosí (Map 4.1), a region inhabited by Quechua and Aymara peasants. Potatoes are very important in peasants’ territories, both as the staple food and for trade (as commodities for sale and exchange products for barter). This analysis therefore focuses on potato crop systems, and not only because potatoes form the basis for the survival of peasants and their communities, but also because they represent the many cultivation problems with which these people have to deal and which might be solved by ‘local sustainable biotechnological developments’.

The geographic and climatic disparities of highland agriculture in the Andes lead peasants to depend on a multiplicity of native potato varieties adapted to the different conditions. This requires complex agrarian skills, which are embedded in the local Quechua and Aymara societies. Due to these skills, some peasants still conserve a good number of potato landraces. Nevertheless, in general, diversity is decreasing. This erosion of potato landrace diversity has

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110 In this chapter, potato landraces are also referred to as ‘peasant varieties’.

111 Notwithstanding the fact that some households still manage a huge potato diversity (Haan 2009), in the departments where this study was conducted, others households and communities are losing diversity (Herbas, Torrez, Almanza et al. 2000, Mujlli and AGRUCO 2005, Terrazas, Guidi, Cadima et al. 2005) as confirmed to me in respect of the Cochabamba and Norte de Potosí region at the end of 2006 (Ximena Cadima, personal communication)
been occurring for two main reasons. Firstly, Andean societies and their agrarian practices have been undergoing a rapid transformation due to a variety of interconnected factors, including an increasing industrialization and modernization of agriculture with the introduction of the so-called ‘improved varieties’ that compete with native varieties for space (Brush, Taylor and Bellon 1992), the expulsion of peasants’ varieties from markets, and the large-scale migration of peasants. Secondly, with the general transformation of these agricultural systems, the traditional circuits of seeds are also disappearing. The end result of this is germplasm degeneration to the point that some varieties become extinct, a loss that reduces the diversity essential for peasants.

In this context of generalised pressures on the traditional cultures and agriculture of the Andes, developing and conserving genetic variety and productive diversity become particularly important as key aspects in the continued survival and growth of small-scale potato systems. There are several existing genomic technologies that may be used to strengthen these agrarian systems by enhancing the management of peasants’ potato diversity, of which two main applications are addressed here. The first application is the use of molecular markers (MMs) to study the local potato biodiversity. The second is plant breeding assisted by molecular marker technologies, marker assisted selection (MAS). These techniques allow breeders to introgress selected traits found during biodiversity studies into both commercial and native varieties.

Within these two technological applications, two very different, competing – indeed, contradictory – discursive frameworks around potato biodiversity are here identified and explored: biodiversity understood as raw material and as cultural material. These discursive conceptualizations are shaping two very different cultural environments for the deployment of genomics. The conceptual approach to biodiversity can have marked political consequences, such as specifying who is to benefit from potato biodiversity. It might also outline what type of genomics will emerge. On the one hand, there is a deterritorializing genomics that uses local potatoes as raw materials without any intrinsic value and in which peasants’ varieties can be freely used as breeding inputs to develop commercial varieties. On the other hand, there is a different type of genomics (territorial) which handles native varieties as final entities constructed (historically nurtured and developed) by peasants – cultural materials. This might help to protect peasants’ varieties from the biopiracy tendency, or search for traits which are interesting for local (Andean) small-scale potato systems.

The raw material conceptualization of the deterritorializing approach is developed in this case by international agencies such as the Consultative Group on International Agrarian Research (CGIAR) centres through the Generation Challenge Program (GCP), and it is implemented locally by the research and development foundation PROINPA (Fundación para la Promoción e Investigación de Productos Andinos). Interestingly, the cultural material conceptualization embedded in the territorial approach to genomics – named here the Whipala genomics (explained below) – is also implemented by these organizations, the two alternative and competing discursive positions co-existing within the same organizational framework.

It is in the context of this internal tension or contradiction, the multiple institutional orientation – or polypotency, following Sclove (1995) – that this chapter addresses the

11 October 2006; Eloina Chavez, personal communication, 17 October 2006; Domingo Torrico, personal communication, 20 October 2006; Franz Terrazas, personal communication, 2 November 2006; ).

112 Introgression is in this chapter defined as the introduction of certain traits (e.g. disease resistances) of one variety into another one. This can be achieved by traditional breeding, by genetic modification, or by MAS.

113 In defining concepts like biodiversity, contradictory meanings are given by different actors to what is nominally the same concept. Following Foucault (e.g. 2006): as a discourse – a system of idea or knowledge inscribed in a specific vocabulary – the conceptualization of biodiversity is used to legitimate the exercise of power.
appropriateness of some of the existent *participatory plant breeding networks* as social platforms for the deployment of molecular markers within subsistence agriculture to generate a local sustainable development.

In accordance with the theoretical frame of reference sketched in Chapter 2, we are here interested in the study of how culture, politics and economics shape science and technology and how these in turn shape society. In fact, this chapter attempts to go beyond merely demonstrating the social contingency of biotechnologies in order to establish strategies or moments that social actors may use to guide biotechnological developments. Rather, (as in the Bt biopesticide case in Andhra Pradesh described in the previous chapter) it extends its aim to that of furthering our understanding of how different dynamics in the development of genomics might create spaces for peasants and local development organizations to gain control of biotechnological developments.

As mentioned above, the local development organization deploying genomics applications in the context investigated here is PROINPA. From 1989 to 1998, PROINPA was part of the Bolivian national research institute IBTA. In 1998, the government hauled the national programme for agricultural research (following the neoliberal strategies of the IMF), and PROINPA continued as a private, non-profit making research foundation. PROINPA specializes in (bio)technological developments for Andean crops in small-scale agriculture, and has had facilities for the development of genomics technologies since 2003, at its installations in Cochabamba.

This chapter starts with an analysis of the technological domain (Section 4.2). This provides some background information on the potentialities and constraints operative in and on peasants’ potato systems, and on the two (aforementioned) genomics applications of molecular markers that might strengthen these agrarian systems. For the sake of comprehensibility, the relevance and problems of local potatoes are discussed within the technological domain – although according to the research schema provided in Chapter 2 (i.e. the three interrelated analytic domains) these themes fall more naturally under the territorial domain. The technological domain section here also addresses some redesign features required of the material elements of MMs if they are to be able to perform well in the local conditions. The territorial domain is covered in Section 4.3 divided into two subsections. The first subsection discusses the application of molecular markers in biodiversity studies in more detail. This subsection also analyzes the two contradictory discursive positions around Andean potato diversity, and posits the Wiphala Genomics as a constructive dynamic for small-scale agriculture. The aim of the second subsection is to develop a better understanding of the potentialities of participatory plant breeding networks as a social structure for the deployment of genomics in these territories. The socio-political implications of these biotechnological developments for the further reterritorialization process are considered in the concluding section (4.4) by applying the concept of the *polypotency of technology* (Sclove 1995) and expanding the *invisibility metaphor* of peasants’ knowledge (Ploeg 1989). This section works also as the chapter’s conclusion.

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114 *‘Instituto Boliviano de Tecnología Agropecuaria’*.  
115 International Monetary Fund.  
116 In addition to PROINPA, two other local development organizations have been involved in this study: AGRUCO ([www.agruco.org](http://www.agruco.org)) and CENDA ([www.cenda.org](http://www.cenda.org)). Although these two bodies have no technical expertise as such in the development of genomics, their opinions about its application on local potatoes may be influential in biotechnological developments in the territory.
4.2. The importance of potatoes to Andean societies and the importance of genomics to Andean potatoes – The technological domain

Bolivia is one of the poorest countries in Latin America with an annual average income of just US$1,153 per person (2006) and almost 40 per cent of the population living in extreme poverty – figures that could be compared with some of the poorer African states. Bolivia has one of the highest levels of income inequality with 10 per cent of the population (mostly white) accessing over 40 per cent of the total income.\(^{117}\) Poverty is especially concentrated in the rural highlands of the country. These areas are populated by the Quechua and Aymara cultures. A recent survey (Melgar-Quinonez, Zubieta, McNelly et al. 2006) based on the World Bank criteria for the definition of food security has found that more than 70 per cent of a representative region of the High Plain experiences moderate or severe food insecurity. In these highlands, households build their survival upon agriculture. Potatoes are the ‘daily bread’ of small-scale farmers here providing 40-50 per cent of total calories consumed by rural highland households.\(^{118}\)

It is estimated that around 400,000 Quechua and Aymara indigenous smallholders are involved in the production of potatoes. These smallholdings were restructured after the revolution and subsequent land tenure reform of 1952.\(^{119}\) The two departments where this study is concentrated (Cochabamba and Potosí) produce almost half of the total potato production of the country (Zeballos 1997) – yet peasants here generally cultivate less than a hectare a year each.

The traditional potato growing systems of these regions are low input and low yield. The harvested potatoes are used to feed the household, or as seed for the next planting season. Eventually, if it has been a ‘good year’, any surplus potatoes will be sold or exchanged.

Moreover, peasants grow a huge diversity of potato varieties, which seems to be the consequence of the long term triangular relationship between these agrarian societies, the wide diversity of climates and altitudes, and the fact that the Andes are part of the potato’s centre of origin (Vavilov 1951). It is estimated that around 31 potato wild relative species of potato are grown in Bolivia.\(^{120}\) Moreover, peasants grow eight different species of cultivated potatoes.\(^{121}\) A study conducted in just 16 highland dry communities in the Tapacarí province of the Cochabamba department (Mujlli and AGRUCO 2005), showed that some peasants cultivated 63 varieties of five different species. It appears that some communities around Llallagua city in the province of North Potosí in the Potosí department manage as many as 180 varieties.\(^{122}\) Furthermore, there are around 1700 accessions of around 700 native varieties stored at the national gene bank, which is managed by the PROINPA foundation at the Toralapa research station.


\(^{118}\) Bolivians in general are estimated to eat an average of 100kg potatoes per year (Ugarte and Iriarte 2002).

\(^{119}\) An appreciation of the revolution process of 1952 is essential to understand modern agriculture in Bolivia (see e.g. Delgado 2002, Regalsky 2003)

\(^{120}\) Ximena Cadima, personal communication, 11 October 2006.

\(^{121}\) There are six species of sweet potatoes – *Solanum stenotomum*, *Solanum x ajanhuiri*, *Solanum goinocalyx*, *Solanum phureja*, *Solanum chaucha*, and *Solanum tuberosum spp andigena* – and an additional two species of bitter potatoes – *Solanum x jucquezkii* and *Solanum x curtisibum*.

\(^{122}\) Franz Terrazas, personal communication, 18 October 2006.
Potato diversity is strategically used by peasants to spread the perceived risks in specific agroecologies (Haan 2009). Different varieties have different levels of resistance against biotic and abiotic stresses and are planted together to reduce the risk of crop failure (Morlon 1996). Some bitter varieties are especially cultivated in the higher lands because they can stand the frost during their growth. After harvest, these bitter potatoes are dried in the night frost and day sun of Andean highlands, a process that facilitates storage for long periods. These dried bitter potatoes (‘chuño’) form a food supply for peasants throughout the year. Some varieties might be narrowly adapted to some micro-climatic conditions whether the rest can not survive there (Haan 2009).

Because potatoes are one of the few crops grown in the hard conditions of highland agriculture and are, therefore, the constant element of peasant’s cuisine, the high diversity of varieties provides a wealth of tastes and flavours that are employed differently (for example, some varieties are used for soups, others roasted) and enjoyed on different occasions. Within the multiple cultural meanings given to potatoes we have, for instance, the variety Pinta Boca which is served to guests/family at the Easter holiday, while the Condor Imilla is used to celebrate bird days, or when a man returns safe from his military service (Cadima, Gonzales, Almanza et al. 2004). In general we can argue that diversity of potatoes is intimately related with the Quechua and Aymara identities (Delgado 2002) – and it is in this social context that the loss of potato diversity is occurring today.

As mentioned, potato diversity is decreasing because of agricultural transformation and pressure on the health of crop stocks. Regarding the former, particularly important is the ongoing massive migration out of rural areas and the modernization of agriculture. With the Bolivia’s poor level of economic development, moreover, the movement is not only from rural to urban areas, but also emigration abroad. This migration constitutes a relentless human drain on the traditional communal life supporting the agrarian systems that maintain the diversity of potato varieties.

The effect that this damage to the traditional agrarian systems has on maintaining potato diversity is compounded by the re-shaping of these systems with the introduction of improved varieties. Purchased in the valley markets or distributed by development organizations, these varieties compete with the native varieties for territory (Brush, Taylor and Bellon 1992, Zimmerer 1998). Indeed, wealthy farmers have specialized in those varieties demanded by the urban markets.

The dynamics of rural depopulation and competing varieties are re-shaping the potato systems by, for instance, cutting the traditional circuits of potato seeds (and their agro-political structures). The traditional potato seed systems in Bolivia have a cyclical form in which peasants periodically acquire virus-free potatoes, especially from the higher lands where infectious disease is a less acute problem and a larger number of peasants’ varieties is generally grown. Seed produced in the ‘virus free’ highlands supplies the lower lands with ‘clean and fresh’, regenerated potatoes (Thiele 1999, Zimmerer 2003). This becomes crucial because agricultural potato seeds are vegetative – tubers are used as seed, asexually propagated instead of ‘true seeds’ derived from cross-pollination – which means that the viruses and other diseases that affect crop potatoes are accumulated and transmitted to new crop generations. Thus it is that potato diversity is reduced.

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123 By way of example of the massive emigration, around a quarter of the total population (350 people from 1,400) have left from the valley of Piusilla, in the municipality of Morochata, Cochabamba over recent years (Justo Lopez, personal communication, October 2006).
124 Especially to Spain where in 2007 around 600 Bolivians arrived every day (Junquera 2007).
which affects peasants the most, this contributing in turn to another round in the vicious circle of systematic breakdown of traditional agrarian forms.

In this chapter, two genomics applications are considered which might strengthen these agrarian systems supporting diversity by re-orienting biotechnologies to peasants’ systems. These genomics applications are both based in the use of molecular markers. Molecular markers (MMs) are identifiable DNA sequences, found at specific locations of the genome, and transmitted by the standard laws of inheritance from one generation to the next. They can be identified by DNA assays, in contrast to morphological markers, based on visible traits, and biochemical markers, based on proteins produced by genes (FAO 2003). The first application analyzed in this chapter consists in the use of molecular markers for the study of, and to enhance potato diversity.

Molecular markers can be used to analyze germplasm collections (wild ones, or those belonging to peasants, or to research institutes), and in doing so, to search for valuable traits that might be helpful for peasants. The genomic information produced by these technological developments will be, moreover, connected to global databases. This information can be used by public or private organizations in their breeding programmes, since the germplasm might contain materials resistant to stress, both biotic (e.g. fungi, bacteria, viruses, nematodes) and abiotic (e.g. drought, frost). In the case of the potato, the introgression of this germplasm has been minimal to date, and it is possible that these materials are still evolving in peasants’ fields (Ugarte, Estrada, García et al. 1994, Gabriel, Coca, Plata et al. 2007). The use of genomics technologies in the study of this biodiversity might increase the value of the germplasm managed by farmers (Reece 2007) – which is why the way in which different actors handle the concept of biodiversity (of potatoes) might have political implications regarding who is to benefit from any value increase and how genomics will be developed within this biodiversity context.

The biodiversity located in peasants’ varieties might be understood in two different ways. Firstly, there is biodiversity as raw material, without any intrinsic value, and where any value is added by breeders when they introduce these materials in breeding programmes. This approach is implicit, for instance, in the Generation Challenge Program (GCP) of the Consultative Group on International Agrarian Research (CGIAR). Actually, the potato biodiversity studies with MMs by PROINPA could be easily led by the GCP, and the genomic information could be linked to the GCP data base and therefore freely accessible.

Secondly, peasants’ varieties are seen as final entities, with an intrinsic value given by the long-term interaction between the potato-wealthy diversity of these territories, the environmental conditions and peasants’ knowledge. Regarded thus, potato biodiversity becomes cultural material. This approach is used in some participatory plant breeding programmes, in which peasants’ varieties are used as parental material to develop new peasants’ varieties. Somewhat curiously, perhaps, some CGIAR centres are also involved in some of these projects. The projects involve the use of molecular markers to develop fingerprints of the new varieties to assure that no commercial firm will claim these materials. This approach is also used to develop products (concepts) like the Wiphala potato, in order to open new markets for native varieties by utilizing the biological and cultural diversity embedded in native varieties. Which one of the discursive approaches to diversity is materialized in the deployment of genomics would appear extremely

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125 There are several types of techniques to identify MMs, such as microsatellites, AFLP, RFLP, etc.
126 Gabriel, Coca, Plata, et al. (2007) report that only 25 per cent of peasants’ varieties have been used in breeding programmes.
127 Genetic fingerprinting is based on the assumption that every plant individual variety of population has a representative genetic profile. This technique can also be used to support property claims.
important both to the degree of control peasants have in this area – control, over their varieties and any increased value resulting from genomics applications – and to the power exercised by peasants and local development organizations over the molecular marker technologies themselves.

The second application to be addressed here consists of the use of molecular markers for breeding purposes, or marker assisted selection (MAS). The presence of a particular marker in a plant might indicate the presence of the particular trait associated with this marker. In addition, molecular markers can be detected at almost any stage of development of new varieties (Peleman and Voort 2003). Consequently, within the context of the plant breeding activity of crossing two plants with different traits to get one line with the combined desirable characteristics, the use of MMs might enable detection, at an early stage, of offspring with desired traits. In this way, the breeder does not need to wait until the plants grow and fully express their phenotypes. Then, the offspring that lack these traits can be discarded. That is why, the use of MMs can sometimes reduce the time and space necessary in traditional plant breeding by consecutive crossings (Mohan, Nair, Bhagwat et al. 1997, Young 1999, Dekkers and Hospital 2002). Therefore, when interesting individuals with the desirable characteristics are found, they can be used in plant breeding programmes to develop varieties which might address some of the problems (drought, late-blight, viruses, etc.) faced.

These are two developments in genomics that might be utilized to strengthen the small-scale potato systems of peasants. Molecular markers have mainly been developed in the so-called ‘industrialized’ world (FAO 2003), however, and consequently a concrete technological-social structure has been created that facilitates (with varying degrees of efficiency) the applications of MMs. Since technology is not a neutral entity disconnected from societal influences but is continuously interacting with its social context, a single technology cannot just be transferred from one socio-technical reality to another as though no consequences ensue. This remains, however, the usual practice in the application of biotechnologies to peasant contexts. Certain socio-material readjustments in developing MMs within subsistence agriculture would, therefore, seem to be apposite. The following subsection looks at some of the (socio)material readjustments that MMs are undergoing and which are required for their usage in the labs of PROINPA.

**Territorially readjusting and commanding genomics**

This subsection introduces some constraints that scientists face, and the strategies they employ for implementing genomics in a situation of scarcity concerning social and technological genomics-like resources. In this way, the close relationship (co-construction) between society and technology is addressed empirically. Moreover, in all the different examples, re-designing strategies are indicated in which material readjustments are applied by local actors for the production of local specific molecular markers. These strategies are searching for and creating some room for manoeuvre for the territorial development of genomics within the Bolivian socio-material reality which eventually might facilitate a further local sustainable development of genomics.

The first identified practical constraint faced by molecular biologists of the PROINPA foundation in Cochabamba which influenced their strategies for developing genomics within the locality was the polymerase. A good number of the applications of genomics (and of MMs) is
based on the technique Polymerase Chain Reaction (PCR). The PCR is used to amplify specific regions (i.e. to make multiple copies) of a DNA strand. This can be a single gene, just a part of a gene, or a non-coding sequence. A key element for performing the PCR is the polymerase enzyme which is used to synthesize a DNA copy of the region to be amplified. One particular polymerase, from the *thermophilic bacterium, Thermus aquaticus* (Taq, pronounced ‘tack’) is of vital commercial importance. The thermo-stability of Taq DNA polymerase is the critical feature that facilitated the development of the PCR and ensured its commercial success. The PCR was patented by the Cetus Corporation (the inventor of the engine) in 1983. The Taq polymerase enzyme was also covered by patents. The pharmaceutical company Hoffmann-La Roche purchased the rights to the patents in 1993 and currently holds those that are still protected. A related patent battle between Roche and another company (Promega) over the Taq polymerase enzyme was still going on in (2006) several countries. Somewhat ironically perhaps, it seems that legal arguments have extended well beyond the life of the original PCR and Taq polymerase patents, which expired on March 28, 2005 (Zemlo 2006).

When Roche acquired the patent for the PCR, they interpreted their exclusive rights to this technique as applying to all thermo-stable polymerases. At that time, molecular biologists were all using these enzymes on a large scale in their sequencing reactions, and Roche’s prices became prohibitively expensive for them. The Nobel Prize winner, John Sulston argued on this topic:

‘So we started preparing our own enzyme, hoping that we would be protected by research exemption. We soon started receiving legal advice to the contrary. The situation was eventually resolved when another company challenged Roche on the breadth of the patent, and won the right to market its own enzyme. One of the great problems is that granting patents is relatively cheap, but opposing them is very costly and beyond the means of non-profit organizations. The exact limits of the research exemption still need clarification’ (Sulston 2006).

If those are the problems faced in the industrially developed world by Nobel prize winners, we can imagine how these same problems may be amplified in the resource-scarce world. Until now, the strategy of the PROINPA foundation has been to produce its own polymerase. They use some cloned form of Taq DNA polymerase to produce this enzyme in an *E.coli bacterium*. PROINPA recovers the produced enzyme with a precipitation protocol. By following this protocol, only a partial purified Taq polymerase is obtained. Therefore, this enzyme can not currently be used in protocols where a high purified Taq is required, such as for molecular markers like AFLP, RAPDs, or ISSRs. But it is good enough for microsatellites MMs. This strategy of PROINPA allows the foundation to break through one of the socio-material constraints – this one constructed around intellectual property rights – for the deployment of the molecular markers. The new socio-technical rearrangement thus facilitates then the path for the further deployment of microsatellites, but leaves it constrained for other types of molecular markers.

The second problem that PROINPA’s researchers are facing is the high price of absolute alcohol, ethanol. Ethanol is used to disinfect work surfaces in labs and for some reactions in molecular biology. In Bolivia, where there is no significant (legal) ethanol production, it has to be imported, which raises prices to as much as 30 or 40 US$ per litre (Jorge Rojas, personal communication, 23 October 2006). In addition to the high costs, the purchase of absolute alcohol

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128 As described by Pluthero (1993)
in Bolivia is restricted because it is used for the manufacture of cocaine. Therefore, lengthy bureaucratic procedures are necessary to acquire ethanol even once it has been imported. These procedures are so time-consuming and frequent (meaning that also other reactives have to be imported), that the person in charge of picking up and bringing the substances to PROINPA has to spend whole days at the customs office. In view of these problems, the PROINPA laboratory is also using sugar cane alcohol that is available on the market. This costs around 150 Bolivainos (14.50 € - November 2006) per 25 litres and is used after a re-distillation process in which one litre of that 25 is lost. The performance of this alcohol is ‘good enough’ for some of the genomics requirements.

Another material element that requires PROINPA’s attention when practicing genomics in the local Bolivian context concerns refrigerators. Most protocols of molecular biology advice that used materials be stored at -60 to -70°C. Refrigerators that go down to these temperatures cost between 10,000 and 14,000 US$. PROINPA does not have that money, and so has experimented with refrigerators that only go to -20°C. On the local market, these refrigerators cost around US$300.

Finally, there is a problem related to the use of ice grinding machines. Throughout the daily labour of molecular biologists, most of the materials used must be kept cool. Therefore, the labs that can afford it use a machine to produce and grind ice – or an ice grinding machine. In Bolivia an ice grinding machine can cost around US$3,000 (2007). In PROINPA, the ice is produced by the low-cost refrigerators mentioned and hand-ground in a huge wooden mortar.

Through these examples, we can see how material and social elements are closely related in biotechnological developments. This extends from the hi-tech level of DNA replication to the most basic operation of crushing ice. Importantly for genomics strategies, performing PCR is not a straightforward activity, and creative strategies have to be sought after for circumvent ownership regimes – and which leads a local biotech network to explore certain types of molecular marker technologies. We observe how agro-genomics technologies offer us the means to solve certain problems, but throw up new ones of their own. These problems might sound trivial insofar as they can be addressed simply by, for instance, supplying the right freezers through international development projects. Nevertheless, even resolving problems with such an apparently ‘simple’ solution might itself leads to the emergence of new problems in the specific context of local circumstances. For example, the powerful freezers recommended by MM protocols require a technical and human context (constant power supply, technical assistance for reparation, etc.) that is difficult to reproduce in Cochabamba.

Similar problems to these experienced in Cochabamba are outlined in a recent review of the implementation of plant genomics in West Africa. Richards et al. argue that ‘in Ghana (as in Benin) actual usage of laboratory facilities, however, is limited by staffing levels and lack of funds to cover running costs. In addition to the high costs of trained labour and modern equipment, the consumable materials needed for molecular analyses are expensive. Analysis requires very pure and complex chemical compounds produced under patent protection in the Western world. These are often expensive and hard to obtain by customers in West Africa. A major issue concerns basic infrastructure taken for granted in other regions of the world. A well-equipped lab is nothing without clean water and a steady power supply. In many West African

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129 The current occupant of this position (at the time of writing) even has his own coffee cup there.
130 During field work I had the opportunity to speak to a researcher at the NEIKER – Instituto Vasco de Investigación y Desarrollo Agrario (in the Basque Country, Spain) and who collaborates with PROINPA for deploying MM; he was amazed at the money his lab was wasting on refrigerators and electricity.
countries power outage is relatively frequent, and when it happens, the consequences for molecular analysis are serious. A standby generator is and important facility if loss of material is to be avoided’ (Richards, Bruin-Hoekzema, Hughes et al. 2009; p. 209).

The strategies initiated by the local researchers of PROINPA to address the problems listed illustrate the importance of starting to think about the development of biotechnologies and genomics from within local specific situations, so as to transform or correct the shortcomings of the traditional transfer of technology by which apparatuses and procedures are ‘parachuted’ into certain territories. PCRs are emerging in the landscape of low-income labs, to which end the circulation and interchange of strategies and knowledge between such labs is most desirable. In fact, this could facilitate and give more autonomy to researchers for the development of appropriate genomics in areas that have scarce human and technical resources. The sharing of knowledge between labs would appear to be essential for the maximized application of certain genomics technologies aimed at strengthening peasant systems. Such a circulation certainly occurs at an informal level between researchers, but rarely reaches the scientific literature or is translated into handy manuals for cheaply hacking genomics.

4.3. The territorialization of molecular markers within small-scale potato production systems – The territorial domain

The territorial domain concerns power and locality. Here, this means an exploration of the social dynamics that emerge with the deployment of molecular markers for the study of the local biodiversity of potatoes. It also means an investigation of possible strategies for territorializing molecular markers within the context of some participatory plant breeding networks that might facilitate the access of peasants to specific genomics technologies, namely, those that are producing ‘improved peasant’ varieties’, and which at the same time are reproducing the social life of highland territories.

The use of molecular markers for potato biodiversity study

It is often stated that recent developments in plant genomics have opened up new perspectives for plant scientists, who are now able to apply molecular markers to assess and enhance diversity in their germplasm collections, to introgress valuable traits, and to identify genes that control key traits. The PROINPA foundation has also started using molecular makers to analyze the potato collection stored at the Bolivian gene bank, which is managed by the foundation. These activities are especially concentrated on searching for duplications within the bank collection and on developing core collections as strategic entrance ways into the collection for plant breeders. PROINPA plans, moreover, to initiate studies on the varieties managed in situ. As suggested above (Section 4.2) of this chapter, the effect of applying MMs on peasants’ potato-diversity

131 For these purposes PROINPA uses microsatellites MMs (Jorge Rojas, personal communication, 2 November 2006; Jentzsch 2003).
might be an increase in various global and contradictory interests regarding peasants’ varieties. The way in which the concept of biodiversity is handled in the research with MMs – as raw material or as cultural material – is likely to have consequences for who benefits from potato biodiversity. Due to the close relationship between technological and social dimensions, we might even expect a different type of genomics to emerge when, and according to how, the technologies are deployed (i.e. in the raw material or cultural material context).

The transversal problem of understanding biodiversity

There has been a shift of attention in agricultural research, from the organism (crop) to the biogenetic information within the living organism. This shift has been mediated by biotechnologies. In fact, the production of genetic information with technologies like genomics has become common practice worldwide. New biotechnologies have enabled scientists to screen the earth’s plants, insects, and micro-organisms for useful genetic information at an unprecedented speed. This new capacity has made industry particularly interested in maintaining biodiversity (Pistorious and Wijk 1999). The new situation has opened up a heated debate over who is to benefit from the exploitation of genetic information (e.g. Shiva 2005). Two main antagonistic positions are distinguished. The raw material position holds genetic information derived from landraces or wild plants to be just ‘raw’, a natural resource with hardly any intrinsic cultural or economic value. This position regards value as something created by professional breeders and geneticists, who are able to detect, define, isolate, and use the specific information contained in the resources to develop new crops. It follows from this, therefore, that no compensation is required for the source person, community, or country from which the raw material is first obtained. The opposing, cultural material position holds that genetic information does have intrinsic economic and cultural value, independently of any further application of the information. This takes the view that the end user of genetic information has an obligation to compensate the original source person or source country. Scientists who freely take biological organisms out of a country may thus stand accused of ‘biopiracy’ from this cultural material paradigm.

At this stage, we are therefore confronted with the issue of a discursive construction of the concept of biodiversity. Indeed, biodiversity may itself be considered as a socially constructed concept, around which a deployment of conflicting interests around nature arises. From this discursive perspective, biodiversity does not exist as a fixed concept, but is shaped and reshaped by the relations between nature and society in the global context of science, technology, culture,

132 In his recent book ‘Global Biopiracy’, Ikechi Mgbeoji (2006) uses the term ‘biopiracy’ to describe the process by which industrialized countries appropriate knowledge about the use of plants built up over centuries by peasants in the poor third world and appropriate the genetically wealthy position from the South by building up their own stores of genetic material. Mgbeoji analyzes this process as operating in three main ways. Firstly, it operates at a socio-cultural level. This is expounded in discursive Foucaultian terms with the ‘denigration and denial of the intellectual input of traditional farmers and breeders, particularly women, in the improvement of plants’ (by the scientific discourse). Secondly, it works at the institutional level by the systematic collection of plant materials from the South and the setting up of an international system of gene banks strategically situated in the centres of genetic diversity (like the International Potato Centre in Peru). These centres have been sponsored by the North and their materials have flowed in the opposite direction to the financing. Thirdly, there is a legal operation level of biopiracy. This has been made possible by ‘a deliberate lowering of the threshold for patentability and several other forms of judicial and legislative intervention in the patent law system that have resulted in serving the ever-expanding interests of Western corporate seed merchants and pharmaceutical and biotechnological companies.’
economy and politics (Escobar 1999) – as well as by these relations within local networks and through their conflicting interests.

The following sub-section deals with the construction of the local understanding of biodiversity and how it is shaped by and is itself (contributing to a) re-shaping the global conceptualization of biodiversity.

The local conceptual construction of biodiversity by the emergence of a global legal framework for managing potato biodiversity

The international regulation of genetic resources and information is negotiated by and dictated from international institutions in regulatory frameworks like the Convention of Biological Diversity (CBD), and the agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS). Before these agreements, genetic resources had been considered the ‘heritage of human kind’, and thus open to all (subject to free access). The frameworks established and detailed by these agreements, however, have not yet been fully achieved, primarily because of the conflicting interests involved. Supporters of this global liberalization see regional political structures as trying to regulate the flux of genetic resources. The Andean Community Commission (ACC) in which Andean countries are associated provides a good example of this regulation. In 1996 the ACC established Decision 391 (Common Regime on Access to Genetic Resources) that regulates access to the genetic resources of the Andean region. Since the implementation of this regional regulation, few potatoes have left Bolivia legally. However, just before the implementation of this rule and just after the Rio agreement on biodiversity, researchers from Wageningen University in The Netherlands did manage to gather a collection of wild and native cultivars of potatoes for the Dutch national gene bank (the Centre for Genetic Resources). This collection falls under the international agreement for potatoes before Rio and therefore under free access rule. Naturally, should new Dutch varieties derived from this collection be commercially imported into Bolivia, royalties will be payable.


134 The debates on biodiversity in the trade sector led to the (1994) Marrakech agreement, which included the establishment of the World Trade Organization (WTO) and the TRIPS. The TRIPS specifies minimum standards for IPRs in territories of member countries of the WTO. TRIPS requires that all products and processes must be patentable, with some possible exceptions like diagnostic, therapeutic and surgical methods for the treatment of humans or animals.

135 The ACC is the main policy-making body of the Andes region. Its members are Bolivia, Ecuador, Peru, and Colombia. Its legislative role is affected through the adoption of decisions taken by the Andean Council of Foreign Ministers.

136 Such regional and national regulations effectively allow for bilateral agreements between states. Although not mandated by as such by the CBD, this is how most countries have chosen to exercise their sovereignty (Pistorius and Wijk 1999).

137 Three native varieties have been exported to Switzerland, a process led by the Bolivian potato seed company SEPA (Carol Rocabado, personal communication, 30 October 2006). To my knowledge, this is (2007) the only instance of a foreign organization managing to complete all the bureaucratic procedures required to get potatoes legally out of the country.

138 This penchant for collecting is institutionally recognized by the Centre for Genetic Resources, and operates as a two-way process – an illustration of which would be the ‘repatriation’ in 2006 of 528 accessions of 30 wild relative species from Wageningen ‘back’ to the potato gene bank of Bolivia.
The prime beneficiaries of the new international regulatory framework seem to be the *transnational agro concerns*. They are among the very few actors who have the financial and technological capacity to exploit the global gene pool and to protect modified plant genetic information (Pistorius and Wijk 1999). At the other end of the scale, are the *small-scale farmers* who have neither the knowledge nor the economic resources to even participate in the process. They are supported by *local development organizations*, and *indigenous organizations*. The small-scale agriculture of these peasants provides reservoirs of potato diversity for the world. As things stand, however, the farmers themselves have little to gain from international crop development policies that carry the explicit objective of promoting industrialized and deterritorializing forms of agriculture (Pistorius and Wijk 1999, Ploeg 2008). Peasants are excluded from the industrialization process of agriculture because they lack the land, the credit, the infrastructure, and the markets.

