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Armed conflict and cross-border asymmetries in urban development: A contextualized spatial analysis of Goma, Democratic Republic of the Congo and Gisenyi, Rwanda

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ABSTRACT

Armed conflicts often cause significant structural disturbance and modification to urban areas. These manifest as changes to the built environment either through destruction and diminution of built area or through an increase in extent and the number of buildings. The magnitude of conflict-induced displacement and migration are dependent upon a range of socio-political factors, resulting in variabilities in conflict-induced urban growth. Border cities provide a valuable setting to compare these variations, as they share geographical and cultural similarities, enabling comparative analysis of the conditions leading to divergent trajectories. This study examines the effects of armed inter- and intra-state conflict on urban spatial development both within and across national borders, focusing on the proximal cities of Goma, Democratic Republic of the Congo (DRC) and Gisenyi, Rwanda, between 1989 and 2014 (due to the availability of cloud-free satellite imagery). We conducted a visual analysis of high- to very high-resolution satellite imagery to map spatial development (both urban extent and individual buildings) for both cities. Based on this analysis, we then conducted site visits and interviews, through which underlying drivers of urban development pathways were identified and initial steps were made to disentangle conflict- and non-conflict drivers, as not all urban changes and differences are related to the presence or absence of armed conflict. These are situated in different phases of armed conflict in the region, the governance of their repercussions (or lack thereof), and the complex interdependencies between the two cities. Our analysis revealed remarkable differences in spatial development and urban morphology. While Goma's urban area expands and densifies, Gisenyi's spatial extent remains relatively stable. Stakeholders on the ground identified armed conflict, linked population flows including internal and cross-border forced displacements, as well as differences in handling conflict-repercussions between the states as underlying drivers of the observed spatial changes. This study thus provides detailed evidence on the processes and drivers implicit in urban development and change in cross-border cities, their similarities, differences, and interdependencies, with a particular focus on armed conflicts' domestic and cross-border effects.

1. Introduction

While social, economic, and political aspects of urban development¹ in Africa have been extensively studied (e.g., Murray and Myers, 2007; Myers, 2011; Pieterse, 2011; Simone, 2001), a particular subsection of

recent studies scrutinizes urban topics in conflict and post-conflict scenarios. Studies of Sub-Saharan African cities in conflict areas investigate the interlinkage between state decline and conflict, track displacement patterns, and scrutinize urban socio-economic transformations, or portray how living conditions deteriorate due to armed conflict

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¹ This article employs the term *urban development* in its broader sense in order to include aspects such as changes in urban land use, urbanization, urban growth, urban expansion, spatial development, and urban change processes.

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(Büscher, 2011; Oldenburg, 2016, 2018; Omasombo, 2005; Verhoeve et al., 2004). However, explicitly spatial analyses of armed conflict as a driver of urbanization in Sub-Sahara Africa are, to date, rather scarce (Pech et al., 2018; Wilson, 2014). This paucity is particularly notable for border cities in conflict settings, and as such, border cities provide a valuable point of entry for engaging this gap in the literature, specifically by providing a rich setting to compare variations, as they share geographical and cultural similarities, enabling comparative analysis of the conditions leading to divergent trajectories.

In the presence of armed conflict, border towns become central hubs for political, military, and humanitarian engagement, and feature flows and settlements of displaced persons (Wilson, 2014). Furthermore, they can become the foci of profitable business activities, the commerce of foodstuffs and other essential supplies, trade in natural resources, and real estate speculation, stoked by the presence of well salaried international personnel and national elites (Peyton, 2018). Strong economic opportunities constitute a major pull-factor for border cities, and rural-to-urban migration is observable all across Africa. Nevertheless, economic pull-factors differ between conflict-settings and peaceful areas. Relatively secure urban zones gain attractiveness in zones marked by decades of inter- and intrastate war (Wilson, 2014). This confluence of factors is regarded as one of the primary causes of urban growth along the Congolese-Rwandan border (Soi and Nugent, 2017). Nevertheless, not all urban changes and differences between border cities along this border are related to the presence or absence of armed conflict. Detailed and spatially explicit cross-border research on the resulting urban expansion is necessary to further elucidate these spatial dynamics in conflict zones.

Of the relatively few studies that have examined urban agglomerations divided by a national border, the majority have implemented either long-term qualitative field methodologies or remote sensing. Qualitative field research from various academic disciplines has investigated African borderlands and twin-city constellations for state regulation practices at the border (South Sudan/Uganda, DRC/Rwanda) (Hollstegge and Doeveenspeck, 2017), (in)formal trade and economic networks (DRC/Rwanda/Uganda) (Doeveenspeck and Nene, 2012; Lamarque, 2014; Raeymaekers, 2009), (economic) opportunities for different actors in displacement sites along a border (Chad/Sudan) (Behrends, 2014), or identity formation and transnationalism (DRC/Rwanda) (Mathys, 2014). These studies suggest that the growth of towns along national borders in conflict zones is partially explained by the influx of internally displaced persons and refugees. They furthermore find that conflict can contribute to a decline of border towns, which then is followed by post-conflict conversion into booming nodes of international trade networks (Büscher, 2011; Dobler, 2009; Soi and Nugent, 2017). However, a strong increase in efforts and complications has prevented researchers from completing field-based studies of cross-border conflict zones in an equal way (e.g., paperwork/visas, language, contact persons), most notably in cases of ongoing hostilities between neighboring states. Furthermore, the quality, comprehensiveness, and comparability of official data are unlikely to be collected through the same methods, making comparison difficult. Conversely, border-city research from the domain of remote sensing has equally measured spatial city growth, with the benefit of (impartially) inferring changes on the ground from widely available satellite imagery, across political borders. A recent study examined urban change and growth in paired cities between Mexico and the USA, finding unequal patterns and rates of growth of built-up area between the two sides of the border despite comparable population growth (Zhao et al., 2017). Another study focusing on cities along the U.S.-Canadian border, which combined medium-resolution satellite imagery with census data and building-permit records, also found that an increase of urban residents and growth of impervious surface did not coincide: Vancouver's (Canada) two million urban residents occupy far less land and reside in consistently compact neighborhoods compared to their counterparts in the Puget Sound region (USA) who occupy much more space per

inhabitant (Davis and Schaub, 2005). These studies confirm the utility and validity of remote-sensing methods for exploring and quantifying urban growth. Yet, there is no analysis of border cities that combines remote-sensing techniques and field interviews to investigate urban development in border towns during armed conflict and forced displacement.

Our case study highlights the importance of analyzing asymmetries to unearth divergent patterns and drivers of urban change, aiming at stimulating the discussion and debate between theoretical framings in this regard. Concretely, the study scrutinizes the spatial development of the adjacent border-cities Goma, in the Democratic Republic of the Congo (DRC), and Gisenyi, Rwanda, which have been engaged in inter- and intra-state war for decades that has led to incongruent political regimes. We used a combined approach presented in earlier publications (Pech et al., 2018; Pech and Lakes, 2017). Based on the visual interpretation of very high to high resolution satellite imagery, we mapped, quantified, and analyzed spatial patterns of urban development for both cities between 1989 and 2014. Departing from the assumption that Goma's comparatively more rapid expansion, as observed during the time-series analysis, was linked to the differences in the security situations in the DRC and Rwanda, we subsequently conducted field visits and interviews to obtain narratives and identify underlying drivers for observed urbanization trends. In particular, we compared the spatial development of Goma and Gisenyi in order to identify commonalities and differences in their urban development and the underlying drivers for these commonalities and differences. We furthermore developed a simplified framework of factors affecting urban development in the study area.

2. Methodology and data

2.1. Research area: The cities of Goma and Gisenyi

Current literature pays significantly less attention to Gisenyi in Rwanda than to its Congolese neighbor Goma. These border cities are located at the center of almost thirty years of armed inter- and intrastate conflict². They are situated within the western branch of the East African Rift Valley and share the physical-geographic setting between two active volcanoes and Lake Kivu. Established as colonial border posts in 1905 (Gisenyi) and 1906 (Goma) between Ruanda-Urundi (Germany) and Congo Free State (Belgium), both cities were and are located between different colonial and post-colonial regimes, with the porosity of the border depending on the relationship between them (Doeveenspeck, 2011; Jackson, 2006; Mathys, 2014; Soi and Nugent, 2017). Germany lost Ruanda-Urundi to Belgium in World War I, and during (Belgian) colonial times, Goma's importance derived largely from its role as a hub in directing Rwandan laborers across the border (Soi and Nugent, 2017). In 1930, an urban plan was designed for Goma, including an airstrip, today Goma's International Airport. The urban plan has never been officially updated, despite the city's tenfold increase in area³. Congo became independent from Belgium in 1960, followed two years later by Rwanda. Since 1988, Goma is the provincial capital of North Kivu, a region that has suffered exceptionally from violence since the late 1980s. Urban centers in Congo's east often embody 'safe' spaces for internally displaced persons (IDPs) or refugees, and are at the same time strongholds for rebel movements, or their strategic targets (Büscher, 2016, 2018). Today, in terms of economic and political characteristics,

² The Rwandan civil war and genocide (1990 – 1994), the two great Congo Wars (1996–1997 and 1998 – 2003), the Kivu conflict (2006 – 2009) and its aftermath, and the so called period of 'violent peace' Berwouts, K., 2017. Congo's violent Peace; Conflict and struggle since the Great African War. University of Chicago Press, Chicago. that affects the region until today.

