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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

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ABSTRACT

The effects of armed conflict on cities constitute a large field of research in both conflict studies and urban studies. The topic of urban expansion is also explored by the domain of remote sensing, a subbranch of geoinformation science. Remote sensing researchers analyze the spatial development of cities in conflict and non-conflict environments using satellite imagery.

However, a dialogue or collaboration between these disciplines is virtually non-existent in the scientific discourse, mainly due to stark differences in their methodologies – namely, intensive on-the-ground field research in the case of conflict and urban studies and highly elaborate computer-based analysis of remotely-gathered data in the case of remote sensing.

We aim to demonstrate a simple and thus feasible approach for the use of satellite imagery by non-experts of remote sensing, to add a spatio-temporal dimension to the results of in-depth field studies. We apply our approach to the city of Goma, in the eastern region of the Democratic Republic of the Congo, which is located at the center of protracted armed conflict that has raged for decades. With the support of local knowledge acquired during field visits, we visually analyze a time series of Landsat data and add our own results to those of existing research. Contextualizing the mapped results of Goma's urban expansion between 1986 and 2015, we show how urban growth is linked to particular waves of forced displacement caused by different stages of armed conflict and one particular natural disaster.

1. Introduction

Urban growth occurs rapidly in developing countries (López, Bocco, Mendoza, & Duhau, 2001). The highest growth rates between 1995 and 2015 were observed in the least developed parts of the world, with Africa urbanizing most rapidly (UN Habitat, 2016). Urban expansion processes are often further accelerated by armed conflict near urban centers: In these environments, cities offer spaces of relative security and stability (Verhoeve, Vlassenroot, & Raeymaekers, 2004, pp. 103–122) and thus act as a magnet for internally displaced persons (IDPs) (Branch, 2013). This effect leads to rapid growth, converting smaller urban centers into large cities (Beall, 2007; Beall, Goodfellow, & Rodgers, 2013; Lynch, Maconachie, Binns, Tengbe, & Bangura, 2013).

The relation between armed conflict and urban growth has been explored by the research of conflict studies, on the one hand, and urban studies and urban geography, on the other. Yet, when these two disciplines meet, a methodological void that is rarely addressed emerges.

Research from the area of conflict studies mainly focuses on violence *in* cities (Raleigh, 2015; Rodgers, 2016), to a large extent leaving out the effect of conflict *on* cities. The opposite is the case for the field of urban studies, which explores aspects of forced migration and rural-urban transformation (Branch, 2013) and its effects (Bartlett, Alix-Garcia, & Saah, 2012). Both fields address the topic of spatial processes; however, these fields only seldom utilize spatial data. This is explained by the fact that these disciplines, although scrutinizing the materiality of space, focus more on the social meaning of space (Chojnacki & Engels, 2013).

Spatial data in its *physical* denotation, on the other hand, form the basis for research in the field of so-called remote sensing, a subbranch of geoinformation science. The remote sensing approach

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utilizes satellite imagery to derive measurable spatial (i.e., physical) data for analysis within a wide variety of research interests. In the context of armed conflict, recent studies utilize land-use change analysis, e.g., to understand the impact of warfare by measuring changes in crop area or forest cover during various stages of civil war (Baumann, Radeloff, Avedian, & Kuemmerle, 2014; Butsic, Baumann, Shortland, Walker, & Kuemmerle, 2015; Gorsevski, Geores, & Kasischke, 2013; Lidow, 2010; Nackoney et al., 2014; Wilson & Wilson, 2013). Others examine the sizes and environmental impacts of displacement camps (Giada, De Groeve, Ehrlich, & Soille, 2003; Hagenlocher, Lang, & Tiede, 2012; Kemper & Heinzel, 2014; Kranz et al., 2010; Kranz, Sachs, & Lang, 2015; Lang, Tiede, Hölbling, Füreder, & Zeil, 2010) or mining activities in conflict zones (Kranz, Lang, & Schoepfer, 2017; Luethje, Kranz, & Schoepfer, 2014). Studies of the remote sensing discipline have also focused on the topic of urban growth or sprawl (Bhatta, Saraswati, & Bandyopadhyay, 2010) in a non-conflict context (Griffiths, Hostert, Gruebner, & van der Linden, 2010; Zhou, Hubacek, & Roberts, 2015) and, less often, in a (post-)conflict context (Lynch et al., 2013; Wilson, 2014).

Despite their different understandings of “space”, remote sensing data can provide valuable insights to researchers from the fields of conflict or urban studies as well: Satellite images (literally) supply a “view from above”, which is especially beneficial for areas of limited accessibility. Unlike the indirect information of field research, which is often based on recounted evidence, satellite imagery delivers direct (“hard”) data on the spatial aspects of development. Additionally, satellite imagery is available for long time periods and in consistent data formats, which guarantees reproducibility and inter-temporal comparability. In other words, in addition to the “view from above”, satellite imagery can provide a “view into the past” necessary to understand the spatial dimension of conflict-related phenomena and to prepare for future events (e.g., humanitarian missions, mitigation of humanitarian crises, urban planning).