For peasants, *free access* to genetic resources may mean nothing more than that the established North-South transits (piracy?) of resources will continue unabated. The *strict regulation* closely controlling genetic transit as demanded by indigenous organizations and some local civil society organizations might generate some compensation for small-scale farmers. However, we should recognize that the compensation for these peasants and communities should not be just economic, since their needs are related to a larger range of issues, including access to land, health, education, technology, markets, and non-industrial crop development. These are the demands of indigenous peoples as articulated in the recent insurrections (and especially that of 2003), which contributed to and culminated in the election of the first indigenous president of the Bolivian republic.

The social forces representing and coalescing around the indigenous peoples of Bolivia aim for a new form of multicultural territorial and state governance, including a reformed management of potatoes and their indigenous cultural meanings. This politicization has taken concrete form at the local level (constituting what might be termed a territorilization movement) For instance, the communities of the Llallagua municipality in North Potosí have declared their local government the ‘Bio-Cultural Municipality for the Conservation of the Native Potatoes’, while the municipality of Colomi in Cochabamba now calls itself the ‘Agro-Ecological Biodiversity Municipality’. These self definitions are not officially recognized at the departmental or national level, but are clear statements by local communities articulating their demands within the discursive construction of biodiversity and of the territory itself. However, these movements have not yet matured to the point of offering feasible alternative strategies for regulating the global flux of genetic resources in a way that could be directly controlled by peasants’ organizations of local civil organizations, let alone by the peasants themselves. A
fuller development at the conceptual level thus seems necessary in order to realize the desires and demands of local communities in regard of (their) potatoes.

The following sub-sections examine how molecular markers are deployed within the two contradictory understandings of biodiversity, and how these technological developments might have consequences for the further conceptualization of potato biodiversity. They will also show how the same organizations are employing both understandings.

The conceptual construction of biodiversity within the CGIAR-CGP

It is expected that biodiversity studies with MMs will be supported and led by the Generation Challenge Program. The GCP uses genomics to analyze the genetic materials stored with its parent organization, the Consultative Group of International Agrarian Research, and for the development of new crop varieties. It is stated that new varieties are intended to meet resource-poor farmers’ needs. However, I will argue that the realization of this objective is hindered pragmatically, now and in the immediate future, because there are no designed trajectories to reinvest the knowledge extracted with MMs from the local gene-pool, i.e. back into the locality. Moreover, it is also hindered conceptually, at a fundamental level, because the GCP’s raw material view of biodiversity is in contradiction with the dominant understanding in Bolivia.

The GCP partner for addressing these objectives in Bolivia is PROINPA. Its efforts are materialized in concrete projects in the CGIAR centres that hold the gene-banks. In 2005, for instance, the GCP provided a grant to train a PROINPA researcher at the International Potato Centre (henceforth ‘CIP’, the Spanish acronym) in the use of microsatellite MMs for potato genetic diversity studies. The partnership between PROINPA, CIP and the GCP is now expanded through PROINPA’s participation in the GCP’s Genotyping Support Services for Bolivia’s collections. Although it is not very clear yet whether the genotyping will take place in Peru (CIP) or in the EMBRAPA installations in Brazil, the expected roles in the partnership are as follows:

- **PROINPA will:** (1) Define research goals which address the needs of crop stakeholders, and propose sets of germplasm for genotyping; (2) Extract DNA and ensure compliance in quality and legal requirements for carrying out the genotyping work; (3) Participate actively in data analysis, acquire familiarity with the relevant technologies, and propose ways to improve breeding processes in light of the acquired knowledge; (4) Identify bottlenecks in crop production and propose ways to solve them with biotechnological tools and participatory approaches.

- **The GCP, through the Genotyping Support Services will:** (1) Assist PROINPA in their proposal for germplasm genotyping; (2) Co-develop a programme of activities with PROINPA and the genotyping laboratory; (3) Develop tailor-made training activities to address specific needs; (4) Cover the expenses for genotyping and training.

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regions from the predations from biopirates of the North’ (GRAIN 2005; p. 20). Perhaps the developments in Llallagua and Colomi are the beginning of a new trend.

144 Jorge Rojas, personal communication, 23 October 2006.

145 EMBRAPA (Empresa Brasileira de Pesquisa Agropecuaria) is the public Brazilian agricultural research corporation mandated to ‘provide feasible solutions for the sustainable development of Brazilian agribusiness through knowledge and technology development and transfer’ (www.embrapa.br).
Genotyping laboratory researchers (EMBRAPA, CIP) will: (1) Advise PROINPA on DNA extraction and DNA quality testing; (2) Conduct the genotyping; (3) Assist PROINPA scientists in genotyping DNA-related technologies and data interpretation (Rojas 2006)

The Generation Challenge Program was founded in July 2003 by the Executive Council of the CGIAR with start-up funding from the World Bank and the European Commission. The self-assigned aims of the GCP are:

‘To create public goods from the raw materials of plant genetic diversity and the advances tools of genomics science for use in plant-breeding programmes. These public goods serve to overcome complex agricultural constraints that prevent staple crops from producing reliable harvests for the poor farm families that rely on them daily for food, as well as for income with which to rise one day from poverty’ (GCP 2005; italics added)

Within these aims there are two issues of interest. Firstly, the GCP conceptualises genetic resources as raw materials. Obviously this places the GCP within the discursive position on biodiversity that sees genetic, of even all (natural) resources as cultural-neutral, essentially valueless objects, which can be used for the development of products (new varieties by means of plant breeding strategies) with added value. Secondly, because genetic resources – in this case peasant’s native varieties – are considered raw materials, the GCP might generate a situation in which researchers all over the world have free and direct access to these crop genetic resources, i.e. to the newly created public gene pool (Bruskiewich, Davenport, Hazekamp et al. 2006, Louwaars, Thorn, Esquinas-Alcazar et al. 2006).

The GCP’s raw-material notion and free access strategy might have two main consequences. It might come into conflict with the protectionist Bolivian strategies in the management of genetic resources (as expressed by Bolivia’s adhesion to the ACC Decision 391). Also, it might draw criticism from peasants’ groups and certain civil society organizations that consider farmers’ varieties as cultural materials, rather than valueless materials.

Another reason for these groups to criticize the GCIAR is that they were the core administrators of the Green Revolution, a model which facilitated the agro-industrialization of agriculture. This model has been heavily criticized by peasants’ groups, civil society organizations and scholars (e.g. Goodman, Sorj and Wilkinson 1987, Ruivenkamp 2003, Kloppenburg 2004). The criticisms are mainly focused on the fact that this industrialization promotes a model of commercial agriculture which is driven by the large concerns of agro-business and excludes resource-poor farmers. This model also fails to benefit small-scale farmers insofar as their varieties are treated as a means (raw material) rather than an end (cultural material). This is unfortunately – and tellingly – illustrated by the lack of a parallel process to develop partnerships between GCP and PROINPA for the application of the knowledge that comes out of the biodiversity analyses, i.e. in plant breeding programmes run by PROINPA.

To conclude, although there is a policy shift towards a reorientation of the technological developments to resource-poor farmers, it is not obvious that these organizations should take the lead in the design and implementation of science and technological developments to strengthen

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146 This includes, of course, farmers’ varieties. In fact, the potato collections in Bolivia are formed by some 528 accessions of 31 wild relatives and over 1700 accessions of native or farmers varieties.
small-scale agriculture.\textsuperscript{147} It is not obvious that the generation of knowledge with MMs on biodiversity will produce improvements in local systems without the existence of technological social structures which are able to employ this knowledge within the locality. Nevertheless, as the next subsection shows, the same institutional framework (CGIAR-GCP) is supporting PROINPA to develop the cultural trajectory of understanding potato biodiversity and deploying MMs. In other words, contradictory understandings of potatoes shaping different conceptualizations of biodiversity and technological trajectories are being promoted by the same organizations. Thus, if PROINPA is able to develop capacities for the materialization of the knowledge extracted from the local gene pool by the application of MMs (as is presented in the following sub-section), this might indeed lead to the strengthening of peasant agrarian systems after all.

The Wiphala Genomics

The Wiphala is the Andean emblem. Symbolic of the Inca heritage, the Wiphala flag is generally composed of a 7 X 7 grid (patchwork) of 49 squares in seven rainbow colours arranged in a diagonal pattern, and represents the social and natural diversity of the Andes. During the colonial period this flag, with its multiple meanings, was associated with resistance and suppressed. The Wiphala emblem has various forms, geographically linked to regions of the Inca Empire, with Bolivian forms in particular referring the Quilla Suyu (Inca region), the Aymara peoples and the anti-colonial rebel leader Tupac Katari.\textsuperscript{148} In recent times the Wiphala emblem has been recovered by the Andean indigenous peoples as one of their symbols.

In some communities around Llallagua in Norte Potosí, there is a project to develop the Wiphala potato. In this project, peasants’ associations and trade unions cooperate with the local civil society organization, CAD\textsuperscript{149} and PROINPA. Here, the metaphor of the Wiphala emblem is applied to a commercial product. The Wiphala potato product is an effort to promote native varieties for commercial purposes. The intention is to encourage small-scale farmers in the conservation of their potato diversity by generating an economic interest in their native varieties, the cultural element of these varieties being seen as an added value helping to persuade Bolivians to buy them.\textsuperscript{150} This cultural value of the product is associated with other conceptual frameworks, such as organic food, fair trade and poverty alleviation.

\textsuperscript{147} An interesting GCP approach is the humanitarian licence initiative, according to which farmers below a certain income level do not need a licence in order to use GCP-developed technologies (which includes the reproduction and sale of seeds of varieties that are protected or contain protected inventions) (Louwaars, Thorn, Esquinas-Alcazar et al. 2006). Ironically, these farmers are not used to asking for permission to use new varieties anyway.

\textsuperscript{148} The Quilla Suyu was the south-eastern part of the Inca Empire, covering present day Bolivia. The Quilla emblem sometimes referred to as the Bolivian Indian flag. Tupac Katari (born Julián Apasa) was a leader of the rebellion against Hispanic rule – heading a force that reached 40,000 during a bloody, unsuccessful siege of La Paz, in 1781 – and whose memory was invoked in the first Aymara political parties during the 1970s – the Tupac Katari Revolutionary Movement (MRTK, Movimiento Revolucionario Tupac Katari) and the Tupac Katari Indian Movement (MITKA, Movimiento Indio Tupac Katari) – and then later in the early 1990s guerrilla army (EGTK, Ejército Guerrillero Tupac Katari) (www.crwflags.com, http://migs.concordia.ca/documents/RobinsSymbolicDiscourse.doc, www.zmag.org).

\textsuperscript{149} CAD (Centro de Apoyo al Desarrollo) is supported by the Italian NGO Ricercare e Cooperazione.

\textsuperscript{150} PROINPA supports other similar experiences with retail trade of potato native varieties. One is organized by the peasants’ association PROTAC (Asociación de Productores Andinos 1ra. Candelaria) in the municipality of Candelaria, Cochabamba. Another one is organized by the peasants’ association APR (Asociación de Productores Andinos San Isidro), in the municipality of Morochata, Cochabamba.
The Wiphala potatoes bags are filled with different varieties – continuing the Wiphala metaphor. This diversity of varieties will depend on the different seasons and geographical variables where the bags are filled. The Wiphala potatoes product (its purchase, marketing and sale) is thus adapted to the varying dynamics of peasants’ systems. In this context, biodiversity is considered as cultural material, the idea being to sell biodiversity, the diversity of peasants’ varieties, rather than specific varieties. This conceptualization of biodiversity is obviously very different to that of raw materials. It is exactly within the context of projects like the Wiphala potatoes, which look to the problems, materials and dynamics of peasants’ systems, where the here labelled Wiphala genomics might be developed.

A specific field of application of the Wiphala genomics is the treatment of problems around the pseudo-fungus Phytophthora infestans. Plant breeder for PROINPA, Julio Gabriel, reported on the use of 22 microsatellites MMs to search QTLs/genes of known resistance to Phytophthora in the progeny of crosses between three wild relative potatoes (of the Solanum canasense, S. jamesii, and S. bukasovii) and two native individuals (of species S. goniocalyx, and S. phureja). The lines of the S. goniocalyx showed the lowest resistance to Phytophthora, whilst the S. phureja lines showed a variable resistance. This allowed both the determination of the QTLs and their genomic position in the progenies, and the identification of molecular markers (microsatellites) that can be used in plant breeding or marker-assisted breeding programmes (Gabriel 2006; and personal communication, 23 October 2006). By connecting genomics and Andean small-scale agriculture – with its native varieties and their cultivation specificities – the new socio-technical environment might produce a new genomics (Wiphala?) that might, eventually, break through the conventional (deterrioralizing) orientation of genomics towards industrial agriculture and its commercial varieties.

Another illustration of how molecular markers could be used within the framework of biodiversity considered as ‘cultural material’ is the PROINPA experience of producing genetic fingerprints of the varieties developed in participatory plant breeding projects. For instance, in the communities of Piusilla-San Isidro and Compañía Pampa, in the Morochata Region of the Department of Cochabamba, six new varieties (P’uyuni imilla, P’alta chola, Libertad, Aurora, Anita and Cholita rosada) have been developed – with varying degrees of Phytophtora resistance – in a collaborative project between farmers and researchers (Gabriel, Herbas, Salazar et al. 2004). The genetic fingerprint of the new varieties was elaborated with ten microsatellites MM. The intention here is to develop property frameworks which protect new varieties based on native materials. With the development of the fingerprint, commercial firms will not be able to use these materials without the permission of peasants. Peasants will be the owners, and PROINPA the strategic partner. Although this is the intention, there have not been any practical developments for the implementations of this property framework (Julio Gabriel, personal communication, 23 October 2006).

151 Together with other factors like insect pests and the introduction of improved varieties, damage done by Phytophthora has even led to the complete loss of native varieties in the community of Compañía Pampa, Cochabamba (Herbas, Torrez, Almanza et al. 2000)
152 Though not necessarily genes themselves, quantitative trait loci (QTLs) are stretches of DNA that are closely linked to the genes that underlie a trait. QTLs can be identified molecularly (for example with PCR) to help map regions of the genome that contain genes involved in specifying a quantitative trait. This can be an early step in identifying and sequencing these genes (www.wikipedia.org)
153 STM1104, STPoAc58, STM0019, STM0037, STWAX-2, STM1052, STM0030, STM1016, STM1097, STM1106 (Rojas and Canedo 2005)
To conclude, the participatory plant breeding project in Morochata has been possible due to the wide-ranging CGIAR programme, Participatory Research and Gender Analyses, and the programme, Papa Andina. In the preceding sub-section, the legitimacy of GC-P-CGIAR was questioned, among other reasons because of its consideration of peasants’ varieties as raw materials. Here with this participatory plant breeding project we see that an alternative trajectory might also be developed within this institutional framework, one that considers farmers’ varieties as cultural elements with an intrinsic value. These contradictory tendencies cohabit also within PROINPA. Moreover, we know by now that there is a close relation between the socio-material context in which biotechnologies (molecular markers) are developed and the new socio-biotechnological structures that emerge. Agricultural scientists have to realize the non-neutrality of research. As scientists, we might recognize that the political biases of research are ultimately reflected in socio-technical results. Therefore, the answer to the still open-question of which discursive definition of potato biodiversity will come to dominate the field is crucial to the future development of biotechnologies in general and types of genomics in particular in the small-scale potato systems of the Andes.

The next subsection aims to extend the answer to the main research question of whether the development of genomics in the Bolivian highlands might strengthen both potato small-scale systems, and empower peasants and local development organizations within the MM technological structures. This is tackled by analyzing the potentialities of the deployment of molecular markers – to introgress the interesting traits found in the biodiversity studies on local varieties – in participatory plant breeding as a social structure, in order to perform marker assisted selection within subsistence agriculture.

**Participatory plant breeding as a democratic socio-technical platform for the deployment of marker-assisted selection**

Apparently, the most important function of plant breeding is to develop new varieties by crossing and selecting plants which might perform better than those already existing. Although plant breeding is based on natural truths (e.g. Mendel’s laws), it is also, however, based on social truths and is therefore socially constructed. Researchers do not seek to enable increases in farming production merely because it is scientifically interesting and possible, but also, and importantly, because it is assumed as a social good, first for the alleviation of hunger and then for the expansion of consumer choice. In fact, of course, plant breeders in both the public and private sectors deal continuously with questions such as which crops should be focussed on, where and to what extent new plant varieties should be marketed, which genetic information should be conserved, how and to what extent the resulting varieties should be protected against reproduction by competitors, etc.

Another (social) structural function of plant breeding is the appropriation of the traditional activity of peasants to generate new crop varieties (Quechua and Aymara cultures seem to have mastered the generation of potatoes). This function, we note, is accompanied by a scientific superiority discourse with the deployment of concepts like ‘improved varieties’ referring to the

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154 See www.prgaprogram.org
155 See www.papandina.cip.cgiar.org
156 The laws of the transmission of heredity characteristics between organisms from parent to progeny.
varieties developed in plant breeding programmes or ‘formal seed’ to name the seeds officially certified by scientific methodologies – implying that other varieties are less good and seeds less respected. The Centre for Genetic Resources in The Netherlands (gene bank), for example, calls Quechua and Aymara varieties ‘primitive’ varieties a term that carries obvious pejorative connotations. Peasants and their varieties are generally devalued in or just excluded from the process and project of biotechnological developments. Although this may be the general tendency, here we are interested in finding the spaces within this fundamental agrarian activity of plant breeding, in which both groups of experts (peasants and plant breeders) can come together in order to make a better use of the natural and social truths of plant breeding.

Finding such spaces of encounter is important for the concerns of this chapter since the diversity of potatoes is decreasing, as described above, and hundreds of thousands of peasants are still dependent for survival on the range of native varieties, adapted to the different biotic and abiotic stresses of high mountain agriculture. Genomics could enhance the further analysis of varieties that are vulnerable to loss through the disappearance or the transformation of the human societies that have created and/or sustained them (Sections 4.2 and 4.3). These varieties may be interesting for other communities or generations that may need to cultivate potatoes in these (or similar) regions, now or in the future. Moreover, once the interesting traits for the local conditions are found and introgressed in peasants’ varieties, ‘native improved’ varieties can be delivered to peasants’ systems. This is important since the traditional system of regeneration potatoes is disappearing, so the seeds managed by peasants are becoming ‘tired’.

Certainly, PROINPA orients its activities to the commercial agriculture of ‘lowlands’ of Bolivia. This guarantees the income necessary to maintain the foundation. At the same time, however, PROINPA also produces regenerated native varieties for small-scale farmers. In 2005, for instance, around 1,200 kg of four native varieties were multiplied for the area of Llallagua in Norte Potosí. Moreover, both individual peasants and communities can place orders with PROINPA, from as little as 50 kg. It takes about one year to deliver the potatoes. No private company wants or is able to meet this type of demand, especially at such low volumes.

It is in the participatory research projects that we can find peasants and scientist together generating agrarian technology. The concept of farmers’ participatory research was created by researchers like Stephen Biggs, Robert Rhoades and Paul Richards (Bentley 1994). Strikingly, there have been more scientific articles written on the subject that there are technologies in the field. This might be because farmer participation in research gained academic popularity before it proved its worth in the field (ibid.). Plant breeders do now find participatory plant breeding useful, however: new varieties produced this way are rarely refused because they usually have the characteristics that farmers require. This is the case in Bolivia too (Thiele, Gardner, Torrez et al. 1997, Gabriel, Herbas, Salazar et al. 2004). Furthermore, this methodology is especially implemented in developmental projects oriented to alleviating poverty. In this way, it is possible for peasants to reorient breeding activities that are usually geared towards commercial farmers.

157 See www.cgn.wur.nl accessed March 2007. While such terminology has long since passed out of the vocabulary of the social sciences, the physical sciences would appear to assume an objective distance from such considerations, removing them the socio-political realm. As argued, this really is not appropriate in the case of (bio)technology. While hard sciences might justifiably wish to be spared the passing terminological fashions of the humanities and liberal arts, they cannot claim immunity from a sea change.
158 Tired seeds (semilla cansada) are seeds affected by viruses that are transmitted from generation to generation, a process to which crop potatoes, as tubers, are particularly vulnerable. Because of this, yields are estimated to be cut to up to 20 per cent (Thiele 1997).
159 From the 4,000 kg of seed potatoes produced in 2006, around 3,000 kg were commercial varieties.
An example of this reorientation was detailed by Julio Gabriel and his colleagues (2004), reporting on their participatory plant breeding experiences in the communities of Piusilla-San Isidro and Compañía Pampa in the Morochata Region of the Cochabamba department. In this region, the main constrain on potato farming is ‘late blight’ (Quechua: t’oqtu), caused by Phytophthora. The intention was thus to develop varieties with good resistance levels to late blight, as well as good yield and acceptable culinary qualities for household and industrial consumption. Peasants defined these problems and aims, chose the parent materials, made the crosses, and monitored the growth. And after having received training on evaluating and selecting lines, peasants themselves chose the clones for on-farm multiplication and use (Gabriel, Torrez and Thiele 2000). In each community, six varieties were chosen, of which three are currently known to be maintained (Julio Gabriel and Justo López, personal communications, November 2006). It is hard to know whether the other varieties are still performing in the fields or have been just discarded by peasants, because of the high mobility of potato seed among peasants and the few scientific human resources available to follow up the developed technologies.

And what about genomics? Just as with the concept of participation, the developmental promise of genomics to provide molecular markers for the biotechnologization and hopefully the acceleration of plant breeding projects has been more evident in the literature than in the field (see Young 1999, FAO 2003, Fears 2007). Some specific socio-technical constraints have to be addressed before genomics can be efficiently applied on peasants’ fields in Bolivia. Such constraints include the allocation of capital to purchase PCR (polymerase change reaction) machines, and finding technicians who know how to use and, especially, how to repair them. Once these needs have been addressed, these participatory plant breeding networks look like they may well comprise an appropriate platform for the deployment of molecular markers to be focally oriented in order to strengthen subsistence agriculture. In addition to the previously mentioned use of molecular markers to develop the genetic fingerprints of the varieties produced in these participatory plant breeding programmes (this section above), it is expected that the knowledge developed around the molecular marker technology in the study of potato biodiversity will indeed be applied in participatory plant breeding programmes assisted by molecular markers technologies. The interesting traits that are found could be introgressed into peasants’ varieties. These traits are not only based on biotic stresses (such as Phytophthora, viruses, or nematodes) or abiotic stresses (frost, drought), but also traits of interest for peasants such as cooking time or how fast potatoes mature. These last (cultural) traits have been sometimes forgotten by professional breeders, often working in relative isolation from peasants.

The constraints on participation

Peasant participatory research is difficult, if for no other reason than because it is hard to get scientists and peasants together. Chambers (1983) wrote more than 25 years ago that researchers often have limited access to representative peasants because scientists stay close to cities, visit fields under the influence of specific projects, stay on the paved road, travel during the dry season

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160 Both men and women; they were equally involved in the process.
161 Almost all based in the most popular variety, Waych’a.
162 Notice that in most participatory plant breeding projects, crosses are performed by plant breeders (Bentley 1994).
163 PROINPA’s potato plant breeder, Julio Gabriel, is currently (2009) conducting his PhD on this topic.
164 Due to the high ecological diversity of Andean high mountain agriculture, there is also a high range of frost intensity and water precipitation.
and talk to men, especially the wealthier ones. The situation has not improved much since. The class, ethnic, gender, geographic, economic and linguistic differences between scientists and peasants means that establishing interaction between them is easier said, or written, than done (Bentley 1994).

As Horkheimer (2004) comments in relation to the misuse of democracy when it is deprived of its rational foundation of liberation to become a form of domination, participation has become a fashionable term to be used in most of the so-called development projects. Participation, rather than a genuine strategy to empower peasants in respect of biotechnological developments, has become a kind of justification for continuing with the traditional transfer of technologies, in which peasants are ultimately regarded as little more than receivers, and biotechnologies as neutral instruments (for the manipulation of raw materials).

Conventional breeding has tended to focus heavily on the capacity of a commercially relevant plant to produce a high average yield over a range of growing environments and years. Unfortunately, there has been less attention paid to ‘marginal’ crops, such as native potato varieties, that have little importance in global markets, but constitute a staple food for peasants; nor have many varieties been developed for the environmentally-diverse and stress-prone marginal areas where peasants live (Almekinders and Hardon 2006). And the resulting ‘improved’ varieties often require heavy doses of fertilizers and pesticides, which most poor farmers cannot afford. Professional breeders, often working in isolation from peasants, have failed to take into account peasants’ preferences beyond yield, and resistance to diseases and pests; preferences such as cooking time (in conditions where fuel is scarce or expensive), speed of crop maturation, storage problems (in difficult environments) or the suitability of crop residues (for livestock feed and other uses).

Despite the wealth of knowledge, peasants’ participation in conventional breeding programmes has commonly been limited to evaluation and comment on a few advanced experimental varieties just prior to their official release. Such token participation means that few peasants feel that they have a real stake in the research or any sense of ownership of its products. Moreover, and more importantly perhaps, they are not able to contribute their technical expertise to projects. Andean peasants, for whom potatoes and their development are vital for family nutrition and cultural life, have been the chief engineers of potatoes for thousands of years. They continue today to actively select and breed them, and the neglect of their practical wisdom is a loss to all involved in and affected by research.

In this subsection we have seen that some multi-stakeholder networks are working with broader understanding of participation in the Andes region. Some organizations in the Andes are integrating women in their projects, extending peasants’ and local community participation to include the selection of materials and crossings, and addressing not only problems of resistance to diseases and pests, but also other problems such as culinary qualities, differential water tolerance, or speed of maturation. If we hope to put genomics to work within development, and for peasants to gain power within its socio-technological assemblage – in short, to territorialize genomics –, then these participatory plant breeding networks would seem an appropriate environment (structure) in which to work.

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165 For other interesting examples of participatory plant breeding in which PROINPA plays an important role, see Danial, Parlevliet, Almerkinders et al. (2007), and Gabriel, Coca, Plata et al. (2007). However, because the economic restrictions that typically characterize ‘pro-poor’ institutions like PROINPA, and since there are no large public extension facilities, their projects are usually limited in scope, oriented to just few communities instead of wider areas and larger groups of peasants. The structural impact of these interesting projects is consequently rather small.
4.4. On the polypotency of technology and on the invisibles – The reterritorialization domain

Dynamite was the invention that made the Swedish chemist-engineer Alfred Nobel rich. The Nobel Prize was founded after Nobel realized with regret the potential military uses for dynamite and wished to encourage peace, and science for 'positive' uses. Dynamite is a good illustration of Sclove's (1995) concept, the *polypotency of technology*.\(^{166}\) Sclove argues that all technologies are polypotent in their social functions, effects or meanings. This term is used in modern technology assessments to speak about the unintended or secondary consequences of technologies. The usage can be expanded, however, to express the idea that we do not know which of a technology's functions are the most important, or even which are intended; during the phase of deployment especially, no-one – including researchers and research-funding institutions – can presume to be very certain about how a specific technology will be employed and what it will come to mean.\(^{167}\) Given that technology structures society in so many ways, it is therefore very important to critically address the structural polypotency of concrete technological developments, to learn from the historically structuralizing moments, and to try, consciously, to re-structure technology towards the purposes of reaching intended social aims – in this case, the democratization of the deployment and further development of genomics within subsistence agriculture.

By way of example in the field of biotechnology, one of the elements of Green Revolution seeds was their capacity for economic restructuring, to increase productivity, whereas their social function has been to effect a restructuring of relations between suppliers and users, a reduction, in fact, of farmers’ autonomy in agrarian activities. The reasons for this are various, but include the (predictable but in fact barely considered) reliance of the new seeds on inputs such as pesticides and fertilizers that farmers have to purchase from a restricted range of external organizations. Choices about pest management and soil fertilization have traditionally been in the hands of farmers. Some (Oasa and Jenning 1982, GRAIN 2000, Dowie 2001; pp. 108-114), indeed argue further that the research centre founders of the original Green Revolution – IRRI and CIMMYT\(^{168}\) – actually had the aggregate intention of preventing the extension of communism by increasing the production of food, especially in those countries with a strategic geopolitical situation.\(^{169}\)

Technologies do occasionally structure society through their focal purpose – weapons, for example, function coercively because they are designed to do just that (Sclove 1995) –, but more often and more subtly, it is technologies’ latent polypotency that accounts for their structural impact on society. In the sphere of biotechnology, critical thinkers have illustrated the structural features of these technologies beyond the explicit economic function of increasing productivity. Goodman et al. (1987) identified what they called the *industrial appropriation* of some key farming activities, like crop and pest management, by external institutions through the supply of industrial inputs. Van der Ploeg (1987) tackled the *scientification* of agrarian research and the subsequent increasing prescription of farming practices from the scientific domain. Ruivenkamp

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\(^{166}\) Polypotent: potent in many ways.

\(^{167}\) Indeed, the foregoing section showed how research institutions can also be polypotent, i.e. institutions function in ways that imply more than one assumption about a technology’s aim and effects, especially in regard to the social dimensions.

\(^{168}\) International Rice Research Institute and International Maize and Wheat Research Institute.

\(^{169}\) Both IRRI and CIMMYT were co-founded by the Rockefeller Foundation.
Redesigning Genomics – Reconstructing Societies

(2005b) has addressed the remote control exercised by the agro-industry on certain farmers’ activities (Section 2.4). And Kloppenburg (2004) has addressed the further extension of commodification into the sphere of the natural resources which form the basis of agriculture.

These structural potencies of biotechnologies are embedded in the industrialization and scientification process of agriculture, and therefore of agrarian societies. The field of genomics has developed within this historical framework. It is in view of these considerations therefore, that this chapter has focused on the democratization potentialities in the deployment of genomics in a social context (that of the Bolivian potato systems), with particular attention to the potential use and further development of molecular markers for studying local potato-biodiversity and its usage in participatory plant breeding.

For many years, agricultural technology operated within the framework of a linear model – or ‘ready-made science’ (Latour 1987) – whereby research was done by scientists, translated into technologies by extension labour and delivered on peasants’ fields. This model disconnects scientific creation from agricultural application. It also disconnects peasants’ knowledge form the process. It is therefore important to appreciate how the design of biotechnologies reflects the hegemonic beliefs, values and norms of the dominant groups. Thus, the influence of peasants and other (peripheral) groups in the technological design process has been minimal. The technologies developed are expressed in discourses that, in Foucault’s terminology, legitimate the power of formal scientific knowledge to the detriment of the expelled discourse of peasants. In the potato highlands of Bolivia, we can see the deployment of concepts (discourses) like ‘improved varieties’ for the varieties that are originated in plant breeding projects: they are deployed as superior to peasants’ varieties. Moreover, in his study of Andean potato peasants, van der Ploeg (Ploeg 1989; p. 15) described this self-proclamation of superiority by scientific knowledge with a metaphor. He referred to the feeling of invisibility experienced by Andean peasants (‘people pass by, as if one does not exist … One only exists if others – technicians, bankers, bureaucrats, etc. – are so kind as to remember that one exists’), and suggested this as a good metaphor for the relation between local knowledge and scientific knowledge. As a reaction, the expelled or subjugated knowledge of peasants, especially when it is articulated and amplified by indigenous groups and activist local developmental organizations, tends to distrust the dominant scientific discourse, for instance seeing the ‘improved varieties’ as political (neo-liberal) enemies, and ultimately rejecting science and even development itself.

This chapter has attempted to go beyond the radicalized pro-anti debate around biotechnologies and biodiversity by finding places of encounter from which genomics (in the form of molecular markers) may be democratically territorialized and put to work for local sustainable development within the potato systems of the Bolivian highlands.

The technological domain (Section 4.2) has presented the relevance that potatoes and their diversity have for Aymara and Quechua peasants, as well as the potentialities that molecular markers have for strengthening these agrarian systems. It also explored some material readjustments that molecular markers must undergo to be able to perform in the local socio-material circumstances. Moreover, because the social environment shapes technologies and because technological developments simultaneously structure society, the territorial domain has discussed how in the deployment of MMs it is important to elucidate the ways this co-construction takes place and the impact the MMs deployment process could have on peasants’ systems. The CGIAR-GCP organizational framework, it has been suggested, ought perhaps not to be considered as an appropriate actor for leading the further deployment of MMs in biodiversity studies within this concrete social context. This is not only because it is expected that some NGOs and peasants’ organizations will criticize the legitimacy of these institutions because of
their top-down history and industrial orientation, but also because it is expected that their strategy in developing genomics for the study and management of crop genetic resources – considered as raw materials – and subsequent free access strategy might benefit industrial agriculture and international agro-concerns rather than small-scale farmers. For instance, although Bolivian potatoes will be studied through the GCP genotyping support services, still there are no parallel projects to apply the generated knowledge within the territory. Therefore, MMs are used for extracting information out of local biodiversity, but the further development of MMs for further applications that introduce some of the interesting traits found through plant breeding strategies back into this social (institutional) framework is not anticipated. Against this, however, the CGIAR centres do also participate in the development of territorial, social-based genomics (Wiphala), which might take into consideration and work from within both the local socio-technical potentialities and constraints, and peasants’ potato-resources as cultural materials, i.e. with an intrinsic value. In my opinion, this second tendency should be considered by researchers if the intention is to re-orient biotechnologies towards small-scale agriculture and its needs. Although it is still at an embryonic stage, the Wiphala genomics is oriented towards peasants’ varieties and might be implemented in synchronization with peasants’ needs, problems and dynamics.

Finally, some of the currently existent small-scale oriented, participatory plant breeding socio-technical structures have been suggested as appropriate potential environments for the territorialization of genomics, in the form of molecular markers for maker-assisted selection. This is because some participatory plant breeding strategies practised by these networks are oriented to peasants and their varieties. That is why, a larger set of actors, including peasants and local development organizations are collaborating for the development of new (bio)technologies. Strengthening these collaborative tendencies might give Quechua and Aymara peasants a level of control over the development and deployment of the genomics technology.
Chapter 5

5. The biotechnologization of Jatropha for local sustainable development

‘The fundamental concept in social science is Power, in the same sense in which Energy is the fundamental concept in physics’
Bertrand Russell (1938-2004; p. 4)

‘Energy for the poor’

5.1. Introduction

*Jatropha curcas* is emerging within academic, civil society, and policy circles as an interesting crop for strengthening the agrarian systems of resource-poor farmers. Despite its long history of usage in such systems, Jatropha has not traditionally been used as a crop. Still, efforts are being made to initiate a scientification and biotechnologization process of Jatropha, aimed primarily at increasing efficiency in its cultivation as an energy crop. This scientification and biotechnologization processes are partially being conducted through genomics. Genomics technologies have mainly been developed in high-tech labs in the industrially developed parts of the Northern Hemisphere (see Chapter 1), so developing trajectories aimed at orienting the biotechnologization of Jatropha towards local sustainable developments within peasant agrarian systems would appear to be a rather difficult task. Taking the ideas developed through the case studies reported in Chapter 3 and 4 a stage further, this chapter takes up the challenge of exploring whether and how a biotechnologization process conducted – through genomics – in a relatively ‘new’ crop might in fact strengthen local sustainable developments, employing as a case study the process that the fuel-plant *Jatropha curcas* is currently undergoing in Yoro, Honduras.