³ Interview with a professor at ISAU Kinshasa, 2016. Interview # 20, Institut Supérieur d'Architecture et d'Urbanisme (ISAU), in: Pech, L. (Ed.).

the Congolese side of the border displays weak, locally contested state authority, insecurity, negotiable and inconsistent economic regulation, but also greater employment opportunities. Goma is the center of Congo's 8th military region, housing the army's (FARDC) 5th brigade, and since 2013/14⁴ the United Nations (UN) peacekeeping mission's (MONUSCO) eastern headquarters ([Secretary-General of the United Nations, 2014](#)).⁵ Additionally, Goma counts a large UN agency and (international) NGO presence. The UN Office for the Coordination of Humanitarian Affairs (OCHA) lists more than 270 humanitarian organizations with bases of operation in Goma for 2013 ([Peyton, 2018](#)). This and the fact that Goma is situated at the center of two major Congolese trading axes, makes the city an important economic hub, with, e.g., a booming construction industry. Furthermore, Goma mediates Gisenyi's international access as it represents a node in regional trading networks and international commerce with Africa's East coast and beyond, facilitated through the border location and the presence of a port and international airport ([Büscher, 2011](#); [Lamarque, 2014](#)). Goma also prospers due to the proximity to several artisanal mining and (illegal) charcoal production sites, and its fertile hinterlands provide agricultural production possibilities, even though this production is strongly affected by the security situation.⁶ Approximately 20,000–22,000 people per day are engaged in cross-border trade. Minerals are exported to or via Rwanda, and in return, construction materials, petroleum, agricultural products and consumer goods are imported from Rwanda and distributed all over eastern DRC. (Small-scale) trade generates important revenues on both sides of the border, and it furnishes the most visible evidence of the economic interdependence between the cities. Nevertheless, Goma has prospered more from cross-border trade than Gisenyi ([Hollstegge and Doeveenspeck, 2017](#); [Lange and Kimanuka, 2010](#); [Tegera et al., 2007](#)). Goma experiences growing real estate speculation, and the city's construction industry provides employment for Congolese and Rwandans ([Peyton, 2018](#)).⁷ Currently, Goma expands over 60 km², has eighteen neighborhoods and an estimated 800,000 to 1,500,000 inhabitants ([Kanene, 2014](#); [Mairie de Goma, 2016](#)). These estimates are based on samples⁸, since the last population census in the DRC was conducted in 1981, making existing demographic records difficult to rely on ([Mairie de Goma, 2015](#)).⁹

Chaotic and vibrant Goma is contrasted by the calm, well-organized,

and tidy Gisenyi, which is well equipped with urban infrastructure, despite a recent history of violence and conflict.¹⁰ Rwanda's security apparatus is tightly organized, since the end of the Rwandan genocide (1994) and crime rates are low. Conversely, Goma's crime rate ranks among the highest in Congo.¹¹ Gisenyi shares similarities with Goma such as a colonial past and city center and a history of violence. Today, the city differentiates itself from its Congolese counterpart primarily through its smaller area (~11 km²) and population of only 53,603 according to the 2012 census ([Government of Rwanda and GGGI, 2015](#)). Gisenyi's inhabitants find regular employment in Gisenyi's financial sector, that benefits from the unstable economy and security and situation in (eastern) DRC ([Doeveenspeck and Nene, 2012](#)), in educational institutions, or at one of three of Gisenyi's markets. Many of Gisenyi's inhabitants depend on agricultural activities, despite an ambitious modernization program initiated by the Rwandan government ([Huggins, 2017](#)).¹² The city has a small tourism sector, with hotels that serve as base camps for visitors of north-western Rwanda, but also as main weekend destinations for Goma's more affluent Congolese and international population. Unlike Goma, Gisenyi features a brewery, where beer is produced and exported into Congo.

Gisenyi has always been more accessible over land than its Congolese counterpart in terms of distance and transport infrastructure from the respective capital. It is approximately 150 km west of Kigali, reachable via a continuously tarred and well-lit road.¹³ Goma is located over 1500 km east of Kinshasa, from where it is only accessible via airplane. These different degrees of physical connectedness between the respective secondary city and its capital reflect how administrative and economic integration differ. While the authority of the Congolese central administration is fragmented and locally contested, and was completely cut off during the Congo Wars ([Büscher, 2016](#); [Verhoeve et al., 2004](#); [Vlasenroot and Büscher, 2013](#)), Gisenyi is effectively controlled by the central government, which has direct control over local governments. The Rwandan administrative system is generally held to be one of the most effective in Africa ([Huggins, 2017](#); [Lamarque, 2014](#)).

2.2. Spatial data and processing steps

To compensate for the lack of reliable data on population growth and urbanization in the DRC, and the existence of such data for Rwanda only since the beginning 2000s, we measured urban extent and its expansion as an approximation for population growth. We used high-resolution Landsat imagery (30 × 30 m) to map the urban extent, Landsat 5 for the years 1989, 1995, and Landsat 7 for 1999. For the years 2005, 2010 and 2014 we used very high-resolution (VHR) satellite imagery (50 × 50 cm) from three different commercial earth observation satellites to estimate the urban extent, count the number of buildings within the cities' margins, and calculate housing densities. Unfortunately, no VHR data exists for previous years. (For detailed information on data processing steps see [Pech and Lakes, 2017](#) and [Pech et al., 2018](#)). (Table 1).

In collaboration with inhabitants of the study area, we manually digitized urban extents based on the Landsat images and individual built-up structures based on the VHR imagery for 2005, 2010, and 2014.

⁴ Approximately 800 civilian and military 3000 personnel was additionally deployed to Goma and the city of Sake in Goma's vicinity when Goma became the operational hub and the force headquarters in 2013/2014 [UN Security Council \(2013\)](#). Resolution 2098 (2013)., Interview with an employee of MONUSCO, 2016. Interview # 5, informal background talk, in: Pech, L. (Ed.).

⁵ Communication with an employee of MONUSCO, 2016. Interview # 5, informal background talk, in: Pech, L. (Ed.).

⁶ Interview with an inhabitant of Goma, 2016. Interview # 13, several interviews with the same interviewee, in: Pech, L. (Ed.)., Interview with a researcher of Pole Institute Goma, 2017. Interview - Cross Border Migration due to Insecurity/Infrastructure/Livelihood Opportunities, in: Pech, L. (Ed.).

⁷ Interview with an inhabitant of Himbi/local construction entrepreneur - Goma, 2016. Interview # 41, in Himbi, in: Pech, L. (Ed.).

⁸ Interview with the [Maire de Goma \(2017\)](#). in: Pech, L. (Ed.).

⁹ This data unreliability or total lack certainly applies for the Congolese side of our research area, Goma, where conflict and state informalization have severely weakened the administrative apparatus, and therefore services related to demographics, cadastres, and urbanism are being run by bureaucrats who are often unpaid and highly corrupt, which makes obtaining demographic statistics a tough mission [De Herdt and de Sardan \(2015\)](#). Real governance and practical norms in Sub-Saharan Africa: the game of the rules. Routledge, Pech, L., Büscher, K., Lakes, T., 2018. Intraurban development in a city under protracted armed conflict: Patterns and actors in Goma, DR Congo. *Political Geography* 66, 98–112. The introduction of [Jerven \(2013\)](#). Poor numbers: how we are misled by African development statistics and what to do about it. Cornell University Press., describing the situation in Zambia, gives an almost identical description of the Congolese administrative institutions visited during our research stays in the DRC.

¹⁰ Own observations during research (stays between February 2016 and October 2017)

¹¹ Interviews with a Congolese Prosecutor, 2016. Security Situation and Crime Rates/DRC, in: Pech, L. (Ed.)., a researcher of Pole Institute Goma, 2017. Interview - Cross Border Migration due to Insecurity/Infrastructure/Livelihood Opportunities, in: Pech, L. (Ed.).

¹² Interviews with a member of the Rwandan Red Cross, 2017. Interview - Genocide, Civil War and (Forced) Migration, in: Pech, L. (Ed.).and an employee of the One Stop Center of Rubavu District, 2017. Urban Planning and Administrative Structures of Rwanda, in: Pech, L. (Ed.).

¹³ Own observation during several trips between Kigali and Gisenyi/Goma, in 2016 and 2017

Table 1
Spatial Data.

