The Professional Geographer

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/rtpg20

Between Replacement and Intensification: Spatiotemporal Dynamics of Different Land Use Types of Urban and Peri-Urban Agriculture under Rapid Urban Growth in Nakuru, Kenya

Maximilian Willkomm, Alexander Follmann & Peter Dannenberg

To cite this article: Maximilian Willkomm, Alexander Follmann & Peter Dannenberg (2021) Between Replacement and Intensification: Spatiotemporal Dynamics of Different Land Use Types of Urban and Peri-Urban Agriculture under Rapid Urban Growth in Nakuru, Kenya, The Professional Geographer, 73:2, 186-199, DOI: 10.1080/00330124.2020.1835500

To link to this article: https://doi.org/10.1080/00330124.2020.1835500

Published online: 15 Dec 2020.

Between Replacement and Intensification: Spatiotemporal Dynamics of Different Land Use Types of Urban and Peri-Urban Agriculture under Rapid Urban Growth in Nakuru, Kenya

Maximilian Willkomm, Alexander Follmann, and Peter Dannenberg
University of Cologne

Urban and peri-urban agriculture (UPA) contributes to urban food security and provides important livelihood opportunities. Due to rapid urbanization, though, UPA is subject to increasing land use pressure. Existing studies indicate gradual replacement of UPA in favor of other land uses. This study controverts this unidirectional narrative to show that UPA simultaneously persists and intensifies. Using remote sensing and qualitative data in the case of the rapidly growing, medium-sized Kenyan city Nakuru, we analyze spatiotemporal dynamics of four agricultural land use types (large-scale open-field production, smallholder production, intensive small-scale open-field production, and large-scale greenhouse production) to better understand different sociospatial trajectories. The findings show the coexistence of complex patterns of replacement, fragmentation, and intensification. We thus examine the extent to which detected dynamics can be explained by the socioeconomic characteristics of the four UPA land use types. Whereas large-scale production is increasingly fragmented and replaced by both small-scale agricultural production as well as residentially or industrially built-up areas, more intensive land use types focusing on high-value cash crops proliferate and intensify production in the research area. The study clarifies the dynamics of ongoing UPA transformations and is relevant for urban planning policies in rapidly changing urban and peri-urban environments. **Key Words: agricultural types, East Africa, land use dynamics, RapidEye, urban and peri-urban agriculture.**

For a large number of East Africans, urban and peri-urban agriculture (UPA) is of high relevance as it fulfills crucial multisided functions particularly for food security, income, and employment (Zezza and Tasciotti 2010; Orsini et al. 2013). In Kenya, for example, more than 3.5 million people are directly engaged in UPA (Traoré 2012). As urban and peri-urban areas are highly dynamic and shaped by competition over space, however, UPA is subject to high land use pressure (Cohen 2006). Rapid urban growth strengthens this pressure, as it is driven by strong natural population increases and rural-to-urban migration.

Against this background of increasingly competitive peri-urban land markets, existing literature (Satterthwaite, McGranahan, and Tacoli 2010; Cobbinah, Gaisie, and Owusu-Amponsah 2015) suggests that UPA is being replaced by nonfarming land uses that capture higher land rents. In contrast with these results, Pribadi and Pauleit (2015) indicated that UPA can also persist in and around fast-growing urban areas (see also Drechsel and Dongus 2010). Increasing and changing consumer demand offers vital commercialization opportunities for farm managers (Moustier and Renting 2015). In particular, the demand for high-value, perishable goods produced near urban areas is rising (Gockowski et al. 2003). Therefore, the dynamics of UPA and different types of land use, and in particular the question of whether agriculture is replaced or not, at least partly depend on the specificity of local agricultural practices and markets.