In order to address this central question, we examine here the interaction between two networks. The first one is organized around a project conducted by the Dutch institute Plant Research International (PRI)\(^7\) at the Wageningen University and Research Centre (WUR), which is applying genomic technologies to analyze the global diversity of Jatropha. The project’s objectives are to map this diversity and develop trait-related molecular markers, and thereby to establish the basis for future plant breeding projects (i.e. the biotechnologization of Jatropha). This project aims to improve the performance of Jatropha for large-scale as well as for small-scale agrarian systems. The second network examined here is a local multi-stakeholder network, Gota Verde\(^8\) (literally, ‘Green Drop’). Gota Verde is comprised of peasants, NGOs and research institutes involved with growing, transforming and using Jatropha and its products by and for the benefit of peasants in the department of Yoro, Honduras (Map 5.1). The chapter specifically addresses the ways in which the biotechnologization of Jatropha conducted through genomics can strengthen local developments in Yoro.

Continuing to investigate case studies through the three-domain concept of *local sustainable biotechnological developments*, this chapter follows a similar schema: Section 5.2 (territorial domain) explores the territorial approach of the multi-stakeholder network, Gota Verde, for developing local sustainable Jatropha production and utilization systems in Yoro; Section 5.3 (technological domain) examines the technological aspects of the Jatropha genomics research conducted by PRI; and Section 5.4 considers the domain of reterritorialization, discussing the question of whether and how the biotechnologization process (through genomics) that Jatropha is undergoing might strengthen the local developments in Yoro. The conclusion

\(^7\) [www.jatropha.wur.nl](http://www.jatropha.wur.nl)

\(^8\) [www.gotaverde.org](http://www.gotaverde.org)
(Section 5.5) stresses that, although the biotechnologization process within the socio-technological framework of these multi-stakeholder networks is an ongoing process – and that, therefore, different and even contradictory trajectories are still open – the current process may well strengthen local sustainable development in Yoro.

5.2. The territorial domain – Harnessing Jatropha within local sustainable production systems in Yoro, Honduras

Honduras is a ‘poor’ country. Most of the country’s poor live in rural areas and depend on agriculture to survive. Poverty in these areas continues to increase (Jansen, Siegel, Alwang et al. 2006). In the rural department of Yoro (only a quarter of the total population lives in towns of over 2,000 inhabitants), the average income is US$1.8 a day, the malnutrition rate is 33 per cent, and only 10 per cent of the population are connected to a sewerage system (MAMUNCRAC 2007). Honduras is sometimes seen as the archetype of a ‘banana republic’ – and over half of the arable land is owned by either the government or the two largest banana companies (Humphrey 1997). The main crops cultivated in the local, low-input agriculture are maize and beans, used for household consumption, but the huge majority (72 per cent) of agricultural producers own very little (11.6 per cent) of the cultivated area. In fact, 35.8 per cent of rural families are landless (Gottret 2007). In Honduras then, we have on the one hand a land-dominating industrial cash-crop production system and on the other hand the marginalized low-input agrarian systems of peasants.173 This is a rather extreme situation in which to investigate the benefits of local sustainable development, and certainly represents a challenge for territorializing biotechnologies. Jatropha could be deployed within both types of agrarian systems and their social specificities, but our interest clearly is in its potential within peasant agrarian systems.

The developmental efforts of Honduras are vulnerable to, among other things, natural adversities,174 shifting international agrarian power relations,175 and to fluctuations in the price of oil. The country also depends heavily on external petroleum (Rothkopf 2007). It was in this context that the then President of Honduras, Manuel Zelaya, announced in April 2006 that the domestic energy consumption would be based primarily on biodiesel within five years (La Prensa 2006), and the ‘Bio-fuels Production and Consumption Law’ for the promotion of biofuels was introduced.

The majority of biodiesel produced in Honduras comes from palm oil. The production of palm oil is in the hands of two large companies (Rothkopf 2007).176 Honduras ranks sixth in the

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173 In between those two systems we have, of course, a spectrum of variation of production systems.
175 The agricultural sector has lost about one third of its value over the past two decades, largely due to the decline in prices for export crops, particularly bananas and coffee. The impact of the 1997-2001 coffee crisis was particularly severe, and between 1999 and 2001 export earnings dropped by nearly a third. Small farmers (accounting for 90 per cent of coffee producers and 45 per cent of production) were the hardest hit (source: ‘Honduras Country Brief’ www.worldbank.org, accessed 9 April 2009)
176 Honduras currently produces some 56,800 -75,700 litres of biodiesel per day. Of this, 45,400 -56,800 litres are derived from palm oil. The production of palm oil is in the hands of two large companies; DINANT (producing 22,700 litres daily) and Haremar Group (producing 11,350 litres daily). The remaining biodiesel production comes
world in terms of area of palm oil cultivated and the production of palm oil has more than doubled over the last decade. Over half of this palm oil was not used to cover local energy needs, however, but was exported (ibid.).

**Territory, energy and Jatropha**

The *Jatropha curcas* is a shrub belonging to the *Euphorbeaceae* family. There are several species of Jatropha, but when people nowadays refer to ‘Jatropha’ they mean *Jatropha curcas Linnaeus* – for simplicity’s sake the usage assumed here also. Due to the toxicity of its leaves, the Jatropha is extensively used for hedging to protect arable land and orchards from cattle (‘cerca viva’ – ‘living fences’). In Yoro, it has also been a garden tree, with its seeds used to produce soap and medicines. Although it is not uncommon to find women in rural communities of Yoro who know how to make soap or prepare a dosage for laxative purposes, the use of Jatropha does seem to have been decreasing in recent years, due to the introduction of industrial soap, and pharmaceutical medicines, along with the use of other tree varieties for living fences. From fieldwork in Yoro, it is clear that Jatropha oil is rarely extracted by the peasants there for use as fuel. Nevertheless, the plant might have significant potential for lighting and cooking purposes in this region, since few households have access to electricity (5 per cent) and the vast majority rely upon wood as their source of energy (86 per cent) (MAMUNCAR 2007). The official figure for the area planted with Jatropha in Honduras (March 2008) was around 424ha, with 350ha of that owned by the corporation Agroipsa (and located in the southern department of Choluteca). There are two other small areas with a total of 13ha. 6 ha owned by the Dinan Corporation (in the department of Comayagua), while the farmer Federico Mejía has 7 ha (in the San Esteban area in the Olancho Department) (Victor Iscoa, personal communication, 12 March 2008).

The Gota Verde network

The multi-stakeholder network coordinated by the project Gota Verde is oriented to the local production and utilization of biofuels, organized mainly around Jatropha. The project is financed by the European Community (COOPENR projects) and two Dutch foundations (HIVOS and DOEN), and coordinated by the Dutch NGO Social Trade Organization (STRO). From fish oil, particularly from tilapia. The Aquafinca Saint Peter Fish company produced 16,300 tons of tilapia fillets for export. Its biodiesel production capacity is of 22,700 litres per day (Rothkopf 2007).

177 6 ha owned by the Dinan Corporation (in the department of Comayagua), while the farmer Federico Mejías has 7 ha (in the San Esteban area in the Olancho Department) (Victor Iscoa, personal communication, 12 March 2008).

178 Now (January 2010), Gota Verde has 230ha.

179 Gota Verde is also currently producing some 800 litters of biodiesel from used cooking-oil from restaurants. Also, a scheme has been initiated – organized in coordination with the Spanish NGO Movimiento por el Desarme hacia la Paz y la Libertad (MPDL) and local schools – to involve local children in the recollection of domestic oil.

180 HIVOS: [www.hivos.nl](http://www.hivos.nl)  DOEN: [www.doen.nl](http://www.doen.nl). The total budget is € 1,158,002 over a three year period (2007-9). Almost half of this (48 per cent) comes from the EU, and flows through six European organizations:

- STRO, NL ([www.stroholm.nl](http://www.stroholm.nl)). Project coordination
- HIVOS, NL. Economic management
Composed of several bodies (see Figure 5.1) with different funding sources, the Gota Verde network structure is organized around small to medium-scale farmers, with some 200 peasants and farmers currently linked to the network. The Gota Verde is supporting the foundation of a company *Biocombustibles de Yoro S.A.* (BYSA) whose objective is to grow oleaginous crops (including castor, sunflower, soybean, and canola, but with Jatropha as the core plant) for the production and distribution of biofuels, and their derivates (soap, bio-fertilizers, biogas, etc.). BYSA is being supported during its initial, set-up phase by the Honduran non-profit private organization *Fundación para el Desarrollo Empresarial Rural* (FUNDER).\(^{181}\) FUNDER has taken a 51 per cent stake in the company, which it will keep until BYSA is economically viable, at which point it will withdraw. Other than FUNDER, only Jatropha producers are permitted to own BYSA shares. The farmers involved in the project have all been issued with ten shares, representing the estimated value of their investment in Jatropha.\(^{182}\) To avoid a takeover of the company by an external investor, the BYSA general assembly has put a cap of 5 per cent on company share ownership by any one individual or company. FUNDER is monitoring the BYSA management and giving farmers agrarian support to grow Jatropha. BYSA employs mainly local technicians for its agrarian activities.\(^{183}\)

Concerned with agricultural matters, the other main Honduran organization coordinated within the Gota Verde network is the *Fundación Hondureña de Investigación Agrícola* (FHIA).\(^{184}\) FHIA work focuses on the agronomic performance of Jatropha, for which purpose it cultivates the 11ha set aside for research.\(^{185}\) Six imported varieties are planted in these fields. The project studies how these lines grow under different conditions with respect to pruning, irrigation, fertilization (related to soil characteristics), intercropping, and marginal soils. FHIA has also established nurseries to deliver seeds to peasants. FHIA is the organization that should play the major role in the translation of the genomic knowledge produced by PRI to the locality – or the reintegration back into the locality of knowledge extracted from local varieties of Jatropha by PRI in the Netherlands (discussed below). In theory FHIA has the knowledge and capacity to implement this, but the fact that it works primarily of the basis of contracts and does not have

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\(^{181}\) The main objective of FUNDER is to promote local development by supporting small to medium-scale farmers through (micro)credit, and the allocation of start-up funds for small-scale companies and cooperatives in rural Honduras. It is formed of members of the government, rural civil society organizations, and international development agencies ([www.funder.hn](www.funder.hn)). FUNDER works with 22 different projects (Angel Meza, personal communication, 15 March 2008).

\(^{182}\) The investment has been supported with credit from the project, in which farmers received seeds, inputs and some economic support for the management of the crop. Loans for the plants are to be issued interest-free for an indefinite period, and additional loans for inputs and land preparation will be accessible at below market interest rates. All loans are to be issued in kind and it is proposed to withhold 30 per cent of the value of the seeds sold to BYSA, in order to repay the loans, with the remaining 70 per cent to be paid in cash or (later on in the project) by BYSA product vouchers (see below, main text).

\(^{183}\) There are also conversations with local cooperative saving-bank COOPACYL (Cooperativa de Ahorro y Crédito Limitada) to embark on a joint venture together with Gota Verde for the exploitation of COOPACYL’s underused grain drying installations in Yoro. Seeds could be gathered and dried here before the pressing process.

\(^{184}\) FHIA is a non-profit private research institute offering its expertise and services to (non-)governmental organizations and industry ([www.fhia.org.hn](www.fhia.org.hn)).

\(^{185}\) One ha is in their extension field, near their headquarters in La Lima. The rest is spread across the Yoro department and is managed by farmers.
additional funds for its own research agenda might jeopardize this if no supplementary funding is found once the project is concluded.

Figure 5.1: The Gota Verde’s network.

The Dutch NGO STRO coordinates Gota Verde, and is also responsible for the design and implementation of a complementary currency system. The intention here is to create a preferential trade space at the local and regional levels. Within this space, a certain amount of the BYSA inventory will be used to back vouchers issued as partial payment. The vouchers circulate in the local territory as an alternative currency (at an exchange rate of 1:1 to the Honduran Lempira) and ultimately are used to buy BYSA products (fuel, cattle concentrate, organic fertilizer, etc.). In Yoro, meanwhile, there are 10,000 vouchers in continuous circulation.\(^{186}\) This new currency is supported by the material goods of BYSA, and more vouchers will be introduced into the system when more investments are made or when production increases. Although this seems to be a very promising economic system for a region like Yoro – where it is very difficult to access external investments and where the local circulation of money is very limited – it is difficult to estimate the extent to which people will understand and accept the complementary currency. At the moment, over 26 local enterprises accept the vouchers.\(^{187}\)

Another important link within Gota Verde is the local vocational and technical training institute, CEVER. Gota Verde is currently developing two types of Jatropha seed presses. One is a very low-tech machine (easy to build, repair, and transport) that will be used by more isolated communities, and built at CEVER. The other is more sophisticated and requires the support of a specialized workshop in the industrial city of San Pedro Sula for its construction. The intention is to have one press unit housed at CEVER and a system of decentralized units in the department of Yoro. In this context, the NGO MDPL is searching for women’s groups in different communities

\(^{186}\) It is estimated that there are around 185,000 vouchers already emitted (Peter Moers, personal communication, 5 January 2010).

\(^{187}\) Recently, the American NGO (Sustainable Harvest International) working with organic farming in Yoro has bought 15,000 vouchers for their financial structures.
that are starting such units for collecting, drying and pressing Jatropha seed. Additionally, the Gota Verde’s own small-scale biodiesel unit was built with the collaboration of CEVER students and is located at a CEVER installation. Local students also play an important role in the adaptation of (non-stationary) motors to the pure plant oil (PPO) of Jatropha, while CEVER tractors have been test run on PPO extracted form local Jatropha seeds.

Reflections on the territorial approach of Gota Verde

Briefly, Gota Verde’s approach is territorial in that it supports the development of sustainable structures based on primarily (though not exclusively) locally available human and natural resources for the purposes of strengthening peasant agrarian systems; local actors (including peasants) are empowered in the development process. Three main aspects of this may be noted. Firstly, there is the creation of local social structures aimed at developing sustainable production and utilization systems of Jatropha and its related products. These local structures are formed by the aggregation of peasants, researchers, NGO practitioners, workers of the BYSA, and local businesses that collectively generate local development. Given that the production of biofuel within Gota Verde is intended to be for local consumption, and that the exchange of Jatropha-oil will take place in a complementary currency space with a value only within the territory, it is anticipated that the resulting economic, social and energy gains will remain within the locality. In terms of economic revenues, a focus on the production of biodiesel is generally expected to be specifically profitable, as the demand for fuels for transport is increasing and as world market oil prices are expected to increase once the world economy shows its first sing of recovery. In Honduras, however, in 2007 and 2008, the prices of diesel and petrol have been kept low by government subsides with the intention of mitigating the effects of the high oil prices. This policy became financially unbearable for the government that abolished the subsidies in March 2008. Fuel subsidies had negative consequences for Gota Verde and the commercialization of biodiesel in Yoro. At current diesel prices (around US$0.6 per litre) pure plant oil may be a feasible diesel substitute, but biodiesel probably not. Against this, however, one might suggest that the multi-stakeholder network is now focusing more on biodiesel than in PPO, since a small-scale biodiesel unit is already running whereas no concrete PPO project is in place yet. Meanwhile, at the level of socio-energetics, although it might be more desirable to focus on the local needs of peasants that could be covered with PPO (stationary motors, lighting or cooking facilities), biodiesel still remains an interesting product for the locality because it could serve as fuel for (highly used) public transport without having to adapt engines. There are also considerations of dependability, as diesel is also an important input for agrarian activities. In May 2008, for example, diesel was in short supply in large parts of Honduras due to a combination of factors, including poor planning on the part of importers and speculation by distributors. May is a critical month for agriculture because it is then that the rainy season begins. Due to its access to self-produced biodiesel Gota Verde was able to implement its ploughing plan, while many other peasants had to postpone this activity (Peter Moers, personal communication, 11 February 2009).

Gota Verde has estimated (March, 2008) their production costs to be 33.25 Lempiras (around US$1.75) per gallon (3.785 litters) of PPO, and 56.86 Lempira (around US$3) for the same quantity of biodiesel. The costs of producing biodiesel are high because expensive substances like methanol are required for transesterification (Titus Galema, personal communication, 3 March 2008).
Secondly, there is the creation of a complementary production system of Jatropha and food crops. A possible problem with the cultivation of Jatropha would be that it might take territory from other food crops. To avoid the substitution of food crops by fuel crops, therefore, Gota Verde does not support peasants wishing to dedicate their land entirely to the cultivation of Jatropha. The strategy of Gota Verde is to promote Jatropha in living fences and in intercropping plantations. Since living fences are very popular in the region, this recommendation to plant Jatropha is well received. Peasants see it as a development that adds a new value to a traditional activity. In fact, 40 per cent of the total Jatropha planted for the 2008 season was for living fences. Moreover, 100 per cent of the 100ha planted in 2009 are mixed cropping, involving Jatropha in association with corn in the early season, and in the after season with beans, sesame, sunflower or other edible oil crops. Gota Verde recommends particularly the intercropping of Jatropha with maize and beans. In this way, not only is the direct competition with the local production of food crops reduced, but so also is the economic risk of planting Jatropha, given that plantations are only expected to deliver a profitable harvest five years after planting. The intercropping system is constantly being re-evaluated and improved, leading to new recommendations for planting density, facilitating maintenance of the crop and reduction competition over sunlight.189

Practically, however, there is little to fear from Jatropha in terms of competition for crop space because most arable land in the country goes underutilized (EarthTrends 2003, Cerrato 2008). The main reason for this is the generalized lack of access to credit. For peasants especially, Jatropha has an advantage here in that once a plantation is established, the main inputs are labour and fertilizer (in this case, organic, the press cake supplied by BYSA), which means that peasants who supply their own labour can continue the production cycle with little or no further financial investment. Rather than raise problems of competition for space, the dynamics generated by Gota Verde might, in fact, stimulate the cultivation of fields that currently lie fallow.

Thirdly, because Honduras is situated within the centre of origin of Jatropha the local multi-stakeholder network ought to develop and conserve the genetic variety and productive diversity of Jatropha. In this context, the possible risk of the program currently being developed would be that regional biodiversity could decrease. The fear is that the widespread cultivation of a very limited number of Jatropha lines might jeopardize the local traditional genetic diversity, which is an important potential source for future plant breeding programs. Peasants might, for example, replace the range of Jatropha varieties growing in their fences with the Cabo Verde variety (see below) promoted as a high yielding variety. Moreover, the currently popular imported varieties of Jatropha might in fact turn out to be relatively ill-adapted to local conditions. Gota Verde is testing these lines in different environmental conditions in Yoro, to see which lines do best in each location. In fact, because countries outside the centre of origin are demanding a diversity of Jatropha lines to counterbalance their poor genetic diversity (Basha and Sujatha 2007) and since Yoro (and Honduras in general) does include a variety of ecological environments, it would seem to be responsible practice, as well as expedient, to research the wealth of local diversity before taking any decisions about which lines should be promoted in

189 Another important element of these complementary production systems is their effect in controlling erosion, an acute problem in Honduras. The use of the tree-like Jatropha for living fences along with intercropping on slopes might help to reduce soil erosion, particularly with over 80 per cent of the country being mountainous what make hillside agriculture an important area for food production (Jansen 1998, Southworth and Tucker 2001).
which parts of the territory. Gota Verde is starting to appreciate this point, and plans to investigate some local lines.

This section has analyzed the most relevant strategies emerging from the territorial approach of Gota Verde to the development of Jatropha in Yoro. Locally, agricultural considerations suggest the approach of promoting Jatropha usage in intercropping and living fences to be well-chosen. Globally, as well as locally, the responsibilities and potential for Jatropha diversity at its centre of origin present issues that the network has begun to address. Potentially other interesting territorial aspect of this network is its application to the development of a local, sustainable source of biofuel. Access to energy is considered by the United Nations as one of the measurable elements that might lead to achieve the Millennium Development Goals. Worldwide, the total amount of people that lack access to reliable, clean and affordable energy lies between 2 and 3 billion (Ouwens 2007), it is estimated that 1.6 billion people have no access to electricity and over 2 billion still rely on traditional biomass for the everyday cooking and heating needs which are fundamental for human life (Practical Action Consulting 2009). The energy supply of the rural poor, in Yoro (MAMUNCRAC 2007) as in so much of the developing world, consists mainly of wood or waste that is burnt with low efficiency and which causes, among other things, a variety of health problems. The current cost of electricity makes this ‘clean’ energy source inaccessible to the Yoro peasantry, while for the future, the supply of fossil fuels on which Honduras and the world has mainly relied is limited. It is the potential for Jatropha to be used as a biofuel then, which promises the most exciting application of Gota Verde. The energy supply has great influence for the development capacities of any territory. It can be concluded therefore, that the social structures emerging in Yoro facilitate the construction of a system for the sustainable production and consumption of energy through, among other sources, a local specific Jatropha. The Gota Verde multi-stakeholder network both itself represents and in its work promotes local sustainable development – which lead us next to investigate how the latest biotechnology is contributing to this, and what potentials and pitfalls this contribution may hold. Specifically we need to explore the biotechnologization process (through genomics) conducted by PRI that Jatropha is undergoing.

**5.3. The technological domain – The biotechnologization of Jatropha**

Notwithstanding its variety of traditional uses, Jatropha has primarily come to public attention because the high oil content of it seeds (see Table 5.1). The PPO extracted by pressing the seeds is of high quality and can be used directly to power stationary motors with a constant rpm (electricity generators, water pumps, etc.), lamps or kitchen appliances, or in adapted diesel motors (with a changing rpm). Jatropha oil can also be processed (through transesterification) into biodiesel. Jatropha offers peasants a potential source of extra income – which is all the more attractive as this plant is able to survive on marginal land, in relatively dry, poor soils.

<table>
<thead>
<tr>
<th>Plant</th>
<th>Litres of oil per hectare</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil palm</td>
<td>2,400</td>
</tr>
<tr>
<td>Jatropha</td>
<td>1,300</td>
</tr>
<tr>
<td>Rapeseed</td>
<td>1,100</td>
</tr>
<tr>
<td>Sunflower</td>
<td>690</td>
</tr>
<tr>
<td>Soya bean</td>
<td>400</td>
</tr>
</tbody>
</table>

*Table 5.1. Crops’ fuel production – Source: UNDP/WB. Jatropha figure from Indian Planning Commission, in Fairless (2007).*

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190 It is considered within goal number seven (‘environmental sustainability’) of the eight development goals (see: [www.undp.org/energyandenvironment/sustainabledifference/PDFs/SustainableDifIntro.pdf](http://www.undp.org/energyandenvironment/sustainabledifference/PDFs/SustainableDifIntro.pdf))
These features have led to a good deal of publicity, hype even, around Jatropha leading to a veritable rush to invest in the plant (see Box 5.1). The rationale given for these investments makes it manifest, however, that while most of the Jatropha production systems are located in developing countries, the biodiesel produced will be utilized in wealthier territories – a situation that functionalizes the territories where Jatropha is produced, intrinsically relegating local needs, especially those of the poor, the peasant communities, to the level of secondary considerations, at best.

**Box 5.1. Jatropha’s business**

There is a significant lack of hard data about the real potentialities of Jatropha, but this has not prevented large concerns and public institutions from heavily investing venture capital into Jatropha. D1 Oils plc the UK-based global biodiesel producer is one of the major players. Among its many Jatropha operations worldwide is a (50/50) joint venture with BP, ‘D1-BP Fuel Crops Limited’, aimed at the cultivation of Jatropha for the large-scale production of biodiesel. As of 31 May 2009 D1-BP Fuel Crops had interests in approximately 220,000 hectares of Jatropha in Africa, India and South East Asia, which currently represent approximately 25 per cent of the estimated total global planting of *Jatropha curcas*.\(^{191}\) Another company, Mission Biofuels Australia, has more than 40,468 ha in India and several nurseries producing Jatropha to feed its Malaysian refinery.\(^{192}\) The English company NRG Chemical Engineering Pte. signed a US$1.3 billion deal with the state-owned Philippine National Oil Co. in May 2007. NRG Chemical will own a 70 per cent stake of the joint venture, which will involve the construction of a biodiesel refinery and two ethanol distilleries, and a US$600-million investment in Jatropha plantations that will cover over 1 million hectares, mainly on the Philippine islands of Palawan and Mindanao (GRAIN 2007b).

Large public investments are also shaping the emerging Jatropha regime. In India, the government has already cultivated around 500,000 ha.\(^{193}\) In February 2007 China, which claims to have 2 million hectares of Jatropha already under cultivation, announced plans to plant an additional 11 million hectares in its southern states by 2010. Neighbouring Myanmar (Burma) apparently has plans to plant several million hectares; and the governments of the Philippines, as well as several African countries, have also initiated large-scale plantations (Fairless 2007).

The massive investments in Jatropha are linked to scientific research (Jatropha scientification). Genetics and genomics play an important role in this scientification process (Jatropha biotechnologization). For instance, D1 Oils, the largest multinational investing in Jatropha, has signed an agreement with KeyGene N.V. (NL), a global leader in the science of genetic fingerprinting, to pursue genomics research in Jatropha. KeyGene genetic fingerprinting technology enables the identification of different Jatropha cultivars through genetic markers, and is expected to significantly increase the efficiency of the D1 breeding program for the development of high-yielding Jatropha cultivars. After having scientificized and

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191 On 17 July 2009 D1 Oils plc announced that it had reached a conditional agreement with BP International to acquire BP’s 50 per cent interest in D1-BP Fuel Crops Limited, and thereby to take back into D1’s sole ownership the global planting assets and interests of the venture (http://www.d1plc.com/news.php?article=197, accessed August 2009).


193 This is the first phase of a national program. Biodiesel production is intended to be managed by local governing bodies at villages level, and coordinated nationally by a consortium of government departments. Should this succeed, then a second phase will commence involving the planting of 12 million ha and privatization of Jatropha biodiesel production (Fairless 2007).
biotechnologized Jatropha through genomics, D1 aims to increase oil yield from 1.7 tons per ha to up to 2.7 tons (Manis 2007).

The biotechnologization process is thus strengthening the conversion of the plant into an industrial input for the production of biofuel. Jatropha is appropriated by external actors and structures are created that produce Jatropha as a commodity to be traded in global markets. New labour and power relations emerge as a result. For instance, a situation is introduced whereby small-scale Jatropha farmers find themselves in competition with the giant fuel multinationals (insofar as they both produce fuel for transportation). The potential that Jatropha might have as source for a locally-oriented production and consumption becomes constricted.

Nevertheless, alternative production systems like Gota Verde with a more locally-oriented (territorial) approach are also shaping the Jatropha future, both through their engagement in a trajectory of scientification and biotechnologization of the plant at the local level, and through their horizontal connectedness with international research institutes.

An alternative biotechnologization approach

The Plant Research International (PRI) Jatropha project is financed by a Dutch charitable foundation, Stichting Het Groene Woudt (SHGW). PRI Jatropha research falls into three main areas: agronomic performance, global genetic diversity, and process/product optimization. Research findings are made public and information widely disseminated. The focus here is on the first two areas of investigation, agronomic and genomic research. These studies are coordinated by PRI within the programme ‘Jatropha curcas evaluation, breeding and propagation’, which is expected to work as a basis for future plant breeding programs to be coordinated or monitored by local networks, such as Gota Verde.

The agronomic study

The agronomic study of Jatropha is based on a literature review, contacts with experts, and field trials in projects in the tropics – in Mali and in Mozambique, as well as in Honduras with Gota Verde. Further field trials are planned for the future in which the performance of representative Jatropha individuals from different genetic groups clustered in the genomic study will be checked at suitable research institutes in different climatic regions.

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194 PRI is a business and research centre working within the WUR Plant Sciences Group and Applied Plant Research and serving (non-)governmental organizations and industry.
195 SHGW was established by De Rijcke family, owner of the conglomerate Kruidvat until 2002 when it was sold to the Chinese holding A.S. Watson for €1.3 billion (Woude 2002). There had been an initial intention to invest in Jatropha for the production of bio-fuel for global markets through the family’s investment society (De Hoge Dennen), but the potential of the plant for large industrial production was not found to be convincing. Jatropha matters were subsequently picked up by SHGW for its humanitarian purposes. In addition to its support for the PRI Jatropha-related research activities, SHGW also addresses the immediate needs of peasants and poor communities, by giving local economic support to a number of biofuel producing projects in developing countries.
196 This last area of research is conducted by a different department at the WUR (the Agrotechnology and Food Sciences Group – AFSG) and focuses on maximizing the efficiency of the seed pressing process and studying the potential of Jatropha products beyond fuel applications (soap, press cake, paints, etc.)
197 www.malifolkecenter.org
198 www.arrakis.nl/jatropha.html
The central finding of PRI agronomic research to date (Jongschaap, Corré, Bindraban et al. 2007, Ouwens, Francis, Franken et al. 2007) is to confirm the production potential that Jatropha has in its natural environment of arid and semiarid lands previously stressed by other researchers (Francis et al. 2005, Asselbergs et al. 2006, Achten et al. 2007). Successful traditional applications additional to those already mentioned include employment of the plant for soil water conservation and soil regeneration, and for the production of insecticides, bio-fertilizer and firewood. At the same time, questions are raised about the feasibility of large-scale industrial production of Jatropha for biofuels, which, taken together, undermine confidence in its likely success. Firstly, yield cannot yet be predicted with any degree of accuracy, and promising seed sources that perform successfully in one location may under-perform in another (Ouwens, Francis, Franken et al. 2007). Secondly, little is known about the environmental conditions for flowering and fruit setting, which might have significant consequences for mechanical harvesting. Also, Jatropha seems to be resistant to plagues and diseases in its traditional environment (in living fences or as isolated trees), but this resistance is expected to disappear when the crop is cultivated in plantations. Finally, the production of Jatropha might not be a low labour input as has been claimed, so the cost-effective relation for large-scale monoculture plantations might be unprofitable (Jongschaap, Corré, Bindraban et al. 2007).

The genomic study

The PRI genomic research process can be divided into three main stages: Collection, genotyping, and the development of molecular markers related to specific traits. Regarding the first, activities begin with PRI collecting samples of Jatropha worldwide. Leaves and seeds are sent to the Netherlands by companies, NGOs, and research institutes, along with information about the accessions (on productivity, oil contents, growth conditions, etc.). Although two countries are over-represented, the project seems to have access to significant biodiversity worldwide. After collection, the accessions are characterized with molecular markers (genotyping). Genotyping with molecular markers offers the advantage of being able to cluster accessions in genetically similar groups. In this way, a core collection of accessions can be defined that is reduced in size, since (near) identical accessions can be classified as a single entry. This will facilitate future breeding projects. To carry out this activity, the preferred choice at PRI had been to use AFLP molecular markers. This technological choice is not a neutral one, however, as

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199 See also Achten, Mathijs, Verchot et al. (2007).
200 PRI is also conducting studies into comparative genomics with which the molecular technologies referred to are used to analyze the similarities between the Jatropha genome and other members of the Euphorbiaceae family, to which Jatropha belongs, and on which PRI has genome information (e.g. rubber, castor, cassava). The identification of similarities at the genome level will reduce the research effort for Jatropha, insofar as it facilitates the annotation of genomic regions and their functions, along with possible future breeding activities through the use of markers already developed for the Jatropha relatives.
201 For more details about the collected data see: http://www.jatropha.wur.n. In Gota Verde it is claimed that the amount of information collected by the questionnaires is so large that just filling one in takes a whole day.
202 As of January 2008, PRI has received 168 leaves accessions and 165 seeds samples (with 75-100 seeds for each accession). The Guatemala collection forms around one third of total samples while the 90 samples sent by just one institution in India make up nearly half of the total number of accessions. The variability within the Indian varieties seems to be very low (Basha and Sujatha 2007). A study in the Guatemala collection with AFLP molecular markers showed the high diversity harboured in the collection (Luis Montes, personal communication, 26 November 2008). Moreover there are accessions from other world regions making the collected materials indeed representative of the global biodiversity.
AFLP is a patented technology. The patent rights are owned by the company KeyGene which as mentioned above, delivers its technology to D1 – under an exclusive contract. The two year agreement provided D1 with exclusive rights to applied contract research and molecular services carried out by KeyGene on Jatropha with AFLP (KeyGene 2007). PRI therefore decided to conduct the genotyping with another unpatented DNA marker technology, Nucleotide-Binding Sides Profiling (NBS profiling). NBS profiling is a gene-targeting marker system that efficiently produces multiple markers in or close to genes of interest.203 It is a PCR molecular based approach (Linde, Wouters, Mihalka et al. 2004). The technical requirements to perform this marker technology are similar to the requirements for AFLP. A lab needs facilities for DNA-isolation, restriction enzyme use, adaptor ligation, PCR and running gels. The highest repeatability is obtained using radioactive labelling, but adequate repeatability is found also with fluorescent labelling combined with a gel running system (for example PRI is using the costly Li-cor). Low-tech labs that do not own a gel running system that detects fluorescent signals can produce their own PCR-products and send them to a high-tech lab (in Wageningen a ‘routine marker lab’) to run. This technology might, therefore, be more accessible especially since the marker technology is not patented. Summarizing, this molecular marker technology seems to be an appropriate tool for genotyping genetic diversity within the socio-technical context of PRI.

In order to achieve an optimal Jatropha production system in a given territory, it is important to know which varieties are used locally. Molecular marker analysis can achieve this identification (when a local variety is identical to a well-described accession), or else assess the similarity of local varieties to known accessions. The classification of local varieties might also help in selecting parent lines for crosses to be made within local breeding programs in order to achieve locally desired traits. For instance, Gota Verde is working with a variety they call India-Salvadorian (since they believe it to have been imported to Honduras from El Salvador, and before that from India). As the India-Salvadorian is the best performing line in Gota Verde peasants’ fields, it could be interesting to investigate whether it is indeed a well-adapted Indian variety or actually a local line from Central America. Such knowledge might facilitate future breeding projects.

After the samples have been characterized with molecular markers, the research process will move on to its third stage, which concerns the development of markers related to specific traits. First, markers are placed near functional genes responsible for the expression of certain desirable traits. In this way, molecular markers can be found which are related to certain traits considered interesting for the cultivation of the plant. For PRI these traits are: oil content per seed, number of seeds per hectare, growth-form (e.g. plant height, branching pattern, and leaf size), timing of flowering, disease resistance, toxicity level, and fatty acid composition of the oil. While some traits which are particularly important for Gota Verde – such as the growth pattern or number of seeds of plants used as living fences and in intercropping systems with maize or beans – are not considered, the traits cited are, nevertheless, all interesting for the Honduran multi-stakeholder network. If some of the traits being searched are not present in local Jatropha varieties, they might be introduced – by crossing varieties, using traditional plant breeding or marker assisted selection, or by genetic manipulation – into the local Jatropha diversity in order to enhance the local production systems.