Data and Source	Properties	Use
<i>Satellite Raster Data</i>		
Quickbird02	Bands 1–4: 2.4 m, Pan: 0.6 m	Visual interpretation, building extraction, mapping of expansion and densification of built-up area
Digital Globe	2005/02/18 coregistered to WorldView02 (2010), ortho image based on SRTM	
WorldView02	Bands 1–8: 2 m, Pan: 0.5 m	
Digital Globe Foundation	2010/01/29	
GeoEye01	Mosaic, pan-sharpened, ortho image Bands 1–4: 2 m, Pan: 0.5 m	
Digital Globe Foundation	2014/04/02	
	mosaic, pan-sharpened (0.5 m), ortho image, coregistered to WorldView02 (2010)	
Landsat 5, Landsat 7	Bands 1–5 + 7 (30 m) 1986, 1995, 1999	Visual interpretation, city extents
SRTM DEM	Elevation at 30 m ground sampling distance	Orthorectification of Quickbird02 imagery (2005), cartography
NASA	2000	
<i>Additional Geodata</i>		
OpenStreetMap vector data (buildings)	2005	Basis vector data for further digitization
Goma topographic map	1:11.000	Orientation, identification of neighborhoods
GIS unit MONUSCO	2012	
Gisenyi/Rubavu District	1:35,000	Orientation, identification of neighborhoods
administrative map, 2016, from: Rubavu One Stop Center (urban planning unit)	2016	
Boundaries/ infrastructure Référentiel Géographique Commun (RGC)	2015/2016	Cartography

The resulting vector data sets were corrected for geometric and topological errors in order to facilitate an accurate comparison between years. A spatial shift of up to 3 m remained after image-to-image coregistration due to different image acquisition angles and orthorectification procedures upon delivery. To minimize this effect, we aggregated the vector data to a coarser spatial resolution by converting the building polygons to centroids, then assigning each centroid to a 10-hectare cell of a hexagonal vector-grid. Again, this was necessary in order to minimize errors due to image shifts and distortions, and to facilitate comparability between years. While a hexagonal grid is most often used for precise spatial sampling, it facilitates more effective visualization of spatial variations than a rectangular grid (Birch et al., 2007). We calculated building numbers and building density as well as their absolute and relative changes between the time periods within these hexagonal grid cells. The resulting density maps served to identify points of interest for field visits, particularly areas that displayed a prominent increase or decrease in built-up area. To assess statistically significant differences in urban development (building density) between cities, we used Student's *t*-test with previous F-tests to control for heterogeneity of variances and considered differences to be statistically

significant if *p*-values were below the 5% level.

2.3. Field work

The quantitative findings were explored and contextualized through field observations and interviews conducted in Gisenyi and Goma in 2016 and 2017. During the fieldtrips, interviews and informal conversations were conducted on both sides of the border with various stakeholders such as informants with a long period of residency in Goma and/or Gisenyi, members of local research institutions, the national and provincial administration and of religious and educational institutions, and UN and NGO staff. Interviews with local residents were the most crucial support for image interpretation (e.g., delimitation of city limits, validation of digitization results, explanation of reasons for certain spatial developments). Interviews with staff members of the different institutions where above all important for the provision of background information on topics such as for example, urban planning and management, the security and humanitarian situation, and (further) patterns of and reasons for urban growth and development in either country. Twenty-seven interviews were conducted for this article explicitly. Furthermore, background information was also drawn from 35 interviews conducted for previous research in and on the border region (for more details, see also: Pech et al., 2018; Pech and Lakes, 2017). The interviews aimed at understanding the interviewees' perspectives and were semi-structured. Each interviewee with a long residency in either town was asked about: their personal history, including their migration history, their housing circumstances, and changes to the city. When possible, sites or neighborhoods mentioned or cartographically identified by the interviewees were visited personally. Depending on their field of expertise, the interviewees focused on socio-economic, political, and administrative topics, e.g., population movement to and between the cities, economic linkages, urban planning mechanisms, and humanitarian issues, with an emphasis on the role of armed conflict in these processes. Interviews were conducted in French or English, sometimes with the help of a translator (e.g., Swahili-French). Handwritten notes were taken during all interviews.

3. Results and interpretation

At the center of our analysis is Goma's comparatively more rapid expansion, which we mapped and contextualized in Section 3.1. Security appears to be a notable driver of urban growth, as differences in the spatial configuration and temporality of urban change are observed. Our results suggest that Goma's and Gisenyi's developments are also largely shaped by (in)formal urban planning, and the economic situation, and integration of each city within its country. All key factors are interrelated and exhibit cross-border effects, as Fig. 1 summarizes.

The framework is based on own observations. As it is difficult to decipher rural-urban voluntary migration and forced displacement it explains how rural-urban migration is increased by violent conflict on one side of the border, while on the other side, urban growth is not (continuously) accelerated by the repercussions of armed conflict.

3.1. Mapping and contextualizing urban development

Since Rwanda gained independence from Belgium in 1960, the principal victims of exclusion were its Tutsi inhabitants, which in turn rooted in political exclusion of Rwanda's Hutu under German and Belgian colonial rule. In Congo's North Kivu province, the closest analogs to the Rwandan population are the Banyarwanda (Rwandophones). The Banyarwanda include Hutu and Tutsi who migrated before, or were re-settled during the colonial regime, and Tutsi who fled to Congo in 1959, in the wake of a Hutu revolution (Lemarchand, 2004). In 1990, the Rwandan Patriotic Front (RPF), primarily consisting of Rwandan Tutsi-exiles from Uganda, invaded Rwanda, and many of the Tutsi located in Congo since 1959 joined the rebellion (Prunier, 1997, 2008).

Fig. 1. Simplified framework of factors affecting urban development in the study area.

The resulting Rwandan civil war culminated in the genocide against Rwanda's Tutsi, and politically moderate Hutu. Gisenyi was the last Rwandan city to fall to the victorious RPF in July 1994, which marked the end of the genocide. By this time, Gisenyi had experienced the near extinction of its Tutsi population and was nearly deserted (Prunier, 1997, 2008). The victory of the RPF in turn caused over a million Hutu to flee into eastern Congo in fear of retaliation. Amongst these refugees were members of the former Rwandan government, army and militias, and hence people responsible for the genocide (Stearns, 2011; Umutesi, 2004; Vlassenroot, 2004). Many of the refugees settled close to the border in five different camps around Goma, large enough to be visible on relatively coarse Landsat imagery (Fig. 2, center).¹⁴ Goma expanded from 7 to 21.3 km². 9 km² of which were covered by urban sprawl and 5 km² by refugee camps. Mugunga and Lac Vert being the main civilian camps, even though they were tightly controlled by (former) Rwandan army and militia members, while the Bananeraie and Kituku were the residences of higher army and militia ranks.¹⁵ (Pottier, 1996; Prunier,

2008; Stearns, 2011; Umutesi, 2004).

At the same time, in Gisenyi, a countermovement from Congo also led to an urban expansion (Fig. 2, bottom), as parts of Congo's Tutsi left the country in fear of reprisals by the newly arrived Hutu. Between 1995 and 1996, 34,000 Tutsi moved or returned from North Kivu to Rwanda, taking up residence wherever they could find space, occupying houses and expropriating land of people who had died or fled. Others stayed in camps (Newbury, 2011; Stearns, 2011). In Gisenyi in an uninhabited area named Mbugangari, north of the city center, housed 3000 to 5000 inhabitants between 1994 and 1995.¹⁶ The Rwandan administration supported this settlement, granting every returnee a land title in the area of this make-shift camp. Parcels were assigned based on a law that permitted the erection of makeshift buildings on the administered parcel, and assistance with construction materials was provided by donor aid, and the camp was converted into an official neighborhood.¹⁷

By the end of 1996, the new Rwandan Patriotic Army (RPA) invaded Congo, due to the security problems associated with these (Hutu) refugee camps, and the international community's failure to demilitarize them (Prunier, 2008). The stated target of the Rwandan troops were former army and militia responsible for the genocide, but many civilian refugees were forced to flee or killed during these attacks (Mathys, 2017; Newbury, 2011). The refugee camps around Goma were emptied and removed within days, according to contemporary witnesses. Due to

¹⁴ Interviews with a member of the Rwandan Red Cross, 2017. Interview - Genocide, Civil War and (Forced) Migration, in: Pech, L. (Ed.), an employee and a volunteer at the Don Bosco Center, 2017. Interview # 49, Interview at Don Bosco Center Ngangi, in: Pech, L., Schuh, P. (Eds.), an employee and a volunteer of the Congolese Red Cross, 2016. Interview # 14, Congolese Red Cross Goma (Interview in Gisenyi, Rwanda due to problems at the border), in: Pech, L. (Ed.), Croix Rouge Congolaise, an employee of UN Habitat Goma, 2016. Interview # 20, Interview in Gisenyi due to problems at the border, in: Pech, L. (Ed.), an employee of UNHCR Goma, 2016. Interview # 21, UNHCR Goma (Interview in Gisenyi, Rwanda due to problems at the border), in: Pech, L. (Ed.), UNHCR, an inhabitant of Himbi/local construction entrepreneur - Goma, 2016. Interview # 41, in Himbi, in: Pech, L. (Ed.).

