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published in
Journal of Environmental Planning and Management
2022

DOI (link to publisher)
10.1080/09640568.2021.1905620

document version
Publisher’s PDF, also known as Version of record

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To cite this article: Dula Etana, Denyse J. R. M. Snelder, Cornelia F. A. van Wesenbeeck & Tjard de Cock Buning (2022) Review of the effectiveness of smallholder farmers' adaptation to climate change and variability in developing countries, Journal of Environmental Planning and Management, 65:5, 759-784, DOI: 10.1080/09640568.2021.1905620

To link to this article: https://doi.org/10.1080/09640568.2021.1905620
The objective of this study is to examine the effectiveness of adaptation. We reviewed and thematically synthesized 42 household-level studies published from 2000–2019 to explain how multiple processes interact to affect the effectiveness of adaptation. The findings show the positive impacts of adaptation in increasing crop yields and income, improving food security, and enhancing environmental protection. Not all adaptation strategies are effective, due partly to differences in sensitivity to climate problems, access to livelihood assets, diversification of adaptation strategies, and flexibility and cultural relevance of institutional support. For households with lower adaptive capacity, limited adaptation choices and reliance on climate-sensitive strategies fail to unshackle them from cyclical vulnerability. Improving adaptive capacity and facilitating diversified adaptation strategies are important to address the livelihood challenges of smallholder farmers. Understanding the complexities underlying the effectiveness of adaptation necessitates evaluation focusing on multidimensional livelihood outcomes to disentangle implications for sustainable livelihoods and socio-ecological resilience.

Keywords: livelihood; vulnerability; adaptive capacity; impact assessment; resilience

1. Introduction
Climate change and variability (CCV) pose enormous livelihood and food security challenges, particularly among smallholder farmers in developing countries (Williams et al. 2018). Smallholder agriculture is the source of livelihoods for large populations and responsible for the production of a high proportion of food and cash crops (Arias et al. 2013; Morton 2007). According to Arias et al. (2013), about 80% of the food consumed in developing countries is produced by smallholder farmers. These farmers are distinctly vulnerable to CCV because of their characteristics, such as heavy reliance on natural resources and subsistence farming, farm operation in risk-prone environments, limited access to resources, inadequate utilization of agricultural technologies, poor access to markets, and exposure to climate and non-climate risks (Arias et al. 2013; Cohn et al. 2017; Morton 2007; Williams et al. 2018). Adaptation
of smallholder agriculture that supports millions of farming households is therefore vital to promote sustainable livelihoods.

In a plethora of studies in Africa (Asfaw et al. 2016; Di Falco and Veronesi 2013; Douxchamps et al. 2016; Osbahr et al. 2010; Osbahr et al. 2008), Asia (Islam and Nursey-Bray 2017; Jones and Boyd 2011; Lei et al. 2016a), and Latin America (Burney et al. 2014; Da Cunha, Coelho, and Feres 2015), adaptation is recommended as an important strategy, complementing mitigation, to reduce vulnerability and enhance resilience. Although adaptation is widely considered as a means for addressing vulnerability to CCV, not all adaptation strategies are effective (Eriksen et al. 2011; Jain et al. 2015). Adaptation may turn out to be maladaptation (Moser and Ekstrom 2010) which, according to Juhola et al. (2016), refers to strategies “directly increasing vulnerability for the targeted and/or external actor(s), and/or eroding preconditions for sustainable development by indirectly increasing society’s vulnerability” (page 139).

Adaptation actions may have an unintended negative impact on the adapting households, and compromise the livelihood viability of other groups (Eriksen et al. 2011; Goldman and Riosmena 2013; Moser and Ekstrom 2010). Even if it has positive effects on households’ livelihood, adaptation actions could erode farming systems’ resilience (Nelson 2011). Hence, ensuring the effectiveness of adaptation is as important as advocating for adaptation to respond to the threats posed by CCV.

There is a mounting interest among policymakers, funding organizations, and the scientific community to know more about the effectiveness of adaptation. Moser and Boykoff (2013) espoused that evidence of effective adaptation is essential for various purposes. These include provision of communication to enhance public engagement, rigorous planning and decision-making that fit with the broader policy goals, justification of adaptation expenditure, improvement of accountability, and greater support for learning and adaptive management. Evidence on the effectiveness of adaptation to CCV is particularly imperative in the wake of the increasing prominence of sustainable adaptation. Sustainable adaptation stresses the importance of ensuring social equity, environmental integrity, and economic development in the process of poverty reduction initiatives (Eriksen et al. 2011). Identifying and promoting strategies that contribute to sustainable adaptation requires a good understanding of the sustainability implications of adaptation actions and types of adaptation strategies that produce desirable outcomes (Engle 2011).

Nevertheless, there is limited understanding of how effective adaptation strategies are in improving the livelihoods of smallholder farmers. Few of the previous reviews of adaptation studies in developing countries focused on the occurrence of adaptation, identification of adaptation strategies, barriers to adaptation, and state of adaptation policy and practice (Berrang-Ford, Ford, and Paterson 2011; Lwasa 2015; Shaffril, Krauss, and Samsuddin 2018). In the absence of literature that critically addresses the effectiveness of adaptation, a review of pertinent studies is important to document empirical knowledge on the evaluation of adaptation and identify research gaps (Berrang-Ford, Ford, and Paterson 2011; Berrang-Ford, Pearce, and Ford 2015). Thus, the objective of this review is to consolidate quantitative and qualitative evidence on the effectiveness of adaptation. Specifically, the review addresses two research questions: a) How effective is an adaptation in reducing smallholder farmers’ vulnerability to CCV? b) What factors can explain the effectiveness of adaptation strategies pursued by smallholder farmers? The review contributes to the dearth of evidence on the livelihood impact of climate change adaptation among smallholder farmers and uncovers factors that explain differential impacts of adaptation, ultimately supporting informed
decision-making in the identification, prioritization, and implementation of adaptation strategies. It also gives theoretical insights for the evaluation of adaptation impacts.

2. Conceptual framework

Understanding adaptation to CCV and ensuring its effectiveness are concerns dominating the discourse on the linkage between vulnerability, adaptation, and resilience. These three concepts are closely interrelated, and vulnerability and resilience are increasingly being discussed in relation to adaptation to CCV (Nelson 2011). Vulnerability is the degree to which a system [smallholder farming] is susceptible to, or unable to cope with, the adverse effects of CCV (Smit and Wandel 2006). It is the function of exposure of smallholder farmers to climate risks, the sensitivity of their livelihoods, and their capacity to adapt. Vulnerability is the combined effect of external biophysical factors and internal demographic and socio-economic characteristics of farmers as well as the institutional contexts of livelihood functioning (Bassett and Fogelman 2013; Engle 2011). Resilience is the capability to respond to and recover from risks (Osbahr et al. 2008). It is characterized by buffer capacity (the capacity to achieve better livelihood outcomes), self-organization (the degree to determine one’s actions and outcomes), and learning capacity (learning from previous experience and translating into action to persistently adapt to changing conditions) (Speranza 2013). Vulnerability and resilience are concepts useful for local-level analysis of livelihood decision-making (Clay 2018) in which resilience entails indirectly addressing root causes of vulnerability (Speranza 2013). According to Moser and Ekstrom (2010), adaptation is a change in social-ecological systems in response to the impacts of climate change in the context of interacting non-climate changes. Adaptation involves addressing the underlying causes of vulnerability (Bassett and Fogelman 2013).