The extent to which and how different agricultural land use types transform in and around cities is only poorly understood, however (Thebo, Drechsel, and Lambin 2014). Lerner and Eakin (2011) emphasized that the location and the way UPA changes are key to understanding the social and economic implications of urbanization patterns. Knowledge of such processes not only advances scientific understanding of structural transformations in peri-urban areas, but it also informs policymakers seeking to both support and regulate different types of UPA. In this context, there have been strikingly few empirical studies of various temporal dynamics of UPA (Zezza and Tasciotti 2010; Pribadi and Pauleit 2015). This is particularly the case for small and medium-sized cities, which are currently the fastest growing cities in Africa (Cohen 2006).

In this study, we address these issues through an analysis of spatiotemporal dynamics and development pathways for different types of agricultural land use in urban and peri-urban areas. Our cases center on the fast-growing, medium-sized town of Nakuru, Kenya, and address the following research questions:

1. What major types of agricultural land use exist in urban and peri-urban areas of Nakuru?

The Professional Geographer, 73(2) 2021, pages 186–199
Initial submission, November 2019; revised submissions, May and July 2020; final acceptance, August 2020.

2. How have these agricultural types changed between 2010 and 2019 under rapid urban growth?
3. What are the proximate and underlying drivers of spatiotemporal changes affecting each type of agricultural land use?

To answer these questions, we first outline the current state of literature on the dynamics of UPA under rapid urban growth. Second, we introduce the case study of Nakuru, including the research methodologies we deployed. Based on multitemporal RapidEye satellite imagery and field mapping, we identify four main types of agricultural land use. Based on images from the years 2010 and 2019, we analyze how and where each respective type changed. By using a multitemporal, quantitative approach, our methodology advances beyond existing research that has largely focused on static characteristics in specific temporal moments, or else the general dynamics of UPA (e.g., Satterthwaite, McGranahan, and Tacoli 2010; Schlesinger 2013). Based on qualitative interviews with farmers and local experts, we conclude by discussing the extent to which these dynamics can be explained by different socioeconomic drivers.

UPA under Rapid Urbanization: Pressures and Opportunities

As cities grow into their surroundings, predominantly agricultural areas are transformed in multiple ways (Simon, McGregor, and Nsiah-Gyabaah 2004). To varying degrees, these transformations result in both new pressures and new opportunities for farming.

The proliferation of built-up areas results in pressure on agricultural land uses (Asiama 2006). According to Aragrande and Argenti (2001), UPA competes with increasing demand for residential, industrial, and infrastructural land. As UPA often generates relatively low profits compared to other urban uses (Kuusaana and Eledi 2015), land owners abandon farming by selling their land or by shifting it to other uses (Cobbinah, Gaisie, and Owusu-Amponsah 2015). In addition, new cultural preferences induced by urban growth, especially concerning younger generations, accelerate the abandonment of farming (Lerner and Eakin 2011). These processes can lead to the replacement and fragmentation of agriculture (Abo-El-Wafa, Yeshitela, and Pauleit 2017).

On the other hand, strong cultural preferences for engagement in agriculture, as well as relatively easy access to UPA as a comparatively informal activity, encourage many urban and peri-urban dwellers to continue farming or else to undertake new farming activities (Lerner and Eakin 2011). Moreover, urban growth presents new opportunities, as growing populations lead to larger demand for food (Tacoli and Agergaard 2017). As long-distance transport logistics in Kenya are still limited, fresh and perishable agricultural products (e.g., vegetables, meat, dairy products) often need to be produced near sites of consumption (Gockowski et al. 2003). Changing urban lifestyles, furthermore, have also led to increasing demand for fresh products (Schmidt, Magigi, and Godfrey 2015; Tacoli and Agergaard 2017). These dynamics create new market opportunities. Recent studies suggest the emergence of professional UPA enterprises applying intensive forms of cultivation, including greenhouses and irrigation systems (Moustier and Renting 2015). In addition to traditional distribution channels (e.g., to neighbors, local shops, and wet markets), UPA farmers have increasing access to new marketing channels. These include supermarket procurement systems (Andersson et al. 2015), and global export markets to which smallholders in Kenya, for example, also have access (Dannenberg and Nduru 2013). Therefore, UPA not only persists, but farmers also develop vital commercialization strategies for their businesses (Krishnan 2018).