¹⁵ Interviews with an employee and a volunteer of the Congolese Red Cross, 2016. Interview # 14, Congolese Red Cross Goma (Interview in Gisenyi, Rwanda due to problems at the border), in: Pech, L. (Ed.), Croix Rouge Congolaise, an employee of the Congolese Red Cross, 2016. Interview # 45, visit of IDP Camp Mugunga I and former IDP Site Lac Vert, Buhimba, Bulengo and Bananeraie, in: Pech, L. (Ed.), an employee of UN Habitat Goma, 2016. Interview # 20, Interview in Gisenyi due to problems at the border, in: Pech, L. (Ed.).

¹⁶ Interviews with a member of the Rwandan Red Cross, 2017. Interview - Genocide, Civil War and (Forced) Migration, in: Pech, L. (Ed.). and a researcher of Pole Institute Goma, 2017. Interview - Cross Border Migration due to Insecurity/Infrastructure/Livelihood Opportunities, in: Pech, L. (Ed.).

¹⁷ Interviews with an employee of UN Habitat, 2016. Interview # 37, UN Habitat Goma, in: Pech, L. (Ed.), UN Habitat Goma., an employee of the Congolese Red Cross, 2016. Interview # 45, visit of IDP Camp Mugunga I and former IDP Site Lac Vert, Buhimba, Bulengo and Bananeraie, in: Pech, L. (Ed.), a researcher of Pole Institute Goma, 2016. Interview # 17, Interview in Gisenyi due to problems at the border, in: Pech, L. (Ed.), Pole Institute Goma., a researcher of Pole Institute Goma, 2017. Interview - Cross Border Migration due to Insecurity/Infrastructure/Livelihood Opportunities, in: Pech, L. (Ed.). and a member of the Rwandan Red Cross, 2017. Interview - Genocide, Civil War and (Forced) Migration, in: Pech, L. (Ed.).

Fig. 2. Goma/Gisenyi before the conflict onset (top); Refugee camps in Goma (center); Refugee/returnee camps in Gisenyi, converted into neighborhoods by the time of image acquisition (bottom).

unfavorable cloud conditions, the earliest available imagery dates from October 1999 (Fig. 2, bottom), and we thus relied on information from the literature and contemporary witnesses.¹⁸

During the first Congo War (1996–1997) directly following the Rwandan invasion in 1996, Congo's¹⁹ president Mobutu was overthrown by a Rwandan and Ugandan backed insurgency, led by the Congolese Laurent Désiré Kabila. At the same time, Rwanda's northeast, including Gisenyi, suffered from cross-border attacks orchestrated from Congo by (Hutu) guerrillas. Targets were army installations and Tutsi refugee and

returnee-camps close to the border (Johnson, 2014; Newbury, 2011).^{20 21}

The First Congo War was followed almost seamlessly by the Second Congo War (1998–2003), which split the country into various zones of military control. Goma was conquered in August 1998, and from then on administered by the Rwandan backed faction of the rebel movement Rally for Congolese Democracy (RCD-Goma). Being a rebel stronghold, Goma did not suffer from extensive destruction as other cities located between front lines, as for instance the city of Kisangani. Laurent Désiré Kabila was assassinated in 2001 and succeeded by his son Joseph

¹⁸ Interview with an inhabitant of Goma, 2016. Interview # 13, several interviews with the same interviewee, in: Pech, L. (Ed.), an employee of UN Habitat Goma, 2016. Interview # 20, Interview in Gisenyi due to problems at the border, in: Pech, L. (Ed.), an employee and a volunteer of the Congolese Red Cross, 2016. Interview # 14, Congolese Red Cross Goma (Interview in Gisenyi, Rwanda due to problems at the border), in: Pech, L. (Ed.), Croix Rouge Congolaise.

¹⁹ Back then named Zaire, but for simplicity reasons we only use Congo and DRC throughout this article.

²⁰ (Therefore, today, refugee camps are no longer part of Gisenyi's cityscape, as they are located in central parts of Rwanda, motivated by a decision of the Rwandan government and the UN High Commissioner for Refugees (UNHCR).

²¹ Interview with an employee of the Congolese National Commission for Refugees (CNR), 2017. La Situation des Réfugiés en RDC, in: Pech, L. (Ed.). The African Union Convention on the Governance for Specific Refugee Problems in Article 2 (6) states: "For reasons of security, States of asylum shall, as far as possible, settle refugees within a reasonable distance of the border of their country of origin."

Fig. 3. Goma's and Gisenyi's Built-Up Area in 2005, 2010 and 2014. Buildings per 10.4 ha.

Fig. 4. Differences in building densities.

(Berwouts, 2017; Stearns, 2011; Tull, 2005). Amidst the second war, Mount Nyiragongo, located 12 km north of Goma erupted in January 2002. The eruption destroyed a third of Goma's built-up area, leaving between 12,000 and 14,800 families homeless (Kanene, 2014; Pech and Lakes, 2017). The lava did not cross into Rwanda, and Gisenyi was mainly temporarily affected through people from Goma in search for shelter. Nevertheless, due to the RCD's inaction concerning evacuation and humanitarian aid, people who had the financial means moved permanently to Gisenyi, also out of the (persisting) believe that Gisenyi is not under volcanic threat. Furthermore, higher RCD-G ranks moved to Gisenyi²², encouraged by strong ties between the RCD-G and Rwanda and the (related) relaxed border regime (Doevenspeck, 2011; Tull, 2005). The RCD-G cadres mostly rented or bought parcels in an area along Gisenyi's border with the Congo, a no-mans-land named Bugoyi. The cities began to merge physically and Bugoyi was nicknamed Quartier RCD (1999, Fig. 2, bottom).²³ As the analysis of our VHR data shows, no fallow land remained in 2005 (50–200 buildings per 10.4 ha hexagon) (Fig. 3, top).

Following several peace agreements in 2003, the RCD was integrated into the Congolese transitional government located in Kinshasa (Veit, 2010). Many of Quartier RCD's inhabitants moved to Congo's capital. In Gisenyi, they were replaced by middle class Congolese, and Quartier RCD continued to grow. Reasons this Congolese migration to Gisenyi were the loss of homes in Goma during the volcanic eruption and the fear of a new eruption, and the administrative incapacity of the RCD-G. A better quality of life on the Rwandan side including better urban

infrastructure (electricity, water and sanitation), lower crime rates, better schools and health services, lower rents, and a more trustworthy land title awarding system also draw people from Goma to live in Gisenyi. Furthermore, houses in Gisenyi often feature small gardens, which render subsistence gardening feasible, and are also attractive for leisure, as both cities suffer from a lack of public (green) spaces²⁴.

Despite the peace accords, violence did not come to a halt on the Congolese side. The violence led to a radical decline of agricultural modes of production in Kivu's rural areas. The combination of insecurity and a decline in rural livelihood opportunities accelerated rural-urban migration to Goma (Raeymaekers, 2013). In Goma's western neighborhoods, at the locations of the post-genocide (Hutu) refugee camps, IDP camps were erected throughout these episodes of insecurity. Former camp structures, such as parcels and paths were reused.^{25,26}

In October 2008, the Congrès National pour la Défense du Peuple (CNDP), a Tutsi rebel movement, threatened to capture Goma. Simultaneously, Joseph Kabila allowed Rwandan soldiers into the DRC to neutralize Hutu militia forces, 6000 former CNDP combatants were integrated into the Congolese army, and a peace treaty was signed on March 23 of 2009 (Johnson, 2014; Johnson et al., 2016). Armed confrontation resumed in 2012, as integrated CNDP combatants mutinied and founded the M23 movement, named after the date of the peace

²² Even though, depending on the location of volcanic fissures, Gisenyi is exposed to the same volcanic threat as Goma, the believe that only Goma is threatened persists among Goma's inhabitants an employee of Goma's Observatoire Volcanologique (OVG), 2017. Volcanic Vents, Hazard and Affected Areas in the Case of Future Outbreaks, in: Pech, L. (Ed.), an employee of MONUSCO's GIS Unit, 2016. Work of GIS Unit, mapping, hazard analysis, in: Pech, L. (Ed.). Further interviews with an employee of UN Habitat Kinshasa, 2016. Interview # 6, UN Habitat Kinshasa in: Pech, L. (Ed.), UN Habitat., a member of the Rwandan Red Cross, 2017. Interview - Genocide, Civil War and (Forced) Migration, in: Pech, L. (Ed.), a Rwandan inhabitant of Bugoyi/Quartier RCD in Gisenyi, 2017. Histoire du Quartier RCD, in: Pech, L. (Ed.), an inhabitant of Goma, 2016. Interview # 13, several interviews with the same interviewee, in: Pech, L. (Ed.).

²³ Interviews with a Congolese inhabitant of Bugoyi/Quartier RCD in Gisenyi, 2017. Interview Goma-Gisenyi - Migration between the two cities, in: Pech, L. (Ed.), a Rwandan inhabitant of Bugoyi/Quartier RCD in Gisenyi, 2017. Histoire du Quartier RCD, in: Pech, L. (Ed.).