Our analysis of the effectiveness of adaptation is guided by the Sustainable Livelihoods Framework (SLF) (Scoones 1999). A livelihood comprises the capabilities, assets, and activities that contribute to a means of living (Chambers and Conway 1992). The livelihoods approach helps to understand dynamic and complex rural contexts (Scoones 2009) through holistic characterization of its vulnerability and resilience (Carr 2014). Clay (2018) argues that SLF gives clarity to the assessment of adaptive capacity, understanding of the uneven distribution of adaptive capacity, and interdisciplinary investigation of the link between social and biophysical factors. Integration of the concepts of resilience and vulnerability into the livelihoods approach helps to thoroughly understand livelihood dynamics and the effectiveness of adaptation to CCV (Scoones 1999; Speranza 2013). The livelihoods framework includes five complex and interrelated concepts that together influence livelihood functioning. These are vulnerability context, livelihood assets, transforming structures and processes, livelihood strategies, and livelihood outcomes (Scoones 1999). The relationship between these components shows how smallholder farmers differ in terms of utilizing assets to undertake a set of activities, being mediated by institutional processes, to respond to climate and non-climate risks.

Multiple sources of vulnerability challenge the livelihood of smallholder farmers (Morton 2007). In addition to climate-related events, farmers are vulnerable to non-climate risks. For instance, in Ghana, Nyantakyi-Frimpong and Bezner-Kerr (2015) showed that non-climate factors rooted in political-economic and cultural processes were critical challenges to livelihoods. The decision to use and the effectiveness of
adaptation are thus shaped not only by a changing climate but also by its flexibility to manage multiple risks across time (Burnham and Ma 2018). Farmers respond to these multiple risks based on their adaptive capacity. Adaptive capacity is the ability to mobilize resources to respond to risks (Engle 2011). Livelihood assets (i.e. natural, human, physical, financial, and social capital) constitute the capacity to adapt (Scoones 1999). Adaptive capacity conceptually links vulnerability, adaptation, and resilience (Clay 2018; Engle 2011). The capacity to adapt is dynamic as it may be produced, reproduced, and negotiated (Clay 2018). Access to resources promotes livelihood flexibility to effectively respond to multiple risks (Derbile, File, and Dongzagla 2016). It also increases resilience by maintaining livelihood or transforming it into a new state when the existing state is untenable (Engle 2011). A wide variety of assets gives farmers a broad range of options to respond to multiple risks. On the other hand, low adaptive capacity is not only a barrier to adaptation (Eisenack et al. 2014) but also a constraint to its effectiveness (Engle 2011; Moser and Ekstrom 2010).

Farmers utilize several adaptation strategies to respond to climate and non-climate risks. These include actions taken by farmers (autonomous adaptation) and government and non-governmental organizations (planned adaptation). These responses could be anticipatory or reactive (Berrang-Ford, Ford, and Paterson 2011; Engle 2011). In particular, autonomous adaptation takes place in response to environmental change and resource scarcity, and that the responses reflect what these changes mean to the smallholder farmers and how the changes impact their livelihoods (Forsyth and Evans 2013). In addition to scientifically identified strategies, farmers use indigenous knowledge derived from long-term experience and experimentation to design adaptation strategies pertinent to their knowledge system and specific to their local contexts (Makondo and Thomas 2018; Nkomwa et al. 2014). Indigenous knowledge is particularly important for adaptation because of its cultural relevance, community engagement through participatory approaches, alignment with the principles of sustainable development, and convenience for effective communication and increased utilization (Nyong, Adesina, and Osman Elasha 2007). Integration of indigenous and modern knowledge contributes to the effectiveness of adaptation (Nkomwa et al. 2014; Nyong, Adesina, and Osman Elasha 2007). Adaptation is a contested process shaped by political dynamics (Manuel-Navarrete and Pelling 2015). The politics of adaptation involves understanding the differences in the utilization of adaptive capacity to its full potential (Clay 2018). This underscores that adaptive capacity may not be translated into action due to political, economic, and cultural enabling or constraining factors, leading to differential use of adaptation strategies. In Botswana, Shinn et al. (2014) explained that micro-politics plays a role in shaping differential adaptation responses. They found a disparity between state-sponsored adaptation responses and the preference for farmers to maintain the cultural identity of their livelihood practices, resulting in divergent desires for adaptation. Due to these power dynamics, adaptation may aggravate socio-economic, political, and cultural inequalities (Sovacool, Linnér, and Goodsite 2015).

Institutions, both formal and informal, play mediating roles in adaptation (Clay 2018). As explained by Gupta et al. (2010), they support adaptation by “empowering social actors to respond to short and long-term impacts either through planned measures or through allowing and encouraging creative responses from society both ex-ante and ex-post” (461). Institutions support effective adaptation by overcoming low adaptive capacity and other barriers to adaptation (Eisenack et al. 2014) through the facilitation of access to resources (Derbile, File, and Dongzagla 2016; Goldman and
Riosmena 2013). The role of institutions in supporting adaptation depends on their flexibility to learn from and promote new insights and experiences as well as their robustness to maintain some degree of identity (Gupta et al. 2010).

Livelihood outcomes show the objectives that smallholder farmers aim to achieve through the use of adaptation strategies. The achievement of these objectives signals the effectiveness of adaptation (Adger, Arnell, and Tompkins 2005). However, the determination of effectiveness is highly contested. Adaptation is value-laden (Clay 2018) that people have different definitions and priorities for adaptation. The effectiveness of adaptation is also embedded and emergent in environmental, socio-economic, and institutional contexts (Burnham and Ma 2018; Goldman and Riosmena 2013; Manuel-Navarrete and Pelling 2015). There is a continual change in the livelihood context and institutional support schemes in response to changes in vulnerability factors. These changes cause variation in access to resources and availability of adaptation options, with differing adaptation outcomes. Furthermore, effectiveness is rooted in micro-political dynamics in which use or non-use of an adaptation strategy reflects power relationships, governance, and differential capacity to adapt in desirable and culturally suitable ways (Shinn et al. 2014). Due to unequal power structures, there could be diversity in benefiting from adaptation in which some benefit whereas other lose, leading to inequitable livelihood outcomes and inequality in the distribution of wealth (Sovacool, Linnér, and Goodsite 2015). Based on insights from vulnerability and resilience thinking, adaptation is assumed to be effective if it reduces smallholder farmers’ vulnerability to the impacts of multiple stressors and builds resilience by maintaining key functions (e.g. reducing poverty, achieving food security, raising income) (Adger, Arnell, and Tompkins 2005; Osbahr et al. 2010; Osbahr et al. 2008; Speranza 2013). From the perspective of sustainable adaptation, it involves achieving social equity, environmental integrity, and economic development (Eriksen et al. 2011). Hence, in this review, we aim to explain how the components of the livelihoods framework interact to influence the multidimensional outcome of adaptation strategies pursued by smallholder farmers in developing countries.