203 These markers can be either directly used in the breeding program using the NBS profiling protocol or converted into gene-specific PCR markers. NBS profiling is ‘ready to use’ in a large number of crops and has already been applied by PRI in e.g. potato, tomato, lettuce, rice, wheat, apple and rose
A logic and desirable follow-up to the PRI project within Gota Verde would be the use of the molecular markers in future breeding programs to speed up the breeding process. In many breeding programs, including Jatropha, trait evaluation is a time-consuming process, and, it would be helpful if the time gap between initial cross and offspring selection for the next cycle of crosses could be reduced. In the case of Jatropha, determining the yield potential using a classical breeding approach is possible after one or two years, but more accurate and relevant data can only be obtained another year or two after that. The identification of a superior genotype after the evaluation is finished will thus take some four years. If information on the yield potential of a Jatropha genotype could be determined in the seedling stage, for example, the process might take as little as six months at most – the time needed for a seed to grow to a flowering (seeding) plant (and produce new seeds). This is possible with a selection based on the presence/absence of molecular markers.

In the following section we will focus on how this biotechnologization process can strengthen local sustainable developments in Yoro.

5.4. The domain of reterritorialization – Local and global interactions

Many philosophers of technology (Mackenzie and Wajcman 1985, Bijker, Hughes and Pinch 1987, Feenberg 1999) have argued that the human capacity to model what a technology will become is especially significant during the first phase of its development, after which technologies normally lose flexibility. The choices made in this early stage of the biotechnologization of Jatropha are therefore crucial if the plant is to be oriented to the strengthening of peasant agrarian systems.

As mentioned, the PRI objective is to strengthen both small-scale and large scale production systems. This wide objective range leads to tensions in the choices made during the biotechnologization process. For instance, the choices made by PRI concerning the traits to be searched through molecular markers are not neutral ones. One of the searched traits, for example, is the number of seeds per hectare – but how are Jatropha plants to be arranged in the unit area? PRI desires to obtain knowledge derived from a production system in which Jatropha plants will be arranged in plots of two by three metres, whilst the number of seeds produced in living-fence systems or intercropping systems is not considered. It might well be argued, therefore, that the biotechnologization process is introducing into the reterritorialization process a bias for monoculture cultivation, as against the intercropping and living-fence production systems typically favoured by small-scale Jatropha agriculture.

Likewise, there is an interest in lowering toxicity levels of Jatropha, primarily because reduced toxicity could enable the plant-pressing process waste to be used as cattle feed. Large-scale plantations might favour the creation of spin-off factories for the production of cattle feed, a strategy that has been followed with other energy-plants. Such a technology pathway is somewhat in contradiction to some of the interesting social traits of Jatropha, however – for instance, Jatropha is traditionally used as living fences for cattle, or for medical purposes precisely because of its toxicity. Furthermore, since the pressing process is easily performed in small-scale units in the locality, it seems easy to return the press-cake to the fields as fertilizer. In
other words, the current PRI research strategy here appears to imply a preference for the usage of waste for cattle feed as opposed to the usage of waste for fertilizer and of the plant for fencing, effectively aiming research at industry rather than farming communities. Nevertheless, despite these criticisms on the traits researched, there are perspectives for a flexible use of the produced knowledge. The traits searched are indeed all interesting for Gota Verde, as the network is working with small-scale Jatropha plantations (2m x 3m, and 5m x 1m) with and without intercropping, as well as with living fences. Equally, knowing more about the oil percentage of the seeds, or understanding the timing of flowering can be interesting for all imaginable production systems.

Indeed, the choices made in the early stages of sciences and biotechnological research can have significant consequences for the final structural impact that biotechnologies will have in the territories where they are deployed. This structural potency on rural societies of the biotechnologization process of agriculture – biotechnologization as de-territorialization – was elaborated in Section 2.4 where we saw that several critical thinkers have introduced concepts illustrating the structural features of the new biotechnologies and their implications beyond the explicit economic function of increasing productivity. These included Ruivenkamp’s remote control (1989, 2005b), Goodman and colleagues’ industrial appropriation (1987), and van der Ploeg’s scientification (1987, 1992). In the biotechnologization process of Jatropha, we can perceive the continued reproduction of these patterns. For instance, through the knowledge about Jatropha – on biodiversity and agronomic performance – produced (appropriated?) by PRI through different local networks, we see a research institute located in Western Europe, where Jatropha cannot survive outside greenhouses, acquiring and important position within the Jatropha world (control at a distance?). We can imagine that the standing of PRI in regards Jatropha-related matters will become well respected, and the empowerment of the institute translated into new partnerships, biotechnological capacities and prestige in the field (scientification?).

Notwithstanding these points, however, it should be also emphasized that the empowerment potentiality of the genomics research (biotechnologization) of Jatropha conducted by PRI is oriented not only towards actors and relationships between actors external to the local production systems, but also towards local sustainable developments. This emphasis on local sustainable development is highlighted by comparing the Jatropha biotechnologization process conducted by PRI with that being conducted by the company D1. D1 is developing a similar biotechnologization of Jatropha through genomics – i.e. gathering accessions worldwide, developing marker technology, and performing field trials in different places across the globe in order to generate high productive varieties that can stand local biotic and abiotic stresses. But there are fundamental differences between the approaches of D1 and PRI including their attitude to the spread of information and their scope of production, as well as their working ethos.

Regarding information, the sharing of knowledge carries financial implications for profit making for D1, so it will most probably not make public its research on Jatropha; PRI, on the other hand, has a mandate to put all the knowledge that it produces on this project into the public domain. Moreover, for PRI knowledge is importantly a tool to be used for the benefit of local sustainable developments, and its strategy is specifically to link its research findings to local projects by reporting findings to small-scale networks of Jatropha production (e.g. Gota Verde). Regarding production, D1 seeks to maximize financial return for investments made, and will

204 This assumed choice might be ameliorated were the development of cattle feed to possibly profit farmers by enabling them to diversify activities.
most probably produce biofuels, especially biodiesel, for the global market outside of the production territory through its 50/50 partnership with BP. PRI, however, also targets the strengthening of the locally oriented development of the Jatropha system (local production for local consumption). In respect to the working ethos, D1 operates with an abstract, financial model of development (which includes a classical top-down business mode of operation), whereas PRI embraces emerging alternative approaches, characterized, for example, by the loosely-knit, multi-faceted networking structures (like Gota Verde). Finally, D1 policies (ultimately driven by the profit motive) one would argue, tends to have the effect of deterritorialization – whereas the semipublic research institute PRI within the working framework generated for the Jatropha project facilitates policy decisions supportive of territorialization.

It is important to remark, however, that while these differences between the D1 and PRI Jatropha biotechnologization processes are clear at the project level, there is some ambivalence at the institutional level. This is due to the privatization process that Dutch universities are currently undergoing. State educational facilities not only conduct research aimed at producing public goods these days, but also sell their services as a source of income. Indeed, the PRI Jatropha project could easily have been financed by, for instance D1, rather than a charitable foundation, and oriented towards commercial agriculture rather than small-scale production systems. Fortunately, that has not been the case.

Just as the two biotechnologization trajectories represent, to a certain extent, two rather different worldviews, so also do they face quite different challenges. The possible problems for D1 are not our concern here, but one difficulty that PRI faces might be mentioned. Local Jatropha networks do need a certain level of expertise in order to be able to understand and translate the agronomic, genetic, and genomic knowledge developed into something useful for the local conditions. The importance of workshops, constant networking and communication cannot be overstressed. The provision of systems of sufficient capacity aimed at meeting this in an ongoing, open-ended fashion certainly presents PRI with a managerial challenge. Scientific research maybe useless if practically valuable information is not disseminated at the local level.

The biotechnologization process as a catalyst for local development

Regarding the Gota Verde Jatropha project in Honduras, the biotechnologization process conducted by PRI is strengthening and has the potential to further empower local development in Yoro in several ways:

- It has increased awareness among Honduran agrarian researchers that their native Jatropha is a plant with an added value in contemporary societies. However, this appreciation has not yet extended to a full understanding of the genetic wealth of the

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205 Although the D1 BP 50/50 joint venture has come to an end (see footnote 191), BP will retain an interest in D1’s planting activities through an extension and amendment of the existing option and relationship agreement between BP and D1 (originally signed in 2007); the two parties have agreed to maintain an ongoing dialogue in relation to the potential supply of crude Jatropha oil to BP (http://www.d1plc.com/news.php?article=197, accessed September 2009).

206 This is a demand that works even at the level of language: not all local researchers or NGO practitioners know English, so it is also important to translate the English-language scientific publications to other languages spoken in the different localities (at least to Spanish for Honduras).
country’s natural Jatropha stock. This is reflected in the present lack of coordinated research investments in Honduras into Jatropha genetic diversity. Nevertheless, some recent initiatives indicate that this may be changing. Gota Verde is starting to investigate Jatropha diversity in Yoro, and a researcher from FHIA has collected thirteen accessions from living fences in Honduras, from which he selected eight samples that were sent to Wageningen for analysis.

- It might help Hondurans not only to learn about the Jatropha genetic wealth of Honduras, but also to show it to and exploit it in the world.\(^{207}\) For instance, one study conducted in Guatemala by a Jatropha expert on the oil content of Gota Verde’s seeds showed the oil content potential of their Cabo Verde to be 21.72 per cent, whereas that of a local accession collected from a living-fence in a local community was startling high, at 52.29 per cent.\(^{208}\) Since the oil content potential of the native accession is significantly superior to the Cabo Verde, and since this native line is, of course, well-adapted to local environmental conditions, it is manifest that further studies of this line (e.g. at Wageningen) would be useful.

- The molecular characterization in Wageningen of these local samples, and of the other imported cultivars, will be of assistance to Gota Verde in learning the place of origin of their imported lines, and the genetic relation of imported and local lines of other Jatropha lines. Given the desirability of crossing genetically separate lines, this is important as an input for future breeding programs.

- The molecular analysis may help in finding out whether local lines (native and imported) are valuable materials in respect of specific genetic characteristics (oil content, growth form, etc.). If PRI is able to develop molecular markers for these traits, then the Honduran samples can be tested for them, which, in turn, can accelerate the development of lines with the desired qualities for local production.

- The technological knowledge of PRI regarding molecular markers could play an important role in the design of local projects. If the already established global and local partnerships are strengthened at the local level to facilitate the research of Jatropha in Yoro, the traits that are interesting for the local production systems but which are still not present in the used cultivars could be introduced into these cultivars through breeding projects. It is now up to the different institutes and organizations to search for funds and strengthen the partnerships that can operationalize this trajectory.

The generation of molecular markers related to certain traits is a costly activity (Reece and Haribabu 2007). The knowledge and capacities for this are mainly based in industrially developed regions, which have good technological facilities (Fears 2007). For this reason, the centralization of research oriented to marker discovery could be necessary. The fact that the present research is conducted by PRI is beneficial to countries like Honduras and networks like Gota Verde both insofar as it enables both costs savings and access to advanced technological capacities and knowledge. However, such centralization does require that the research institution working on genomics development remains in continual contact with plant-experts all around the

\(^{207}\) As an example of the genetic wealth of the region expressed in financial terms, we observe the recent sale of the Guatemalan company Octagon for over two million Euros (BioDieselSpain 2007), a major reason for this valuation being the company’s germplasm collection of 42 Guatemalan accessions collected in living fences.

\(^{208}\) The extraction was done with hexane from the seed’s kernel (Daniel Krabatsch, personal communication, 17 March 2008).
world, to guarantee that the markers they discover are indeed relevant for specific localities and available in local accessions that show good combining ability with elite cultivars.

This section has introduced some divergences in the understanding of Jatropha’s future. However, it has also shown how the biotechnologization of Jatropha conducted through the organization of social relationships within the multi-stakeholder network of PRI’s Jatropha programme and Gota Verde can strengthen local sustainable development in Yoro. We can conclude, therefore, that the territorialization of genomics, as far as for its labour on Jatropha is concerned, can be accomplished through the horizontal relationships which characterize the Gota Verde-PRI cooperation. This process opens the possibility of strengthening peasant agrarian systems and empowering peasants, civil society organizations, and local researchers within socio-technological (genomics) systems. Theoretically, local diversity can be now studied at the molecular level, and marker assisted selection, if performed (and controlled) by the local networks, might, in a near future, accelerate the introduction of locally desired or required traits (e.g. resistance to biotic or abiotic stresses) into local Jatropha production systems.

5.6. Conclusions

The socio-agronomic characteristics of Jatropha make it an interesting source of energy and other inputs in rural isolated areas. A scientification and biotechnologization of Jatropha seems to be necessary, however, if sustainable production systems of the plant are to be developed. Against this background, contradictory dynamics in the biotechnologization of Jatropha are in play. On the one hand, Jatropha is being decoupled from its socio-cultural environment to be imbued with the development logic of the global market. On the other hand, local multi-stakeholder networks are collaborating with international research institutes to harness Jatropha for local sustainable developments. This chapter suggests that the biotechnologization of Jatropha (through genomics) might be deployed not only through bioindustrial conglomerates in extending their control over agriculture, but also within the framework of the types of organizations, relationships and interactions here presented, geared towards local sustainable developments. The three domain concept of local sustainable biotechnological developments has been employed to analyze the biotechnologization process of this ‘new’ crop here.

In the territorial domain we have seen the struggles of the multi-stakeholder network Gota Verde to harness Jatropha within the small-scale agrarian system of Yoro. Difficult choices remain to be made regarding the local implications of emphasizing the commercialization of biodiesel or the use of PPO for fuel, as well as researching, maintaining, and developing the local genetic diversity wealth of Jatropha. Nevertheless, Gota Verde is constructing a sustainable local production and utilization system of Jatropha and its related products. This is being achieved without jeopardizing the capacity of peasant agrarian systems to produce food by establishing a complementary production system of Jatropha and food crops and encouraging its use in useful ‘living fences’.

In the technological domain, the possibilities of the plant and strategies for genomic development have been considered. A one-dimensional trajectory to develop (at an abstract global level) a single best performing Jatropha line for global purposes (as is the case with the Cabo Verde line) does not appear advisable, since the genetic make-up is just one part of the total
phenotypic expression of the crop. The production of a technology in isolation (e.g. an elite line of Jatropha) is not in itself bad, but is only appropriate within a specific context. Considering the territorial approach as outlined here, a strategy to develop a multitude of Jatropha lines adapted to a diversity of local production systems might thus be the most appropriate way of linking global and local biotechnological capacities. For instance, when a fuel-crop is intended to add value to marginal areas, it is obviously important to consider the balance between food and energy crops and other needs (financial, ecological, etc.) in the territory. A complementary system of food and fuel corps might be preferred to the substitution of one by the other (e.g. for commercial purposes). In practice, this should mean introducing into the Jatropha research agenda its performance in living fences and in location-specific intercropping systems (in Yoro, for example, especially with maize and beans).

The domain of reterritorialization has presented the biotechnologization of Jatropha as an ongoing process. Gota Verde is able to take some advantage of the research conducted by PRI. Instead of leading to a dependency relationship, such horizontal networks facilitate the use of international genomics facilities in applications at local levels. At the same time, however, there are clear risks here of a non-territorial approach within the technological domain (e.g. from a PRI move towards emphasis on research that assumes industrial production), which could easily have a deterritorializing effect – by undermining, for example, the effectiveness of Gota Verde to maximize the local potential for sustainable development among the peasant communities of Yoro.

Reece and Haribabu argue that, ‘perhaps, the main constraint to [molecular] marker discovery is the shortage of people able to do field experiments with phenotypes’ (Reece and Haribabu 2007; p. 467). Fortunately, however, this is hardly a concern in the case of Jatropha, where a multitude of networks worldwide are experimenting with different phenotypes to understand and sculpt the plant’s behaviour, including Gota Verde. It seems important, therefore, for all concerned to support these horizontal global-local networks. From the abstract scientific perspective, as well as for commercial interests, local-global networking provides a vital stock of organized, informed and highly motivated labour for phenotype experimentation. From the perspective of the local networks, a territorialization is necessary to access contemporary (bio)technological capacities and incorporate the research data internationally available. It is also necessary in order to enable the integration of local needs into and reorientation of international R&D scientific agendas towards the interest of local sustainable developments.
Chapter 6

6. Conclusions: Territorializing genomics

'It is possible to evolve societies in which people live in greater freedom, exert greater influence on their circumstances, and experience greater dignity, self-esteem, purpose, and well-being. The route to such a society must include struggles toward democratic institutions for evolving a more democratic technological order. Is it realistic to envision a democratic politics of technology? Isn’t it unrealistic not to?’

(Sclove 1995: p. 244)
6.1. Introduction

In my conversations with scientists I have tried to encourage them to talk about the socio-technical arrangements that are required to include a wider scope of actors within their (bio)technological schemes – especially peasants. Once day, puzzled by my persistence in wanting to find more or better ways to include peasants within his research agenda, a molecular biologist with whom I was conversing in his lab in Cochabamba, Bolivia, said: “If you want to have milk in the kitchen, you don’t need to milk the cow there, do you? You can do that in a better place. In the same way, there’s a place to do molecular biology, a lab, and another to do farming, the fields”. In a way he was right of course; we are not claiming here that peasants should get a PhD on molecular biology. However, while we might not want the cow (laboratory facilities, etc.) actually in the kitchen (peasants’ fields), the argument here is that it is good to have one somewhere nearby.

Some of the participatory structures that this particular research institute (in Cochabamba) is building together with peasants are fascinating. Nevertheless, this does not mean that there are enough labs and enough scientists in Bolivia to attend to peasants’ needs – to milk the cow. It might be tempting to hold local researchers responsible for this shortage, but such blame would be misplaced because the problem is much more profound than the particularities of a single situation: biotechnologies are just not structurally organized to serve peasants’ needs. Indeed the Bolivian lab in question seems to be one of the few active labs in the country developing or applying molecular technologies for peasant agrarian purposes. One is led to suggest that if the so-called poor countries were to invest in local rural development, then, the influence of development aid from abroad on local science and technology would be diminished, and ‘development’ could become more a genuinely developmental force – and power would probably be exercised more directly by local actors in the development of agrarian biotechnologies.

Regardless of developmental issues related to the source of funding, the subject of ‘genuine’ development through biotechnology in the context of peasant farming needs a firm theoretical grounding if it is to stake out a serious alternative approach especially in the face of entrenched conventions and the power of international agro-business. It is to this end, therefore that this research has aimed at highlighting whether and how agrarian systems might be strengthened by the local specific development of genomics, and whether and how peasants, civil society organizations, and local researchers might be empowered within socio-technological structures of genomics. Or, in other words, we have been looking at whether and how biotechnological and genomics type of developments might become a catalyst for local development.

This research started with a desk study of genomics and development. From this review of the literature it was argued that, from the perspective of peasant agrarian systems, the approach taken by mainstream genomics development is deterritorializing. This approach is deterritorializing in so far as it usually focuses on commercial and industrial agriculture, and therefore excludes the local peasants, civil society organizations, and researches from the so-called developing countries from the biotechnological decision-making process. As a consequence of this, when genomics is presented as a technology which could work for development, then what is proposed assumes (an approach based on) a straightforward transfer of technology. Directly antithetical to this, however, the present research has searched for alternative territorial trajectories for the development of biotechnologies aimed at strengthening
peasant agrarian systems and empowering local groups within biotechnological structures. These territorial alternatives have been captured within the concept of local sustainable biotechnological developments.

There have been many studies which argue that genomics could invigorate the agrarian practices of peasants, but rather less research has been conducted on the actual application of genomics within specific peasant agrarian systems. This research has attempted to contribute to filling the gap in this area of actual application by studying the potentialities and issues that emerge from the development of certain biotechnologies within specific peasant territories – i.e. the three case studies.

This overarching aim has led us to the formulation of the following research question:

To what extent do local sustainable biotechnological developments appear to be a viable territorial alternative to the currently prevalent deterritorializing development of biotechnologies and of genomics for and within peasant agrarian systems?

The theoretical frame of reference for answering this research question is situated within the intersection of the following conceptual frameworks: science and technology studies (e.g. Mackenzie and Wajcman 1985, Bijker, Hughes and Pinch 1987, Sclove 1995, Feenberg 1999); territorial studies (e.g. Sack 1986, Hettne 1995, Magnaghi 2005b); developmental studies (e.g. Bunders 1990, Friedmann 1992, Sachs 1992, Magnaghi 2005b, COMPAS 2007); and critical studies concerning the biotechnologization and industrialization process of agriculture (e.g. Goodman, Sorj and Wilkinson 1987, Ploeg 1987, Ruivenkamp 1989, 2005b, Kloppenburg 2004, Ploeg 2008). Within these frameworks, the new concept of local sustainable biotechnological developments has been elaborated for defining a type of development which is based on the reconstruction of biotechnologies mainly (though not exclusively) by local social groups and which is thought to strengthen peasant agrarian systems and to empower peasants, civil society organizations, and local researchers within biotechnology socio-technological structures. Local sustainable biotechnological development has, moreover, been employed as a research method by which to analyze the three case studies made. The case studies have been tested in the three interrelated analytic domains that structure the concept, namely:

1. *The territorial domain*, which explores power and locality, the social dynamics involved in biotechnology development and the power exercised by peasants, civil society organizations and local researchers in decision-making related to biotechnological developments.

2. *The technological domain*, which explores power and the material dimensions of technology, the material redesign processes that genomics technologies have to undergo in order to be developed or deployed within peasant territories. These territories usually lack the knowledge resources and technological capacities to reproduce genomics according to the parameters of the wealthy laboratories from where genomics originates.

3. *The reterritorial domain*, which concerns the empowerment of the territories where local sustainable biotechnological developments occur, and which also reflects on the alternative structural tendencies that these developments constitute (within the historical context of an increasing industrialization and biotechnologization of agriculture).

The central concept of local sustainable biotechnological developments encompasses two core elements – (bio)technology and territoriality. Considering the first of these, technology has been
here defined as a social structure, a system formed by social and material elements, and which has politics (i.e. defined by, and maintained within systems of power relations). This research suggests that rather than assuming there to be one single path for the development of (bio)technologies, different technological trajectories can, in fact, be not only imagined but also considered feasible, and, moreover, not only for different, but also within a given territory(s). **Territoriality**, the second core element of the central concept, is formed by the intersection of power and locality. Within the context of biotechnology development, territoriality has been here defined as the power exercised by local actors over biotechnological developments. In this context, the cases have been presented as illustrations of biotechnological developments that can strengthen peasant agrarian systems, and in which power is, to a certain extent, exercised by local actors. Thus, answering the main research question of this research, the case studies do indeed constitute illustrations of alternative, territorial trajectories for the development of genomics within development. Quite why and how these biotechnological developments represent a territorial alternative is considered in the following sections of this chapter. Next section (6.2) addresses the first research sub-question, that is:

**What power relations (social) unfastened by local multi-stakeholder networks formed by peasants, civil society organizations, and researchers strengthen peasant agrarian systems through the development of local specific biotechnologies and empower these networks within genomics socio-technological structures?**

This research sub-question concerns the territorial analytic domain. Section 6.3 addresses the second research sub-question which concerns the technological domain:

**What material redesign processes are conducting these networks to attune biotechnologies to local specific capacities and needs?**

Section 6.4 focuses on the conclusions extracted in the domain of reterritorialization. It gives an answer to the third and fourth research sub-questions:

**Which new dynamics bring about local sustainable biotechnological developments within the historical trends of industrialization and biotechnologization of agriculture?**

**Whether and how are the local sustainable biotechnological developments analyzed empowering the territories where they occur for future negotiations in biotechnological developments?**

Section 6.5 outlines recommendations for further research building on some of the conclusions extracted in the other sections of this chapter to more fully elaborate the challenges and opportunities of local sustainable biotechnological developments. Finally, the epilogue reflects on the quasi-Promethean character of the local networks here studied, networks aimed at stealing the fire (genomics) from the gods (scientists) to use it for the betterment of human kind. The epilogue, therefore, is a discussion on value.
6.2. Territorializing genomics – Territorial conclusions

The act of territorializing biotechnologies, and therefore genomics, is an act of exercising local power over biotechnological developments. Territoriality in humans is best thought of not as biologically motivated, but rather as socially and geographically rooted (Sack 1986; p. 2). Its employment depends on who is influencing and controlling whom, on how people use their land, how they organize themselves in space, and how they give meaning to place (ibid.). This conceptualization of territoriality has been here extended to the study of biotechnological developments. Therefore, in this research we have studied how a local specific power can be exercised over biotechnological developments, how these developments are organized in space, and how by way of territorializing biotechnologies a process of reterritorialization is provoked in the course of time, one that reshapes the meaning of place. Or, in other words, how through the democratic organization of biotechnological developments from within the locality, these types of developments can work as an engine for development.

Power is then an important analytic aspect of territoriality and of the territorial domain. Following Foucault (see Section 2.2), we have argued that the power involved in biotechnological development is not directly possessed by scientists but exercised through a certain organization of social relations. Thus, it follows that the reorganization of social relations might transform power within biotechnological developments. From our territorial perspective, we are here interested in a reorganization of social relations that facilitates the exercise of power from within the locality; i.e. a reorganization that enables the exercise of power mainly (though not exclusively) by peasants, civil society organizations, and local scientists.

The reorganization of social relations within biotechnological developments

Three main issues are outlined here, related to the reorientation of development and of investments and the democratization of science and (bio)technology. Together, these give an answer to the first research sub-question (concerned with the territorial analytic domain) and highlight some of the multiple reorganizations that are required for the territorialization of genomics. These issues are extracted from the case study analyses comprising Chapters 3, 4, and 5, and elaborate further on the idea of a possible territorialization of biotechnologies.

Reorienting biotechnological developments towards peasants’ needs

If biotechnologies and genomics are to play a role in strengthening resource-poor farmer agrarian systems, then, the social structures that apply and reproduce these technologies should reorient these technologies towards specific problems affecting those systems. So far, there have been few relevant genomics developments within these agrarian systems (Jefferson 2006, Fears 2007). Nevertheless, through the involvement of local actors and agrarian systems in biotechnological developments, we have seen how multi-stakeholder networks are addressing some relevant pesticide problems in specific agrarian territories. The first case study shows that the available pesticide products to manage a relevant insect pest (semilooper) in one of the most important crops (castor) grown by peasants in the Mahaboobnagar and Nalgonda districts of Andhra
Pradesh (India), are inappropriate, dangerous, and/or unaffordable. The reorganization of social resources available at the locality has facilitated the development of a biopesticide which is efficient against the pest, the production of which is feasible at the village level, and which is accessible and affordable for peasants. Set within a general context in which potato biodiversity is decreasing in the Andean highlands, the second case explores how molecular markers could be deployed aimed at conserving and developing the genetic variability and productive diversity of native potatoes in the small-scale and low-input agrarian systems of the Bolivian Andes. This is relevant because potatoes and their diversity form a core element of the indigenous Quechua and Aymara peoples’ food sovereignty and security, and culture. Finally, the third case study looks at how the genomics biotechnologization process that Jatropha is undergoing might be relevant for producing locality specific biofuels in Yoro, Honduras. This is relevant both for the local production of energy and for the strengthening of peasant agrarian systems by introducing a complementary energy-crop (Jatropha), i.e. one that does not occur in competition with the demands of food production.

So far, the reorientation of these technologies towards peasant needs is constricted among other things, because of economics. Biotechnologies, and specially genomics, are expensive technologies. Next paragraph tackles some monetary matters that challenge the development of local specific genomics aimed at addressing peasant’s agrarian problems.

Reorienting investments

Until now, the reorientation of these technologies towards peasant needs has been constricted by, among other things, economics. Biotechnologies, especially those in the field of genomics, are expensive technologies. It is necessary, therefore, to briefly consider some financial matters that challenge the development of local specific genomics aimed at addressing peasant agrarian problems and at empower local actors.

Biotechnological developments can be controlled and might be applied to exercise power within territories in many different ways – for example to exercise control at a distance (Ruivenkamp 1989, 2005b), to commodify nature (Kloppenburg 2004), as a biopiracy tool (Mgbeoji 2006), or even to strengthen local sustainable development (Puente-Rodríguez 2009). According to a Spanish aphorism “the one that pays is the boss”209 – in this case, he or she who makes the investment exercises power over the decision-making of genomics (or decides who will). It is in this context of controlling the purse-strings, therefore, that a remark is appropriate on the financial context that usually facilitates the establishment and evolution of structures for the development and deployment of biotechnologies in developing countries, i.e. external funding. We have seen that all three multi-stakeholder networks addressed in the case studies of this thesis operate in this financial context. That is, they depend on international financial support. In the Bt biopesticide case the support has come mostly from the Dutch Development Agency of the Ministry of Foreigner Affairs; in the Bolivian case mainly from the CGIAR; and in Honduras mostly from Dutch NGOs and charitable foundations, as well as from funds of the European Community. This is not inherently negative and can have positive consequences for peasants. A case in point is the first case study addressed here in which the external financial institution (DGIS) proposed (top-down) a methodology (the interactive bottom-up approach)210

209 From the Spanish ‘el/la que paga, manda’.
210 The quality of the interactive and participative features of the interpretation made by DGIS on the IBU approach has been criticized elsewhere (Broerse and Bunders 1999, 2000).
that could provoke a bottom-up or territorial development with empowering consequences for peasants (see Chapter 3). However, Olsson (2009) argues that most founding concerned with research in low-income countries goes to commissioned studies in specific areas, prioritised for their potential to promote development; governments and external funding agencies are anxious to get immediately useful results, to have an impact. She says that this impact oriented work tends to engage researchers from developed countries that already have the research capacity needed. A principal investigator in the North usually gets the grant and may – or may not – choose to collaborate with individual researchers in the South, who are closer to local realities and data. Those local researchers are tempted by the income opportunities afforded by external projects as they commonly offer higher financial rewards than those gained from the standard local salaries (ibid.). Sometimes, funding might even hinder the fragile local research structure by orienting it towards the project demands.

Following this line of argumentation, it follows that supporting research structures as such rather than particular projects (a territorial approach to research funding?) could enable science to provide a more sustainable aid to development. The facilities of local research structures are ideal places for the elaboration of (new) research questions that engage with the issues of local stakeholders, i.e. locality specific research. A territorial approach demands that research organizations and policy makers in low-income countries elaborate strategies based on local conditions and problems – with which external agencies can align their own research funding, partnership projects, etc. By decentralizing and building locality based research capacities, sciences and biotechnologies can grow within and strengthen the multitude of existing local agrarian systems. If we are serious about territorializing genomics in low-income regions, we have to support and foster local research capacities over the long term. Short-term and impact oriented projects and programmes have a role to play and require support, but it is also necessary to finance a decentralized system of local structures and their research facilities which might work as territorial scientific engine of development.

**Decentralizing and democratizing science and technology**

While several biological processes such as plant growth or a micro-organism’s multiple activities remain relatively poorly characterized, the pace of advanced research has been increasing dramatically (EASAC 2004). The cutting edge of basic plant research is evolving from understanding the function of single genes to studying the networks of genes that control biological processes. The new era of genomics is enabling us to gain a better understanding of how the interconnected networks of genes and gene products work together in steering biological processes. For instance, to study the performance of a plant under different specific environmental conditions (European Technology Platform 2007). Advances in genomics and cognate biosciences are beginning to explain the fundamental elements of plant biology with regard to growth, development, reproduction, photosynthesis and the responses to environmental conditions and pathogens (Fears 2007). This can strengthen further basic research and applications on biodiversity conservation or breeding activities. While genomics research is producing knowledge that is broadly useful for the scientific community, however, the reduction to practice of genomics presents several challenges – for example, the extrapolation from model plant genomics to crop plant genomics and other Omic technologies, and the translation from scientific advances to breeding programs. The new routes to crop improvement accessing greater genetic diversity bring together the advantages of marker assisted breeding (faster and more
targeted) and the understanding of the science underlying attributes of crop domestication, to capitalize on wild species resources (Fears 2007).

In line with the argument that we have elaborated here in Chapter 1, Fears (2007) argues that impediments to the reduction to practice of genomics in developing countries is often compounded by policy makers taking too narrow a view of the transfer of technology. This approach pays no heed to the fact that technologies, and therefore genomics, are structures formed by the interaction between material and social elements (Bijker, Hughes and Pinch 1987, Sclove 1995, Feenberg 1999). A straightforward transfer of technologies is an incomplete process, therefore, because a decentralized system of social structures is required for the translation of genomics knowledge and technologies into locality specific applications. The deployment of, for instance, molecular marker technologies to improve crop breeding is not merely a matter of linear technology transfer, of moving inventions and procedures from labs to fields. Molecular biology (and genomics) type of knowledge and its technology forms have to be actively engaged with the uses to which they will be put, as determined by other actors outside this ‘pure science’ community, such as plant breeders and agrarian communities. The genetic elements of a crop are just one of at least three elements that have an influence on the development and final performance of a crop plant, the other two being the environmental conditions and human management. As we have seen in our case studies, the knowledge of and practices within this trinity, the ways the various constituents of the three elements act and interact, are essential to the practical application of biotechnology research, to bringing genomics down to earth, especially to the earth inhabited by peasants.

Many scholars have argued that science and technology developments are highly context dependent and value laden, and that, therefore, a wider set of actors has to be involved in these developments (Sclove 1995, Feenberg 1999, Nowotny, Scott and Gibbons 2001, Ruivenkamp 2008a). In Chapter 3 (the study on the locality specific Bt biopesticide), it is argued that the engagement of a wider set of actors be considered not as a strategy to secure the acceptance of the technology by peasants and thereby avoid a possible rejection, but as an end in itself. In Chapter 4 (on the Wiphala Genomics) moreover, an argument is made for the relevance of finding places of encounter from which genomics can be territorially reconstructed and therefore democratized. And in Chapter 5 (on a local specific Jatropha), we saw how these considerations might even contribute to strengthen local agrarian systems and ways of life that maintain biodiversity. The engagement of a wider set of social actors in science and technology developments is not only morally desirable, therefore, but can also be more efficient, with consequences that are important locally, regionally, and even globally. In the case studies analyzed here we have seen three multi-stakeholder networks aimed at territorializing genomics scientific knowledge and biotechnologies within peasant agrarian systems. These networks are characterized by a reorganization of social relations in which power is exercised on biotechnological developments mainly (though not entirely) by local actors.