²⁴ Similar to the current law in the DRC, all Rwandan soil belonged to the state according to a law passed in 1961, until the reform in 2005. The new law facilitates the transfer of land titles and legalized land acquired under traditional law Ilberg, A., 2009. Einflussfaktoren auf Wachstum und Morphologie informeller Siedlungen. Most of the parcels in Gisenyi are "private state land" and rented or leased for 99 years. (Interviews with a Congolese inhabitant of Bugoyi/Quartier RCD in Gisenyi, 2017. Interview Goma-Gisenyi - Migration between the two cities, in: Pech, L. (Ed.). and an employee of the One Stop Center of Rubavu District, 2017. Urban Planning and Administrative Structures of Rwanda, in: Pech, L. (Ed.).

²⁵ Interviews with an employee and a volunteer of the Congolese Red Cross, 2016. Interview # 14, Congolese Red Cross Goma (Interview in Gisenyi, Rwanda due to problems at the border), in: Pech, L. (Ed.), Croix Rouge Congolaise, an employee of the Congolese Red Cross, 2016. Interview # 45, visit of IDP Camp Mugunga I and former IDP Site Lac Vert, Buhimba, Bulengo and Bananeraie, in: Pech, L. (Ed.), an employee of UNHCR Goma, 2016. Interview # 21, UNHCR Goma (Interview in Gisenyi, Rwanda due to problems at the border), in: Pech, L. (Ed.), UNHCR.

²⁶ Interview with an employee of UN Habitat, 2016. Interview # 37, UN Habitat Goma, in: Pech, L. (Ed.), UN Habitat Goma.

treaty. M23 seized Goma between November and December 2012. By September 2013, the estimated number of IDPs in North Kivu was more than a million (IDMC, 2014; UN OCHA, 2012).

The incessant insecurity in North and South Kivu drove the densification of Goma's urban built-up area. IDPs settled in up to seven camps at peak times, and independently or in host families throughout the city, requiring rapid residential construction (Fig. 3, center and bottom).²⁷ Up to 62% of North Kivu's IDPs were estimated to live outside of camps, and between 2012 and 2013, Goma's population increased approximately 45% due to waves of violence and increased forced displacement (Norwegian Refugee Council, 2014). Among the highest building densities with up to 700 buildings per hexagon in 2014 were measured in Goma's traditional business district Birere along the border (dark red tones in Fig. 3), and, more impressively, in Goma's main military camp Katindo, with up to 1000 buildings per 10 ha hexagon (brown tones, lower third, Fig. 3). While Birere has always been characterized by being built at close quarters, Katindo only was built up entirely between 2005 and 2014, largely due to the influx of military members, joined by their families, and by internally displaced persons and other civilians with no alternatives to settle (Pech et al., 2018). As a matter of contrast, on the Rwandan side, where the conditions since the early 2000 s are relatively stable, Gisenyi's main military camp remained almost devoid of buildings, while Gisenyi itself also remained at a lower building level than Goma. As refugees in Rwanda are no longer allowed to settle close to the border, Congolese displaced persons intending to cross into Rwanda and late Rwandan returnees are accompanied to the border by the Congolese National Refugee Commission (CNR), and in Gisenyi brought to the UN HCR transit center. Congolese refugees are transferred to one of the five Congolese refugee camps in central Rwanda, some of which exist since 1996. Rwandan returnees, including demobilized (rebel) combatants, are registered and provided with basic assistance, and transported to their districts of origin, where they receive reintegration assistance.²⁸ Today, permanent settlement of cross-border migrants from Goma to Gisenyi comprises two main groups: international staff with family (since Goma is a non-family duty station), and Congolese middle-class citizens in search of a safer setting with less delinquency, a reliable urban infrastructure (paved roads, electricity network, sanitary infrastructure etc.), affordable food, and housing costs.²⁹ Privileged locations in Goma are scarce, and prices are more affected by speculation and corruption (Peyton, 2018).

²⁷ Interviews with *ibid.*, an inhabitant of Goma, 2016. Interview # 13, several interviews with the same interviewee, in: Pech, L. (Ed.). and an employee and a volunteer of the Congolese Red Cross, 2016. Interview # 14, Congolese Red Cross Goma (Interview in Gisenyi, Rwanda due to problems at the border), in: Pech, L. (Ed.), Croix Rouge Congolaise.

²⁸ Interviews with a Congolese inhabitant of Bugoyi/Quartier RCD in Gisenyi, 2017. Interview Goma-Gisenyi - Migration between the two cities, in: Pech, L. (Ed.), a researcher of Pole Institute Goma, 2017. Interview - Cross Border Migration due to Insecurity/Infrastructure/Livelihood Opportunities, in: Pech, L. (Ed.), an employee of the Congolese National Commission for Refugees (CNR), 2017. La Situation des Réfugiés en RDC, in: Pech, L. (Ed.), a member of the Rwandan Red Cross, 2017. Interview - Genocide, Civil War and (Forced) Migration, in: Pech, L. (Ed.), an employee of UN OCHA Kinshasa, 2016b. Interview # 2, Coordination and Evaluation Officer: Planning and Ressource Mobilisation Unit at UN OCHA, in: Pech, L. (Ed.). and an employee of UN Habitat, 2016. Interview # 37, UN Habitat Goma, in: Pech, L. (Ed.), UN Habitat Goma.

²⁹ Interview with a researcher of Pole Institute Goma, 2017. Interview - Cross Border Migration due to Insecurity/Infrastructure/Livelihood Opportunities, in: Pech, L. (Ed.).

3.2. Differences in expansion, densification, and building loss, 2005–2014

3.2.1. Statistical analysis

Based on the analysis of our VHR data (2005–2014), Goma's extent in built-up area (39 km²) was more than four times Gisenyi's size (9 km²) in 2005. Goma covers a substantially larger area than Gisenyi and expanded more rapidly throughout ten years of urban development. This timeframe also covers several armed rebellions in Goma's rural hinterlands, that led to hundreds of thousands of forcibly displaced persons, many of which did eventually settle in Goma (Norwegian Refugee Council, 2014) (see also Section 3.1). The city's extent was 44 km² in 2010 (+5 km² or +12.8%) and 57 km² in 2014 (+18 km² or +46.2%), while Gisenyi's extent was 10 km² in 2010 (+1 km² or +11.1%) and 11 km² in 2014 (+2 km² or +22.2%).³⁰ Nevertheless, Goma's 7.17 buildings per hectare and Gisenyi's 6.60 buildings per hectare demonstrate that building densities did not differ significantly in 2005 ($p = 0.400$, $CI = -0.77, 1.92$) (Fig. 4, left panel). This changed in 2010 and 2014, when mean building densities were significantly higher in Goma (2010: 11.54; 2014: 15.76) compared to Gisenyi (2010: 9.16; 2014: 11.58) with $p < 0.005$ (2010) and $p < 0.005$ (2014) as well as $CI = 0.77, 3.99$ (2010) $CI = 2.24, 6.12$ (2014). Additionally, very high building densities characterized several areas of Goma, while the density in Gisenyi was distributed homogeneously with very few outliers. Though both cities exhibited an increase in building density between 2005 and 2014, Goma's mean building density increased significantly more (+8.59 buildings per hectare) than Gisenyi's (+4.98 buildings per hectare) with $p < 0.0005$ and $CI = 2.25, 4.96$.

The change analysis (Fig. 5), based on the 2005 image footprint, shows relative changes in built-up area between 2005 and 2014. The (northward) expansion (gray-brown) and densification (red) is stronger in Goma than in Gisenyi. In Goma's western neighborhoods Mugunga and Lac Vert, an area with 600 buildings per 10.4 ha in 2005 was joined by four areas of between 600 and 1600 buildings per hexagon in 2014 (red tones). These spots mark the areas where IDP camps are frequently placed, especially during the CNDP and M23 rebellions (see Section 3.1). Densely built-up areas also sprung up in central Goma, within a kilometer-wide fringe north of the westbound main road, and in Goma's military camp (red tones). Higher density of built-up area exists in Gisenyi to a much smaller magnitude than in Goma, with 400 buildings per hexagon in the (colonial) center (Rubavu neighborhood) and north of this center (Byahi). A loss of buildings (blue tones) occurred in Goma along the border, mostly in Birere neighborhood and along Goma's westbound main road. In Gisenyi, loss of buildings happened along Mount Rubavu's western slope. In both cities, this diminution in the number of buildings was not related to the security situation, but to targeted demolitions of buildings for different reasons (see below). Due to topographic constraints, such as the lake and the national park, and to administrative boundaries (national and municipal), both cities expand predominantly northwards.

Changes in built-up structures on either side of the border are in many instances not related to conflict. However, while on Goma's side rural-urban migration is most often linked to the security situation, and reliable demographic data does not exist for Goma, we will here discuss the disappearance of buildings to illustrate how urban growth is controlled on both sides of the border.