3. Review method

This review used peer-reviewed publications between 2000 and 2019. The search databases were Web of Science, Scopus, and Google Scholar. They were selected because several multidisciplinary research areas are indexed in them, which allows the coverage of a wider range of publishers and publications. The search terms were shown in Figure 1. The identification of the search terms was guided by the sustainable livelihoods framework to capture concepts referring to the conditions and processes underlying sustainable livelihoods, as well as the diverse outcomes of adaptation actions (mainly conceptualized in terms of increased income, improved food security, and sustainable use of natural resources) in the context of vulnerability to CCV. Besides, the keywords used in relevant articles were considered in refining the search terms. We started with broad interdisciplinary search terms to identify papers which describe the interaction of factors that support or hinder sustainable livelihoods under climate change. To ensure comprehensiveness and relevance, the search terms were combined through an iterative process in which the terms were utilized with Boolean operators. References of the most pertinent studies were scanned to include additional relevant
After exporting the citations to EndNote X8, a selection of the studies was made in three consecutive steps (Figure 1). In the first step, the three databases were merged, and 548 duplicate references were excluded. In the second step, the titles of the retrieved documents were assessed, and 3,714 studies were excluded based on the exclusion criteria listed in Table 1. Due to the differences in socioeconomic settings that determine vulnerability and adaptation, studies pertaining to developed countries were excluded. We followed the definition and classification of the United Nation’s World Economic Situation and Prospect (United Nations 2020) to identify developing countries. Adaptation in natural systems and other aspects of human systems (e.g. urban context, transportation, industry) were excluded. In addition, conceptual/theoretical/methodological articles as well as reviews were excluded.

In the third step, the abstracts of the short-listed 926 studies related to adaptation to CCV were assessed based on the inclusion criteria given in Table 1 to determine their eligibility for review. When it was not possible to determine the relevance of the article from the title and abstract, the full text was skimmed. Since we aim to unravel the implications of farmers’ responses for sustainable livelihoods, only studies about adaptation under small-scale agriculture were considered. Owing to diversities between...
different types of agricultural systems in vulnerability structure and response mechanisms, only studies on mixed-farming were included. The review did not include studies focusing only on types and determinants of adaptation strategies; adaptation studies that did not investigate impacts or evaluate impacts at higher spatial scales; and impact studies not disaggregated by specific types of adaptation strategies. Besides, studies focusing on farmers’ vulnerability to, and perceptions of, climate change without making a clear link to adaptation outcomes were not included. To delimit the scope of the review to smallholder mixed farming, other livelihood systems such as commercial farmers and pastoralists were excluded. The selection focused on micro-level studies to synthesize empirical evidence of households, the level at which adaptation decisions are often made. Although smallholder farmers in developing countries widely use coping strategies, they were not considered in this review. Although the conceptual difference between coping and adaptation is less clear and sometimes used interchangeably, coping generally involves short-term reactive responses including asset disposal to ensure survival, whereas adaptation is intended to manage climate risks. To reduce selection bias, careful assessment of the retrieved studies and discussion on the selection procedure were made based on the review protocol. The reasons for exclusion were separately indicated for each study and summarized, as shown in Figure 1, to minimize the risk of biased selection decisions.

Finally, the full text of 42 studies focusing on the impact of adaptation strategies on the livelihoods of smallholder farmers were considered for final review. Since autonomous adaptation cannot be entirely independent of planned adaptation (Burnham and Ma 2016), both types of adaptations were considered in the review. Although separately reporting adaptation to climate change and climate variability has important policy implications, we did not consider them separately in this review as the two concepts were reported in multiple and inconsistent ways. In most of the studies, climate change and variability were either considered in combination or reported a priori without making specific and clearly established links to the use of adaptation strategies. Although location matters in adaptation, we did not include it as a search string for three reasons. First, the exclusion criteria (e.g. urban, developed countries) limits geographical location to the rural context of developing countries. Second, we preferred to focus on conceptual factors defining relevant sub-types of locations. For instance, the focus on smallholders limits the study to locations where farming is the dominant economic activity, implying that locations where other livelihood systems (e.g.

<table>
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<td>Developing countries</td>
<td>Developed countries</td>
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<tr>
<td>Farming system (mixed farming)</td>
<td>Natural system and other human systems (e.g., urban livelihood, transport, industry, etc.)</td>
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<tr>
<td>Empirical studies</td>
<td>Conceptual/theoretical/methodological subjects as well as reviews</td>
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<td>Micro-level studies Assessment of the impact of adaptation</td>
<td>Macro-level studies (regional and national studies)</td>
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<td>Studies merely focusing on mitigation, coping strategies, climate change, impacts of and vulnerability to climate change; identification of adaptation strategies used by farmers; and determinants of the use of adaptation strategies</td>
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commercial farming, pastoralism) are the dominant means of living are excluded. Third, the use of specific location factors (e.g. agro-ecology zones) narrows down the scope of the search as smallholder farmers can operate in different agro-ecological environments. However, duly acknowledging the roles location factors can play in adaptation and its effectiveness, they are explained, based on the reviewed data, under contextual factors.

A checklist was prepared to extract pertinent information from each document for further analysis and synthesis. The checklist captures information about the characteristics of the reviewed studies (the type of document, study area, and research methods), types of adaptation strategies, adaptation outcomes, and context of effectiveness (see online supplementary information). Due to epistemological complexity and methodological diversity in adaptation research (Berrang-Ford, Pearce, and Ford 2015), a quantitative meta-analysis was not performed. The results of the review were summarized using descriptive statistics (percentage distribution) followed by thematic analysis and narrative synthesis.