The first case study focuses on a multi-stakeholder network formed by peasants, peasants’ groups, civil society organizations, extension labour, and researchers of public institutes. This diverse set of actors shares its diverse knowledge and technological capacities. Peasants have defined one of their agrarian problems, i.e. castor semilooper. The whole set of actors has cooperated in the redesigning process of the Bt spray to deal with this pest, experimenting with it and learning to produce and to use it. Peasants get the Bt powder from one of the bioresource centres established at the village level. Run by local civil society organizations, these centres investigate and produce efficient and affordable agribiotech. For their part, the CSOs running the centres, have added the role of biotechnology developers to their portfolio, in addition to their
developmental activities in the area of education, health, gender, etc. They facilitate the flow of information between peasants and formal researchers. The diverse set of researchers within the Bt spray network produces knowledge at different levels of the biotechnological development. There are molecular biologists in the city of Hyderabad, who have characterized the local Bt isolates; agronomists in the rural research stations, who have cooperated with the local CSOs (at village level) to test the Bt product; the social scientists who have coordinated the process; and entomologists who have developed the novel process to multiply Bt spores which is reproducible in a decentralized system of production units at the village level. Collectively, these production units (*places of encounter*) are the crystallization of a decentralized socio-technological structure which can develop local specific biotechnologies.

The second case study involved an exploration of social structures that might facilitate the deployment of genomics technologies (here, in the form of molecular markers) within the small-scale potato production systems of the Andean highlands. Here some participatory plant breeding networks – in which peasants play an important role – have been suggested as appropriate social platforms for this purpose. They can link molecular biologists, plant breeders, and peasants’ groups. These networks are concerned with peasant’s potatoes varieties, and aimed at developing improved native varieties that contain local needs (e.g. certain levels of resistance to phytophthora) and desires (e.g. cooking time, floury consistency). In this way, they are correcting the incapacity of international research organizations to reinvest the knowledge from the local potato biodiversity extracted through genomics within the locality. In that social environment, molecular biologists are already studying potato diversity through molecular markers within the social relations organized in partnerships with global oriented networks that treat local diversity as a raw material. Whilst the social relations that characterize these local participatory plant breeding networks that work in different Andean valleys should become representative example of how to bridge the gap between genomics and peasants’ potato fields. They can become the platforms in which local actors can model (power) biotechnologies attuned to local needs and capacities, i.e. the Wiphala Genomics.

Our third case study considered how multi-stakeholder networks are building structures for the local production and use of Jatropha and its derivate products. In this case, we can find peasants integrating the plant within their agrarian systems intercropping it within their food crops, and extending the traditional use of the plant for the construction of living fences. Jatropha producers co-own an emerging company which processes the plant into different products. The company is also co-owned and supported by a Honduran developmental non-profit private organization. Other social actors involved in the web of activities around Jatropha include civil society organizations that are organizing, among other things, a decentralized system of gathering and press units for Jatropha’s seeds, units which are themselves run by local women’s groups. Further actors involved in these networks include a local technical training institute whose students are producing appropriate press machines for the local circumstances; some local business, which are helping to close the circle of production, transformation, distribution, and usage (through their acceptance of the complementary currency introduced in the system); and a Honduran research institute, which is focussing on the agronomic performance of different varieties of the plant in different locations. Local (regional or national) research institutes are essential if poorer countries are to catch-up and keep pace with the global genomics. The focus of the case study is on how the knowledge and technological applications of genomics research on Jatropha which is conducted by a semi-public research institute in the Netherlands might be oriented by local actors towards strengthening local development in a rural region of Honduras. For this purpose, the *active engagement* of all the actors listed is indeed vital. For example, local...
actors should decide on the accessions of Jatropha that ought to undergo the biotechnologization route. Rather than selecting a global Jatropha (a industrial commonly used variety from outside the region with specific agrarian needs), local actors will tend to choose local jatrophas with a proven adaptation to local conditions (e.g. biotic and abiotic stresses) and high oil content; varieties that will be probably, also better adapted to the local socio-agrarian conditions. In this way, the local reorganization of social relations is both producing local specific biofuels, and also, by way of gaining terrain on the biotechnology decision-making process, leading to local sustainable biotechnological developments.

In order to territorialize genomics within peasant agrarian systems, multi-stakeholder networks are required. These networks can break through the monopoly of power in genomics knowledge and technologies exercised by formal scientists in expensive labs working remotely (in the cities, in the North) for remote organizations (government institutes and multinational corporations). Indeed, the organization of knowledge is one of the most important forms in which power is organized and transmitted through society (Ploeg 1999). Within the networks explored in this thesis we have found molecular biologists, plant breeders, agronomists, social scientists, peasants, and civil society practitioners playing different roles in the sharing of their technical, environmental, agricultural, organizational and business experience and knowledge. Different types of information flow through these networks and are translated into different types of knowledge, or into practical technological applications – for example, from the knowledge about the timing and the form in which the semilooper attack the castor plant, to a management strategy with a Bt spray; or from the knowledge about how to mark identifiable DNA sequences found at specific locations of the genome to the development of microsatellite molecular markers to study, at the molecular level, the biodiversity of peasants’ potatoes or jatrophas.

Within local biotechnological developments, the exercise of power is influenced by a wide range of natural and cultural resources including land, finance, information, and political power. These differences are exhibited in the relationships between stakeholders, both within the locality and in the relationships between local and regional, national, and global stakeholders. In a context of social differentiation based on power, the capacity of local biotech multi-stakeholder networks for self-governance is key. The capacity to organize the relationships – those within these networks, and those with external actors, or overarching (political, religious, gender, etc.) social systems and networks – in such a way that the necessary functions of power can be exercised without the intervention of actors of authority which are beyond the control of the networks, might guarantee the access of relatively weak stakeholders to decision-making activities in biotechnological developments; in short, it will territorialize them.

No matter how dynamic and powerful biotechnologies might be, biotechnological trajectories that are not used for a good number of the rural population who are sustained by agriculture can and must be radically transformed. This redesign is required to reach the invisibles (as peasants are characterised in the closing section of Chapter 4). The conventional social relationships that structure the socio-technological systems of agro-genomics are usually unable or unwilling to orient these technological capacities towards peasant agrarian systems. Therefore, these social relations should be restructured. The three case studies addressed here outline alternative trajectories for so doing. These trajectories are including a wider set of social actors (e.g. peasants, and civil society organizations), and facilitating the share of knowledge through the democratization and decentralization of science and technology developments. The aim of a local sustainable biotechnological development is to humanize a system that has shut peasants and their agrarian problems out, and to accomplish this through forms of everyday resistance and political struggle that insist on the rights of the excluded and invisible populations,
as dwellers of territories and as (re)designers of biotechnological structures. The central practice of such a development is the inclusion of the invisible in a restructured socio-technological system; i.e. one that does not make them redundant.

6.3. Reorganizing the materiality of biotechnologies – Technological conclusions

The local exercise of power on the development of biotechnologies is the core characteristic of our territorial approach of ‘local sustainable biotechnological developments’. A Foucaultian understanding of power guides us to a central concern with the largely unrecognized ways in which knowledge is not only power, but also involves relationships of power that privilege some and oppress or exclude others. We have seen how, in order to facilitate the local exercise of power on biotechnological developments a reorganization of social relations and their knowledge exchange is required. In his book *Discipline and Punish* (Foucault 1977), Foucault employs his general theory of ‘power-knowledge’ to show how ‘technologies of the self’ or behavioural technologies are produced in which the scientific conception of rationality and irrationality is employed to classify, isolate, and discipline ‘deviant’ individuals. At some point, Foucault’s all-embracing behavioural technologies come to resemble Mumford’s ‘megamachine’ (Mumford 2003), which is a technological apparatus consisting of human beings, thus a ‘biomegamachine’. Foucault’s view also appears to share common ground with Ellul, who also refuses to tie ‘technique’ solely to the involvement of hardware but conceives of it instead as involving the rationalisation of all aspects of life for the purpose of maximizing efficiency (Scharff and Dusek 2003). Of course, some elements of these technologies are material as Foucault demonstrates. For example, the introduction of Bentham’s famous panopticon in the architecture of prisons or schools can be seen as an illustration of the hardware of power, the material design of power relations, its physical expression.

Our case studies have shown us that in order to democratize the power exercised in respect of biotechnologies, not only is a reorganization of the social relations organized around biotechnological developments required, but also some material readjustments. We look next into the material redesigns conducted by our local networks.

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211 In another of his influential books, *The History of Sexuality* (Foucault 1980a), Foucault argues that the deployment of these technologies of the self in society has brought about a new era. Foucault states that the old power of death that symbolized sovereign power was now carefully supplanted by the administration of bodies and the calculated management of life. During the classical period, there was a rapid development of various disciplines – universities, secondary schools, barracks, and workshops; there was also in the field of political practices and economic observation, of the problems of birth-rate, longevity, public health, housing, and migration. Hence there was an explosion of numerous and diverse techniques for achieving the subjugation of bodies and the control of populations, marking the beginning of an era of ‘biopower’ (ibid; pp. 139-140).

212 In the panopticon a single individual can survey a large group of prisoners without her/himself being seen.
Material changes required for the territorialization of genomics

What usually happens is that human beings have to adapt themselves to technological systems that are designed somewhere else and by somebody else for reasons of profit. In contrast, what ought to be the case is that the emerging socio-technological structures are constructed as much as possible, by and/or with the involvement or at least the agreement of the groups that will be coexistent within those structures upon their realisation.

In order for those who will live and work with new technologies to be able to adapt, improve, or reconstruct them, changes are necessary at the material as well as at the social level. Feenberg says that in theory, one can decompose any technical object and account for each of its elements in terms of the goals it meets, whether it be safety, speed, reliability, etc. (Feenberg 2003; p. 660). As has been explained, although both material and social elements are intrinsically interrelated within technological structures, for analytical reasons, social power strategies are here mainly elaborated at the territorial domain, while the technological domain concerns material changes – i.e. power exercised by social actors on the material elements of genomics. Among the material changes analyzed in the case studies, there are some that respond to the incompatibility between on the one hand, genomics functioning requirements and, on the other hand, the local conditions. Genomics related technologies are usually costly and often require highly specialized skill competences that often cannot be met in low-income labs. Changes in this area, in the type of labs that usually support peasant agrarian systems, are, one could argue, an unavoidable step in the territorialization of genomics. A different way of perceiving these material changes as described here is that they are a basic condition for governing genomics from within the locality.

In Chapter 3, we have seen that in order to be able to produce a Bt spray that is affordable, accessible, and feasible at village level, the industrial approach for producing Bt sprays in which Bt spores are multiplied through a liquid-state fermentation has been transformed into a solid-state fermentation. In the liquid-state process, the fermentation takes place in costly fermentors which require, among other things, a continuous power supply and high technical skills input. Reproducing these requirements is difficult to impossible in rural India. Substantial material changes accomplished by the redesign process that ensure a new production procedure include for example, the use of, local agricultural waste/by products as solid medium for Bt’s fermentation, plastic basins as containers for the solid medium in which Bt is multiplied, and the design of a chamber where the desired conditions of a laminar air-flow cabinet are simulated to facilitate the fermentation process. These material changes facilitate the production of the Bt spray at the village level, enabling a decentralized system of production units, and which has generated a new technical code which includes peasants, civil society organizations, and local researchers and which effectively manage an important pest affecting local agrarian systems. These production units are themselves further instances of a material reorganization, and new buildings containing biotech facilities for the production of local specific biotechnologies.

Chapter 4 explores some ingenious material readjustments that local researchers are implementing in their molecular biology lab in Cochabamba for the deployment and control of genomics, such as the production of local polymerase and ethanol, or the use of conventional kitchen refrigerators213 rather than the expensive refrigerators recommended by scientific

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213 Since we address the high-tech of genomics, mention of apparatus as refrigerators might appear trivial. Nevertheless, a (electrically driven) facility to enable cooling and provide cold storage is mandatory in the
protocols. These types of changes and adaptations are expected to be taking place in the large majority of molecular biology labs that have low economic capacities. Fortunately, there is an informal flow of information on these strategies which allows low-income labs to experiment and to enrich genomics practices, and hopefully, to strengthen peasant agrarian systems.

Unfortunately, molecular markers are a fairly new development in Bolivia’s labs so far, so we are not able yet to see the material changes that will occur within the Wiphala Genomics developmental path. A possible technological choice that might inform differences in the deployment of genomics between low-income labs like the one in Bolivia addressed here, and wealthy labs elsewhere might be the decision to work with microsatellites molecular markers rather than with the patented AFLPs, which require, among other things, very pure and complex reagents produced under patent protection in the Western world. The microsatellites are simple DNA sequences (FAO 2003). Although the initial identification of microsatellites is time-consuming, once developed the reliability of the technology does not depend on the conditions of the laboratory. Therefore, microsatellites can be applied almost everywhere, regardless of where they are developed. For other type of molecular markers (such as RAPDs, or AFLPs) the lab conditions can determine the reliability of the results (Korzum 2003). It is difficult to predict which type of molecular marker technology will be the most adequate for low-income labs, particularly because this decision will most probably depend on several factors and circumstances, such as the funds or the partners that a lab or project has, and even the specific research questions formulated (e.g. AFLPs are recommended for biodiversity studies in organisms where no previous work has been done at the molecular level, as it is possible to start studying genetic resources from scratch with them).

Chapter 5 did not detail material readjustments of genomics related technologies from within the locality. In this third case study concerning the biotechnologization of Jatropha, the genomics research occurs in the wealthy labs of a Dutch university and semi-public research institute. Were this research to be conducted in the low-income labs of Honduras we could most probably expect similar readjustments to those occurring in Bolivia (for instance, the high polymerase enzyme prices are an issue of concern everywhere). Nevertheless, we have still seen that certain choices have been made involving the type of molecular marker technology. The initial choice of AFLP as molecular technology to study the Jatropha biodiversity has been changed due to the patented condition of this technology. Therefore, a new set of artefacts with their material specificities are called into action to go beyond the AFLP socio-technological structure. Moreover, one of the most important and desirable material changes that molecular marker technology needs to undergo is the development of capacities to understand, also at the molecular level, the productive capacity of Jatropha in living fences and in intercropping production systems.

Allow me to close this sub-section with two observations concerning the required material changes for the territorialization of genomics. Firstly, when it comes to the deployment of high technologies such as genomics within low input science and technology systems that are employed in the service of resource-poor agrarian systems, it is necessary to combine different types of knowledge (formal with informal) and of technologies (high with low tech). Both basic
and advanced technologies are required to strengthen agriculture practices. Genomics in isolation is particularly useless in peasant agrarian context. Where the science and technology structures are such that it is very difficult to reproduce the socio-material conditions required to perform genomics. The Bt network presented in Chapter 3 is a fascinating example of how low technologies become crucial in linking genomics developments to peasants’ practices. This is especially relevant not only for the local exercise of power on biotechnologies, but also to reorient the power of biotechnologies towards resource-poor farmers and their agrarian systems. In this case study, we have seen how it has been possible to employ molecular markers (high tech) technologies to detect the most efficient Bt isolates against the castor semilooper through the development of a solid-state fermentation process (low tech) which can be reproduced at the village level. The marker technology could have been employed to analyze these Bt isolates elsewhere, in other types of social networks, but what has been essential to link these technologies with peasants systems in Mahaboobnagar and Nalgonda has been the specific assemblage of low-high tech and in-formal knowledge within the Bt network.

In a different research field, as has been noted earlier, the traditional plant breeding knowledge of peasants and researchers concerning the phenotypic biodiversity of plants needs to be coupled with the new potentialities of molecular markers for selecting lines or individuals based on knowledge at the genetic level. However, the risk does exist that if a molecular marker approach takes the lead in breeding projects, then, the holistic advances achieved by the phenotypic selection will be lost, and the new varieties might become vulnerable to future shifts in production systems, climate, end uses, and so on.

Secondly, the dynamics of centralization combined with a decentralization of research and technology facilities seems also to be necessary in order to link peasants’ fields to genomics labs. Here, we would repeat a conclusion made in Chapter 5 concerning the biotechnologization of Jatropha but relevant also to a general analysis of the global application of genomics within small-scale and low-input agrarian settings. This conclusion concerns with the high costs associated with the development of molecular markers (Korzum 2003, Reece and Haribabu 2007), for which reason, the centralization of research oriented to marker discovery would appear to be unavoidable, as it promises reduced costs and guarantees the access to ready-made technologies. However, such centralization does require that the research institution working on genomics development remains in contact with plant-experts all around the world, so as to guarantee that the markers they discover are indeed relevant for specific localities and available in local accessions that show good combining ability with elite cultivars. On the other hand, we have also seen how it is the decentralization of the system of Bt production units in Andhra Pradesh that guarantees peasants access to agrarian technologies, and enables their exercise of power over biotechnological developments. Furthermore, it is the S&T decentralization which allows labs like the one in Cochabamba that are experimenting with, for example, molecular markers, to generate alternative paths of biotechnological development (the Wiphala Genomics). The balance between centralization and decentralization in S&T developments might generate a dynamic for their democratization. Decentralization dynamics usually bring about the empowerment of larger sectors of the population (Kropotkin 1899-1998, Sclove 1995, Bookchin 2007), and are required in order to ensure control by those larger sectors of biotechnological developments. A balance needs to be found, as the importance of developing the sciences for their own sake is undeniable, which in the case of genomics, means laboratories, knowledge, and technical skills that are expensive and that can currently only be reproduced in a small number of localities (i.e. in centralized systems). This balance between centralization and decentralization
can be found in the, to a certain extent, horizontal relationship of external scientific and globally oriented networks with the local multi-stakeholder networks analyzed in our three case studies.

Local specific redesign of biotechnological codes

We have argued that from the perspective of peasant agrarian systems, genomics is usually developed in a deterritorializing way, one which commonly fails to represent and thus excludes the wide variety of spaces in which peasants perform agriculture, their needs, and even their knowledge. This particular path along which agricultural genomics has been developed is not (yet) an intrinsic characteristic of the technology itself. In the case study analyses, therefore, we have seen real, practical examples of how alternative and (re)territorial(izing) development paths can be outlined by restructuring social and material elements of agro-genomics. In so doing, we have posed an empirical challenge to technological determinism, both in its utopian variant of technological progressivism and in its dystopian variant of sustaintivism (Chapter 2). But, it is important to emphasise that by elaborating an argument which points to a particular reconfiguration of social forces to define a specific road to development, we are not trying to substitute technological determinism with a kind of social determinism. Technological progressivism, as it is sometimes understood within the ‘transfer of technology’ approach, suggests that it is the technology itself that will automatically stimulate development in a particular way, when that technology is transferred to a new social context. We do not mean to say instead that social stakeholders can fully govern technology through a specific pre-designed developmental path. It is true that different trajectories of technological development are indeed the results of social struggles grounded in the existing organization of societies and the configurations of power. Technologies are socially contingent; they are also determined by scientific capability given physical resources – technologies are materially contingent (in the way, in fact, that they are conventionally understood). In short, technologies are the result of mutual social and material adaptations.

These social and material contingencies can lead to unexpected and even undesired outcomes – or in Sclove’s words, the polypotency of technology (Sclove 1995). Technology interacts with all the other social structures of society and so is just as difficult to change or to govern as the rest of social structures. In the same way that it is very difficult to predict how a political or religious structure will look like after a revolution, or even after a planned reform, it is quite complicated to ensure that after a democratization process of technology development we will obtain democratic and democratizing technologies.

Nevertheless, here we claim that such a democratization process of agrarian genomics is necessary if we want to put genomics to work for peasant agrarian systems. The participation of subordinate social stakeholders in the struggles of writing biotechnological codes can change outcomes. In his review of the historical developmental path that some agrarian technologies have followed, Kleinman (2005; p. 33) argues that the existing organization of society – by shaping the relative power of actors and the extent to which particular technological choices appear legitimate and appropriate – does increase the likelihood that a particular direction of development will be followed. Therefore, if peasant agrarian systems with their potencies and deficiencies, and if peasants, civil society organizations, local communities and researchers are brought into the equation, considered and given a voice in the decision-making processes of
agrarian genomics, the probability that genomics will strengthen peasant agrarian systems and that these actors will be empowered within the biotechnological structures is hugely increased.

### 6.4. Reterritorializations

In the three cases studied we have seen how local multi-stakeholder networks are territorializing genomics within three specific localities. The domain of reterritorialization aims to analyze the outcomes that this territorialization brings about – specifically, it explores the empowerment of localities through and within biotechnological developments. In this section, we first look at these alternative territorial developments in the light of the historical processes of industrialization and biotechnologization of agriculture. Here, it is argued that these historical processes are potent in many ways (i.e. polypotent) in respect of their possible structural force on agriculture. Secondly, that through the reorganization of social relations and the redesign of some material aspects of biotechnologies, new social environments or structures are generated which empower local groups within biotechnological developments. Thirdly, we argue that ‘local sustainable biotechnological developments’ ought to lead to a socio-political sustainability within the territories where they evolve.

#### The polypotency of the scientification and biotechnologization processes

The large majority of us generally take technologies as a given fact, assuming that their final appearance and functioning respond to efficient estimations made by ‘neutral’ engineers. We don’t usually think about the myriad ways by which technologies are designed and shaped by cultural, economic or politic factors. Moreover, we hardly reflect on the consequences that the deployment of technologies have for societies. Bijker and Law (1992) argue that our lack of curiosity about these things makes perfect sense, but exacts a price:

‘If we stopped to think why our artefacts – our saucepans, our cars, our refrigerators, our bridges – work or take the form that they do, we would never get around to boiling the water to make coffee each morning. The conduct of daily life surely demands a tactical lack of curiosity! But that lack of curiosity carries costs and overhead expenses as well as benefits. Our artefacts might have been different. They might have worked better. They might not have failed. They might have been more user – or environmentally – friendly.’ (Bijker and Law 1992; p. 2)

In the same text, these scholars also argue that if it is true that we get the politicians we deserve, then we also get the technologies we deserve; our technologies mirror our societies (ibid.). Elsewhere in this book we have argued that technologies are one of the social structures that shape society. Technologies form the resources for new structural forms of society and they also constrain (rules) the developmental path for arriving to these future societies. If we look to the general history of humanity, we find different concrete understandings of technology for different productive sectors. Usually, it will be the understanding within the most relevant productive
sector of a historical period that leads to the understanding of technologies within society at large. It should not surprise us that an industrialization process of agriculture started in certain societies, concomitant with the development of industrialization of manufacturing production in those same societies. Actually, Genomics is a brainchild of our time. Two leading technologies of our time converge in genomics, namely biotechnologies and information technology – in fact, one might suggest, genomics is the convergence of these. The contemporary character of genomics is visible not only at the technological level, but also at the level of social form. Some of the primary socio-political dynamics of today coalesce and manifest within genomics, such as the further industrialization and informatization of science and technology practices; the extension of private property regimes; and the knowledge and power acquired by large multinationals and the hegemonic position they hold in business and R&D.

The structural power created through the industrialization and biotechnologization process of agriculture has been studied by critical literature. Goodman, Sorj, and Wilkinson (1987) exploit the industrial appropriation by external institutions of farmers’ activities like pest or soil management, and a parallel development of industrial substitution for rural products; Ploeg (1987) observes a process of scientification of agriculture (Ploeg 1987) through which an increasing number of agrarian activities and an amount of farmer labour are controlled by scientific expertise, and through which a process of biotechnologization has taken place; and Ruivenkamp (1989, 2005b) argues that a control at a distance is exercised on agrarian labour from the scientific domain through the introduction of politicizing products. One of the most significant and far-reaching outcomes of these processes is farmers’ loss of autonomy in their agrarian practices. As an example, one can think of hybrid maize that forces farmers to buy seeds each season instead of sparing seeds from one season to the other (Chapter 2).

We have argued that the content of technology is not essentially destructive; rather, it is a matter of design and its further deployment into the realm of the social. Agrarian and scientific networks are not just the mere receptors of technologies, and therefore they don’t automatically reproduce the politics encoded in their design. Here, we have seen how some multi-stakeholder networks are challenging this structural power, the conventional effects of biotechnological developments on agrarian activities, and how they are also, to a certain extent, reversing it in a territorializing move towards local sustainable developments. For instance, the industrial appropriation of farming activities is challenged by the self-organized practices of local multi-stakeholders networks. We have seen how the reorganization of the available natural and human resources in Mahaboobnagar and Nalgonda (Andhra Pradesh) has been self-managed by the local actors. Instead of waiting for the next parachuted pesticide technology they created one of their own; rather than participate in a technology transfer structure they challenged it, collectively and politically. The networks ‘hacked into’ the biotechnological system and turned it to new purposes – to their advantage. Their struggle represents a counter-tendency to appropriationism, an attempt to rediscover the caring and communal functions of biotechnology development – caring for the local agrarian problems of peasants, and building new forms of communality in which (bio)technologies and their development are seen and employed more as a catalyst than a challenge to local development.

Equally, the control at a distance exercised through the scientification and biotechnologization processes is reversed in a way by a local-specific power exercised on biotechnological developments and on agrarian labour (territoriality). The cases of the Bolivian Andes and the Honduran Yoro show how the construction of horizontal global-local structures where knowledge and technologies can be shared might function to facilitate the development of appropriate and efficient local specific biotechnologies, like the Wiphala Genomics (which is
specific to the Andes). The demand for, and the practices of the communication and democratization of biotechnologies that these movements represent are so fundamental that they can serve as a touchstone for our claim regarding the polypotency of scientification and biotechnologization processes. These networks challenge the rationality under which biotechnologies are currently designed. Within and through these networks, the dwellers of peasant agrarian systems become empowered engines of biotechnology and of local development.

Feenberg argues that ‘the narrow focus of modern technology meets the needs of a particular hegemony; it is not a metaphysical condition [...]. It is that hegemony, as it has embodied itself in technology, which must be challenged in the struggle for technological reform’ (Feenberg 2003; p. 663). Indeed the local practices of our multi-stakeholder networks are not challenging genomics as a total entity or as a metaphysical apparatus; rather, they are challenging the politically constructed organization in which the technologies are embedded, which is benefiting a certain set of actors and their agrarian systems and excluding others. This exclusion is restricting the opportunities of a larger set of actors and agrarian systems to participate in the design of biotechnologies, as well as restricting the development of technologies with a wider range of values (e.g. with participatory democracy and locality specific orientation), or the generation of a multiplicity of (i.e. alternative) developmental paths.

Empowered social environments for biotechnology development

The three case studies analyzed here have shown that by reorganizing social relations and redesigning the materiality of biotechnology, power within biotechnological developments might be exercised, to a certain extent, by local actors. Moreover, it is argued here, in so doing, these new social relations are both building and themselves constitute alternative and empowered social structures and environments facilitating the deployment and further development of territorial biotechnologies. These structures form an alternative organization of social relations to those organized around the currently standard deterritorializing genomics. The territorial(izing) and the deterritorializing environments are characterized by different understandings of the natural and social elements that constitute the agrarian world. Thus, for instance, we have conventional social environment of a deterritorializing genomics, which views local biodiversity in terms of raw materials that have no intrinsic value – as in the case of Andean peasants’ potatoes (Chapter 4) – and to which value is given by formal researchers, through things like breeding programs. The Andean case study shows also how the social relations organized within this type of environment (with globally oriented organizations, such as the Generation Challenge Program) tend to research local (in this case potato) biodiversity through genomics, but without generating the social relations necessary for the application of that genomics knowledge at the local level. Against this, we have the alternative social environment of a territorial genomics – in the Andean case study labelled the Wiphala Genomics – which acknowledges and is guided by the variety of cultural aspects that are intrinsic to the local biodiversity, and which may employ (e.g. molecular) biotechnologies to strengthen the local management of potatoes. From these two, radically different types of social environment we might expect to obtain very different types of technological codes – indeed, a different type of genomics.
Agriculture and biotechnology are social activities. The way in which social relations are organized within these activities might eventually settle the kinds of agrarian systems and products, the technological systems and technologies that we will obtain. By reorganizing the social relations required for the development of technology in which local biodiversity is understood as a cultural value, then we might begin to obtain a territorial genomics. This type of genomics, in its turn, could shape agrarian systems and their constituent parts, leading, for instance, to crops adapted to the multiple needs and stresses of a locality.

Chapter 5 suggests that local sustainable biotechnological developments could shape, for example, a Jatropha development adapted to the local natural and social conditions of the Honduran Yoro. A Jatropha which is integrated in the pre-existing agrarian production systems of food crops, and will thus generate or contribute to a complementary production system of food and fuels crops. This process might also facilitate the extension of and add some value to the traditional use of Jatropha for the construction of living fences, for soap production, and medical applications. From the perspective of a deterritorializing genomics social environment, on the other hand, we would expect to obtain an industrial Jatropha capable of producing maximum yields…within an industrial environment. Richard Jefferson (2007) argues that the greatest successes coming from industrial agriculture – with their concomitant problems – come from homogenizing the environment in which agriculture occurs with massive inputs, and then breeding and managing these artificial, unstable, and unsustainable conditions to get maximum yields. This is of course a luxury exercise that the peasant agriculture in Yoro (and elsewhere) cannot afford.

The management of natural resources, whether endogenous or enhanced, is the most critical and challenging bottleneck in agriculture (Jefferson 2007). In order to have a sustainable and scalable impact, such a management decisions must generally be made by local problem solvers, and many such people are extraordinary poor. Genomics and other biotechnologies have the potential to eventually help with the management of such resources, which is why biotechnology’s social structures need to be democratized and decentralized – for relevant biotechnologies to be able to address the problems of the multitude of agrarian ecosystems. A decentralization of such problem-solving capabilities might be realised by harnessing the science and genomics technologies within local development, and by empowering peasants, civil society organizations, and local researchers and their knowledge within biotechnological developments. Currently, these groups are usually involved as mere passive receptors. In other words, problem-solving decentralization is achieved through local sustainable biotechnological developments.

The case study concerning the redesigning of the production of a Bt pesticide (Chapter 3) shows a possible developmental path from which a reorganization of the social relations for the development of biotechnologies generates a decentralized social environment from which territorial biotechnologies can be developed. The decentralized system of bioresource centres in which peasants, civil society organizations and researchers encounter one another is an illustration of a cultural understanding of agriculture and of biotechnology development that produces local specific biotechnologies – such as Bt biopesticides. ‘Local sustainable biotechnological developments’ are shaping the local social environments which are indeed empowered for future negotiations and developments in the field of biotechnology.
A brief comment on the sustainability aspect of local sustainable biotechnological developments is appropriate here, and, in my view, one that looks in particular at social sustainability. Unlike much of the research done in sustainability, there has been no exploration here of the possible effects of biotechnological developments for human health, or their possible environmental impacts. These are relevant issues, of course, but they are also covered elsewhere. Instead, the focus here has been on the social and political processes that lie behind the particular trajectory of development of the biotechnologies addressed. In assuming, therefore, the importance of sustainability as a crucial ingredient of local sustainable biotechnological developments, the reference here is to a socio-political sustainability.

Magnaghi (2005b; p. 49) defines social sustainability as a greater involvement of weak stakeholders in the local decision-making system. Translating this general definition into our biotechnological concern, we might say that this means a system of multi-stakeholders cooperating to take decisions about the objectives of these developments. The structures that route biotechnological developments should be sufficiently complex to guarantee the participation of politically weaker stakeholders and response to their problems. Following Magnaghi, mechanisms need to be created to guarantee that territorial (natural and human) resources are not exploited by the local strongest, or else external social actors, and that these resources are used in the service of local equality (ibid). This is important because in most instances local development projects are deployed by those stakeholders ‘with a voice’, i.e. wealthy farmers, those who control local politics, and those with access to culture, information, or economic resources.

One example of the mechanism that can be institutionalized within local developments is given in the third case study (Chapter 5), with a (co-operative) company established for the transformation and distribution of products originated from the Jatropha plant and from other fuel-crops. Ownership of the company is determined by shares issued only to a Honduran non-profit private developmental organization (that facilitates the process) and fuel-crop producers. The (consensus-oriented) decision-making organ of the company, its general assembly, meets twice a year. During the constitutive assembly it was decided to limit individual ownership to a maximum of five per cent of the company’s shares, in order to avoid a takeover by an external investor, or by rich farmers. Owner-members started with an initial ten shares, representing the estimated value of their investment in Jatropha, and establishing an egalitarian structure within the company. In this way, peasants are empowered as co-owners of a small-scale manufacturing industry. This example illustrates one of the mechanism that might guarantee the participation of politically weak groups in local development. Moreover, while small-scale farmers’ agrarian products usually are bought by intermediaries and sent outside of the locality for their manufacture and use – which is, also usually, the place where the real economic business is done – in this case, because the manufacturing company is situated in Yoro and in the hands of the Jatropha small-scale farmers, it follows that control will rest in the locality. Therefore, the Jatropha biotechnological trajectory will in this case orient genomics towards sustaining local agrarian needs, with a guarantee, furthermore, that the association of peasants will have a voice in deciding which traits of Jatropha are deemed important in the locality.

Another example is provided by the case study reported in Chapter 3 from Mahaboobnagar and Nalgonda (India), where peasants produce castor as a cash-crop. Generally,
peasants produce relatively small quantities of castor-seeds (from less than a hectare per household in which castor is intercropped with other crops, like groundnut), which they then dry and sell in local markets at a price dictated by international markets. These structures give peasants an essentially passive role as impersonal producers within the global castor production system. On the contrary, the local biotechnological development conducted around the Bt spray addressed in this thesis generates a different type of agrarian structure. In this case, a decentralized system of production units is established to develop agrarian technologies. The production of biotechnologies is performed at village level in units run by local civil society organizations and employing local youth. All actors maintaining these units are familiar and concerned both with the limited economic capacities of peasants to purchase agrarian inputs, and with the importance of such inputs for local agriculture. By establishing the production units in villages the units are exposed to the demands and capacities of the local rural societies which purchase their products. This type of social (local communal) control is strengthened with the institutionalized practices of these centres which directly involve peasants in the assessment of their needs and in the search for new agro-technologies (in tune with local economies), as well as through the employment of the local youth.

Not can only mechanisms be created, but specific technological codes can also be developed to ensure that territorial (natural and human) resources are not exploited by stronger social actors (local or external), but employed in the service of local equality. In Chapter 4, for example, we have seen that molecular markers are used within the social environment of the Wiphala Genomics to produce genetic fingerprints of the varieties developed in participatory plant breeding projects, the intention being to develop property frameworks which protect new varieties based on native materials. With the development of the fingerprinting, commercial firms will not be able to use these materials without the permission of peasants, who will be the owners in strategic partnership with the local research organization. Although as yet little developed, this application of molecular markers might become the cornerstone of a new code of technology with the potential to protect local resources.