Gisenyi's moderate expansion is not only due to the absence of open armed conflict in Rwanda's recent past. The Rwandan capital Kigali has been at the center of the attention of urban modernization endeavors in Rwanda since the end of the civil war (Pätsch, 2018). Federal development mandates for secondary towns have mostly been sidelined (Hug-gins, 2017; Newbury, 2011). Thus far, the capital has attracted most of the rural-urban migration within the country, and half of Rwanda's

³⁰ Measurements based on original shapefiles of built-up area.

Fig. 5. Expansion, Densification and Building Loss in Goma and Gisenyi between 2005 and 2014.

urban inhabitants live in Kigali (Goodfellow, 2014). The first masterplan for Gisenyi was published in 2015, as part of national ambitions to promote secondary cities, involving Gisenyi's promotion as tourist hub (LODA, 2017). Prior to the enactment of the masterplan, the Rwandan government handled uncoordinated urbanization by designating urban zones into building plots to provide relevant infrastructural services for all cities, which to a great deal involved the clearance of unplanned urban areas (Ansoms and Rostagno, 2012; Huggins, 2017; Newbury, 2011). A result of such clearances is the destruction of built-up area in Gisenyi. More than hundred buildings were demolished on Mount Rubavu's western flank between 2010 and 2014 (light to dark blue hexagons in Fig. 5), officially ordered due to the exposition to landslide hazard. Subsequently, Mount Rubavu was declared as a natural preserve.³¹ Since a land reform in 2005, the Rwandan state officially recognizes the right to own land. Land titles enable possession for 99 years or a 20-year leasehold unless the government decides to expropriate in 'public interest' (Ilberg, 2009; Patsch, 2018). Officially the expropriated inhabitants must be compensated. Therefore, inhabitants of Mount Rubavu who lost their homes were granted monetary aid and replacement parcels in Gisenyi's north. Nevertheless, in practice, many people were obligated to destroy their homes and then construct elsewhere with too little to no assistance³² (Newbury, 2011). The establishment of

informal settlements is significantly hampered in Gisenyi and nationwide by neighborhood monitoring efforts that render illegal settlement difficult.³³ These mechanisms of governance collectively inhibit unplanned urban change, in stark contrast to Goma, where the urbanization process has unfolded in a relatively organic, spontaneous, and unplanned way (Pech et al., 2018). By contrast, Goma's larger city area and the state's administrative (in)capacity, combined with a permanent crisis situation, render the planning and controlling of Goma's ongoing expansion difficult.³⁴

The change analysis (see also Fig. 5) also shows building loss on Goma's side along the border, due to an endeavor to create an avenue using uncoordinated bulldozing. This haphazard plan left many buildings partially or fully destroyed and their inhabitants homeless without compensation.³⁵ Additionally, between 2015 and 2016 (after our satellite imagery analysis ends) at least 198 buildings were destroyed in a similar manner along the border in Birere. Allegedly, this clearance of the 'neutral zone' between the DRC and Rwanda took place to prevent further territorial conflicts and infiltration (armed groups, bandits). The idea was born in 2009 by a joint commission between the DRC and Rwanda, but demolition began only in August 2015, supervised by Congolese and Rwandan soldiers. It was agreed that 6.25 m should be cleared on both sides of the border, with compensation for the

³¹ Interviews with a member of the Rwandan Red Cross, 2017. Interview - Genocide, Civil War and (Forced) Migration, in: Pech, L. (Ed.), a researcher of Pole Institute Goma, 2017. Interview - Cross Border Migration due to Insecurity/Infrastructure/Livelihood Opportunities, in: Pech, L. (Ed.), a Congolese inhabitant of Bugoyi/Quartier RCD in Gisenyi, 2017. Interview Goma-Gisenyi - Migration between the two cities, in: Pech, L. (Ed.) and an employee of the One Stop Center of Rubavu District, 2017. Urban Planning and Administrative Structures of Rwanda, in: Pech, L. (Ed.).

³² Interview with a member of the Rwandan Red Cross, 2017. Interview - Genocide, Civil War and (Forced) Migration, in: Pech, L. (Ed.).

³³ Informal background talk with an employee of the Rwandan Ministry of Infrastructure, 2017. in: Pech, L. (Ed.). Interview with an employee of UN Habitat Goma, 2016. Interview # 20, Interview in Gisenyi due to problems at the border, in: Pech, L. (Ed.).

³⁴ Interview with a researcher of Pole Institute Goma, 2017. Interview - Cross Border Migration due to Insecurity/Infrastructure/Livelihood Opportunities, in: Pech, L. (Ed.).

³⁵ Interview with an employee of UN OCHA Kinshasa, 2016a. Interview #, Humanitarian Affairs Officer, UN OCHA Kinshasa, in: Pech, L. (Ed.), a master's student from Goma at ISAU, 2016. Interview # 32, Institut Supérieur d'Architecture et d'Urbanisme (ISAU), in: Pech, L. (Ed.), Titres Fonciers, Planification Urbaine et Développement Urbain - Goma.

expropriated on the Rwandan side (Belga/La Libre.be, 2015).³⁶ During the first author's last visit to the border strip in October 2017, still, no clearance had occurred on the Rwandan side. Lacking alternatives, the affected Congolese continued to live in partly demolished buildings, in tents, or banana groves.³⁷ They were not compensated, as the Congolese authorities claim that they knowingly settled illegally, despite the inhabitants claiming to have built their accommodations after obtaining approvals issued by a mayor or traditional chief³⁸ (Belga/La Libre.be, 2015). However, as two land-tenure systems co-exist in Goma, given land titles are not necessarily a reliable guarantee of possession.

3.3. Study limitations

This analysis was limited by poor data availability and quality in the region (e.g., reliable population estimates), constituting a significant barrier to quantitative analysis and necessitating on-the-ground empirical observation and predominant focus on qualitative evidence. Additionally, bureaucratic challenges to accessing data and conducting fieldwork rendered a symmetrical application of empirical methods on either side of the border difficult, such that data collection in Rwanda was more challenging. Further intensive development of contacts and networks in Rwanda will be necessary to successfully complete further detailed observation and data collection in Gisenyi, for instance in order to filter out more precisely violence-related population movement from such that is caused by other factors. More broadly, the region's dense and varied network of actors, policies, and conditions pose significant challenges when seeking to understand causative factors and conditions leading to urban development. Several key influences were evident through the fieldwork and interviews (e.g., conflict-induced population flows), while others are more difficult to pinpoint (e.g., variable degrees of efficacy among urban planning policies). This is particularly true in a cross-border context, where a high degree of variation in the policies between the respective states and non-state actors may hinder definitive inference, thereby necessitating a broad methodological and empirical scope to develop and advance understandings of cross-border asymmetries. Extensive field surveys could investigate the importance of, e.g., security from conflict or delinquency, reliable urban infrastructure, or a reliable land-tenure system to move from Goma to Gisenyi. The link between different growth rates of Goma and phases of violence and stability could be investigated on a (statistically) representative scale, in order to further decipher the importance of economic factors versus physical security.

4. Conclusion

As revealed by our analysis there are remarkable differences in spatial development and urban morphology between the two cities. While Goma's urban area expands and densifies, Gisenyi's spatial extent remains relatively stable. The main underlying drivers of the observed

spatial changes and differences were identified as being armed conflict and linked population flows, as well as between-state differences in handling the effects of conflict.

The border cities of Goma and Gisenyi provide a valuable setting as they share many geographical and cultural similarities, enabling comparative analysis of the conditions – with a special focus on the influence of armed conflict – leading to divergent trajectories. They feature distinct parallels in their development, such as their increased spatial extent due to the influx of forcibly displaced persons. The time spans and intensities in terms of numbers of displaced persons differed, as did and do the ways in which these flows of displaced persons are (spatially) governed by the respective country. Due to the absence of armed conflict in Rwanda since the early 2000s, no conflict-induced internal forced displacement to urban areas occurs, and (Congolese) refugees are not allowed anymore to settle close to the border. These flows and their effects on urban configurations and (non-)governmental structures underscore their importance in policy, meriting further research on the specific linkages between cross-border migration and urban change in (post-)conflict settings.

Goma exhibited rapid and extreme densification of buildings in many areas marked by poor living conditions, especially in the inner city. These densely populated neighborhoods were furthermore characterized by very small building sizes and the number of inhabitants per dwelling increased with the level of poverty. Equivalent spaces in Gisenyi often featured small yards or gardens, despite the modest living conditions. Furthermore, Gisenyi displays an urban-to-rural occupancy direction: the more rural a neighborhood is, more like people are to share one roof.