The dynamics just described indicate that future trajectories of urban or peri-urban farms depend at least partly on different UPA land use types. Different approaches in the existing literature classify UPA into different types. Robineau and Dugué (2018) distinguished between typologies based on spatial characteristics and those based on socioeconomic characteristics. Spatial characteristics of UPA distinguish location and type of spaces within urban and peri-urban areas (Mougeot 2000; Asomani-Boateng 2002). Socioeconomic characteristics consider dimensions including the farming system (Bellwood-Howard et al. 2015), the actors involved (Moustier and Danso 2006), UPA's integration in household strategies, and degrees of commercialization (Maxwell 1994; Moustier and Danso 2006). Whereas most studies of UPA focus on capital-poor smallholders (e.g., Foeken and Owuor 2008), other more capital-intensive types of UPA (both large- and small-scale) are gaining in importance (Orsini et al. 2013; Robineau and Dugué 2018). The latter are often managed by professional firms that achieve high profits and create jobs for urban dwellers, while intensifying other resource uses (Moustier and Danso 2006).

Existing typologies, however, often lack empirical evidence to adequately characterize spatiotemporal dynamics of multiple UPA types, as most studies typically focus on one specific type of UPA. Nevertheless, following Robineau and Dugué (2018), we argue that a typological analysis that differentiates forms of UPA along different axes (e.g., proximity to the city center, holding sizes, degrees of intensification, spatiotemporal trajectories of farmers) can contribute to a more nuanced understanding of conditions under which UPA is either