4. Results

4.1. Description of the reviewed studies

For this review, a total of 42 studies were considered. Most of the studies were from Africa (60%), followed by Asia (26%) and Latin America and the Caribbean (12%) (Figure 2). The review recovered a total of 31 developing countries across the three regions. About 60% of the reviewed studies used quantitative studies that were mainly based on cross-sectional surveys. Nearly one-third of the studies utilized mixed research methods (quantitative and qualitative methods). Only about 10% of the studies used qualitative evaluation approaches. This approach includes life history interviews focusing on changes in livelihoods, participatory rural appraisals, participant observation, and interviews and focus group discussions to narrate people’s experiences and perceived changes.
The studies identified numerous adaptation strategies which were broadly categorized into five in this review. These were climate-smart agricultural practices (e.g. conservation agriculture, agro-forestry, minimum soil disturbance, legume intercropping, organic fertilizer), an adjustment in farming practices (changing planting date, changing from single to sequential cropping, changing crop type – e.g. rice to millet, grain corn to forage corn), sustainable land management (planting trees, soil and water conservation activities, constructing terraces and stone barriers), diversification of sources of income (production of vegetables, livestock production, non-farm works, diversification of crops and land use patterns, commercialization of agriculture, and migration), and use of technologies (drought- and pest-tolerant crops, fast-maturing crops, irrigation, water harvesting, inorganic fertilizer). The reviewed studies used various indicators to investigate the impact of adaptation (Figure 2). Most of the studies examined the impact of using adaptation strategies on farmers’ crop yields, income, and food security. The findings of the review are presented according to the conceptual blocks given in Figure 3. It begins with a review of studies on the outcome of adaptation (Block H in Figure 3) in section 4.2 and works from left to right to analyze the underlying reasons for (in)effectiveness in section 4.3.

4.2. Adaptation outcome: how effective is adaptation?

Despite variation in research design and analytical techniques, the reviewed studies showed the positive impact of adaptation on livelihoods in terms of economic, social, and environmental benefits.

4.2.1. Economic impact of adaptation

The majority of the reviewed studies reported the significant contribution of adaptation strategies to farmers’ income and crop yields (Table 2). The positive impact of climate-smart agricultural practices on crop yields was reported in studies in Zambia (Arslan et al. 2015), India (Aryal et al. 2016), Kenya (Boillat et al. 2019), Malawi (Asfaw et al. 2016), Guatemala (Sain et al. 2017), Tanzania (Hong, Mkonda, and He 2018), Mozambique (Kidane et al. 2019), and Sri Lanka (Williams and Carrico 2017), Zimbabwe (Michler et al. 2019). Changing cropping patterns from water-demanding to water-saving crops reduced crop production risks and increased crop yields in China (Lei et al. 2016b). An increase in income associated with irrigation was reported in Kenya (Lasage et al. 2008), Brazil (Burney et al. 2014; Da Cunha, Coelho, and Feres 2015), and India (Jain et al. 2015). Changing planting dates increased income in Cameroon (Molua 2002). Changing crop type increased income in China (Lei et al. 2016a). Three studies reported the positive effect of adaptation on resilience (conceptualized in terms of income, livelihood improvement despite disturbances, livelihood flexibility and renewal, and buffer capacity) (Ayeb-Karlsson et al. 2016; Osbahr et al. 2008; Speranza 2013). Crop diversification as well as the use of drought-tolerant crop varieties have also increased farmers’ income and productivity (Amondo et al. 2019; Asmare, Teklewold, and Mekonnen 2019; Makate and Makate 2019). Three studies reported the economic profitability of using adaptation strategies (Lan et al. 2018; Lei et al. 2016b; Mutenje et al. 2019).
4.2.2. Social impact of adaptation

As shown in several studies, adaptation had positive impacts on food security (Ali and Erenstine 2017; Cholo et al. 2019; Douxchamps et al. 2016; Waha et al. 2018) and nutrition (Teklewold, Gebrehiwot, and Bezabih 2019). Five studies reported other aspects of the social impacts of adaptation. Lasage et al. (2008) found that sand dam construction had improved farmers’ access to drinking water, particularly during the dry season in Kenya. The use of climate-smart practices improved employment opportunities through demand for additional labor in Guatemala (Sain et al. 2017). Lei et al. (2016b) found that farmers’ decisions to change crop type from water demanding to drought-tolerant crops, as well as the use of irrigation, increased crop yields, which in turn improved social benefits through increased regional grain security in northern China. This study further noted that the use of mechanized sprinkler irrigation reduced the demand for labor which increases farmers’ time to engage in non-farm activities.
Nevertheless, some studies reported mixed findings on the impact of adaptation. In a study in West Africa, Douxchamps et al. (2016) found that adaptation improves the food security status of some households but not all. A qualitative study in Bangladesh showed that achieving sustainable livelihoods was unusually difficult for most households due to a failure to reduce their vulnerability (Collins 2014).

4.2.3. Environmental impact of adaptation

Sain et al. (2017) showed the biodiversity benefits of agroforestry and conservation tillage in terms of improvement of environmental services such as temperature regulation and soil moisture retention. These strategies also reduced soil and water contamination. The authors noted that the payback period of these strategies was relatively longer (about eight years). In another study in Mexico and Guatemala, generation of income from forest and forest products enhanced forest conservation by increasing the opportunity costs of clearing forests, which had dual benefits of livelihood improvement and long-term social-ecological benefits (Rodriguez-Solorzano 2014). In northern China (Lei et al. 2016b), planting trees on sloping drylands improved the environment and reduced crop production risks. According to this study, the shift from water-demanding spring wheat to forage corn substantially reduced the pressure of agricultural production on the ecosystem in meeting the crop’s water requirements and saving a significant amount of water. Diversification of adaptation strategies by including conservation agriculture activities enhanced soil fertility, and regulated soil moisture and temperature (Makate et al. 2019).

4.2.4. Maladaptation

Unexpected consequences of adaptation strategies were reported in five studies. In Mexico and Guatemala, farmers who live close to commercial centers extensively participated in cattle ranching by clearing forests, which had adverse effects on biodiversity and long-term farmers’ welfare (Rodriguez-Solorzano 2014). In India, although irrigation (based on groundwater) was found effective to adapt to delayed monsoon onset, it was noted to be maladaptive in the long-term due to the rapid decline of the water table (Jain et al. 2015). Lei et al. (2016a) in their study in China, found that farmers’ decisions to respond to drought by changing from rice-dominant to cotton-dominant cropping patterns had an adverse impact at a higher spatial scale due to the decline in regional grain output. The labor-saving advantages of adaptation strategies reduced job availability for poor farmers who rely on casual jobs in Kenya (Speranza 2013). A study in Cambodia showed that migration may be a maladaptive response to climate change due to labor shortage and welfare problems, resulting in a climate-induced poverty trap (Jacobson et al. 2019).