Despite their interdependencies, Gisenyi remains less internationally integrated, both economically and politically, than Goma. These processes and configurations are not exclusively resultant from armed conflict, but also through interplays of livelihood opportunities, cross-border economies, divergent trajectories and degrees of statehood, and transnational actors (such as the UN). The main flow of Rwandans to Goma consists of commuters, while Gisenyi is home to some Congolese and other international inhabitants who make their living in Goma but prefer to live in Gisenyi. In Rwanda, the capital Kigali is still a significant magnet for rural-urban migration. Nevertheless, our results indicate that conflict serves as a driver or intensifier of urban change in the study area. This may also be true in other border regions experiencing conflict, particularly in cross-border cities. Further comparative research is required to examine the generalizability of our results and identify unique endemic factors driving the variations in urban change. However, the drivers of urban change are not strictly separable nor linkable to only one growth phenomenon. The study showed how different political regimes can cause different urban patterns – e.g., organic (Goma) vs. rectangular (Gisenyi) structures, or, that one of Goma's most intensely densifying areas was a military camp, while Gisenyi's military installation stayed void of buildings. A deciphering of these and further details was only possible through their detection on satellite imagery times series, followed by thorough research on the ground. While this research laid the foundation for further comparisons of twin cities, notably in conflict-affected settings and with a combination of methods, further research efforts should utilize comparative approaches to identify, situate, and disentangle the factors driving urban growth and decline in conflict-affected borderlands. In order to support both research and policy, household surveys or enumeration programs could use similar building data layers as a basis for improved estimation of the number and composition of the population, or a comparison of the quality of life on both sides of the border.

The ability to leverage remote-sensed imagery poses an invaluable tool for identifying patterns and areas of interest, and recent advances in image analysis may provide semi-automated tools to better quantify changes in urban structure. Crucial to their use is the elucidation of complex and intertwined social, political, and economic ecologies, and the tracing of their endemic effects on urban change. Inter-regional

³⁶ Interview with a member of the Rwandan Red Cross, 2017. Interview - Genocide, Civil War and (Forced) Migration, in: Pech, L. (Ed.).

³⁷ Interviews with a master's student from Goma at ISAU, 2016. Interview # 32, Institut Supérieur d'Architecture et d'Urbanisme (ISAU), in: Pech, L. (Ed.), Titres Foncières, Planification Urbaine et Développement Urbain - Goma., a member of the Rwandan Red Cross, 2017. Interview - Genocide, Civil War and (Forced) Migration, in: Pech, L. (Ed.), an inhabitant of Goma - Mikenko, 2016. Interview # 40, in Mikenko/Birere, in: Pech, L. (Ed.), Nielsen and D'haen (2015). Discussing rural-to-urban migration reversal in contemporary sub-Saharan Africa: The case of Ouagadougou, Burkina Faso. Humboldt-Universität zu Berlin, IRI THESys., an employee of Bureau d'études d'aménagement et d'urbanisme (BEAU), 2016. Interview # 31, Office for land-use planning and urban planning, in: Pech, L. (Ed.).

³⁸ Interview with a master's student from Goma at ISAU, 2016. Interview # 32, Institut Supérieur d'Architecture et d'Urbanisme (ISAU), in: Pech, L. (Ed.), Titres Foncières, Planification Urbaine et Développement Urbain - Goma.

comparisons could be conducted, to see whether (twin-)cities' spatial behavior shows similarities if, e.g., economical settings or the type of warfare is similar. We assert that this relies on communication with a diverse set of actors, and therefore underscore the utility of integrated approaches to urban research.

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Interviews

a Congolese inhabitant of Bugoyi/Quartier RCD in Gisenyi, 2017. Interview Goma-Gisenyi - Migration between the two cities, in: Pech, L. (Ed.).

a Congolese Prosecutor, 2016. Security Situation and Crime Rates/DRC, in: Pech, L. (Ed.).

a master's student from Goma at ISAU, 2016. Interview # 32, Institut Supérieur d'Architecture et d'Urbanisme (ISAU), in: Pech, L. (Ed.), Titres Fonciers, Planification Urbaine et Développement Urbain - Goma.

a member of the Rwandan Red Cross, 2017. Interview - Genocide, Civil War and (Forced) Migration, in: Pech, L. (Ed.).

a professor at ISAU Kinshasa, 2016. Interview # 20, Institut Supérieur d'Architecture et d'Urbanisme (ISAU), in: Pech, L. (Ed.).

a researcher of Pole Institute Goma, 2016. Interview # 17, Interview in Gisenyi due to problems at the border, in: Pech, L. (Ed.), Pole Institute Goma.

a researcher of Pole Institute Goma, 2017. Interview - Cross Border Migration due to Insecurity/Infrastructure/Livelihood Opportunities, in: Pech, L. (Ed.).

a Rwandan inhabitant of Bugoyi/Quartier RCD in Gisenyi, 2017. Histoire du Quartier RCD, in: Pech, L. (Ed.).

an employee and a volunteer at the Don Bosco Center, 2017. Interview # 49, Interview at Don Bosco Center Ngangi, in: Pech, L., Schuh, P. (Eds.).

an employee and a volunteer of the Congolese Red Cross, 2016. Interview # 14, Congolese Red Cross Goma (Interview in Gisenyi, Rwanda due to problems at the border), in: Pech, L. (Ed.), Croix Rouge Congolaise.

an employee of Bureau d'études d'aménagement et d'urbanisme (BEAU), 2016. Interview # 31, Office for land-use planning and urban planning, in: Pech, L. (Ed.).

an employee of Goma's Observatoire Volcanologique (OVG), 2017. Volcanic Vents, Hazard and Affected Areas in the Case of Future Outbreaks, in: Pech, L. (Ed.).

an employee of MONUSCO's GIS Unit, 2016. Work of GIS Unit, mapping, hazard analysis, in: Pech, L. (Ed.).

an employee of MONUSCO, 2016. Interview # 5, informal background talk, in: Pech, L. (Ed.).

an employee of the Congolese National Commission for Refugees (CNR), 2017. La Situation des Réfugiés en RDC, in: Pech, L. (Ed.).

an employee of the Congolese Red Cross, 2016. Interview # 45, visit of IDP Camp Mugunga I and former IDP Site Lac Vert, Buhimba, Bulengo and Bananeraie, in: Pech, L. (Ed.).

an employee of the One Stop Center of Rubavu District, 2017. Urban Planning and Administrative Structures of Rwanda, in: Pech, L. (Ed.).

an employee of the Rwandan Ministry of Infrastructure, 2017. in: Pech, L. (Ed.).

an employee of UN Habitat, 2016. Interview # 37, UN Habitat Goma, in: Pech, L. (Ed.), UN Habitat Goma.

an employee of UN Habitat Goma, 2016. Interview # 20, Interview in Gisenyi due to problems at the border, in: Pech, L. (Ed.).

an employee of UN Habitat Kinshasa, 2016. Interview # 6, UN Habitat Kinshasa in: Pech, L. (Ed.), UN Habitat.

an employee of UN OCHA Kinshasa, 2016a. Interview #, Humanitarian Affairs Officer, UN OCHA Kinshasa, in: Pech, L. (Ed.).

an employee of UN OCHA Kinshasa, 2016b. Interview # 2, Coordination and Evaluation Officer: Planning and Ressource Mobilisation Unit at UN OCHA, in: Pech, L. (Ed.).

an employee of UNHCR Goma, 2016. Interview # 21, UNHCR Goma (Interview in Gisenyi, Rwanda due to problems at the border), in: Pech, L. (Ed.), UNHCR.

an inhabitant of Goma - Mikeno, 2016. Interview # 40, in Mikeno/Birere, in: Pech, L. (Ed.).

an inhabitant of Goma, 2016. Interview # 13, several interviews with the same interviewee, in: Pech, L. (Ed.).

an inhabitant of Himbi/local construction entrepreneur - Goma, 2016. Interview # 41, in Himbi, in: Pech, L. (Ed.).