Technology is one of the structures that reproduce territories. It is another political arena where struggles of inclusion and exclusion are fought. Involving the dwellers of a locality in the decision-making process about the future of a territory (its constant reterritorialization) is a complicated business, but effective in striking a more evenly distributed balance of power in processes of change (Magnaghi 2005b). The biotechnological futures and the futures of territories are usually bent to those social actors with access to the negotiations. These futures become more diverse, fascinating, and fair when less powerful stakeholders acquire a voice in those negotiations, have a say in the direction of development, that is, when they gain power.

6.5. Challenges and follow-up research questions

This section outlines recommendations for further research. Building on the case study analyses and on the conclusions developed in this chapter through the three domains of the thesis’ central concept, it elaborates the challenges and opportunities concerning the local specific development of biotechnologies and genomics. The research scope of this study points to the need for further research for the elaboration of these challenges and opportunities. This research has sought to
highlight the appropriateness of some agrarian genomics applications for certain peasants’ agrarian problems and the local strategies employed to govern genomics. The analyses of the cases provides a positive perspective on these topics. However, there is no doubt that there are significant and identifiable challenges to the potential for improvement of ‘local sustainable biotechnological developments’ as a research method and as a desirable biotechnology developmental path.

Some of the areas recommended for further work include:

**Develop sustainability criteria for local sustainable biotechnological developments**

Although substantial work is conducted internationally on sustainability criteria for the industrial application of biotechnologies in large-scale production systems there has not yet been a corresponding body of systematic research undertaken for the locality specific development of biotechnologies. Work on filling out such criteria might assist in improving the redesign of sustainability (social and natural) of future biotechnological developments within small-scale and low-input agrarian systems at local levels. Moreover, it could also offer an opportunity for the juxtaposition of opposing paradigms in the currently polarized global biotechnology debate. Ideally, this will result in a democratization of biotechnologies and of genomics assisting the development of a range of alternative trajectories to the now established developmental path, which is generally focussed almost exclusively towards large-scale and commercial agrarian systems and in which production is dominated by Western business. This will lead, hopefully, to a more balanced process of technological decision-making. The cases analyzed in this thesis as well as some of the frameworks and approaches employed could make a significant contribution to such a process.

**Work on the incentives and constraints faced by peasants/rural people in respect of their participation in biotechnological developments**

Actually, when we start to think of how peasant agrarian systems could be strengthened, we might well think first of other issues or technologies than agro-genomics. Health care, schools, or ownership regimes to guarantee peasants access to land and water are obvious examples of things that would appear to be more directly relevant to peasant needs than the development of cutting edge biotechnology. The hype over genomics seems to have reached even the world’s poor, at least through some concrete projects, and certainly at the academic level. Indeed, this PhD research project is a case in point. Genomics can indeed strengthen peasant agrarian systems after a reorganization of its institutionalized power structures. But it is not the only tool, and definitely not the most important for sociologists and philosophers, or for funding agencies making use of public investments derived from tax revenues. For publicly and privately financed researchers the aim of making poverty history is indeed a worthy intellectual endeavour, but whether the locality specific redesign of agro-genomics is the route for this is, of course, highly questionable. To this end, the potential and practical role of local sustainable biotechnical developments within various agrarian systems in respect of other developmental courses of action – including how local sustainable (biotechnical) development might be integrated into or happen to develop synergies with other approaches to empowerment or poverty alleviation – is suggestive of fascinating possibilities and certainly a matter for further investigation.
Develop more detailed territorial differences for the analysis of biotechnological developments: Develop understanding of the cases further from an equity and gender perspective

The case studies research scope allowed for a focus on some local redesign strategies primarily at the ‘group level’. It is unfortunate that peasants, civil society organization practitioners, and researchers have not been more finely described, leaving them presented somewhat as homogenous social groups with identical interests. The motivations, capacities, and impact among these groups and of the different individuals within them can, of course, vary considerably. One obvious, major concern that has not been explicitly addressed in this research is that of gender. An analysis of the relevance of local sustainable biotechnological developments for women in terms of their impact and issues of social power has not been conducted. An extension of this research through a gender studies perspective on the initiatives here presented and analyzed will add important information to that already developed. As women constitute the poor within the poor, a redesign strategy for biotechnologies which empowers this social group (once again, recognizing its internal social and individual differences) should be highly valuable.

Also, at the ecological level of territory, it is highly recommended that a further understanding on the mutual shaping processes of local societies and their environments be developed. Only through a previous assessment of these specificities can genomics knowledge and technologies be optimized for and within the pre-existing and usually well adapted agrarian practices of peasants. That type of research is particularly pertinent as the unpredictable and apparently quickening effects of climate change could throw local agrarian systems out of balance; agrarian genomics might be hoped to facilitate the necessary adaptation to these changes, through, for instance, the production of varieties suitable for the newly emerging environmental – and social – conditions.

Develop more detailed technological differences for the analysis of biotechnological developments

Foucault (1977) explains in his theory of ‘power/knowledge’, that modern forms of oppression are not so much based on false ideologies but on the specific technical ‘truths’ which form the basis of the dominant hegemony, and which reproduce it. Thus, to the extent that the contingency of the ‘truth’ remains hidden, a deterministic image of a technologically justified social order can be – and is – projected.

At the level of what the agrarian applications of genomics can do, the narrative presented in this thesis might lead to the elaboration of an argument suggesting, for instance, that genomics knowledge and technologies first can enhance our genetic understanding and access to biodiversity, which will facilitate our choices of individuals (e.g. plants) or specific DNA sequences (like those concerned with desired features for crop improvement) through the application of molecular technologies within plant breeding activities. This technological path can be found reproduced also in specialized scientific literature as a logical route for the deployment of genomics within agriculture (e.g. Dekkers and Hospital 2002, Delmer 2005, Yano and Tuberosa 2009). This represents what Foucault might call a technological truth. Different trial and success-failure experiments, socio-technological futures imagined and designed by the scientist elites, or just the economic interests of agribusiness will combine to consolidate or debilitate this developmental path. Further critical studies aimed at analyzing the effectiveness and multiple consequences of technology are required in order to gain a better understanding of
what genomics really can do for peasants. The extension of the territorial approach for the study of genomics as it has been outlined here can uncover that truth, demystify a possible illusion of technological necessity, or nuance concrete genomics applications and their required social reorganizations for the specific ecological, social, and technological characteristics of an agrarian system.

**Develop more detailed understanding of local-global dynamics**

The capacity to govern biotechnological developments does not depend only on local networks and dynamics, but also on global ones. Massey (2007; p. 21) argues that an imaginary of territory which focuses solely on its internal construction, and thereby obscures the potentiality of an outward-looking local consciousness, identity and politics, fails to take account of those relations that run out from a territory – that help construct its identity and on which it depends. In Massey’s analysis of the city of London, for example, she says that most analyses focus on the internal hybridity, or the triumphs of finance, without imagining the wider global geographies which they are set (ibid.). She goes on to argue that the view of ‘the global’ as no more than an aggregation of ‘locals’ can also be related to a counterposition of local and global in which the local is revered as the hearth of authenticity, real lives, cultural wealth, and so forth, while the global is imagined as some kind of place-less realm (a ‘nowhere’) which, by contrast, is powerful, inauthentic, somehow abstract (ibid.). In such an imaginary the local is perpetually the victim of the global. Global forces arrive from ‘elsewhere’ and wreak havoc on a previous local embeddedness. And often – in territory after territory in the global South, in devastated mining and manufacturing areas of the global North – this is not an unrealistic reading (ibid.). The response to this situation tends to be a spontaneous defensive effect of the local territory. This oppositional inequality and the attitudes it encourages has generally been implicit here. But I hope that a parallel narrative emerges also, that the global is locally produced, and that global forces, especially within science and technology developments are just as material, and real, as is the local embeddedness. Massey argues that ‘some places are the seat of global forces. And in such a situation it may be the local place itself – what it stands for, what its identity depends upon –that must be challenged’ (ibid.; p. 21). Territories and technologies are the consequence of the coalescence of global and local forces. If territoriality and technology as analytic dimensions are anything, they are the dimensions of coexisting actors and their strategies, dimensions that require and enable their own multiplicity. The dwellers of territories and the global or local developers of technologies are condemned to collaborate. Further case-related research is required to understand these bidirectional dynamics.

**Replicate and test the approaches taken in the case studies in other suitable contexts**

The information provided in the case studies and the way that it has been approached and analyzed, although incomplete, will certainly provide ideas and insights for models, practices, and technologies which might be replicated in other biotechnological developments in different localities. This with the purpose of highlighting the social forces that are writing the code of genomics and at the same time of highlighting the strategies of social multi-stakeholder networks that are struggling to reconstruct and reorient the deterritorializing developmental path of genomics. Engaging in such reflective research together with participatory (action) research methodologies would provide valuable feedback on replicability and applicability, which in turn
could help verify or modify the three domain analytic approach. This also includes the following area for further research.

**Consider local sustainable biotechnological developments as a referential framework for the design of new biotechnological trajectories – drafting the territorial route-map of genomics**

Maps are visual representations of space, real or conceptual. Real space is usually depicted in a way that is geometrically accurate (to scale), and often features symbols for natural features (such as lines for rivers), or political and social characteristics (e.g. lines for national borders and roads). These latter types of representation introduce a rudimentary concept of territory, with a conceptual (social) space grounded in the real (physical). Because territory has a conceptual reality grounded in yet transcending beyond the physical, it might be mapped better by schematics, like the use of differently sized representative symbols occupying areas on maps of production – with, for example, images of towers to represent petroleum production sites, or ears of corn for cereal output, etc. (Allen and Massey 1995, Allen, Massey and Cochrane 1998, Magnaghi 2005b). This type of representation, however, is still very basic. Most fundamentally, territory is interpreted as merely as a support for economic activities, in which everything without function goes unrepresented.

It seems immediately apparent that territory is such a complex concept that any visual depiction, any mapping, is going to be selective and simplistic. Our interest in genomics might suggest a different type of schematic, a flow diagram of biotechnical exchange – showing, for example, R&D coming from the West – but this type of biotechnological route-mapping will still fail to capture the essence of territory and will thus come nowhere near depicting a territorial route-map of agro-genomics developments. For this, we need to start with the territory, and with the specific qualities of the locality that establish – through the energies of societies – the specific style of local sustainable development. Clearly, the description and interpretation of these qualities become the central themes of the map (Magnaghi 2005b: 90-92). In other words, the idea of a territorial route map of genomics is essentially metaphorical. Rather than a pictorial representation, we use words. The direction of development is shown by, for example, the case studies reported here.

In the map that we have drawn of genomics within development, we have tried to investigate the trajectories that are orienting genomics towards problems and actors that usually do not appear on biotechnological route-maps – such as in the case of the development of pesticide products suitable for the conditions of peasants in the dry land agriculture of Mahaboobnagar and Nalgonda in India, or the search for desirable traits that might help solve the multiple problems of peasant’s potatoes in the highlands of Cochabamba and Norte de Potosí. These trajectories are not fully designed yet. The reports of the three case studies thus represent the points at which the route-map of these biotechnological developments has arrived. We have tried to imagine how that trajectory might look like if continued. A case in point is the argument developed in Chapter 4, that certain participatory plant breeding networks would be appropriate social platforms for the further territorialization of molecular markers for marker assisted selection in the small-scale potato production systems in the Bolivian Andes.

Biotechnologies, from the perspective developed here, are conventionally decoupled from territorial parameters – i.e. deterritorialized. This is done in order to maximize profit or to propose one-dimensional, silver-bullet solutions for complex problems. Technologies are developed in one place (in the physical and social map) and transferred to other places. While, our territorial route-map of agro-genomics developments is filled with the qualitative social
aspects of technology and of territoriality. In our case studies, the biotechnologies are developed territorially; that is, there has been a location specific power exercised on the biotechnological development aimed at addressing a relevant agrarian problem of peasants, and local actors have been empowered within these types of developments. The types of schematic diagrams given in Chapter 3 and 4 depicting the social networks involved in the biotechnology developments analyzed in the case studies do, therefore, comprise a visual representation of an important aspect of a territorial route-mapping of agro-genomics developments. An aggregation of social groups constructs the socio-technological structures of these technologies and writes and rewrites their codes – their route-maps.

The question I would like to answer in this closing section concerns the consequences that the extension of the metaphor of drafting of territorial route-maps might have for developing the agrarian applications of genomics locally and sustainably. Within these parameters, to plan a route-map for genomics means to recognize the social and natural founding features of territories and the social and material founding qualities of technologies… to smoothly integrate technological systems within multiple and diverse social dynamics that construct and develop specific agrarian territories. To integrate genomics in the reproduction (or reterritorialization) of territories. This requires that science comes down to earth, and that scientists from all disciplines reflect on their social embeddedness and get (socially) dirty hands by looking at relevant human problems rather than orienting research questions to profit making through the commercialization of sciences. At the same time, however, the extension and integration of multi-stakeholder networks should also include globally relevant scientific actors. This requires a continuous process of centralization and decentralization of knowledge fluxes.

The territorial route-map of genomics cannot be simply an administrative bureaucratic tool. It can not be simply designed by local or international administration offices, or research institutes, and/or funding agencies working with a single ‘silver-bullet’ solution. This new route-map transforms the activity of ‘administering’ just a place, a technological development, or its transfer, into a self-management process of territories and of biotechnological developments.

The agents of change of this shift from administration to self-management, might be the aggregation of social groups in multi-stakeholder networks similar to those of our case studies. During the coalescence of self-managerial activities for the territorialization of biotechnologies, these networks and their actions become socio-technological structures that promote a reterritorialization which in turn reflects and reproduces these same political and politicizing self-managerial capacities of territoriality. Feenberg (2003; p. 664) argues that a relevant question concerning technology and power is: ‘Why has democracy not been extended to technically mediated domains of social life despite a century of struggles?’ which he pursues with the rhetorical follow-up, ‘Is it because it has been used to suppress it?’ Feenberg’s answer is to assert that ‘The weight of the argument supports the second conclusion. Technology can support more than one type of technological civilization, and may someday be incorporated into a more democratic society than ours.’
6.6. Epilogue: Anarchotechnology, the technologies of freedom

‘Today is the future’
(La Polla Records)\(^{214}\)

Feenberg’s conception of a technology incorporated into a more democratic society, a radically different form of technological civilization, finds expression in the (utopian?) future vision of anarchotechnology and technoliberation, with its free use of technologies by free citizens that has led to the possible development of a free and sustainable new world…

Today (2055), the technoliberatory theories, ascribed among others to Muteba Kazadi – poet, ICT engineer, sciences liberator and Zairian former minister for development\(^ {215}\) – maintain that technology can become a vehicle for the development and liberation of all human beings. These theories argue also that before that technology should first be taken from the hands of those who have used it in an exclusive and elitist way. This concentration of power has resulted in the majority of humanity being excluded from fully understanding, and utilizing the power that technological applications have. They speak of a domination exercised by the scientist elites who use technologies for their own benefit (and that of their companies) and who deny others access to fundamental technologies such as vaccines and other medicines, or biotechnological applications for agriculture. Therefore, one of the demands of technoliberation is free access to scientific and technological knowledge and applications. One of the strategies to secure this demand is to liberate biotechnologies, gene sequences, organisms, medicines, and any other relevant technology from patents and their property frameworks. It is not just a coincidence that an African is found at the core of such an approach, since, it is indeed the poorest continent that has been hardest hit by the elitist policies of the technology monopolies. Technoliberation not only argues for the recession of patents, but also for the public control and socialization of all communication technologies and of biotechnologies without legal, gender, ethnic, or national restriction.

Technoliberation is not just another radical theoretical approach, however, for it is also a radical social movement – and radical in the sense of the word’s etymological origin, the Latin ‘\textit{radix}’, or ‘root’, going, that is, to the root of the problem, and instigating changes at the roots of society. Inspired by the radical writings of Technoliberation, an initial group of primarily pan-African men and women has been joined by a larger international set of anarchists and technopirates in the group Free Science Pan-African Union (FSPAU). Some years ago, FSPAU militants were able to get themselves contracts with some of the largest North American biotech multinationals. Contra-information websites run by libertarian groups reported that the infiltration was successful in the Californian biotech company EnGeneUity, and some of these anarchists were able to escape with the knowledge and some engineered cells they themselves had produced during long hours of work in the company labs (a brain drain you may say, but in

\(^{214}\) La Polla Records was a Basque punk band.

\(^{215}\) Muteba Kazadi claims that for ‘the use of knowledge in the service of freedom’; he had called for an end of the patenting of engineered crops, public ownership of communication resources, and a universal right of access to scientific information. As well as championing the obvious pragmatism of ‘liberation biology’ (though Zaire had never gone renegade and used unlicensed crops), he had spoken for the long-term need for African nations to participate in pure research in every area of basic science.
the opposite direction as what we are accustomed). The technopirates not only escaped the EEUU authorities and from the clandestinity announced their intention to free their knowledge in the web, but have also been able to put that knowledge into practise. The biotechnology they first produced and then expropriated from EnGeneUity was engineered coral cells, easy to reproduce and use as building blocks to create uniform artificial structures. The strength and plasticity of the technology is such that after years of experience skilful biotechnologists are now able to build coral bridges and houses.

Recently, the libertarian movement has used the liberated technologies and built a coral island in international waters. The artificial island was anchored to an unnamed guyot – a submerged, flat-topped, extinct volcano – in the middle of the South Pacific, and named Stateless. From Stateless there has been a call to all people who do not feel free in their countries, who share totally or partially the principles of technoliberation and who desire to construct a libertarian society aimed at the correction of human multiple hierarchies and nationalisms. The people of Stateless are developing a whole new set of free biotechnologies allowing them to produce their own food and buildings, and they are also engaged in sharing their knowledge and technologies with others around the world...

This scenario forms the background to the science fiction book ‘Distress’ (Egan 1995). That it is presented in a science fiction format does not mean that the proposal is not valid. It is as amazing as it is comprehensible that there are so many contradictory feelings, dreams, and ideas projected around (bio)technology. Technology has enabled our survival in the biosphere for millennia, it is as intrinsic to the human condition as love or power. The challenge we now face is how to deal with the technology we are developing, a question that raises issues just as profound as those associated with the perennial human experiences of power, or love, and which thus invites the inclusion of technology with power and love in existential questions. How does love, power or technology work? Who has them? And who knows how to extract the best out of them? What should we do to maximise their potential for humanity?

Magnaghi (2005b; p. 117) elaborates an argument concerning the role that utopian socialism can play to concretize the design of strategic planes for the Utopia, and of the feasibility of such a future. In this context, he argues that Owen and Fourier brought about a deep change in the role of the utopianist, developing it into offering a vision of the future that was placed not only within a real time framework, but also in the context of an appreciation of the social parameters necessary to accomplish it. In utopian socialism, the reference point is the strong social aggregation (the labour of subordinate classes). The case studies analyzed here can be seen as utopianesque experiments, in which a diverse set of social groups aim to claim the future, now, by territorializing the agrarian applications of genomics. This takes place against a background in which the apparently utopian strategies are beginning to emerge as alternatives to the mainstream developmental path of genomics. We can see these dynamics as an attempt to create spaces for social action, as visions of the future where democratic and territorial social and technological strategies and partnerships are designed and practiced. Within these strategies, one set of social actors and relations are working at the molecular level, within complex societal, organizational, institutional and technological structures, writing the multiple routes of Local Sustainable Biotechnological Developments, writing the codes to generate the technologies of freedom.
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Redesigning Genomics – Reconstructing Societies

Recursos genéticos de papa, raíces y tubérculos andinos, Cochabamba, Bolivia: IBTA, PROINPA, IBTA-CIP-COTESU:


Summary

Genomics is a brainchild of the high-tech, knowledge intensive mode of production of Western economies. Not surprisingly, within agriculture, the developmental path of biotechnologies generally and genomics in particular is dictated by agribusiness and public research institutes generally based on the Western world, and mainly oriented towards commercial agriculture. The great mass of the world’s poor and the rural structures they inhabit and operate, peasants and their agrarian systems, are typically excluded from this developmental path. In this thesis, this type of development is labelled *determinitalizing* (in Chapter 1). It is determinitalizing insofar as it excludes the local people and their socio political structures from the biotechnological decision-making process. In the rural third world, furthest from the techno-economic centres of power, this means that peasants, civil society organizations and local researchers have little or no voice in science and technology R&D processes that may affect them more than anyone. As a consequence, when genomics is presented as a technology which could work for development, an approach based on the straightforward transfer of technology is usually assumed as the means to achieve this.

Taking this analysis as normative, our present day conventional reality, the present research has searched for alternative, *territorial trajectories* for the development of biotechnologies aimed at strengthening peasant agrarian systems, and at empowering local groups within biotechnological systems. These territorial alternatives are captured under the concept of *local sustainable biotechnological developments*. Local sustainable biotechnological development is defined as *a type of development based on the reconstruction of biotechnologies mainly (though not exclusively) by and for local actors, and which strengthen peasant agrarian systems and empowers peasants, civil society organizations and local researchers within biotechnological structures.*

Local sustainable biotechnological development is described (in Chapter 2) as encompassing two core elements – *(bio)technology and territoriality. Technology* is here defined as a social structure, a system formed by social and material elements, which has politics. This builds on Critical Theory approaches to technology (e.g. Andrew Feenberg), and forms of constructivism, including Social Construction of Technology (e.g. Wiebe Bijker, Thomas P. Hughes and Trevor Pinch), Social Shaping of Technology (e.g. Donald MacKenzie and Judy Wajcman), and Actor Network Theory (e.g. Bruno Latour). The theoretical frame of reference for the politics of *biotechnologies* is concerned with the historical processes of the industrialization (e.g. David Goodman, Bernardo Sorj, and John Wilkinson), scientification (Jan Douwe van der Ploeg) and biotechnologization (Guido Ruivenkamp) of agriculture. This research suggests that rather than assuming a unilinear path for the development of *(bio)technologies (the dominant conventional path described), multiplicity and variety may be considered feasible, with different technological trajectories applicable and appropriate for different – and within – given territory(s).

*Territoriality* is formed by two main elements, power and locality. Within the context of biotechnology development, territoriality is here defined as the power exercised by local actors on biotechnological developments. In this regard, the conceptual frameworks employed are territoriality (Robert David Sack, and Alberto Magnaghi), alternative development approaches (Alberto Magnaghi, Björn Hettne, or John Friedmann), and tailor made biotechnologies (Guido
Redesigning Genomics – Reconstructing Societies

Ruivenkamp). In this context, the case studies addressed here are presented as illustrations of biotechnological developments that can strengthen peasant agrarian systems, and in which power is, to a certain extent, exercised by local actors.

The concept Local sustainable biotechnological developments is situated at the intersection of territory and biotechnology; it is concerned with the exercise of power by local actors on biotechnological developments. It is argued here that a territorial approach to biotechnology development should consider at least three interrelated analytic domains:

1. The territorial domain concerns the social dimensions of power and locality for the development of biotechnologies. It involves the study of the socio-political dynamics engaged by multi-stakeholder networks to address the agrarian problems of peasants in a given territory through biotechnology. It tests the horizontality (the, to a certain extent, non-hierarchical structuring) of the social relations between the different social groups involved in biotechnological developments by looking at whether and how (mainly) peasants, civil society organizations, and local researchers are included in them.

2. The technological domain analyzes power and the material dimensions of technology. It explores the material changes that are required for the local specific (territorial) development of biotechnologies. Actually, insofar as the material level is partially a function of the political (qua the power dimension of technology), it is closely interrelated with the social, the two are co-constructive of each other within socio-technological structures. They are differentiated and considered here separately purely for ease and clarity of analysis.

3. The reterritorialization domain focuses on the empowerment of territories regarding biotechnological developments. It studies the position in which ‘local sustainable biotechnological developments’ place the territories where they occur in respect of future negotiations for biotechnology development. In this way, it reflects on how the process of territorializing biotechnologies generates new socio-technological structures which strengthen peasant agrarian systems and the position of peasants, civil society organizations, and local researchers within biotechnological structures. It also reflects on the new dynamics that this type of development brings about within the historical context of an increasing industrialization and biotechnologization of agriculture.

There have been many theoretically based studies that argue that genomics could invigorate the agrarian practices of peasants, but rather less research has been conducted into the actual application of genomics within specific peasant agrarian systems. This research has attempted to contribute to filling the gap in this area by studying the potentialities and challenges that emerge from the development of certain biotechnologies within specific peasant territories. Three case studies have been analyzed.

Case 1 (Chapter 3): Territorializing the production of a Bacillus thuringiensis biopesticide within the context of peasant agriculture in Andhra Pradesh, India

This case study explores the development of biopesticides for pest-management in the peasant agrarian systems of the semiarid districts of Mahaboobnagar and Nalgonda, in the state of Andhra Pradesh, India. In these territories, the main cultivated crop is castor (Ricinus communis), and the castor semilooper (Achea janata) one of the most important pests. The majority of chemical and bio-pesticides available in the locality to address the problem of the heavy losses to castor
production caused by the semilooper are unaffordable and/or unsuitable for peasant practices. This case study looks at how the human and material resources of the territory are mobilized to address castor semilooper through biotechnological means. Based on local strains of the soil bacteria Bt (Bacillus thuringiensis) effective against the semilooper – strains studied with genomics technologies –; multi-stakeholder networks of peasant groups and civil society organizations, public research institutes, and agricultural extension systems have developed a new process to produce a Bt-spray to manage the pest which is cost-effective and which requires small-scale technical capacities that can be reproduced at the village level. Further to this, a decentralized system of production-units has been established in some villages to manufacture and distribute the Bt-spray. A system employed also for the manufacture of other biopesticides and biofertilisers which are adapted to local needs and capacities.

This case study also focuses on the material redesign process of production of Bt-biopesticides in the form of sprays. Bt-sprays are normally produced by a liquid-state fermentation process, but the network has developed a new production process employing a solid-state fermentation. This redesign makes possible the production of the Bt biopesticide at the village level in the aforementioned production units. The case shows that the social and material rearrangements around the Bt-spray create a new understanding, both of the territory and of the development of biotechnologies. Biotechnologies are not longer created far away and ‘parachuted’ into peasant territories, but are developed from the bottom-up, according to the local perception of needs and assessment of optimum techniques and procedures by local peasants, and civil society organizations, empowered, thereby, in the development of pest-management technologies, and also within their own territory.

Case 2 (Chapter 4): The Wiphala Genomics: the territorialization of molecular markers in small-scale potato crop systems in the Bolivian Andes

The second case study addresses the deployment of molecular markers within the small-scale and highland potato crop systems of the departments of Cochabamba and Norte de Potosí in the Bolivian Andes. In these territories, the wealthy diversity of peasants’ potato varieties is essential for the survival of peasant households, as this diversity is used strategically to produce potatoes in the high-diverse ecosystems of the Andean Highlands. Moreover, potato diversity also has an important cultural meaning for the Quechua and Aymara populations living in these territories. Unfortunately, this diversity is apparently decreasing.

This case study outlines two contradictory understandings of potato diversity. On the one hand, potato biodiversity is understood in terms of raw materials, according to which peasants’ varieties have no intrinsic value, the value of (new/different) varieties being something created (added) by breeders in breeding projects. On the other hand, biodiversity is understood as cultural material, according to which, potatoes are final entities produced by peasants and which therefore do have an intrinsic value. It is argued that the development of biotechnologies aimed at addressing the problems of local varieties would be beneficial from the territorial perspective of community survival and empowerment as well as the global perspective of maintaining (developing) diversity. Therefore, it is suggested that the deployment of molecular markers within the cultural understanding of biodiversity – termed the ‘Wiphala Genomics’ – has potentialities to address some agrarian constraints of resource-poor farmers. Furthermore, some participatory plant breeding networks are found as appropriate social platforms (environments) for the deployment of molecular markers, platforms which are already shaping the Wiphala Genomics.
This case study also explores the material readjustments that molecular markers need to undergo in order to be able to properly perform within the Bolivian territories. Ultimately, the reflection has to consider the current reality of how, when molecular markers are deployed within a raw material understanding of diversity, peasant potato varieties are extracted from the territory and appropriated by global networks to serve as a basis for plant breeding outside the territory for ends that, predictably enough, do not serve the territory itself. Within the social environment for the development of the Wiphala Genomics, however, Quechua and Aymara peasants are empowered, and the conservation and development of potato genetic variety and productive diversity are strengthened. By deploying molecular markers with a specific social and technical code the developmental capacities of these Andean territories can be strengthened.

Case 3 (Chapter 5): Biotechnologizing Jatropha for local sustainable developments in Yoro, Honduras

Against the background of an expanding biofuels regime within agriculture, the third case explores the ongoing efforts of local multi-stakeholder networks formed by peasant groups, NGOs, and research institutes in the department of Yoro, Honduras to give a new energy meaning to *Jatropha*, a shrub-like plant traditionally used more for other purposes (such as in ‘living fences’ for cattle, for soap production, and medical usage). The socio-political organizational structure – the Gota Verde network – that has been constructed for the local and sustainable production and consumption of (Jatropha) biofuel is examined.

This case study also addresses the scientification and biotechnologization process (through genomics) that Jatropha is presently undergoing. With this purpose in mind, a focus is placed on a global oriented genomics network that is working with the plant. Coordinated from the Netherlands, this network is engaged in collaborations with local networks (including the Honduran Gota Verde network) which might lead to an improvement in the local production of Jatropha. Emphasis is given to a detailing of the interaction between these two networks; that is, the analysis here concentrates on how the scientification and biotechnologization process that Jatropha is undergoing might strengthen the local development in Honduras.

Chapter 6 unfolds the conclusions extracted from the case studies in the aforementioned three analytic domains to develop further the concept ‘local sustainable biotechnological developments’.

Territorial domain

*Local sustainable biotechnological development* is an act of territorializing biotechnologies and therefore, genomics. This research argues that the act of territorializing biotechnologies is an act of exercising local power on biotechnological developments. Following Foucault, the suggestion made here is that power is not possessed (like a substance), but exercised (as a dynamic) by a certain organization of social relations. Therefore, a reorganization of social relations can transform power within biotechnological structures. To begin with, if biotechnologies and genomics are to play a role in strengthening resource-poor farmer agrarian systems, then, the social structures that apply and reproduce these technologies and these sciences need to reorient them toward specific problems affecting those agrarian systems. So far, there have been few relevant genomics developments in this area. Through the involvement of local actors and agrarian systems in biotechnological developments, we see in the three case studies analyzed here
how multi-stakeholder networks are nevertheless addressing some relevant peasant agrarian problems in specific territories.

The three local biotechnological developments addressed here have all been activated by external financial sources. International funding in agrarian biotechnology usually supports impact oriented projects in third world regions around what are seen as relevant global issues. For this reason, it can hinder local research agendas built around locality specific aims. In order to avoid this, it is argued, funding agencies ought to support research structures rather than particular projects. In this way, science could support and facilitate a more sustainable development in these regions of the world. In the facilities of local research structures, new research questions can be elaborated and answered in the form of locality specific research (like the Wiphala Genomics). The research organizations and policy makers of low-income countries, the argument continues, should elaborate strategies based on local conditions and problems with which external agencies can align their research funding. By decentralizing and building local research capacities, sciences and biotechnologies can grow within and strengthen the multitude of existent local agrarian systems. In fact, it is only through such a decentralized system development that genomics knowledge and technologies can be properly translated into locality specific applications to the benefit of resource-poor farmers (as opposed to being merely transferred and of questionable benefit, or worse).

Many scholars have argued that science and technology developments are highly context dependent and value laden, and that therefore a wider set of actors needs to be engaged within these developments. The engagement of a wider set of social actors in science and technology developments is not only morally desirable, but can also be more efficient. In the case studies analyzed here we see three multi-stakeholder networks aimed at territorializing genomics’ scientific knowledge and biotechnologies within peasant agrarian systems. These networks are breaking through the common monopoly of power on genomics knowledge and technologies exercised by formal scientists in expensive labs. Working in and with the networks explored in this thesis are molecular biologists, plant breeders, agronomists, social scientists, peasants, and civil society practitioners. Different types of information flow through these networks and are translated into different types of knowledge, or into practical technological applications (the local specific Bt-spray, Wiphala Genomics, and Jatropha biofuel). Given that the regular social relationships that structure agro-genomics socio-technological systems are usually unable or unwilling to orient their technological capacities towards peasant agrarian systems, it follows that they – the social relations – need to be restructured. The three case studies addressed outline alternative trajectories for doing so. These trajectories involve including a wider set of social actors (e.g. peasants and civil society organizations), and facilitating the share of knowledge through the democratization and decentralization of science and technology developments.

Technological domain

Power is exercised not only through social relations, but also materialized into apparatuses. Therefore, in order to democratize the power exercised on biotechnologies, not only is a reorganization of the social relations organized around biotechnological developments required, but also some material readjustments are needed. Among the material changes analyzed in the case studies, there are some that respond to the incompatibility between genomics functioning requirements and local conditions. Genomics related technologies are usually expensive and often require high specialized skill competences that often cannot be met in low-income labs. These types of changes, it is argued, make the territorialization of genomics an unavoidable step
for such labs, which are frequently the ones that support peasant agrarian systems. A different way of perceiving these material changes addressed here is that they are required for governing genomics from within the locality. For instance, in Chapter 3 we see that in order to be able to produce a Bt-spray that is affordable, accessible, and feasible at village level, the industrial approach for producing Bt-sprays in which Bt spores are multiplied through a liquid-state fermentation has been transformed into a solid-state fermentation. The material changes provoked by the redesign process facilitate the production of the Bt-spray at village level and a decentralized system of production units has generated a new technical code, which includes peasants, civil society organizations, and local researchers and which effectively manages an important pest affecting local agrarian systems. Similarly, Chapter 4 explores some material and clever readjustments that local researchers are implementing in their molecular biology lab in Cochabamba so as to deploy and control genomics – such as the production of local polymerase and ethanol, and the use of conventional kitchen refrigerators rather than the expensive refrigerators recommended by scientific protocols. These types of changes and adaptations are expected in the large majority of molecular biology labs with low economic capacities.

When it comes to deploying high technologies such as genomics within low input science and technology systems that look after resource-poor agrarian systems, a combination of different types of knowledge (formal and informal) and of technologies (high and low tech) becomes necessary. Genomics in isolation of other technological system is useless – and most especially for the types of science and technology structures that usually support the agrarian systems of peasants. The Bt-network presented in Chapter 3 is a fascinating example of how low technologies become a vital step in linking genomics developments with peasants’ practices.