4.3. What explains the effectiveness of adaptation?

The outcome of adaptation may not necessarily be effective due to barriers associated with the selection and implementation of strategies. Barriers are obstacles that can be overcome with concerted effort, and innovative management and institutional approaches (Moser and Ekstrom 2010). The results of the review on the enablers of, or barriers to, effective adaptation are briefly presented below.
4.3.1. Climate and non-climate risks (Figure 3, blocks A and B)

Climate risks affect both adaptation and its outcomes. Climate factors (e.g. rainfall variability, temperature change, as well as temperature and rainfall extremes) were among the drivers of farmers’ decision to adapt and the type of adaptation strategies they use (Asfaw et al. 2016; Jacobson et al. 2019). The negative effects of climate factors on the outcome of adaptation were reported in several studies. Reduced yield impact of sequential cropping due to a shorter growing season (Waha et al. 2013); reduced effectiveness of conservation agriculture in increasing maize yield due to waterlogging caused by too much rainfall (Thierfelder, Matemba-Mutasa, and Rusinamhodzi 2015); decline in maize yield due to an increase in dry spells (Asfaw et al. 2016) attest the direct negative effects of climate factors on livelihood outcomes. Extreme climate events indirectly affect livelihoods through disruption of access to resources (Lei et al. 2016a). Non-climate risks aggravate climate-related problems to constrain effective adaptation. In Bangladesh, Collins (2014) explained that loss of land due to riverbank erosion and the consequent landlessness, coupled with socio-political problems of accessing land, reduced the effectiveness of adaptation responses. However, the combined effects of these factors on adaptation effectiveness are not accounted for in most of the reviewed studies.
4.3.2. Socio-cultural motivation factors (Figure 3, block C)

Adaptation requires acknowledgment of CCV and recognition of the importance of taking action. This shows the crucial role of socio-cultural factors in adaptation action and its effectiveness. These factors include risk perception, knowledge, experience, norms, and values. Denoting the roles of recognizing climate risks to initiate action, Teklewold, Gebrehiwot, and Bezabih (2019) showed that perception of rainfall shocks increased the adoption of climate-smart agricultural practices. A voluntary resettlement program to prevent flood was ineffective in Mozambique due partly to farmers’ lower perception of the seriousness of climate risks (Patt and Schroter 2008). Knowledge about and confidence in adaptation practices (Aryal et al. 2016), knowledge on the use of technologies (Da Cunha, Coelho, and Feres 2015), experience with climate events (Di Falco and Veronesi 2013; Khanal et al. 2018), and the use and management of adaptation strategies (Thierfelder, Matemba-Mutasa, and Rusinamhodzi 2015) were crucial for the uptake, implementation, and effectiveness of adaptation. Despite a lack of strong supporting evidence, norms and values play important roles in adaptation. Societal norms and values are informal rules, standards, and beliefs shared by a group of people. The main functions of norms and values are shaping behavior that is considered acceptable in a society. They govern shifts from and navigation between traditionally held livelihood identities and new innovative practices (Osbahe et al. 2010). Specifically, norms and values influence adaptation behavior in terms of choices of strategies and actions, as well as extent of livelihood changes farmers could accept to respond to the risks of CCV. In their qualitative study in Nepal, Jones and Boyd (2011) revealed the pertinent roles of norms in which farmers remained persistent with traditional coping strategies and failed to adopt appropriate and sustainable livelihood strategies in response to climate shocks and stresses. The study further showed that low self-efficacy (i.e. inability to effectuate change) was among the barriers to effective adaptation responses. Consequently, the attempt made by a non-governmental organization (NGO) to introduce new and efficient methods of production was unsuccessful due partly to the reluctance of the community to deviate from traditional practices and historical norms. Nielsen and Reenberg (2010) conducted an ethnographic study on cultural barriers to adaptation among two ethnic groups (Rimaibre and Fulbe) in Burkina Faso. Unlike the Rimaibre community that adapted to rainfall variability through livelihood diversification such as labor migration and women’s involvement in income-generating activities, the Fulbe community were less involved in these activities due to norms and values such as maintaining freedom and personal integrity, proving worthiness by surviving in the existing way of life, and considering the above-mentioned strategies as shameful.

4.3.3. Livelihood assets (Figure 3, block D)

Households adapt to climate risks in diverse ways and benefit differently due to inequalities in adaptive capacity. Most reviewed studies showed that access to livelihood assets positively influences adaptation action and choice of strategies, the number of adaptation strategies used by farmers, and the outcomes of adaptation. In Malawi, the adoption of sustainable land management practices and the use of improved seeds and fertilizer were high for wealthier and educated households (Asfaw et al. 2016). In India, while rich farmers relied on the use of irrigation, the poor changed planting dates and switched crop varieties to respond to climate variability (Jain et al. 2015). In South Africa and Mozambique, while poor households engaged in risk-averse strategies (e.g. reliance on
social networks), cash-rich households participated in risk-spreading, specialized livelihood strategies (e.g. poultry, horticulture) that are likely to contribute to resilience (Osbahr et al. 2010). Social capital also increased the use of adaptation strategies (Teklewold, Gebrehiwot, and Bezabih 2019). Conversely, low adaptive capacity limits adaptation choices and implementation of preferred strategies. Due to a lack of assets, extremely poor, landless, and female-headed households were particularly unable to effectively respond to climate risks (Collins 2014). Wealth and access to other livelihood assets were positively associated with the number of adaptation strategies adopted by farmers in Pakistan (Ali and Erenstein 2017), Malawi (Asfaw et al. 2016), and Malawi and Mozambique (Makate et al. 2019). The same adaptation strategies may result in distinct livelihood outcomes due to differences in assets (Douxchamps et al. 2016).

4.3.4. Adaptation action (Figure 3, block E)

The effectiveness of adaptation differs based on the extent of dependence of the strategies on climate factors and the number of strategies used by farmers. In Brazil, although irrigation increased production, it was not used, hence less effective, during years of massive drought (Burney et al. 2014). In a study in ten sub-Saharan African countries (Waha et al. 2013), sequential cropping was an effective adaptation strategy where precipitation was adequate and the length of the growing season was longer. Six studies showed the positive impact of using multiple strategies. Di Falco and Veronesi (2013) found that the combination of any two of the three strategies (i.e. changing crop varieties, water strategies [irrigation, water harvesting, water conservation], and soil conservation) significantly increased net revenues of farm households compared with using only one strategy. In Pakistan, compared with those who did not adapt, households using one, two, and three adaptation strategies had 7-8%, 8-9%, and 12-14% higher food security levels, respectively (Ali and Erenstein 2017). The poverty levels of these households consistently decreased by 2-3%, 3-5%, and 6-8%, respectively. In Malawi (Asfaw et al. 2016), the combined use of adaptation strategies (i.e. improved seed and tree planting, improved seed and inorganic fertilizer, legume intercropping, and inorganic fertilizer) increased maize productivity. Similar beneficial impacts of using multiple adaptation strategies were reported in the other studies (Hong, Mkonda, and He 2018; Makate et al. 2019; Mutenje et al. 2019). However, increasing the number of adaptation strategies is not always effective. In Ethiopia, the simultaneous use of three strategies (i.e. changing crop varieties, water strategies, and soil conservation) did not yield a significant difference in income compared to the adoption of two strategies, which reflects, according to the authors, the higher cost of implementing complex adaptation strategies that reduce net revenues (Di Falco and Veronesi 2013).