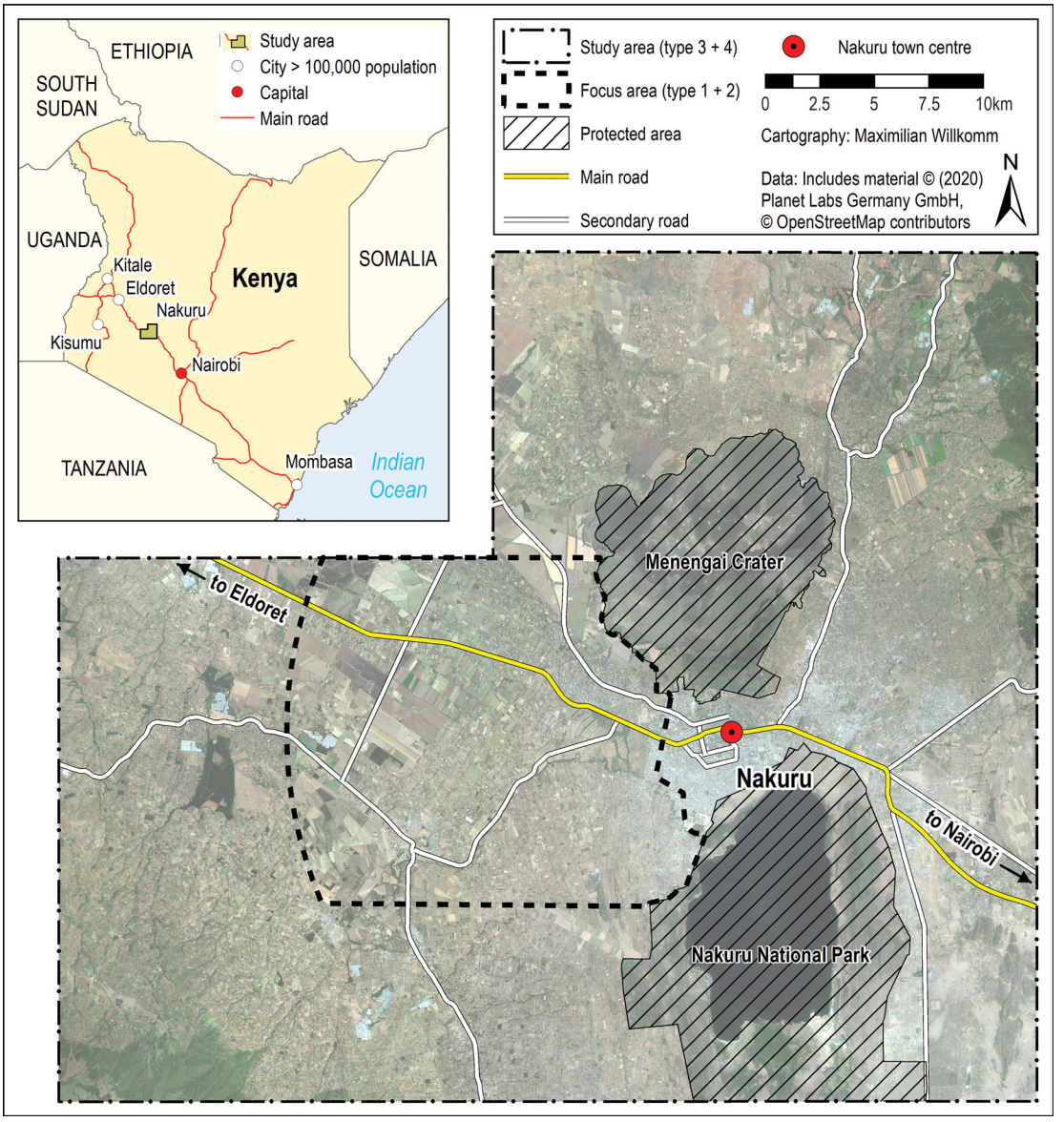


Figure 1 *Nakuru and its peri-urban areas, including the study area: Intensive small-scale open-field production (Type 3) and large-scale greenhouse production (Type 4); and the focus area: Large-scale open field production (Type 1) and smallholder production (Type 2).*

replaced or else persists. Differentiated quantitative studies of UPA that analyze spatiotemporal dynamics in terms of replacement and persistence are so far lacking. In this context, remote sensing analysis has a great potential to generate data from which it is possible (1) to develop UPA typologies based on spatial characteristics, and (2) to verify their spatiotemporal dynamics. Furthermore, triangulating remote sensing data with qualitative and quantitative field work data enables us to link spatial and socioeconomic typologies. Thus, in this study we connect existing typological approaches and multitemporal analyses to study spatiotemporal dynamics of UPA across a range of small- and large-scale farming.

Data and Methods

Study Area

Kenya is experiencing rapid urban growth. In 2019, about one third (31.2 percent; 14.8 million) of Kenya's population lived in cities (Kenya National Bureau of Statistics 2019), which are expected to