However, for the target group of urban and conflict researchers, elaborated remote sensing methods are too complex to be a feasible addition to the common methods of field research. This paper presents a reduced and thus simple and accessible way to interpret visual satellite imagery, which can be combined with classical field research. We demonstrate how this mixed-methods approach can enhance findings with a spatial dimension, i.e., linking observed phenomena to underlying processes and supporting image interpretation through local knowledge.

We demonstrate our approach by using a case study of the city of Goma in the eastern region of the Democratic Republic of the Congo (DRC) for the period between 1986 and 2015.

2. Data and methodology

In this chapter, we introduce our study area (the city of Goma) and our data sources, while also explaining basic terminology and providing key terms from the satellite imagery. Finally, we briefly comment on the software and analysis technique we applied.

2.1. Study area: the city of Goma

Goma has received attention from various research communities, due to its peculiar features: As the capital of North Kivu province in the eastern region of the DRC, the city is located in an area under armed conflict since the early 1990s, and is marked by rapid and dynamic growth. Goma is situated in the western branch of the East African Rift system, bordering Rwanda to the east and Lake Kivu to the south and is situated only 14 km south of Mount Nyiragongo, one of the most active African volcanoes.

The illustration in Fig. 1 shows Goma's area in 1986, before the outbreak of conflict over land in Masisi, a western territory of North Kivu, and before the outbreak of civil war in Rwanda in 1990, contrasted with its area in 2015.

The recent history of Goma has been dominated by various armed conflicts since the early 1990s. The security situation in the eastern DRC has been and continues to be controlled by changing constellations of non-state armed groups, the Congolese army (FARDC), national police, and the UN peacekeeping force MONUSCO (Mission de l'Organisation des Nations Unies pour la Stabilisation en République Démocratique du Congo). In addition to armed conflict, the eruption of the Nyiragongo volcano in January 2002 has had a dramatic impact on Goma's spatial development. Lava flows destroyed nearly 40% of the city, and more than 14,800 families became homeless (Kanene, 2014). Linked to the volcanic activity, a high concentration of methane and carbon monoxide close to Lake Kivu's shore has rendered the city's position additionally hazardous. Despite these difficult conditions, Goma has experienced significant growth over the past few decades.

The impact of protracted conflict on Goma has been investigated from various disciplinary angles. In most cases, information collection has been based on extensive fieldwork. For instance, two studies by Büscher (2011) and Oldenburg (2012) analyze the effect of violent conflict on social, political, and economic processes in Goma. A previous study by Büscher and Vlassenroot (2010) investigates the socioeconomic impact of the humanitarian industry and reveals how the presence of high-salaried international employees accelerates urban gentrification processes. Verhoeve et al. (2004, pp. 103–122) describe Goma as a place of relative security, encouraging the arrival of internally displaced persons. Informal cross-border economies between Congo and Rwanda via Goma are scrutinized by Doevenspeck and Nene (2012), analyzing the effects of specific uncertainties on either side of the border. Further topics of investigation are, e.g., the epidemiological consequences of war and disaster for the city (Bompangue et al., 2009) and the ecological impact of the large number of (Rwandese) refugees to Goma and its outskirts after the Rwandese Genocide in 1994 (Biswas & Tortajada-Quiroz, 1996).

2.2. Data sources

Satellite imagery can stem from commercial, public (civilian), or military programs. Our imagery is sourced from the civilian Landsat program, initially designed to acquire data on earth resources and offering the longest continuous global record of the earth's surface since 1972 (Lillesand, Kiefer, & Chipman, 2014, p. 404; US Geological Survey, 2017). The program was founded by the US Department of Agriculture, the US Department of the Interior, and the National Aeronautics and Space Administration (NASA) (US Geological Survey, 2017). After a change in data policy in 2008, all Landsat data held by the United States Geological Survey (USGS) became freely available (Wulder, Masek, Cohen, Loveland, & Woodcock, 2012). The imagery used for this study was acquired by three different Landsat satellites: Landsat 5 (1986–1995), Landsat 7 (1999–2012), and Landsat 8 (2014–2015). From 1996 until 1998 and again for 2013, no cloud-free data were available; information for these periods is exclusively based on existing research, literature, and interviews. Table 1 provides an overview of the data used for this study.

2.3. Key terms and data formats of satellite imagery

Landsat sensors have a moderate spatial resolution, which varies between 15 m and 60 m per pixel, depending on the satellite-sensor generation and the spectral band. This allows for the