4.3.5. Institutions (Figure 3, block F)

Local institutions1, both informal and formal, are important for adaptation and its effectiveness. Informal local institutions support adaptation mainly through the facilitation of access to and exchange of resources. In South Africa, informal networks helped people to share information, cash loans, food or labor exchange, which were useful to buffer shocks (Osbahr et al. 2010). The role of formal, locally-based institutions in adaptation takes multiple facets. First, they facilitate access to resources. In South Africa and Mozambique, agricultural cooperatives and farmers’ associations helped with the sharing
of information and knowledge (e.g. climate forecast), technologies (new crop trials), and skills (e.g. livestock breeding) that were important for effective adaptation (Osbahr et al. 2010). In Bangladesh, a formal government institution undertaking field-level initiatives supported adaptation through the provision of agricultural inputs (e.g. fertilizer, seed, pesticide), equipment (e.g. low lift pump and sprayer), training in the use of technologies (e.g. use of surface water for irrigation), and motivational activities (e.g. exchange visit) (Islam and Nursey-Bray 2017). It also supported effective adaptation by assisting farmers to change cropping patterns (from water-intensive rice production to the cultivation of pulse crops that need less water), which had the dual benefits of increasing cropping intensity and reducing water consumption. As confirmed in empirical works in Ethiopia (Di Falco and Veronesi 2013), Malawi (Asfaw et al. 2016), and Nepal (Khanal et al. 2018), availability of and access to services of locally based institutions significantly increased households’ adaptation. In Zimbabwe, access to extension services increased the livelihood impact of drought-tolerant crop varieties through its positive effect on the use of fertilizer, organic manure, credit services, and certified seed variety (Makate and Makate 2019). Local formal institutions may also help to ensure the sustainability of adaptation practices. In Kenya, a local NGO supported the construction of a sand dam to store excess water, which helped to effectively adapt to drought by increasing water availability throughout the year (Lasage et al. 2008). Overcoming maladaptive practice is another key role of institutions. In Bangladesh, access to irrigation facilities using ground water was developed to respond to drought. Although it appeared effective in the beginning, it resulted in the depletion of ground water levels. Institutional measures helped to overcome the problem by shifting to the use of surface water (Islam and Nursey-Bray 2017).

Conversely, both informal social networks and formal locally-based institutions may obstruct adaptation. Resistance to change and perpetration of social exclusion were among the limitations of informal institutions (Osbahr et al. 2010). Besides, informal networks that were based on reciprocity excluded the most vulnerable households (e.g. female-headed households) who were unable to invest in social networks (Osbahr et al. 2010). One of the weaknesses of formal institutions was a top-down approach to adaptation interventions that failed to take into account the culture of the local community. In their analysis of the effectiveness of formal institutions in climate change adaptation, Islam and Nursey-Bray (2017) found over-emphasis on technology, lack of acknowledgement of cultural factors, and weak linkage with informal institutions as barriers. Furthermore, social discrimination induced by locally-based institutions may be a barrier to respond to shocks. In Nepal, the social class with dominant power allocated resources (e.g. aid, livelihood options, employment opportunities) to their socio-cultural strata (Jones and Boyd 2011), which reinforced social, power, and entitlement inequalities (Osbahr et al. 2010), further exacerbating vulnerability.

4.3.6. Contextual factors (Figure 3, block G)

Contextual factors refer to environmental, socio-economic, and institutional circumstances unique to a group of farmers or community that influence the livelihood impact of adaptation. The effectiveness of adaptation is embedded in these contextual factors (Burnham and Ma 2018). These factors could either play enabling roles in increasing the benefits of adaptation or they may be risk factors inhibiting the extent of effectiveness of adaptation. Effectiveness is thus multi-scalar as adaptation is
influenced by household characteristics as well as the contexts in which decisions are made and actions are taken. For instance, in Malawi, the positive effects of inorganic fertilizer and improved seeds were contingent on the absence of false onset of rainfall and high temperature, respectively (Arslan et al. 2015). However, legume intercropping was robust to both false onset of rainfall and very high temperature, and maize yield was significantly higher in both contexts. While tillage practices improved economic return in Cameroon when there was an increase in precipitation (Molua 2002), the effectiveness of irrigation was dependent on water availability in Brazil (Burney et al. 2014; Da Cunha, Coelho, and Feres 2015). Access to early warning information as well as the availability of sufficient labor to harvest the first crop and undertake land preparation and sowing of the second group determine the effectiveness of the sequential cropping system (Waha et al. 2013). Availability of labor as well as economic resources was important to participate in, and benefit from, reciprocal social support networks and diversification of livelihood strategies (Osbahr et al. 2008). The effectiveness of migration was conditional on social networks in another place to facilitate access to livelihood assets such as land, housing, and jobs (Ayeb-Karlsson et al. 2016). The effect of climate-smart agricultural practices on nutrition also varied between households due to differential access and return to resources (Mutenje et al. 2019; Teklewold, Gebrehiwot, and Bezaibh 2019). With increasing fragmentation, the use of sustainable land management was not only less likely (Teklewold, Gebrehiwot, and Bezaibh 2019) but also its positive impact on food security was reduced (Cholo et al. 2019).

Location is a vital contextual factor in adaptation to CCV and its effectiveness. In Guatemala and Mexico, access to commercial centers to obtain inputs, technologies, and markets for products were important to engage in and benefit from cattle ranching (Rodriguez-Solorzano 2014). Longer distance to a market/town may discourage farmers from using conservation agriculture due to high transaction costs (Makate et al. 2019), whereas farmers located close to market centers were more likely to participate in, and benefit from, off-farm employment (Khanal et al. 2018). Waha et al. (2018) showed that the beneficial impact of diversifying farming systems was positive only in areas obtaining 500–1000 mm annual rainfall as well as rainfall variability of 17-22%. Different types and combinations of adaptation strategies are also effective in diverse agro-climatic zones (Lan et al. 2018; Mutenje et al. 2019). In Mozambique, for instance, there was agro-ecological variation in maize production performance due to differences in temperature, rainfall distribution, and type of soils which affect crop growing conditions (Kidane et al. 2019).

5. Discussion
Climate change and variability form a critical development agenda with overarching implications for sustainable livelihoods. The concern is high among smallholder farmers in developing countries who are dependent on climate-sensitive economic activities, denoting the need for adaptation. However, as adaptation is a necessary, but not a sufficient, condition for sustainable livelihoods, ensuring that adaptation strategies contribute to economic efficiency, social equity, and environmental protection is important. The findings of this review generally show that adaptation has a positive effect on the livelihoods of smallholder farmers. However, the beneficial impact of adaptation is noticeably different between households, which is mainly linked to the
contexts in which they undertake adaptation actions. These contexts, as briefly discussed below, include the degree of exposure to climate and non-climate risks, differences in adaptive capacity, the extent of diversification of strategies, and institutional support structure.