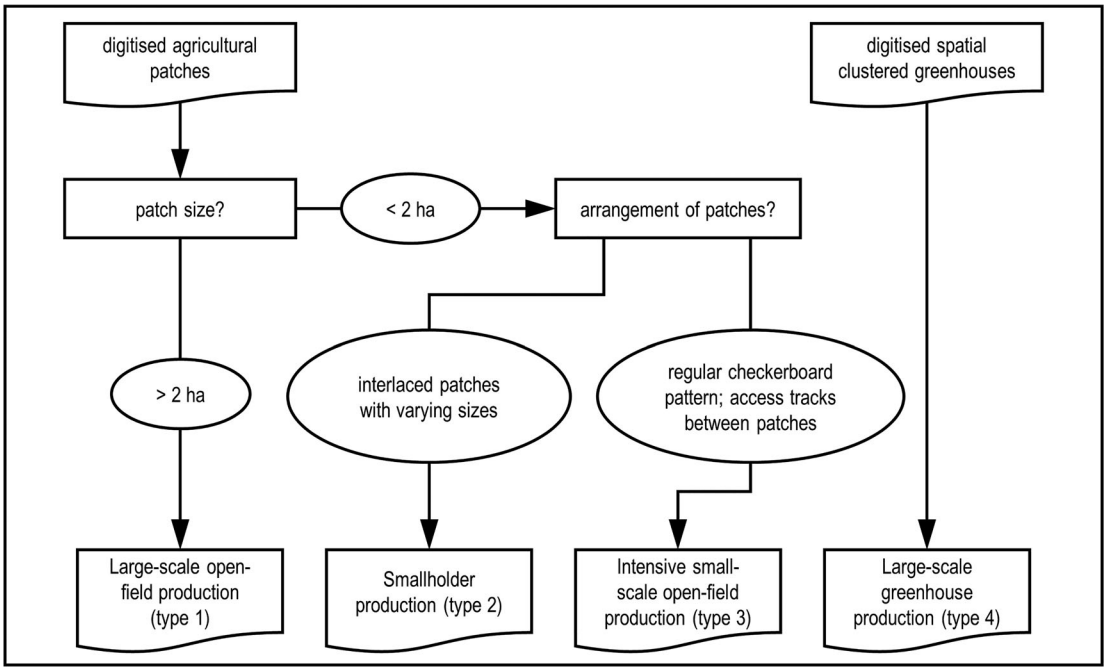


Figure 2 *Decision tree for the demarcation of the four agricultural land use types that shape the urban and peri-urban areas of Nakuru.*

house an additional 38 million urban residents by 2050 (UN-Habitat 2014). In this context, we focus on Nakuru, a medium-sized city located in central Kenya (Figure 1).[1] In 2019, about 370,000 inhabitants lived in this urban agglomeration (Macrotrends 2019). The city center is situated between two protected areas, the Nakuru National Park to the south and the Menengai Crater to the north (see Figure 1). Historically, Nakuru was part of the former White (European colonial) Highlands that were marked by highly politicized land redistributions after independence, and led to a legacy of violent conflicts over land tenure in the region (Kanyinga 2009, Boone 2012).

We selected this city for two characteristics that are exemplary of many East African cities, but are particularly apparent in Nakuru. First, Nakuru is a prominent example of rapid urbanization in eastern Africa. Willkomm, Follmann, and Dannenberg (2019) detected an increase in sealed surfaces (mainly built-up) of 80 percent between 2010 and 2017, making Nakuru one of the fastest growing cities in sub-Saharan Africa (Orsini et al. 2013). Second, Nakuru is marked by the high importance of UPA, which is not only oriented toward subsistence production, but also production for expanding urban markets (Foeken and Owuor 2008). UPA is supported by favorable environmental conditions that allow for multiple harvests per year. Beyond these two main factors, Nakuru also features good infrastructural connections to Kenya's primary city and international transport hub, Nairobi, which connects the region to international markets. Both land use pressure and favorable conditions for agriculture make Nakuru a suitable case study for an analysis of UPA dynamics under rapid urban growth.

Method

This study is based on a mixed-method approach combining the analysis of land use data from satellite imagery and field mapping, as well as qualitative interviews with local stakeholders and experts.

As shown by Brown and McCarty (2017), satellite images afford opportunities to capture quantitative land use data on UPA, both across large spatial areas and across different time periods. In this study, we used RapidEye data with an orthorectified pixel size of 5 m (for details see Planet 2020) to generate land use information on UPA in Nakuru. In doing so, we relied on cloud-free images from the dry season (28 January 2010 and 27 January 2019). From these data, we identified four agricultural land use types (Figure 2): large-scale open-field production (Type 1), smallholder production (Type 2), intensive small-scale open-field production (Type 3), and large-scale greenhouse production (Type 4). We allocated all spatially clustered greenhouses, which are easy to detect, to Type 4. All other agricultural patches were divided into two categories according to their sizes. All patches larger than 2 ha were assigned to Type 1.[2] Those patches smaller than 2 ha were assigned to Type 2 or Type 3 based on the spatial arrangement of neighboring patches.

Interlaced patches with varying sizes belong to Type 2, and patterns of checkerboard patches with access tracks in between for large machinery are part of Type 3 (see Figure 2).