Due to the complexity and high cost involved in genomics practices, this research argues that a combined dynamic of research and technology facilities centralization and decentralization seems to be necessary in order to link peasant’s fields with genomics labs. In this context, the expensive development of molecular markers, for instance, might best be centralized. This can save costs and guarantee access to some ready-made technologies. However, such centralization does require that the research institution working on genomics development remains in contact with plant-experts all around the world so as to guarantee that the markers that they discover are indeed relevant for specific localities and available in local accessions that show good combining ability with elite cultivars. In contrast, it is the decentralized system of Bt production units in Andhra Pradesh that guarantees peasants access to agrarian technologies and, moreover, the exercise of power on biotechnological developments. The decentralization of science and technologies also results in labs such as the one in Cochabamba (Chapter 4) experimenting with, for example, molecular markers and thereby generating locality specific alternative biotechnological developmental paths (the Wiphala Genomics). The equilibrium between centralization and decentralization in respect of science and technology developments might generate new dynamics for their territorialization and democratization.

The local specific redesign of biotechnological codes in which a particular reconfiguration of social forces is aimed at defining a specific road to technology development might appear to some as an intellectual attempt to substitute technological determinism (implicit in the technology transfer approach) with a kind of social determinism. While the social contingency of technologies is fundamental to the theoretical analysis developed here, this is not something that operates in isolation: technologies are also the result of social and material mutual adaptations. Nevertheless, the participation of subordinate social stakeholders in the struggles of writing biotechnological codes can change outcomes. If peasant agrarian systems with their
potencies and deficiencies, their peasants, civil society organizations, local communities, and researchers are considered and given a voice in the decision-making process of agrarian genomics, the probability that genomics will strengthen these systems and that these actors will be empowered within the resulting biotechnological structures is greatly increased.

Reterritorialization domain

Critical literature has studied the structural power that the industrialization and biotechnologization process of agriculture has brought about. Goodman, Sorj, and Wilkinson explore the industrial appropriation of farmers’ activities like pest or soil management by external institutions, and a parallel development of industrial substitution for rural products; Van der Ploeg explains how through the process of scientific agriculture, agrarian activities and farmer labour are becoming increasingly controlled by scientists’ knowledge; while Ruivenkamp argues that through this scientification a process of biotechnologization has taken place in which control at a distance is exercised on agrarian labour from the scientific domain through the introduction of politicizing products. Together, these historical processes have led to a loss of autonomy on the part of farmers in the performance of their agrarian practices.

The content of technology, it is argued, is not essentially destructive; rather, it is a matter of design and further deployment into the social. Agrarian and scientific networks are not just mere receptors of technologies, and therefore they do not automatically reproduce the politics encoded within the technology design. The multi-stakeholder networks analyzed in the three case studies are shown as challenging this structural power of biotechnological developments in the realm of agrarian activities and, to a certain extent, are reversing it towards local sustainable developments. For instance, the industrial appropriation of farming activities is challenged by the self-organized practices of local multi-stakeholder networks. The reorganization of the available natural and human resources in Mahaboobnagar and Nalgonda (Andhra Pradesh, India) has been self-managed by the local actors, who, instead of participating in a technology transfer structure and waiting for the next parachuted pesticide technology, have challenged it collectively and politically. The networks ‘hacked’ into the biotechnological system and turned it to new purposes. Their struggle represents a counter-tendency to appropriationism, an attempt to rediscover the caring and communal functions of biotechnology development – caring for the local agrarian problems of peasants, and building new forms of communality in which (bio)technologies (their development) are seen and employed more as catalyst than as a challenge to local development.

The control at a distance exercised through the scientification and biotechnologization processes is somewhat reversed by a local specific power exercised over biotechnological developments and agrarian labour (territoriality). The cases of the Bolivian Andes and of the Honduran Yoro show how the construction of horizontal global-local structures through which knowledge and technologies can be shared are able to facilitate the development of appropriate and efficient local specific biotechnologies – like the Wiphala Genomics. The demand for, and the practices of communication and democratization of biotechnologies that these movements represent is so fundamental that it can serve as a touchstone for the claim made here for the polypotency of scientification and biotechnologization processes. These networks challenge the rationality under which biotechnologies are currently designed. They generate empowered social environments for biotechnology development. Within and through these networks, the dwellers of peasant agrarian systems become empowered engines of biotechnology and of local development.
One of the desirable outcomes of local sustainable biotechnological developments is argued to be that of social sustainability. Magnaghi defines social sustainability as a greater involvement of weak stakeholders in the local decision-making system. Translating this general definition into our biotechnological focus, we might say that the structures that direct biotechnological developments should be sufficiently complex so as to guarantee the participation of weaker social stakeholders and their needs. Mechanisms have to be created to guarantee that territorial (natural and human) resources are not exploited by the local strongest, or external social actors, and that these resources are used for local equality. One example of a type of mechanism that can be institutionalized within local developments and might guarantee the participation of social weak groups is given in the third case study. Here a co-operative company owned and controlled by the local fuel crop producers is established for the transformation and distribution of products originated from the Jatropha plant and from other fuel-crops. This type of set-up circumvents the usual process in which the produce of peasants is bought by intermediaries and sent outside of the locality for manufacture and use. Because the manufacturing company in Yoro is in the hands of small-scale Jatropha producers, it follows that the biotechnological trajectory for Jatropha through genomics studied here will orient genomics towards local agrarian needs, including a guarantee that the association of peasants will have a voice in deciding which traits of Jatropha are important. In other words, a locality specific power can be exercised on biotechnological developments (territoriality).

Technology is one of the structures that reproduce territories. It is another political arena in which inclusion and exclusion struggles are fought. Involving the dwellers of a locality in the decision-making negotiations about the future of that territory (its constant reterritorialization) is a complicated business, but effective in striking a power balance in processes of change. The biotechnological futures and the futures of territories are usually oriented to benefit those social actors with access to the negotiations. The picture of these futures becomes more diverse, fascinating, and fair when less powerful stakeholders acquire a voice, i.e. power. In order to achieve this, one of the codes that might be able to deliver significant positive results is that of Local Sustainable Biotechnological Developments.
Samenvatting

Het herontwerpen van de genomica – het reconstrueren van samenlevingen: lokale duurzame biotechnologische ontwikkelingen

De genomica is een geesteskind van de huidige hoogtechnologische, kennis intensieve wijze van productie van de Westerse economieën. Het is niet verbazingwekkend dat het ontwikkelingsverloop van biotechnologie in het algemeen en van de genomica in het bijzonder gestuurd wordt door het agrarische bedrijfsleven en publieke onderzoeksinstellingen die vooral gevestigd zijn in de Westerse wereld, en met name georiënteerd zijn op de commerciële landbouw. Het merendeel van de kleinschalige en arme boeren wordt hierdoor buitengesloten van dit specifieke ontwikkelingsverloop. Dit type ontwikkeling is in dit proefschrift betiteld als deterritorializing (Hoofdstuk 1). Het is ‘deterritorializing’ in zoverre dat het de lokale mensen en hun sociaal-politieke structuren uitsluit van de biotechnologische besluitvorming. In de rurale Derde Wereld, die het verste afstaat van de techno-economische machtscentra, betekent dit dat kleinschalige arme boeren, non gouvernementele organisaties en lokale onderzoekers weinig of geen mogelijkheden hebben om hun stem te laten horen binnen wetenschappelijke en technologische onderzoeks- en ontwikkelingsprocessen die juist hen, meer dan dan ook zouden kunnen beïnvloeden. Als gevolg hiervan, wanneer genomica wordt gepresenteerd als een technologie die ontwikkeling zou kunnen bevorderen, is veelal een directe technologie transfer benadering voorgesteld om deze doelstelling te bereiken.

Tegen deze achtergrond is in dit onderzoek gezocht naar alternatieve, territoriale trajecten voor de ontwikkeling van biotechnologieën die zijn gericht op het versterken van kleinschalige boeren systemen en op de versterking (’empowerment’) van lokale groepen binnen biotechnologische systemen. Deze territoriale alternatieven zijn gedefinieerd met het concept lokale duurzame biotechnologische ontwikkelingen. Lokale duurzame biotechnologische ontwikkeling is gedefinieerd als een type ontwikkeling die gebaseerd is op de her-constructie van biotechnologieën vooral (maar niet exclusief) door en voor lokale actoren, en die agrarische boeren systemen versterkt en de positie versterkt (’empower’) van boeren, non gouvernementele organisaties en lokale onderzoekers binnen de biotechnologische structuren.

Lokaal duurzame biotechnologische ontwikkeling wordt omschreven (in Hoofdstuk 2) als bestaande uit twee kernelementen – (bio)technologie en territorialiteit. Technologie is hier gedefinieerd als een sociale structuur, een systeem gevormd door sociale en materiële elementen, die politiek heeft. Er is gewerkt met benaderingen van de Kritische Theorie van technologie (bijv. Andrew Feenberg) en vormen van constructivisme, zoals Sociale Constructie van Technologie (bijv. Wiebe Bijker, Thomas P. Hughes and Trevor Pinch), Social Shaping of Technology (bijv. Donald MacKenzie en Judy Wajcman), en Actor Netwerk Theorie (bijv. Bruno Latour). Het theoretische referentiekader voor de politic van biotechnologieën betreft de historische processen van industrialisatie (David Goodman, Bernardo Sorg, en John Wilkinson), verwetenschappelijking (Jan Douwe van der Ploeg), en biotechnologisatie (Guido Ruivenkamp) van landbouwbeoefening. Dit onderzoek suggereert dat er eerder een verscheidenheid aan geschikte trajecten voor (en binnen) verschillende locaties is dan dat de veronderstelling van een unidirectioneel traject voor de ontwikkeling van biotechnologieën geldt.
Territorialiteit is gevormd door twee hoofdelementen, macht en lokaliteit. Binnen de context van de ontwikkeling van biotechnologie, is territorialiteit hier gedefinieerd als het uitoefenen van macht door lokale actoren op biotechnologische ontwikkelingen. In dit opzicht zijn de gebruikte conceptuele kaders: territorialiteit (Robert David Sack en Alberto Magnaghi), alternatieve ontwikkelingsbenaderingen (Alberto Magnaghi, Björn Hettne of John Friedmann), en biotechnologieën op maat (Guido Ruivenkamp). Binnen deze kaders, zijn de in dit proefschrift behandelde case studies gepresenteerd als illustraties van biotechnologische ontwikkelingen die de agrarische systemen van kleinschalige arme boeren kunnen versterken, en waarbinnen, tot op een bepaalde hoogte, macht uitgeoefend is door lokale actoren.

Het concept Lokale Duurzame Biotechnologische Ontwikkeling is geplaatst op het kruispunt tussen territorium en biotechnologie; het betreft het uitoefenen van macht door lokale actoren op biotechnologische ontwikkelingen. In Hoofdstuk 2 is beargumenteerd dat een territoriale benadering van biotechnologische ontwikkelingen tenminste drie analytische domeinen dient te beschouwen:

1. Het territoriale domein betreft de sociale dimensies van macht en lokaliteit met betrekking tot de ontwikkeling van biotechnologieën. Dit domein bestudeert de sociaal-politieke dynamieken die zijn omarmd door direct belanghebbende (‘multi-stakeholder’) netwerken om agrarische problemen van boeren binnen een bepaald territorium het hoofd te bieden door biotechnologie. Het onderzoekt de horizontale aspecten (de, tot op zekere hoogte, niet-hiërarchische structuur) van de sociale relaties tussen de verschillende sociale groepen betrokken bij de biotechnologische ontwikkeling, door te kijken naar of en hoe (met name) boeren, non gouvernementele organisaties, en lokale onderzoekers zijn opgenomen in het proces.

2. Het technologische domein analyseert de macht en de materiële dimensies van technologie. Het bestudeert de vereiste materiële veranderingen voor een lokaal specifieke (territoriale) ontwikkeling van biotechnologie. In feite, voor zover het materiële niveau deels een functie is van het politieke niveau (wat betreft de machtdimensie van technologie), is het nauw gerelateerd met het sociale niveau, de twee niveaus (co)construeren elkaar binnen sociaal-technologische structuren. Ze zijn hier gedifferentieerd en apart behandeld louter en alleen voor het gemak en de duidelijkheid van de analyse.

3. Het her-territorialisatie domein richt zich op het versterken (‘empowering’) van territoria wat betreft biotechnologische ontwikkelingen. Het onderzoekt de positie waarop ‘lokale duurzame biotechnologische ontwikkelingen’ de territoria plaatst waarbinnen ze plaats vinden met het oog op toekomstige onderhandelingen rondom biotechnologie. Op deze manier, reflecteert dit domein hoe het proces van biotechnologie territorialisatie nieuwe sociaaltechnologische structuren genereert die de agrarische systemen van boeren en de positie van boeren, non gouvernementele organisaties, en lokale onderzoekers binnen biotechnologische structuren versterkt. Het reflecteert ook op de nieuwe dynamieken die dit type ontwikkeling brengt binnen de historische context van een toenemende industrialisatie en biotechnologisatie van de landbouw.

Er zijn veel theoretische studies die beargumenteren dat de genomica de agrarische beoefening van boeren zou kunnen versterken, maar er is minder onderzoek uitgevoerd naar de werkelijke toepassing van de genomica binnen specifieke agrarische boerensystemen. De in dit proefschrift beschreven studie probeert dit gat op te vullen door onderzoek te doen naar de mogelijkheden en
uitdagingen die voortkomen uit de ontwikkeling van bepaalde biotechnologieën binnen specifieke agrarische boerensystemen. Drie casussen zijn in dit kader geanalyseerd.

Casus 1 (Hoofdstuk 3): *De territorialisatie van de productie van een Bacillus thuringiensis biopesticide binnen de context van kleinschalige landbouw in Andhra Pradesh, India*

Deze casus studie kijkt naar de ontwikkeling van biopesticides voor de behandeling van plagen in agrarische boerensystemen van de (half)droge districten van Mahaboobnagar en Nalgonda, in de staat Andhra Pradesh, India. In deze gebieden is de wonderboom (*Ricinus communis*) het voornaamste verbouwde gewas, en de wonderboom semilooper (*Achea janata*) een van de belangrijkste plagen. Het merendeel van de lokaal beschikbare chemische- en bio-pesticiden om het grote productieverlies van de wonderboom door de semilooper aan te pakken, zijn onbetaalbaar en/of ongeschikt voor de boeren. Deze casus bestudeert hoe de menselijke en materiële middelen van het territorium zijn gemobiliseerd om de wonderboom semilooper aan te pakken door gebruik te maken van biotechnologieën. Gebaseerd op lokale bacteriestammen van Bt (*Bacillus thuringiensis*) die efficiënt werken tegen de semilooper – bacteriestammen die bestudeerd zijn met genomica technologieën -, hebben netwerken van boeren, non gouvernementele organisaties, en publieke onderzoeksinstellingen een nieuw proces ontwikkeld om een Bt-spray te produceren tegen de plaag die rendabel is, die kleinschalige technische capaciteiten vereist, en die op dorpsniveau gereproduceerd kan worden. Ook is in sommige dorpen een gedecentraliseerd systeem van productie-units opgericht om de Bt-spray te produceren en te distribueren, een systeem dat ook andere biopesticiden en biomeststoffen fabriceert die aangepast zijn aan de lokale behoeften en capaciteiten.

In deze casus wordt ook gefocust op de materiële kant van het herontwerpproces van de productie van Bt-biopesticiden in de vorm van sprays. Bt-sprays werden gewoonlijk geproduceerd door een fermentatieproces in een vloeibaar medium, maar het netwerk heeft een nieuw productieproces ontwikkeld dat gebruik maakt van een fermentatieproces in een vast medium. Dit herontwerp maakt het mogelijk dat de productie van de Bt biopesticide plaats vindt op dorpsniveau binnen de bovengenoemde productie-units. De casus toont aan dat de sociale en materiële reorganisaties rondom de Bt-spray een nieuw begrip genereren, zowel van het territorium als ook van de ontwikkeling van biotechnologie. De biotechnologieën zijn niet langer ver weg ontwikkeld en in de territoria van boeren ‘geparachuteerd’, maar ze zijn ontwikkeld van onderop, al naar gelang de lokale perceptie van de behoeften en de waardering van geschikte technieken en procedures van lokale boeren en non gouvernementele organisaties, die daarbij instaat zijn gesteld (‘empowered’) tot het ontwikkelen van agrarische plagbestrijdingstechnologieën, en daardoor ook gemachtigd worden binnen hun eigen territoria.

Casus 2 (Hoofdstuk 4): *De Wiphala Genomica: de territorialisatie van moleculaire markers in kleinschalige aardappelsystemen in de Boliviaanse Andes*

De tweede casus behandelt het inzetten van Moleculaire Markers (MMs) binnen de kleinschalige hooglandse aardappelverbouw systemen in de departementen Cochabamba en Norte de Potosí in de Boliviaanse Andes. In deze territoria is de rijke diversiteit aan aardappelvarieteiten van de boeren essentieel voor het overleven van boerenhuishoudens, want deze diversiteit wordt strategisch gebruikt om aardappelen te produceren binnen de sterk verschillende ecosystemen van de Andes hooglanden. Daarbij heeft de diversiteit aan aardappels ook een belangrijke culturele
betekenis voor de Quechua en Aymara populaties die deze territoria bewonen. Ongelukkigerwijze is deze diversiteit blijkbaar terug aan het lopen.

Deze casus schetst twee tegenstrijdige begrippen van aardappeldiversiteit. Aan de ene kant wordt de aardappel biodiversiteit gezien als grondstof; de aardappelen van boeren hebben geen intrinsieke waarde, de waarde van (nieuwe/andere) variëteiten is gecreëerd (toegevoegd) door plantveredelaars binnen veredelingsprojecten. Aan de andere kant wordt biodiversiteit gezien als cultureel materiaal; aardappelen zijn entiteiten (eindproducten) ontwikkeld door boeren en hebben daarom wel een intrinsieke waarde. Het is beargumenteerd dat de ontwikkeling van biotechnologieën die ten doel hebben om de problemen van locale variëteiten aan te pakken, voordelig zou kunnen zijn vanuit zowel het territoriale perspectief op de overleving en versterking (empowerment) van de lokale gemeenschap alsook het globale perspectief van het in standhouden (en ontwikkelen) van biodiversiteit. Vandaar dat in dit hoofdstuk gesuggereerd wordt dat het inzetten van moleculaire markers (MMs) binnen het culturele begrip van biodiversiteit – de hier genoemde ‘Wiphala Genomica’ – potentieel heeft om bepaalde agrarische problemen van boeren aan te pakken. Daarnaast zijn enkele participatieve plantveredeling netwerken waargenomen die een mogelijke geschikte sociale omgeving (platform) vormen voor het inzetten van MMs. Deze sociale platformen zijn al bezig met het vorm geven aan de Wiphala Genomica.

Deze casus bestudeert ook de materiële aanpassingen die nodig zijn voor MMs om goed te kunnen functioneren binnen de Boliviaanse context. Uiteindelijk moet de analyse de huidige werkelijkheid beschouwen rondom hoe, als MMs ingezet worden binnen het grondstof begrip van diversiteit, de door boeren ontwikkelde aardappelvariëteiten uit het territorium zijn gehaald en door globale netwerken zijn toegeegend om gebruikt te worden als de basis voor veredelingsprogramma’s buiten het territorium, voor doeleinden die waarschijnlijk niet het territorium te goede komen. Echter, binnen de sociale omgeving van de Wiphala Genomica worden Quechua en Aymara boeren machtig, en is het behoud en de ontwikkeling van de genetische variëteit en productieve diversiteit van de aardappel versterkt. Bij het gebruik van MMs binnen een specifieke sociale en technische code kunnen de ontwikkelings capaciteiten binnen deze territoria versterkt worden.

**Casus 3 (Hoofdstuk 5): De biotechnologisatie van Jatropha voor lokale duurzame ontwikkelingen in Yoro, Honduras**

In het licht van een toenemend biobrandstoffen regime binnen de landbouw, bestudeert de derde casus de huidige inspanningen van lokale netwerken van boeren, NGOs, en onderzoeksinstituten in het departement Yoro van Honduras om een nieuwe energetische betekenis te geven aan Jatropha. Deze strijd wordt traditioneel gebruikt voor andere doeleinden (zoals ‘levende hekken’ voor vee, voor zeepproductie en voor medisch gebruik). De sociaal-politieke organisatorische structuur – het Gota Verde netwerk – dat voor de lokale en duurzame productie en het gebruik van (Jatropha) biobrandstoffen is geconstrueerd wordt in dit hoofdstuk bestudeerd.

Deze casus onderzoekt ook het verwetenschappelijke en biotechnologisatie proces (doormiddel van de genomica) dat Jatropha thans ondergaat. Om deze doelstelling een bereiken, wordt in deze casus een globaal georiënteerd netwerk bestudeerd dat werkt met deze plant. Het netwerk wordt gecoördineerd vanuit Nederland en is betrokken bij samenwerkingsverbanden met lokale netwerken (inclusief het Hondurese Gota Verde netwerk) die zouden kunnen leiden tot en verbetering van de lokale productie van Jatropha. Het accent ligt op de interactie tussen deze
twee netwerken, dus op hoe het verwenenschappelijke en biotechnologisatie proces dat uitgevoerd wordt met Jatropha, de lokale ontwikkelingen in Honduras kan versterken.

Hoofdstuk 6 concentreert zich op de conclusies die op grond van de casussen getrokken kunnen worden binnen de drie bovengenoemde analytische domeinen om het concept lokale duurzame biotechnologische ontwikkelingen verder te ontwikkelen.

Territoriale domein

Lokale duurzame biotechnologische ontwikkeling is een handeling om biotechnologieën en daarmee genomica te territorialiseren. Dit onderzoek beargumenteert dat het territorialiseren van biotechnologie inhoudt dat lokale macht op biotechnologische ontwikkelingen wordt uitgeoefend. In navolging van Foucault, is hier de suggestie gedaan dat macht niet ‘het bezit is van’ (zoals een substantie), maar dat het ‘wordt uitgeoefend op’ (zoals een dynamiek) door een bepaalde organisatie van sociale relaties. De reorganisatie van sociale relaties kan daarom macht binnen biotechnologische structuren transformeren. Ten eerste, als biotechnologieën en de genomica een rol gaan spelen in het versterken van de agrarische systemen van kleinschalige arme boeren, dan dienen de sociale structuren die deze technologieën en deze wetenschap toepassen en verder ontwikkelen zich te heroriënteren op de specifieke problemen die deze agrarische systemen beïnvloeden. Tot dusverre zijn er weinig relevante genomica ontwikkelingen op dit gebied. In de in dit proefschrift geanalyseerde drie casussen zien we dat, door de betrokkenheid van lokale actoren en agrarische systemen, netwerken niettemin sommige relevante agrarische problemen van boeren binnen specifieke territoria aanpakken.

De drie hier bestudeerde lokale biotechnologische ontwikkelingen zijn geactiveerd door externe financiële bronnen. Internationale financiering in agrarische biotechnologie ondersteunt gewoonlijk impact georiënteerde projecten in de derde wereld rondom wat gezien wordt als relevante globale thema’s. Hierdoor kan het lokale onderzoeksagenda’s, die gericht zijn op lokale specifieke problemen, hinderen. Om dit te vermijden, is beargumenteerd dat financieringsinstanties onderzoeksstructuren zouden moeten ondersteunen in plaats van bepaalde projecten. Op deze wijze zou de wetenschap een meer duurzame ontwikkeling in deze regio’s kunnen ondersteunen en vergemakkelijken. In de faciliteiten van de lokale onderzoeksstructuren kunnen nieuwe onderzoeksvragen gesteld en beantwoord worden door middel van lokaal specifiek onderzoek (zoals de Wiphala Genomica). Dit argument houdt verder in dat de onderzoeksorganisaties en beleidsmakers van lage inkomenslanden strategieën gebaseerd op lokale condities en problemen kunnen uitwerken, waar externe instanties hun financiering op zouden kunnen afstemmen. Door lokale onderzoekscapaciteiten op te bouwen en te decentraliseren kunnen wetenschappen en biotechnologieën groeien binnen, en versterken de veelheid aan al bestaande lokale agrarische systemen. In feite geldt dat alleen door een dergelijk gedecentraliseerd systeem de kennis van de genomica en de bijbehorende technologie op een goede manier vertaald kan worden naar lokale specifieke toepassingen om kleinschalige arme boeren ten goede te komen (in tegenstelling tot slechts één op één overgebracht te zijn en van weinig nut, of erger).

Vele wetenschappers hebben beargumenteerd dat wetenschappelijke en technologische ontwikkelingen zeer context afhankelijk zijn en dat ze gevuld zijn met sociale waarden, en dat er daarom een behoefte bestaat om een bredere set aan actoren binnen deze ontwikkelingen te betrekken. Het betrekken van een bredere groep van sociale actoren bij wetenschappelijke en technologische ontwikkelingen is niet alleen moreel wenselijk, maar kan ook efficiënter zijn. In
de hier geanalyseerde casussen zien we drie netwerken met verschillende belanghebbenden gericht op de territorialisatie van de wetenschappelijke kennis en biotechnologieën van de genomica binnen kleinschalige agrarische systemen in ontwikkelingslanden. Deze netwerken kraken het gangbare machtsmonopolie op de genomica kennis en technologieën die uitgevoerd worden door formele wetenschappers in dure labs. In en met de netwerken die geanalyseerd zijn in dit proefschrift werken moleculaire biologen, plantveredelaars, agronomen, sociale wetenschappers, boeren, en mensen van NGOs samen. Verschillende soorten informatie stromen door deze netwerken en worden vertaald in andere soorten kennis, of in praktische technologische toepassingen (de lokale specifieke Bt-spray, Wiphala Genomica, en Jatropha biobrandstof). Gegeven dat de reguliere sociale relaties die de agro-genomica sociaaltechnologische systemen meestal structureren, in het algemeen hun technologische capaciteiten niet kunnen of niet willen richten op arme boeren en hun agrarische systemen, volgt dat deze – de sociale relaties – geherstructureerd dienen te worden. De drie onderzochte casussen schetsen alternatieve trajecten om dat te doen. Deze trajecten gaan gepaard met het erbij betrekken van een bredere groep sociale actoren (bijv. boeren en NGOs), en met het vergemakkelijken van het delen van kennis door wetenschappelijke en technologische ontwikkelingen te decentraliseren en te democratiseren.

*Technologisch domein*

Macht wordt niet alleen uitgeoefend door sociale relaties, maar ook binnen apparaten. Daarom is, *om de macht uitgeoefend over biotechnologieën te democratiseren, niet alleen een reorganisatie van de sociale relaties rondom biotechnologieën georganiseerd zijn nodig, maar zijn eveneens enkele materiële aanpassingen nodig.* Onder de in de casussen geanalyseerde materiële aanpassingen zijn er sommige die nodig zijn door de onverenigbaarheid tussen de vereisten voor de functionering van de genomica en de lokale condities. De genomica gerelateerde technologieën zijn meestal duur en vereisen vaak zeer gespecialiseerde vaardigheden waaraan regelmatig niet kan worden voldaan in laboratoria met weinig inkomsten. Beargumenteerd wordt dat dit soort veranderingen de territorialisatie van de genomica een onvermijdelijke stap maken voor zulke laboratoria, welke degene zijn die frequent de agrarische boeren systemen ondersteunen. Een andere manier om naar de hier behandelde materiële veranderingen te kijken is dat deze nodig zijn om de genomica beheersbaar te maken voor lokale actoren. Bijvoorbeeld, in Hoofdstuk 3 hebben we gezien dat om een Bt-spray te kunnen produceren op dorpsniveau op een wijze die betaalbaar, toegankelijk en uitvoerbaar is, de industriële benadering van de productie van Bt-sprays waarin Bt sporen vermenigvuldigd worden door een fermentatieproces in een vloeibaar medium is getransformeerd in een fermentatieproces in een vast medium. De materiële veranderingen die door het herontwerpproces veroorzaakt zijn, vergemakkelijken de productie van de Bt-spray op dorpsniveau. En een gedecentraliseerd systeem van productie units heeft een nieuwe technologische code gegenereerd, die boeren, NGOs, en lokale onderzoekers omvat en die effectief een belangrijke plaaig aanpak die lokale agrarische systemen teistert. Hoofdstuk 4 onderzoekt op vergelijkbare manier sommige materiële en slimme veranderingen die lokale onderzoekers in hun lab voor moleculaire biologie in Cochabamba aan het implementeren zijn, om de genomica te kunnen toepassen en beheersen – zoals de productie van lokale polymerase en ethanol, en het gebruik van conventionele koelkasten in plaats van de prijzige koelkasten die worden aanbevolen volgens wetenschappelijke protocollen. Dit soort veranderingen en aanpassingen worden verwacht bij de grote meerderheid van laboratoria voor moleculaire biologie met een lage economische draagkracht.
Wanneer het aankomt op het implementeren van hightech technologieën zoals de genomica binnen lage input wetenschappelijke en technologische systemen die voor arme boeren en hun agrarische systemen zorgen, dan wordt een combinatie van verschillende soorten van kennis (formele en informele) en van technologieën (high en lage technologie) nodig. Geïsoleerd van andere technologische systemen is de genomica nutteloos – met name voor het type van wetenschappelijke en technologische structuren die gewoonlijk de agrarische systemen van arme boeren ondersteunen. Het Bt-netwerk gepresenteerd in Hoofdstuk 3 is een fascinerend voorbeeld van hoe lage technologieën een vitale stap vormen om de ontwikkelingen van de genomica en de boerennieuwkeilen te verbinden.

Dit onderzoek betoogt dat door de complexiteit en hoge kosten die samengaan met het gebruik van de genomica een gecombineerde dynamiek van centralisatie en decentralisatie van wetenschappelijke en technologische capaciteiten nodig lijkt te zijn om de velden van arme boeren met de genomica laboratoria te verbinden. Binnen deze context zou bijvoorbeeld de dure ontwikkeling van moleculaire markers gecentraliseerd kunnen worden. Dit kan kosten besparen en toegang naar kant-en-klare technologieën garanderen. Echter, voor zulke centralisaties is het nodig dat de onderzoeksinvesteringen die met de genomica werken in contact blijven met plantdeskundigen in de gehele wereld, om te garanderen dat de markers die ze ontwikkelen feitelijk relevant zijn voor specifieke gebieden en beschikbaar in lokale variëteiten die een goede kruisschikbaarheid met elite cultivars tonen. Daarentegen biedt het gedecentraliseerde systeem van Bt producenten units in Andhra Pradesh dat wat boeren toegang garandeert tot agrarische technologieën en daarbij tot het uitoefenen van macht over biotechnologische ontwikkelingen. De decentralisatie van wetenschap en technologieën resulteert ook in laboratoria, zoals diegene in Cochabamba die bijvoorbeeld met moleculaire markers experimenteert en daarbij lokaal specifieke alternatieve biotechnologische ontwikkelingstrajecten (de Wiphala Genomics) voortbrengt. Het evenwicht tussen centralisatie en decentralisatie met betrekking tot wetenschappelijke en technologische ontwikkelingen zou een nieuwe dynamiek voor hun territorialisatie en democratisatie kunnen genereren.

Het lokale specifieke herontwerp van biotechnologische codes waarbinnen een specifieke harrangschikking van sociale krachten is gericht op een specifieke weg naar technologie-ontwikkeling, zou door sommigen gezien kunnen worden als een intellectuele poging om technologisch determinisme (impliciet in de technologische transfer benadering) door een soort sociaal determinisme te vervangen. Hoewel de invloed van de maatschappij op technologie fundamenteel is voor de hier ontwikkelde theoretische analyse, is dit niet een geïsoleerde dynamiek: technologieën zijn ook de uitkomst van sociale en materiële wederzijdse aanpassing. Niettemin kan de participatie van achtergestelde sociale belanghebbenden de resultaten veranderen van de worsteling om biotechnologische codes te schrijven. Als er met de potenties en deficiënties van de agrarische systemen van arme boeren, hun boeren, NGOs, lokale bevolking en onderzoekers rekening wordt gehouden en zij een stem krijgen in het besluitvormingsproces van de agrarische genomica, dan neemt de kans danig toe dat de genomica de agrarische boerensystemen zal versterken en dat deze actoren meer macht (‘empowered’) zullen krijgen binnen de biotechnologische structuren.

Kritische literatuur heeft de structurele macht die het industrialisatie en biotechnologisatie proces van landbouw voortbracht bestudeerd. Goodman, Sorj, en Wilkinson onderzoeken de industriële toe-eigening van boerenpraktijken zoals plaag of bodem management door externe instellingen,
en een parallelle ontwikkeling van industriële substitutie van rurale producten; Van der Ploeg legt uit hoe door het proces van verwetsenschappelijking van landbouwbeoefening, agrarische activiteiten en boerenarbeid in toenemende mate wordt gecontroleerd door wetenschappelijke kennis; en Ruivenkamp betoogt dat door deze verwetsenschappelijking een proces van biotechnologisatie heeft plaats gevonden waarin controle op afstand wordt uitgeoefend over agrarische arbeid vanuit het wetenschappelijke domein door het inbrengen van politiserende producten. Samen hebben deze historische processen geleid tot een verlies van autonomie aan de kant van boeren met betrekking tot het uitoefenen van hun agrarische praktijken.

De inhoud van technologie, wordt hier betoogd, is in essentie niet destructief; het is eerder een kwestie van ontwerp en verdere implementatie binnen de maatschappij. Agrarische en wetenschappelijke netwerken zijn niet alleen puur ontvangers van technologieën, en daarom reproduceren ze niet automatisch de gecodificeerde politiek binnen het technologische ontwerp. De netwerken van verschillende belanghebbenden, die geanalyseerd zijn in de drie casussen, dagen deze structurele macht van biotechnologische ontwikkelingen op agrarische activiteiten uit en, tot op zekere hoogte, draaien zij die terug naar lokale duurzame ontwikkeling. De industriële toe-eigening van boeren activiteiten is bijvoorbeeld uitgedaagd door de zelfgeorganiseerde praktijken van lokale netwerken van belanghebbenden. De reorganisatie van de beschikbare natuurlijke en menselijke middelen in Mahaboobnagar en Nalgonda (Andhra Pradesh, India) is door de lokale actoren in zelfbeheer uitgevoerd. In plaats van te participeren binnen een technologische transferstructuur en te wachten op de volgende geparachuteerde pesticidetechnologie, hebben ze deze gemeenschappelijk en politiek uitgedaagd. De netwerken ‘kraken’ bestaande biotechnologische systemen en richten deze op nieuwe doelstellingen. Hun strijd representeert een tegengestelde tendens tot toe-eigening, en een poging om de zorg en communale functies van biotechnologie ontwikkeling te herontdekken – zorg voor de lokale agrarische problemen van boeren, en het opbouwen van nieuwe vormen van communalisme waarin (bio)technologieën (hun ontwikkeling) gezien en meer gebruikt worden als een katalysator dan als een uitdaging voor lokale ontwikkeling.