**Severity of climate problems, coupled with non-climate factors, undermines the effectiveness of adaptation**

Although adaptation is a response to CCV, the effectiveness of adaptation strategies is contingent on favorable climate conditions. Climate risks characterized by high magnitude, a frequent occurrence, and rapid onset undermine the effectiveness of adaptation (Collins 2014; Speranza 2013). They result in huge loss and depletion of livelihood assets of farmers, consequently limiting the options for investment in adaptation. With frequent exposure to climate risks, households, particularly the poor, not only lack the capacity to respond, but the reactive measures they are most likely to pursue, i.e. the indigenous knowledge and skills, may fail to help them to successfully recover from recurrent extreme events (Collins 2014). Also, the time farmers require to recover from successive climate risks becomes shorter. The recurrent occurrence of CCV also reduces the possibility for building adaptive capacity to effectively respond to current and future events. Frequently occurring climate events induce the use of low-cost coping strategies that are often employed to ensure survival and regain livelihoods after the stressors. Extreme climate events can also destroy adaptation processes and make adaptation measures ineffective (Ayeb-Karlsson et al. 2016). These effects of climate risks, being fueled by socio-economic problems, restrain smallholder farmers’ access to, as well as the allocation of, scarce livelihood resources which in turn reduces the possibility of effectively reconstructing livelihoods, further exacerbating vulnerability. Adaptation strategies are also less effective if they fail to synergistically manage multiple climate and non-climate risks experienced by smallholder farmers (Burnham and Ma 2018).

**High adaptive capacity is a key for effective adaptation**

The findings indicate that farmers with high adaptive capacity are more likely to effectively respond to CCV through the use of adaptation strategies. High adaptive capacity, which is the function of access to livelihood assets, gives farmers better opportunities to implement high-return adaptation strategies. As evidenced from a study in India, irrigation, which was effective in increasing income, was mainly used by rich farmers. However, poor households relied on changing planting dates and switching crops which was less beneficial compared to irrigation (Jain et al. 2015). While poor households engage in risk-averse strategies, rich households participate in risk-spreading and specialized livelihood strategies that are likely to build resilient livelihoods (Osbahr et al. 2010). High adaptive capacity gives farmers the flexibility to make livelihood choices and innovative adaptation decisions (Collins 2014). It also allows the use of multiple adaptation strategies that have synergistic livelihood benefits (Ali and Erenstein 2017; Asfaw et al. 2016; Makate et al. 2019). Conversely, low adaptive capacity increases vulnerability by preventing adaptation and forcing smallholder farmers to limit their strategies to inexpensive but less effective ones aiming at ensuring survival instead of investing in intuitive, proactive, and effective strategies.
Since adaptation is shaped by cross-scalar interactions of contextual factors, households’ lack of capacities to invest in effective adaptation strategies are rooted in structural processes underpinning livelihood practices and choices of adaptation strategies. (Burnham and Ma 2018). The effectiveness of adaptation among households with high adaptive capacity entail that the better-off are the winners whereas poor households are losers in terms of social, economic, and environmental benefits (Sovacool, Linnér, and Goodsite 2015). The process of adaptation may thus exacerbate vulnerability of households with lower adaptive capacity.

**Diversifying the number of adaptation strategies increases effectiveness**

Studies that investigated the impact of multiple adaptation strategies consistently found the benefits of combining adaptation strategies. As evidenced by the reviewed studies, the combined use of adaptation strategies enhances effectiveness in different ways. First, multiple strategies help in spreading risks. For instance, the risk of climate-induced losses is lower when different crops are planted than with a monoculture because of the heterogeneity of different crops in terms of growth stages and resistance to drought (Lei et al. 2016a). Second, diversification of adaptation strategies may help to achieve multiple objectives. In Guatemala and Mexico, participation in forest-based non-farm activities (tourism, traditional medicine, and honey production) served the dual purposes of generating income and environmental sustainability (i.e. forest conservation) (Rodriguez-Solorzono 2014). Third, the use of multiple strategies provides opportunities for complementarity or substitutability. Asfaw et al. (2016) revealed that since the use of both inputs boosts productivity, there is complementarity between improved seeds and inorganic fertilizers. There is substitutability between organic and inorganic fertilizers, as the productivity-enhancing benefit can be obtained from either of them. The effectiveness of using multiple strategies is further justified by uncertainties about future climate events that hinder proactive adaptation decisions (Collins 2014). In this vein, multiple adaptation strategies help to effectively respond to and protect livelihoods from the adverse effects of unexpected future climate risks. However, increasing the number of adaptation strategies is less feasible for poor farmers, which is likely to undermine the extent of effectiveness of the adaptation strategies they use. Poor people are not only disproportionately affected by climate change but also inequitably benefit from development practices (Pelling and Garschagen 2019). Unlike better-off farmers, the adaptation options of poor farmers are limited to a few low-cost and low-return strategies, which have little contribution to livelihood improvements. The concentration of adaptation benefits accrued from the use of multiple strategies among the better-off households further widens the inequality between the community (Sovacool, Linnér, and Goodsite 2015).

**Supporting structure, flexibility, and culture-sensitivity of institutions increase the effectiveness of adaptation**

Institutions have several resources (e.g. information, finance, skills, farm inputs) and services (e.g. training, advising) that can support effective adaptation. Time of service provision constitutes institutional support for effective adaptation. Farming activities are time-bound, and if the services are provided at the required time, the livelihood benefit is substantial, as evident from a study in Zambia showing significant yield
increase for farmers who had timely access to fertilizers (Arslan et al. 2015). Flexibility is another feature of formal local institutions that enhances effective adaptation. Since adaptation is a learning process, maladaptive practices can be avoided, or reversed if they have occurred, when there are reflections on past adaptation actions and a flexible institutional framework (Islam and Nursey-Bray 2017). Contrariwise, in some circumstances, institutions hinder the effectiveness of adaptation. For instance, the focus of formal institutions on technical solutions inhibits effective adaptation. As shown in a study in Bangladesh, although enhancing farmers’ skills with using technologies can be a solution for the proximate causes of vulnerability, it does not address the underlying causes due to failure to institutionalize adaptation through cultural integration (Islam and Nursey-Bray 2017). Lack of transparency and inclusivity in interactions with communities and development interventions may also constrain the effectiveness of locally-based formal institutions due to reduced trust by the communities (Islam and Nursey-Bray 2017) and their limited involvement in the envisaged adaptation strategy (Rodriguez-Solorzano 2014).