In addition, we conducted systematic field mapping for a representative number of each type of UPA in March 2016 and February 2019 to get a better understanding of farming strategies. In combination with the remotely sensed data, we identified the following characteristics to describe the four types in more detail: type of agricultural products, irrigation, cultivation method, and distance to Nakuru town center.[3] Furthermore, we used field mapping data to validate our typology.[4]

Based on our typology, we analyzed spatiotemporal changes by comparing the distribution of identified agricultural land use types between 2010 and 2019. For Type 3 and 4, we used the whole study area (defined by the availability of RapidEye data) shown in Figure 1. Farm managers of these types confirmed that even farms located at further distances from the town center remain strongly connected to urban Nakuru (e.g., through the interchange of resources and labor). For Type 1 and 2, visual mapping was labor-intensive and expensive (see Cihlar and Jansen 2001) due to the higher number of Type 1 and Type 2 farms and their more complex spatial structures. Therefore, we chose a focus area (Figure 1), formed by a 20 km buffer west of Nakuru's city center (see Brinkmann et al. 2012 for a similar range) as this area represents a wide range of different agricultural distribution patterns and includes different degrees of built-up density. The focus area was also used to conduct an analysis of patch sizes and their temporal changes, especially to illustrate land fragmentation dynamics.

To develop clearer understanding of causal relations, we connected outcomes of our spatiotemporal analysis of the UPA types with the findings from our qualitative interviews. We conducted a total of thirty-nine semistructured interviews in March 2016 and February 2019. These included twenty-eight interviews with farm managers drawn from all farm types situated at different distances to the town center. In addition, we conducted semistructured interviews with eleven experts from local public authorities, including the Ministry of Agriculture, the Ministry of Lands and Physical Planning, and Egerton University. To validate our land use analyses, these experts were first asked about ongoing transformations to UPA, including reasons for those changes. To discuss the types and transformational processes that we had previously identified, we presented and discussed preliminary results (e.g., figures and maps) of our remote sensing analysis with these experts. These experts' wealth of on-the-ground experience enabled us to increase our understanding of proximate and underlying drivers of spatiotemporal changes. In the interviews with farm managers, we sought further perspectives on causal relations through questions about operational farm characteristics, recent challenges and opportunities, and their future expectations.

Results and Discussion

In this section, we first provide a description of the agricultural land use types and then outline their spatiotemporal dynamics. Based on these results, we then discuss drivers of UPA dynamics in Nakuru.

UPA Land Use Types in Nakuru

We distinguish four main types of agricultural land use in urban and peri-urban Nakuru (see Figure 3). Type 1, *large-scale open-field production*, is marked by crop cultivation and pastoral farming on relatively large fields from 2 ha up to 300 ha. The analysis of satellite imagery for 2019 revealed that Type 1 covered 39.2 percent of the focus area. Crop cultivation usually includes the production of staple crops like maize, wheat, and barley using capital-intensive machinery. Livestock breeding (mainly cattle) also takes place on large fields in the form of open-field grazing. Type 1 farms are managed professionally, usually either by private domestic investors or by local institutions.[5] They typically produce on a contractual basis for national industries (e.g., industrial mills or dairy processing companies) that are often located in Nakuru.

In contrast to the larger fields, Type 2, *smallholder production*, is typically located closer to built-up areas, and sometimes even in densely populated urban wards. Smallholder production is marked by open land cultivation and usually consists of an aggregation of partly interlaced patches ranging in sizes from 0.05 ha to 2 ha, which in 2019 overall comprised 25.8 percent of the focus area. The main products are staple crops, in particular maize and perishable vegetables (e.g., kale, cabbage, spinach, etc.). Some smallholders also use small greenhouses or keep zero-grazing livestock. Depending on the season, intercropping and dynamic crop rotation are common. Different experts from the Ministry of Agriculture in Nakuru emphasized that a large share of smallholder production is managed by urban families or urban individuals from different socioeconomic strata. Poorer households are typically engaged in on-site farming as a livelihood strategy (see also Foeken and Owuor 2008). Those families with greater capital expand production to perishable goods for local and regional markets by coordinating multisited off-plot farms.