De controle op afstand als gevolg van de verwetsenschappelijking en biotechnologisatie processen is enigszins teruggedraaid door een lokale specifieke macht uitgeoefend op biotechnologische ontwikkelingen en agrarische arbeid (territorialiteit). De casussen van de Bolivianse Andes en van het Hondurase Yoro laten zien hoe de constructie van horizontale globale-lokale structuren, waardoor kennis en technologieën gedeeld kunnen worden, in staat zijn de ontwikkeling van geschikte en efficiënte lokale specifieke biotechnologieën mogelijk te maken – zoals de Wiphala Genomics. De vraag naar, en de praktijken van communicatie en democratisatie van biotechnologieën die deze bewegingen representeren, is zodanig fundamenteel dat het als toetssteen kan werken voor de hier gestelde bewering over de polipotentie van verwetsenschappelijking en biotechnologisatie processen. Deze netwerken dagen de rationaliteit uit waarbinnen biotechnologieën tegenwoordig zijn ontworpen. Ze genereren gemachtigde (empowered) sociale omgevingen voor biotechnologie ontwikkeling. Binnen en door deze netwerken worden de inwoners van agrarische boerenystemen ‘empowered’ motoren van biotechnologie en van lokale ontwikkeling.

Een van de betoogde wenselijke uitkomsten van lokale duurzame biotechnologische ontwikkelingen is die van sociale duurzaamheid. Magnaghi definieert sociale duurzaamheid als een grotere betrokkenheid van zwakke belanghebbenden binnen het lokale besluitvormingssysteem. Deze algemene definitie vertaald naar onze biotechnologische focus, zou kunnen betekenen dat de structuren die biotechnologische ontwikkelingen beheren, complex genoeg zouden moeten zijn om de participatie van zwakkere sociale belanghebbenden en hun
Samenvatting

behoeften te kunnen garanderen. Mechanismen zouden gecreëerd moeten worden om te garanderen dat de territoriale (natuurlijke en menselijke) bronnen niet geëxploiteerd worden door de lokaal sterkste, of externe sociale actoren, en dat deze bronnen voor lokale gelijkheid worden gebruikt. Een voorbeeld van een type mechanisme dat binnen lokale ontwikkelingen geïnstitutionaliseerd kan worden en dat de participatie van sociaal zwakke actoren kan garanderen wordt in de derde casus beschreven. Hier is een coöperatief bedrijf in eigendom van en gecontroleerd door producenten van lokale biobrandstoffen opgericht voor de verwerking en distributie van de producten afkomstig van de Jatropha plant en andere brandstofgewassen. Dit type structuren omzeilt het normale proces waarin de productie van kleinschalige boeren wordt gekocht door tussenpersonen en buiten het gebied wordt verwerkt en gebruikt. Omdat het productiebedrijf in Yoro in handen is van kleinschalige Jatropha producenten, volgt dat in het hier bestudeerde biotechnologisatieproces van de Jatropha door middel van genomica, de genomica op lokale agrarische behoeften gericht zal worden, wat een garantie inhoudt dat de associatie van boeren een stem zal krijgen in het beslissen over wat de belangrijkste gewaseigenschappen zijn. Met andere woorden, een lokale specifieke macht kan uitgeoefend worden op de biotechnologische ontwikkelingen (territorialiteit).

Technologie is een van de structuren die territoria reproduceert. Het is een andere politieke arena waarin de strijd van insluiting en uitsluiting zich afspeelt. Het insluiten van de inwoners van een lokaliteit bij de besluitvorming rondom de toekomst van dat territorium (zijn constante herterritorialisatie) is gecompliceerd, maar wel effectief voor het bereiken van een machtsevenwicht binnen veranderingsprocessen. De biotechnologische toekomsten en die van territoria zijn gewoonlijk gericht op het voordeel van de sociale actoren die toegang hebben tot de besluitvorming. Het beeld van deze toekomst wordt meer divers, fascinerend en eerlijker wanneer de minder machtige actoren een stem krijgen, dat wil zeggen macht. Om dit te bereiken, is een van de codes die belangrijke positieve uitkomsten zou kunnen leveren die van Lokale Duurzame Biotechnologische Ontwikkelingen.
Resumen

La genómica es un fruto de nuestro tiempo, producto de la alta tecnología y del modo de producción basado en el conocimiento de las economías occidentales. No nos sorprende que el camino seguido en la agricultura para el desarrollo de las biotecnologías en general y de la genómica en particular sea dictado por la agroindustria y los institutos científicos de carácter público asentados en el mundo occidental, y orientados principalmente hacia la agricultura comercial. La gran mayoría de la población pobre del mundo y de las estructuras rurales en las que viven y trabajan, esto es, el campesinado y sus sistemas agrarios son normalmente excluidos de la senda del desarrollo tecnológico. En el primer capítulo de este libro nos referimos a este tipo de desarrollo como un desarrollo desterritorializador. Es desterritorializador porque excluye a la población local y a sus estructuras sociopolíticas del proceso de toma de decisiones. En el Tercer Mundo rural, alejado de los centros de poder económicos y tecnológicos, esto significa que el campesinado, las organizaciones de la sociedad civil, y la comunidad científica local no tienen voz (o ésta es muy limitada) en los procesos de investigación y desarrollo de la ciencia y la tecnología; procesos estos que pueden afectarles más que a ningún otro grupo. A consecuencia de esto, cuando se presenta a la genómica como una tecnología que puede emplearse para la producción de desarrollo, entonces, para conseguirlo, se propone una transferencia directa de tecnológica.

Asumiendo esto como normativo, la situación convencional del presente, esta investigación ha buscado trayectorias territoriales alternativas para el desarrollo de las biotecnologías dirigidas al fortalecimiento de los sistemas agrarios del campesinado, así como a empoderar a los grupos locales dentro de los sistemas biotecnológicos. Estas alternativas territoriales son capturadas dentro del concepto central elaborado en esta tesis: desarrollos biotecnológicos locales sostenibles. El desarrollo biotecnológico local sostenible se define como un tipo de desarrollo basado en la reconstrucción de las biotecnologías principalmente (pero no exclusivamente) por y para los actores locales, y que fortalezca los sistemas agrarios campesinos y empodera al campesinado, las organizaciones de la sociedad civil, y los/las investigadores/as locales dentro de las estructuras biotecnológicas.

El Desarrollo biotecnológico local sostenible, tal y como se define en el Capítulo 2, se compone de dos elementos centrales – la (bio)tecnología y la territorialidad. La tecnología es aquí definida como una estructura social, como un sistema formado por elementos materiales y sociales, que tiene política. Esta perspectiva está basada en el enfoque de la Teoría Crítica sobre la tecnología (p.e. Andrew Feenberg), y en formas del constructivismo que incluyen la construcción social de la tecnología (p.e. Wiebe Bijker, Thomas P. Hughes y Trevor Pinch), la modelación social de la tecnología (p.e. Donald Mackenzie y Judy Wajcman), y la teoría del actor-red (p.e. Bruno Latour). El marco teórico de referencia en lo concerniente a la política de las biotecnologías atañe a los procesos históricos de la industrialización (p.e. David Goodman, Bernardo Sorj, y John Wilkinson), de la cientificación (Jan Douwe van der Ploeg) y de la biotecnologización (Guido Ruivenkamp) de la agricultura. Esta investigación sugiere que en lugar de asumir un trayecto rectilíneo para el desarrollo de las (bio)tecnologías (el trayecto convencional), se puede considerar una multiplicidad y diversidad de trayectos realizables y apropiados para distintos (y dentro de) territorios (dados).
La **territorialidad** está formada por dos elementos principales, el poder y lo local. En el contexto del desarrollo de las biotecnologías, definimos aquí la territorialidad como el poder ejercido por los actores locales en los desarrollos biotecnológicos. En este sentido, los marcos conceptuales utilizados son el de la territorialidad (Robert David Sack y Alberto Magnaghi), el enfoque del desarrollo alternativo (Alberto Magnaghi, Björn Hettne, o John Friedmann), y el de las biotecnologías hechas a la medida (Guido Ruivenkamp). En este contexto, los estudios de caso abordados aquí son presentados como ejemplos de desarrollos biotecnológicos que pueden reforzar los sistemas agrarios campesinos, y en los que el poder es ejercido, hasta cierto punto, por los actores locales.

El **concepto del Desarrollo Biotecnológico Local Sostenible** está situado en la intersección del territorio y la biotecnología. En esta investigación, este concepto atañe al ejercicio de poder sobre procesos biotecnológicos por parte de actores locales. En esta investigación argumentamos que un enfoque territorial para con el desarrollo de biotecnologías debe considerar por lo menos tres áreas analíticas interrelacionadas:

1. **El área territorial** concierne a las dimensiones sociales del poder y lo local para el desarrollo de las biotecnologías. Esto implica el estudio de las dinámicas sociopolíticas ejercidas por las redes sociales (compuestas por distintos grupos sociales), orientadas a solucionar los problemas agrarios del campesinado, en un territorio dado, por medio de las biotecnologías. Esta área analítica explora los aspectos de una jerarquía horizontal de las relaciones sociales entre los distintos grupos sociales implicados en desarrollos biotecnológicos, examinando si principalmente el campesinado, las organizaciones de la sociedad civil, y los/as investigadores/as locales son incluidos en este proceso, y de que manera.

2. **El área tecnológica** analiza el poder y las dimensiones materiales de la tecnología. Explora los cambios materiales necesarios para el desarrollo específicamente local (territorial) de las biotecnologías. De hecho, como los elementos materiales son parcialmente una función de los políticos (en lo que se refiere a las dimensiones del poder de la tecnología), los elementos materiales y sociales están íntimamente asociados. Los dos se co-construyen mutuamente dentro de las estructuras socio-tecnológicas. Aunque estos están considerados en este estudio separadamente puramente por razones analíticas.

3. **El área de la reterritorialización** estudia el empoderamiento de territorios en lo concerniente a desarrollos biotecnológicos. Investiga la posición en la que los ‘desarrollos biotecnológicos locales sostenibles’ dejan a los territorios donde ocurren, en cuanto a las futuras negociaciones para los desarrollos de la tecnología se refiere. De esta manera, esta área reflexiona sobre cómo el proceso de territorializar las biotecnologías genera nuevas estructuras socio-tecnológicas que fortalecen los sistemas agrarios campesinos y la posición del campesinado, las organizaciones de la sociedad civil, y los/as investigadores/as locales dentro de las estructuras biotecnológicas. También reflexiona sobre las nuevas dinámicas que conlleva este tipo de desarrollo dentro del contexto histórico de una creciente industrialización y biotecnologización de la agricultura.

Ha habido un buen número de estudios teóricos aludiendo a que la genómica puede robustecer las prácticas agrarias del campesinado, si bien se han elaborado menos estudios sobre la aplicación real de la genómica dentro de sistemas agrarios campesinos específicos. Esta investigación ha tratado de contribuir a llenar este vacío estudiando el potencial y los desafíos que emergen con el desarrollo de ciertas biotecnologías en determinados territorios campesinos. Para esto, se han analizado tres estudios de caso.
Caso 1 (Capítulo 3): La territorialización de la producción de un biopesticida de Bacillus thuringiensis dentro del contexto de la agricultura campesina en Andhra Pradesh, India

Este estudio de caso explora el desarrollo de biopesticidas para controlar las plagas en los sistemas agrarios campesinos de los distritos semiáridos de Mahaboobnagar y Nalgonda, en el estado de Andhra Pradesh, India. El cultivo más importante de estos territorios es el del ricino (Ricinus communis), y la oruga del lepidóptero Achea janata una de sus plagas más importantes. La mayoría de los pesticidas de origen químico y biológico accesibles en la localidad para afrontar las grandes pérdidas causadas por esta plaga en la producción del ricino son inasequibles e/o inadecuados para las prácticas campesinas. Este estudio de caso analiza cómo los recursos humanos y materiales del territorio son movilizados para enfrentarse a esta oruga con la biotecnología. Redes sociales compuestas por campesinos/as y organizaciones de la sociedad civil, institutos públicos de investigación y estaciones experimentales han desarrollado un nuevo proceso para producir un pesticida de origen biológico (en forma de spray) con cepas locales de la bacteria Bacillus thuringiensis (Bt) para controlar esta peste. Este proceso productivo es rentable y requiere capacidades técnicas a pequeña escala que pueden ser reproducidas al nivel local (el de las comunidades). Además de esto, se ha establecido un sistema descentralizado de unidades de producción en algunas comunidades para manufacturar y distribuir el spray-Bt. Un sistema éste que también se utiliza para la manufactura de otros pesticidas y fertilizantes de origen biológico, adaptados a las necesidades y a las capacidades locales.

Este estudio de caso también se centra en el proceso de re-diseño de la producción de pesticidas-Bt en forma de spray. Los sprays-Bt se fabrican normalmente por medio de un proceso de fermentación en un medio líquido, pero esta red social ha desarrollado un nuevo proceso de producción utilizando una fermentación en medio sólido. Este re-diseño hace posible la producción del pesticida biológico a nivel de las comunidades locales, en las unidades de producción anteriormente citadas. El estudio muestra cómo los reajustes sociales y materiales producidos en torno al pesticida Bt crean una nueva concepción tanto del territorio como del desarrollo de las biotecnologías. Las biotecnologías ya no se generan a distancia para luego ser espardidas por los territorios campesinos, sino que son desarrolladas con un ‘enfoque ascendente’ (bottom-up). Esto es, de acuerdo con la percepción local de las necesidades y la estimación de técnicas y procedimientos óptimos realizados por el campesinado y las organizaciones locales de la sociedad civil. De este modo, campesinado y organizaciones locales son empoderados en el desarrollo de tecnologías para el control de plagas, y en la (re)construcción del territorio.

Caso 2 (Capítulo 4): La Genómica Wiphala: la territorialización de los marcadores moleculares en los sistemas de producción de patata a pequeña escala en los Andes bolivianos

El segundo estudio de caso se ocupa del despliegue de marcadores moleculares dentro del cultivo de patata a pequeña escala en las tierras altas de Cochabamba y Norte de Potosí en los Andes bolivianos. En estos territorios, la rica diversidad de variedades de la patata del campesinado es fundamental para la supervivencia de las familias campesinas, ya que se utiliza estratégicamente para producir patatas en los extraordinariamente diversos ecosistemas de las tierras altas andinas. Además de esto, la diversidad de la patata tiene también un importante significado cultural para la población quechua y aymara que reside en estos territorios. Desafortunadamente, esta diversidad está disminuyendo aparentemente.
Este estudio bosqueja dos concepciones contradictorias de la diversidad de la patata. Por un lado, la biodiversidad de la patata es entendida en términos de materia prima, de modo que las variedades del campesinado no tienen un valor intrínseco, el valor de las variedades (nuevas/diferentes) es algo creado (añadido) por los mejoradores en proyectos de mejora de plantas. Por otro lado, la biodiversidad es entendida como un material cultural, de modo que las variedades del campesinado tienen un valor intrínseco. En esta investigación se argumenta que un desarrollo de las biotecnologías que tenga como objeto el abordar los problemas de las variedades locales sería beneficioso desde la perspectiva territorial de la supervivencia de las comunidades y del empoderamiento, así como desde la perspectiva global de mantener (desarrollar) la diversidad. Así, el estudio de este caso sugiere que el despliegue de los marcadores moleculares dentro del contexto cultural de la biodiversidad – denominado la ‘Genómica Wiphala’ – tiene un potencial para afrontar algunas limitaciones agrarias del campesinado. Además, la investigación indica que algunas redes participativas de mejora de plantas son unas plataformas apropiadas para el despliegue de marcadores moleculares, plataformas que ya están dando forma a la Genómica Wiphala.

Este estudio de caso explora también los reajustes materiales por los que los marcadores moleculares necesitan pasar para poder funcionar dentro de los territorios bolivianos. Finalmente, esta reflexión tiene que considerar que cuando los marcadores moleculares son desarrollados dentro de la conceptualización de la diversidad en términos de materia prima, las variedades de patatas campesinas son extraídas del territorio y apropiadas por redes globales sirviendo de base para proyectos de mejora fuera del territorio, con fines que, seguramente, no sirvan al territorio en cuestión. Sin embargo, dentro del ambiente social para el desarrollo de la Genómica Wiphala, el campesinado quechua y aymara es empoderado, y la conservación y el desarrollo de la variedad genética y diversidad productiva de patatas se fortalecen. De este modo, si los marcadores moleculares son desarrollados con un código social y tecnológico específico, las capacidades de desarrollo de estos territorios andinos pueden ser fortalecidas.

**Case 3** (Capítulo 5): *La biotecnologización de la Jatropha para un desarrollo local sostenible en Yoro, Honduras*

En el contexto de un régimen en expansión en cuanto a la producción de los biocombustibles dentro de la agricultura, el tercer estudio de caso investiga los esfuerzos de las redes sociales locales formadas por grupos campesinos, ONGs, e institutos de investigación en el departamento de Yoro, en Honduras, para dar un nuevo significado energético a la Jatropha, un arbusto usado tradicionalmente para otros propósitos (como en ‘cercas vivas’ para el ganado, para la producción de jabón, y usos médicos). La estructura sociopolítica organizacional – la red Gota Verde – que ha sido construida para la producción y el consumo local y sostenible de biocombustibles (Jatropha) es examinada.

Este estudio de caso también investiga los procesos de cientificación y biotecnologización (con genómica) por los que la Jatropha está pasando. Con este propósito en mente, nos concentraríamos en una red de la genómica con una orientación global que está trabajando con esta planta. Coordinada desde Holanda, esta red está involucrada en colaboraciones con redes locales (incluyendo la red hondureña Gota Verde) que pueden provocar una mejora en la producción de la Jatropha. El énfasis recae sobre los pormenores de la interacción entre estas dos redes sociales; esto es, el análisis se centra en cómo los procesos de cientificación y biotecnologización de la Jatropha pueden fortalecer el desarrollo local en Honduras.
El capítulo sexto desarrolla las conclusiones extraídas en los estudios de caso dentro de las áreas de análisis anteriormente citadas, para así profundizar en el concepto de los ‘desarrollos biotecnológicos locales sostenibles’.

Área territorial

El desarroll biotecnológico local sostenible es un acto de territorialización de las biotecnologías y, por consiguiente, de la genómica. Esta investigación arguye que el acto de territorializar biotecnologías es un acto en el que el poder local se ejerce sobre los desarrollos biotecnológicos. Siguiendo el ejemplo de Foucault, la investigación sugiere que el poder no se posee (como una substancia), sino que se ejerce (como una dinámica) a través de una cierta organización de las relaciones sociales. De este modo, una reorganización de las relaciones sociales puede transformar el poder dentro de las estructuras de las biotecnologías. Para empezar, si las biotecnologías y la genómica van a jugar un papel en el fortalecimiento de los sistemas agrarios del campesinado pobre, entonces, las estructuras sociales que aplican y reproducen estas tecnologías y estas ciencias necesitan reorientarlas hacia los problemas específicos que afectan a estos sistemas agrarios. Hasta ahora, ha habido pocos desarrollos de la genómica relevantes en esta área. Involucrando a los actores y sistemas agrarios locales en los desarrollos biotecnológicos, vemos en los tres estudios de casos aquí analizados, cómo, no obstante, las redes sociales están afrontando algunos problemas agrarios relevantes del campesinado en territorios específicos.

Los tres desarrollos biotecnológicos locales estudiados han sido activados por fuentes financieras externas. La financiación internacional para la biotecnología agrícola normalmente apoya proyectos orientados a tener un impacto en las regiones del tercer mundo en lo que se consideran temas relevantes globales. Esto podría ser un obstáculo para las agendas de investigación locales, ya que están elaboradas entorno a objetivos específicamente locales. Para evitar esto, aquí se arguye que las agencias de financiación deben apoyar las estructuras para la investigación en lugar de hacerlo solo con proyectos. Así, la ciencia podría apoyar y facilitar un desarrollo más sostenible en estas regiones del mundo. En las instalaciones de las estructuras locales de investigación se pueden elaborar nuevas preguntas de investigación que, a su vez, pueden ser respondidas a modo de una investigación específica para la localidad (como la Genómica Wiphala). Las organizaciones de investigación y los/as responsables de la política de los países con pocos ingresos, continua el razonamiento, deben elaborar estrategias basadas en las condiciones y problemas locales con los que las agencias externas puedan alinear sus fondos para la investigación. Descentralizando y construyendo capacidades locales de investigación es como las ciencias y las tecnologías pueden crecer dentro de, y fortalecer la multitud de sistemas agrarios locales existentes. De hecho, solo a través del desarrollo de un sistema descentralizado es como el conocimiento y las tecnologías de la genómica pueden ser adecuadamente traducidas en aplicaciones específicamente locales que beneficien al campesinado pobre (en contraposición a ser meramente transferidas, o algo peor).

Muchas/os investigadoras/es han argüido que el desarrollo de la ciencia y de la tecnología depende altamente del contexto en el que éstas se desenvuelven, y que implica juicios de valor. Por este motivo es necesario involucrar a un mayor número de actores sociales en estos desarrollos. El involucrar a un mayor número de actores sociales en desarrollos científicos y tecnológicos no es solamente moralmente deseable sino que también puede ser más eficiente. En los estudios de caso analizados aquí estudiamos tres redes sociales que tienen como objeto la territorialización de los conocimientos y biotecnologías de la genómica dentro de los sistemas
agrícolas campesinos. Estas redes están rompiendo el monopolio de poder que comúnmente es ejercido por científicos en lujosos laboratorios sobre el conocimiento y las tecnologías. Trabajando en las redes analizadas en esta tesis o colaborando con ellas hay biólogos/as moleculares, mejoradores/as de plantas, agrónomos/as, investigadoras/es sociales, campesinos/as, y miembros de la sociedad civil. Diferentes tipos de información fluyen a través de estas redes y son traducidas en diferentes tipos de conocimiento, o en aplicaciones tecnológicas prácticas (las específicamente locales: spray-Bt, la Genómica Wiphala, y los biocombustibles de la Jatropha). Dado que las regulares relaciones sociales que estructuran los sistemas socio-tecnológicos de la agro-genómica son normalmente incapaces o reacias a orientar sus capacidades tecnológicas hacia los sistemas agrarios campesinos, se puede deducir que las relaciones sociales tienen que ser reestructuradas. Los tres estudios de caso analizados trazan trayectorias alternativas para hacerlo. Estas trayectorias implican la inclusión de un círculo más amplio de actores sociales (como por ejemplo grupos campesinos y organizaciones de la sociedad civil), e implican también la facilitación de una cooperación para compartir conocimientos a través de la democratización y descentralización de los desarrollos científicos y tecnológicos.

ÁREA TECNOLÓGICA

El poder no solamente es ejercido a través de relaciones sociales, sino que también es materializado en aparatos. De este modo, a fin de democratizar el poder ejercido sobre las biotecnologías, no solamente es necesaria una reorganización de las relaciones sociales en los desarrollos biotecnológicos, sino que también son necesarios algunos reajustes materiales. Algunos de los cambios materiales analizados en los estudios de caso responden a las incompatibilidades entre los requerimientos para el funcionamiento de la genómica y las condiciones locales. Las tecnologías del ámbito de la genómica son normalmente caras y a menudo requieren niveles de competencia y especialización que normalmente no se pueden reproducir en laboratorios de ingresos bajos. Este tipo de cambios, argüimos, convierten a la territorialización de la genómica en un paso forzoso para este tipo de laboratorios, que habitualmente son los que apoyan a los sistemas agrícolas campesinos. Una forma distinta de percibir estos cambios materiales es que estos son necesarios para poder gobernar la genómica desde dentro de la localidad. Por ejemplo, en el capítulo tercero vemos que para poder producir un spray-Bt que sea asequible, accesible, y realizable al nivel de las comunidades, el enfoque industrial para producir sprays-Bt en el que las esporas del Bt son multiplicadas en una fermentación en un medio líquido ha sido transformado en una fermentación en medio sólido. Los cambios materiales provocados en este proceso de re-diseño facilitan la producción en las comunidades. Así, un sistema de unidades de producción descentralizado ha generado un nuevo código tecnológico que incluye a campesinos/as, organizaciones de la sociedad civil, e investigadores/as locales y que maneja efectivamente una plaga importante que afecta a los sistemas agrícolas locales. Asimismo, el capítulo cuarto analiza algunos reajustes ingeniosos llevados a cabo por investigadores/as locales en su laboratorio de biología molecular en Cochabamba para controlar y desarrollar la genómica – como por ejemplo la producción de polimerasa y etanol local, y el uso de frigoríficos convencionales de cocina en lugar de los frigoríficos caros recomendados por los protocolos científicos. Suponemos que estos tipos de cambios y adaptaciones tienen que estar ocurriendo en la gran mayoría de laboratorios de biología molecular con pocos recursos económicos.

Cuando se trata de la implementación de altas tecnologías como la genómica dentro de sistemas científicos y tecnológicos de bajos recursos que ayudan a sistemas agrícolas de recursos...
igualmente bajos, se hace necesaria una combinación de diferentes tipos de conocimiento (formal e informal) y de tecnologías (alta y baja tecnologías). La genómica aislada de otros sistemas tecnológicos es inútil – especialmente para el tipo de estructuras científicas y tecnológicas que apoyan los sistemas agrarios del campesinado. La red-Bt que estudiamos en el capítulo tercero es un ejemplo fascinante de cómo las bajas tecnologías se convierten en un paso fundamental para conectar el desarrollo de la genómica con las prácticas campesinas.

Debido a la complejidad y altos costos que conlleva la práctica de la genómica, en esta investigación argüimos que una dinámica que combine la centralización con la descentralización de instalaciones científicas y tecnológicas parece ser necesaria para que se establezca una conexión entre los campos del campesinado y los laboratorios de la genómica. En este contexto, por ejemplo, consideramos que sería más conveniente que el costoso desarrollo de marcadores moleculares se mantuviera en una posición centralizada. Esto podría ahorrar costos y garantizar el acceso a algunas tecnologías estándar. Aunque tal centralización requiere que la institución científica que trabaja en el desarrollo de la genómica permanezca en contacto con expertos/as agrónomos/as en todo el mundo a fin de garantizar que los marcadores que descubran sean relevantes para localidades específicas y que estén presentes en accesiones locales que muestren buenas condiciones para ser cruzadas con cultivares de élite. En contraste con esto, ha sido un sistema descentralizado de unidades de producción de Bt en Andhra Pradesh el que ha garantizado el acceso del campesinado a las tecnologías agrarias, además de facilitar el ejercicio del poder local en los desarrollos biotecnológicos. La descentralización de la ciencia y las tecnologías también produce laboratorios como el de Cochabamba (capítulo cuarto) que, por ejemplo, está experimentando con marcadores moleculares y de este modo está generando vías de desarrollo biotecnológico alternativos (la Genómica Wiphala). Un equilibrio entre la centralización y la descentralización con respecto a los desarrollos científicos y tecnológicos podría generar nuevas dinámicas para su territorialización y democratización.

El re-diseño de códigos biotecnológicos específicamente locales en los que, con una particular reconfiguración de las fuerzas sociales, se intenta definir una ruta específica para el desarrollo tecnológico, podría parecer una tentativa para sustituir el determinismo tecnológico (implícito en el enfoque de la transferencia tecnológica) por una especie de determinismo social. Aunque la idea de la influencia social en las tecnologías es fundamental en el análisis teórico desarrollado en esta investigación, esto no es algo que opera aisladamente: las tecnologías también son el resultado de la mutua adaptación de elementos sociales y materiales. No obstante, la participación de actores sociales subordinados en las luchas para escribir los códigos biotecnológicos puede transformar los resultados. Si se tiene en consideración y se da voz a los sistemas agrarios campesinos, con sus potencias y deficiencias, sus campesinas/os, organizaciones de la sociedad civil, comunidades locales, e investigadores/as en los procesos de toma de decisión en la genómica agrícola, entonces, incrementará notablemente la probabilidad de que la genómica pueda fortalecer estos sistemas y de que estos actores puedan adquirir poder dentro de las estructuras biotecnológicas resultantes.

Área de la reterritorialización

La literatura crítica ha estudiado el poder estructural producido por los procesos de industrialización y biotecnologización de la agricultura. Goodman, Sorj, y Wilkinson exploran la apropiación industrial de prácticas campesinas como son el manejo de pestes y suelos por parte de instituciones externas, y el desarrollo paralelo de una sustitución industrial de productos rurales. Van der Ploeg explica cómo a través del proceso de cientificación de la agricultura, las
prácticas agrarias y el trabajo agrícola están cada vez más controladas por el conocimiento científico. Ruivenkamp, por su parte, defiende que por medio de este proceso de cientificación, ha ocurrido un proceso de biotecnologización en el que se ejerce un control a distancia sobre la labor agrícola desde el área científica a través de la introducción de productos politizantes. Todos estos procesos históricos han conducido a una pérdida de autonomía, por parte de los/as agricultores/as, para llevar a cabo las prácticas agrícolas.

El contenido de la tecnología, tal y como se arguye aquí, no es esencialmente destructivo, sino más bien una cuestión de diseño y del subsiguiente despliegue dentro de lo social. Las redes agrarias y científicas no solo son meras receptoras de tecnologías, y por lo tanto no reproducen automáticamente las políticas codificadas en el diseño tecnológico. Las redes sociales analizadas en los tres estudios de caso son presentadas como representantes de un desafío a este poder estructural de los desarrollos biotecnológicos en el mundo agrícola y, en cierta medida, están transformando estos procesos en desarrollos locales sostenibles. Por ejemplo, las prácticas autogestionadas de las redes sociales representan un desafío para la apropiación industrial de prácticas agrícolas. La reorganización de los recursos naturales y humanos existentes en Mahaboobnagar y Nalgonda (Andhra Pradesh, India) ha sido autogestionada por los actores locales, que, en lugar de tomar parte en una estructura de transferencia tecnológica y esperar a que les llegue lo último en tecnología-pesticida, han desafiado esta situación colectiva y políticamente. Las redes han ‘ocupado’ los sistemas biotecnológicos y los han transformado para servir a nuevos propósitos. Sus esfuerzos representan una tendencia contraria al apropiacionismo, un intento de redescubrir las funciones comunales y de ayuda propias de los desarrollos biotecnológicos, ocupándose de los problemas agrícolas locales del campesinado, y construyendo nuevas formas de comunidad en las que las (bio)tecnologías (su desarrollo) son vistas y empleadas más como catalizadores que como desafíos para el desarrollo local.

El control a distancia ejercido a través de los procesos de cientificación y biotecnologización es, en cierta medida, transformado por el ejercicio específicamente local, del poder sobre los desarrollos biotecnológicos y el trabajo agrícola (territorialidad). Los estudios de caso de los Andes bolivianos y del Yoro hondureño muestran cómo la construcción de estructuras globales-locales horizontales, a través de las cuales el conocimiento y las tecnologías puedan circular y ser compartidas, es capaz de facilitar el desarrollo de biotecnologías localmente específicas apropiadas y eficientes – como la Genómica Wiphala. La exigencia y las prácticas de comunicación y democratización de las biotecnologías que estos movimientos representan, son tan fundamentales que pueden servir como piedra de toque para la aseveración realizada en esta investigación sobre la polipotencia de los procesos de la cientificación y la biotecnologización. Estas redes sociales desafían la racionalidad con la que se diseñan actualmente las biotecnologías. Ellas son las que crean ámbitos sociales dotados de poder para el desarrollo de las biotecnologías. Dentro de y a través de estas redes, los habitantes de los sistemas campesinos agrarios se convierten en motores empoderados de la biotecnología y del desarrollo local.

Uno de los resultados deseables de los desarrollos biotecnológicos locales sostenibles, se arguye, es el de la sostenibilidad social. Magnaghi define la sostenibilidad social como una mayor implicación por parte de los actores sociales débiles en los sistemas locales de toma de decisión. Traduciendo esta definición general a nuestro enfoque biotecnológico, podríamos decir que las estructuras que dirigen los desarrollos biotecnológicos deberían ser lo suficientemente complejas como para garantizar la participación de actores sociales débiles y de sus necesidades. Es necesario crear mecanismos para garantizar que los recursos territoriales (naturales y humanos) sean usados para la igualdad local, y no explotados por los actores locales más poderosos, o por actores externos. El tercer estudio de caso presenta un ejemplo de mecanismo.
que puede ser institucionalizado dentro del desarrollo local y que puede garantizar la participación de los grupos sociales más débiles. En dicho ejemplo se estudia una compañía cooperativa que se ha establecido para la transformación y la distribución de productos derivados de la planta Jatropha y de otras plantas para la producción de biocombustibles. Esta compañía es propiedad de los/as productores/as locales y está controlada por estos. Dado que la compañía manufacturera en Yoro está en las manos de los/as productores/as de Jatropha a pequeña escala, la trayectoria biotecnológica para dicha planta, orientará la genómica hacia las necesidades agrarias locales, incluyendo la garantía de que la asociación de campesinos/as tendrá voz para decidir qué características de la Jatropha son importantes. En otras palabras, es posible ejercer un poder específicamente local sobre los desarrollos biotecnológicos (territorialidad).

La tecnología es una de las estructuras que reproduce los territorios. Es otra arena política en la que se disputan las luchas de inclusión y exclusión social. La implicación de los habitantes locales en las negociaciones de toma de decisión sobre el futuro del territorio (su constante re-territorialización) es una actividad complicada, pero efectiva para conseguir un equilibrio de poder en procesos de cambio. Tanto el futuro de las biotecnologías como el de los territorios está normalmente orientado hacia el beneficio de los actores sociales implicados en las negociaciones. La imagen de ambos futuros se hace más diversa, fascinante y justa cuando los grupos menos poderosos adquieren voz, esto es poder. Uno de los códigos que puede lograr resultados significativamente importantes en este sentido es el de los Desarrollos Biotecnológicos Locales Sostenibles.
Publications

Scientific journals:


http://www.informaworld.com/smpp/content~content=a901807773~db=all~jumptype=rss

http://www.ris.org.in/article4_v9n3.pdf

Book’s chapters


Conference papers:


Other publications:

Advances in agrarian genomics are writing a new page in the history book of science and technology. ‘Redesigning Genomics – Reconstructing Societies’ analyzes whether and how these advances could be also adding a new page to the work of making poverty history. It focuses on the local specific development of biotechnologies and genomics as a catalyst for development within the agrarian systems of peasants. It takes up the challenge to research whether and how these technologies might be sustainably developed (socially and technically) by local multi-stakeholder networks formed by peasants, peasants’ groups, civil society organizations, and researchers in the so-called Third World. These developmental dynamics are captured within the term Local Sustainable Biotechnological Developments, which can be defined as a type of development that is based in the reconstruction of biotechnologies mainly (though not exclusively) by and for local actors, and which strengthen peasant agrarian systems and which empowers peasants, civil society organizations and local researchers within biotechnological structures.