Reflections on the synthesis model and research gaps

The framing of an integrated livelihood assessment model is a supportive tool to analyze the articles and synthesize the findings as a means to comprehensively understand the key components influencing the effectiveness of smallholder farmers’ adaptation responses to CCV. The model helps to identify associations and empirical relations with specific directions. However, there is notable variation between empirical support of the relationship between the components of the model. Most articles (90%) concentrated on the causal relation between the chosen adaptation strategies and livelihood outcomes. About 38% of the studies investigated causality between livelihood assets and the use of adaptation strategies. Twelve articles examined the influence of contextual factors on the success or failure of livelihood outcomes. Eleven of the reviewed studies showed that institutions shape farmers’ choice of adaptation strategies, whereas five studies revealed the roles of institutions in mediating farmers’ access to livelihood assets. Only one study investigated the influence of institutional factors on both assets and types of adaptation strategies. Three studies showed the direct linkage between institutions and the outcome of adaptation strategies. It was only in one study that the implication of livelihood outcomes back on motivation for adaptation and risk factors was described. Relationships between climate or non-climate risks and adaptation motivation; as well as between the cultural dimension of adaptation actions and livelihood outcomes were rarely investigated in most of the reviewed studies. None of the studies included all the blocks of the model in their evaluation of adaptation.

In spite of the rapidly growing literature on adaptation to CCV, much remains unknown. First, although farmers’ recognition of CCV and the decision to take action are embedded in societal norms and values (Burnham and Ma 2016; Di Falco and Veronesi 2013), evidence of the socio-cultural aspects of risk perception and adaptation are scant, which demands further inquiry. Second, adaptation is a dynamic process. The characteristics of the actors, the types of adaptation strategies pursued by farmers, and the contexts in which adaptation strategies are implemented are dynamic (Di Falco and Veronesi 2013; Jain et al. 2015). This calls for the importance of investigating temporal changes in vulnerability and the adaptation responses that evolve correspondingly. Third, studies investigating the feedback loop between livelihood
outcomes and the adaptation processes (risk factors, motivation, and action) are important to uncover the implications of adaptation for vulnerability or resilience. Fourth, studies addressing all the blocks of the integrated model in this review help to holistically understand the contexts of effectiveness of adaptation as well as to test and refine the framework. Fifth, there is scant evidence on the evaluation of the impacts of adaptation on multiple dimensions (i.e. social, economic, environmental) of the livelihoods of farmers. The development of a comprehensive set of indicators capturing these dimensions of adaptation outcomes that can be flexibly used in different contexts is a huge task awaiting further works. Last but not least, the results of this review need to be interpreted with caution due to the consideration of a limited number of studies with highly diverse methodological approaches. Rigorous evaluation using robust impact analysis techniques and participatory approaches are required to get a clearer picture of the livelihood impacts of adaptation to CCV.

6. Conclusion

With a growing demand for knowledge on the effectiveness of smallholder farmers’ adaptation, we reviewed pertinent studies to explore empirical evidence on the livelihood impact of adaptation strategies which contributes to the current understanding of adaptation as a means to respond to CCV. The reviewed studies showed that taking up adaptation actions is a decisive step toward reducing vulnerability and enhancing resilience through increased agricultural production, generation of additional sources of income, and improved environmental protection. However, there is a noticeable heterogeneity between farming households in terms of benefiting from adaptation. For households with higher adaptive capacity and be able to invest in multiple and high-return strategies, adaptation entails a virtuous circle of improvement. However, for households with lower adaptive capacity and whose livelihood is cyclically threatened by recurrent climate problems, their limited adaptation choices which are mainly reliant on climate-sensitive strategies fail to unshackle them from a vicious circle of vulnerability. The uneven beneficial impact of adaptation is also rooted in institutional disparities in service provision, cultural integration of adaptation initiatives, and community engagement. Reinforcing the existing literature (Bassett and Fogelman 2013; Wise et al. 2014), our findings explicate that the effectiveness of adaptation has to be evaluated against an integrated framework, in view of the achievement of economic, social, and environmental benefits to promote sustainable livelihoods and confirm social-ecological resilience. Understanding the complexities underlying the effectiveness of adaptation also necessitates a detailed analysis of the livelihood contexts in which adaptation decisions are made and actions are taken.

The findings of the review have important implications for interventions aimed at building sustainable livelihood. Smallholder farmers, particularly the poor, are highly vulnerable to CCV and they fail to make significant improvements to their livelihoods with their limited adaptive capacity. Interventions improving poor farmers’ access to, and control over, livelihood assets are important to address their needs and ensure equity in benefitting from the use of adaptation strategies. This could be addressed through effective institutional support in building their adaptive capacity and facilitating the use of feasible adaptation strategies. Support for diversification of livelihood strategies both within and outside farming is important to boost farmers’ effective responses to climate uncertainties. For farmers exclusively reliant on rain-based
adaptation strategies, access to weather information helps them to make uncostly but
effective farming decisions (Jain et al. 2015; Waha et al. 2013). Adaptation decisions
are often made based on access to resources, personal understanding and interests, and
adaptation opportunities. These decisions might be associated with negative external-
ities (e.g. increased vulnerability of other groups of farmers, environmental degradation)
at different spatial and temporal scales. This calls for local agricultural officers’ close
monitoring of farmers’ self-initiated adaptation strategies and improving their awareness
of strategies promoting sustainable livelihoods. Since environment-friendly strategies
such as agroforestry and conservation tillage have a longer payback period (Sain et al.
2017), farmers may opt for adaptation strategies that yield economic benefit in the short-
est possible time. This may undermine the use of long-term strategies that have high
relevance for sustainable livelihoods and social-ecological resilience, which need to be
addressed through planned adaptation interventions. Given that it may not always work,
it is important to carefully develop and plan adaptation based on local agro-ecological
and socio-economic situations through joint efforts of both formal and informal institu-
tions. Since farmers adapt strategies to their socio-ecological contexts, planned adapta-
tion should also take into account their cultural contexts.

Note
1. In this review, informal and formal institutions are distinguished mainly based on
established rules and regulations governing their functioning. Informal institutions are
governed by socio-cultural norms, whereas formal institutions are characterized by official
channels of bureaucracies with legally binding regulatory frameworks and enforcement
mechanisms. These include government offices and NGOs. Grouping of the institutions also
follows the categorizations used in the reviewed studies. The term local here refers to
institutions that are either locally-based or have direct contact with the community to
provide advisory services and other support. However, it is worth noting that the strengths
and weaknesses of these institutions in facilitating effective adaptation are also associated
with the overall organizational performance in terms of knowledge, finance, community
involvement, etc.

Acknowledgements
The authors are very much grateful to the two anonymous reviewers for their valuable
comments and suggestions that helped a lot in improving the paper.

Disclosure statement
No potential conflict of interest was reported by the author(s).

Funding
This work was supported by EP-Nuffic; grant number R/002597.01.

Supplemental data
Supplemental data for this article can be accessed online at https://doi.org/10.1080/09640568.2021.1905620.
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