References

- Ansoms, A., Rostagno, D., 2012. Rwanda's Vision 2020 halfway through: what the eye does not see. *Rev. Afr. Political Econ.* 39, 427–450.
- Behrends, A., 2014. Securing livelihoods: economic practice in the Darfur-Chad borderlands. *Displac. Econ. Afr.: Paradox-- Crisis Creat.* 2.
- Belga/La Libre.be, 2015. A Goma, dans la zone neutre entre RDC et Rwanda, on pleure les maisons détruites. *La Libre.be*.
- Berwouts, K., 2017. Congo's violent Peace; Conflict and struggle since the Great African War. University of Chicago Press., Chicago.
- Birch, C.P., Oom, S.P., Beecham, J.A., 2007. Rectangular and hexagonal grids used for observation, experiment and simulation in ecology. *Ecol. Model.* 206, 347–359.
- Büscher, K., 2011. Conflict, state failure and urban transformation in the Eastern Congolese periphery: The case of Goma. Ghent University.
- Büscher, K., 2016. Reading urban landscapes of war and peace: the case of Goma, DRC, Spatializing Peace and Conflict. Springer., pp. 79–97.
- Büscher, K., 2018. Urbanisation and the Political Geographies of Violent Struggle for Power and Control: Mining Boomtowns in Eastern Congo. *Int. Dev. Policy/ Rev. Int. De. Polit. De. développement* 10, 302–324.
- Davis, C., Schaub, T., 2005. A transboundary study of urban sprawl in the Pacific Coast region of North America: The benefits of multiple measurement methods. *Int. J. Appl. Earth Obs. Geoinf.* 7, 268–283.
- De Herdt, T., de Sardan, J.-P.O., 2015. Real governance and practical norms in Sub-Saharan Africa: the game of the rules. Routledge.
- Dobler, G., 2009. Oshikango: the dynamics of growth and regulation in a Namibian boom town. *J. South. Afr. Stud.* 35, 115–131.
- Doevenespeck, M., 2011. Constructing the border from below: Narratives from the Congolese–Rwandan state boundary. *Political Geogr.* 30, 129–142.
- Doevenespeck, M., Nene, M.M., 2012. Faire face à l'incertitude: la frontière entre le Congo et le Rwanda comme une ressource. *Ann. De. géographie. Armand Colin* 684, 151–171.
- Goodfellow, T., 2014. Rwanda's political settlement and the urban transition: expropriation, construction and taxation in Kigali. *J. East. Afr. Stud.* 8, 311–329.
- Government of Rwanda and GGGL, 2015. National Roadmap for Green Secondary City Development. Global Green Growth Institute., Kigali.
- Hollstegge, J., Doevenespeck, M., 2017. 'Sovereignty Entrepreneurs' and the Production of State Power in Two Central African Borderlands. *Geopolitics* 22, 815–836.
- Huggins, C., 2017. Agricultural Reform in Rwanda. University of Chicago Press Economics Books.
- IDMC, 2014. Democratic Republic of the Congo - Multiple Crises Hamper Prospects for Durable Solutions, p. 15.
- Ilberg, A., 2009. Einflussfaktoren auf Wachstum und Morphologie informeller Siedlungen.
- Jackson, S., 2006. Borderlands and the transformation of war economies: lessons from the DR Congo. *Conflict. Secur. Dev.* 6, 425–447.
- Jerven, M., 2013. Poor numbers: how we are misled by African development statistics and what to do about it. Cornell University Press.
- Johnson, D., 2014. Kongo: Kriege, Korruption und die Kunst des Überlebens. Brandes & Appel.
- Johnson, D., Schlindwein, S., Schmolze, B., 2016. Tatort Kongo-Prozess in Deutschland: Die Verbrechen der ruandischen Miliz FDLR und der Versuch einer juristischen Aufarbeitung. Ch. Links Verlag.
- Kanene, C., 2014. Projet d'Appui au Processus d'Elaboration du Plan de Rénovation Stratégique de l'Agglomération de Goma. UN Habitat.
- Lamarque, H., 2014. Fuelling the Borderland: Power and Petrol in Goma and Gisenyi. *Articul. -J. Urban Res.*
- Lange, M., Kimanuka, C., 2010. The Crossing. Small Scale Trade and Improving Cross-Border Relations between Goma (DR Congo) and Gisenyi (Rwanda). *Intenational Alert*.
- Lemarchand, R., 2004. Exclusion, marginalization, and political mobilization: The road to hell in the Great Lakes. Wimmer, Andreas et al., eds, 61–77.

- LODA, 2017. Abbreviated Resettlement Action Plan (ARAP) - Rehabilitation and Upgrading of Karomero-Karundo Mbugangari Roads in Rubavu District. Local Administrative Entities Development Agency,.
- Maire de Goma, 2017. in: Pech, L. (Ed.).
- Mairie de Goma, 2015. Ville de Goma - Rapport Annuel, DRC.
- Mairie de Goma, 2016. Ville de Goma - Rapport Annuel, DRC.
- Mathys, G., 2014. People on the move: frontiers, borders, mobility and history in the Lake Kivu region 19th-20 century. Ghent University,.
- Mathys, G., 2017. Bringing History Back In: Past, Present, and Conflict in Rwanda and the Eastern Democratic Republic of Congo. *J. Afr. Hist.* 58, 465–487.
- Murray, M., Myers, G., 2007. Cities in contemporary Africa. Springer,.
- Myers, G., 2011. African cities: alternative visions of urban theory and practice. Zed Books Ltd.,.
- Newbury, C., 2011. High Modernism at the Ground Level. Remaking Rwanda.: State-Build. *Hum. Rights Mass Confl.* 223–239.
- Nielsen, J.Ø., D'haen, S.A.L., 2015. Discussing rural-to-urban migration reversal in contemporary sub Saharan Africa: The case of Ouagadougou, Burkina Faso. Humboldt-Universität zu Berlin, IRI THESys.
- Norwegian Refugee Council, 2014. Living Conditions of displaced persons and host communities in urban Goma, DRC. Norwegian Refugee Council,.
- Oldenburg, S., 2016. A Goma On Sait Jamais. Jugend, Krieg und Alltag in Goma, DR Kongo. Unveröffentlichte Dissertation, Berlin.
- Oldenburg, S., 2018. Agency, social space and conflict-urbanism in eastern Congo. *J. East. Afr. Stud.* 12, 254–273.
- Omasombo, J., 2005. Kisangani: a city at its lowest ebb. *Urban. In: Africa: Changing Contours of Survival in the City*, 9.
- Pätsch, C., 2018. The capacity of institutional innovation following the diffusion of urban plans. Explorations of impacts of an urban master plan in Kigali, Rwanda.
- Pech, L., Büscher, K., Lakes, T., 2018. Intraurban development in a city under protracted armed conflict: Patterns and actors in Goma, DR Congo. *Political Geogr.* 66, 98–112.
- Pech, L., Lakes, T., 2017. The impact of armed conflict and forced migration on urban expansion in Goma: Introduction to a simple method of satellite-imagery analysis as a complement to field research. *Appl. Geogr.* 88, 161–173.
- Peyton, D., 2018. Wartime speculation: property markets and institutional change in eastern Congo's urban centers. *J. East. Afr. Stud.* 12, 211–231.
- Pieterse, E., 2011. Grasping the unknowable: coming to grips with African urbanisms. *Social. Dynamics* 37, 5–23.
- Pottier, J., 1996. Relief and repatriation: Views by Rwandan refugees; lessons for humanitarian aid workers. *Afr. Aff.* 95, 403–429.
- Prunier, G., 1997. The Rwanda crisis: History of a genocide. Columbia University Press,.
- Prunier, G., 2008. Africa's world war: Congo, the Rwandan genocide, and the making of a continental catastrophe. Oxford University Press, USA.
- Raeymaekers, T., 2009. The silent encroachment of the frontier: A politics of transborder trade in the Semliki Valley (Congo–Uganda). *Political Geogr.* 28, 55–65.
- Raeymaekers, T., 2013. Violence on the margins: States, conflict, and borderlands. Springer,.
- Secretary-General of the United Nations, 2014. Report of the Secretary-General on the United Nations Organization Stabilization Mission in the Democratic Republic of the Congo p. 18.
- Simone, A., 2001. On the worlding of African cities. *Afr. Stud. Rev.* 44, 15–41.
- Soi, I., Nugent, P., 2017. Peripheral Urbanism in Africa: Border Towns and Twin Towns in Africa. *J. Borderl. Stud.* 32, 535–556.
- Stearns, J., 2011. Dancing in the Glory of Monsters: the Collapse of the Congo and the Great War of Africa. PublicAffairs.
- Tegera, A., Sematumba, O., Kayser, C., Rutinigirwa, L., Hamuli, P., 2007. Les frontières: Lieux de division où passerelles d'échange. *Fissures* 5, 1–74.
- Tull, D., 2005. The reconfiguration of political order in Africa: a case study of North Kivu (DR Congo). GIGA-Hamburg,.
- Umutesi, M.B., 2004. Surviving the Slaughter: The Ordeal of a Rwandan Refugee in Zaire. Univ of Wisconsin Press,.
- UN OCHA, 2012. DR Congo: Stepping up support for two million displaced.
- UN Security Council, 2013. Resolution 2098 (2013).
- Veit, A., 2010. Intervention as indirect rule: Civil war and statebuilding in the Democratic Republic of Congo. Campus Verlag,.
- Verhoeve, A., Vlassenroot, K., Raeymaekers, T., 2004. Conflict and the urban space: The socio-economic impact of conflict on the city of Goma. *Confl. Soc. Transform. East. DR Congo.* 103–122.
- Vlassenroot, K., 2004. Land and Conflict. The Case of Masisi. *Conflict and Social Transformation in Eastern DR Congo*, pp. 81–101.
- Vlassenroot, K., Büscher, K., 2013. Borderlands, identity and urban development: the case of Goma (Democratic Republic of the Congo). *Urban Stud.* 50, 3168–3184.
- Wilson, C., 2014. Spectral analysis of civil conflict-induced forced migration on land-use/land-cover change: the case of a primate and lower-ranked cities in Sierra Leone. *Int. J. Remote Sens.* 35, 1094–1125.
- Zhao, C., Jensen, J., Zhan, B., 2017. A comparison of urban growth and their influencing factors of two border cities: Laredo in the US and Nuevo Laredo in Mexico. *Appl. Geogr.* 79, 223–234.