Type 3, *intensive small-scale open-field production*, represents a capital-intensive approach to high-value horticultural crop production, especially vegetables and herbs. Clusters of smaller fields (< 2 ha) form

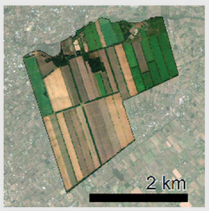
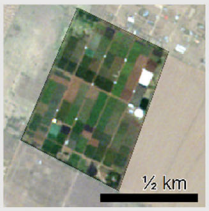
	Large-scale open-field production (type 1)	Smallholder production (type 2)	Intensive small-scale open-field production (type 3)	Large-scale greenhouse production (type 4)
RapidEye excerpt (2019)				
patch size	large (2 – 300 ha)	small (most <1 ha, some up to 2 ha)	small (<2 ha; in aggregation up to 40 ha)	0.5 – 2 ha (in aggregation up to 50 ha)
distance to Nakuru town centre	mainly 10 – 20 km away from town centre	close to built-up areas and roads	mainly 15 – 25 km away from town centre	mainly 15 – 25 km away from town centre
arrangement of cultivated areas	contiguous large fields	small partly interlaced patches, intercropping, crop rotation	regular checkerboard patterns, vehicle access paths between patches	greenhouses: clustered, permanent, large
agricultural products	staple crops (e.g., maize, wheat, barley, hay), pastoral farming	staple crops (in particular maize), horticulture (vegetables, fruits), sometimes combined with zero-grazing livestock	horticulture (especially vegetables), herbs	horticulture (especially vegetables), herbs, cut flowers
cultivation methods	open-field cultivation (intensive and extensive)	open-field cultivation (intensive and extensive); sometimes small greenhouses (intensive)	plastic tunnels, mulch films, sometimes small greenhouses (all intensive)	greenhouse production (intensive)
irrigation	partially	rarely	always	always
profile of farm owner	private domestic investor or local institution (e.g., universities, church-related)	ranges from urban poor households to multi-local urban professionals	ranges from urban-based professional to domestic investor	domestic and international investor
typical trajectory	fragmentation and shift to type 2	former type 1 farms in the outer peri-urban; repl. through build-up; farmers with higher capital persist by intensifying production	some are former type 2 farms, others newly arise	mainly former type 3 farms
area in 2010 (% of study area)[6]	15743.28 ha (60.2 %)	5957.57 ha (22.8 %)	199.46 ha (0.22 %)	134.93 ha (0.15 %)
area in 2019 (% of study area)[6]	10253.36 ha (39.2 %)	6751.35 ha (25.8 %)	264.62 ha (0.29 %)	402.08 ha (0.45 %)

Figure 3 *Classified agricultural land use types in Nakuru (based on RapidEye satellite imagery and field mapping).*

joined checkerboard patterns to efficiently use advanced machinery (e.g., fertilizer spreaders). From the satellite imagery, irrigation can clearly be detected as crops form dense, deep green plots, and large irrigation basins are installed next to the fields. In some cases, plastic tunnels, mulch films, or greenhouses can also be detected. Type 3 farm owners range from urban-based professionals to international investors. We identified twelve clustered Type 3 farms covering a total area of 264.62 ha in 2019. Although this area comprised less than 0.29 percent of the study area, these farms are highly productive per unit of land and generate high shares of value-added produce in the agricultural sector, as reported by several extension officers.

The same also applies to Type 4, *large-scale greenhouse production*, where eighteen clusters covered an area of 402.08 ha (0.45 percent) in 2019. Similar to Type 3, Type 4 is a very intensive form of production. Both types primarily differ in the form of cultivation, as Type 4 exclusively consists of permanent, spatially clustered large-scale greenhouses, some of which are up to 50 ha in size. Type 4 farms are mainly located in peri-urban areas. One

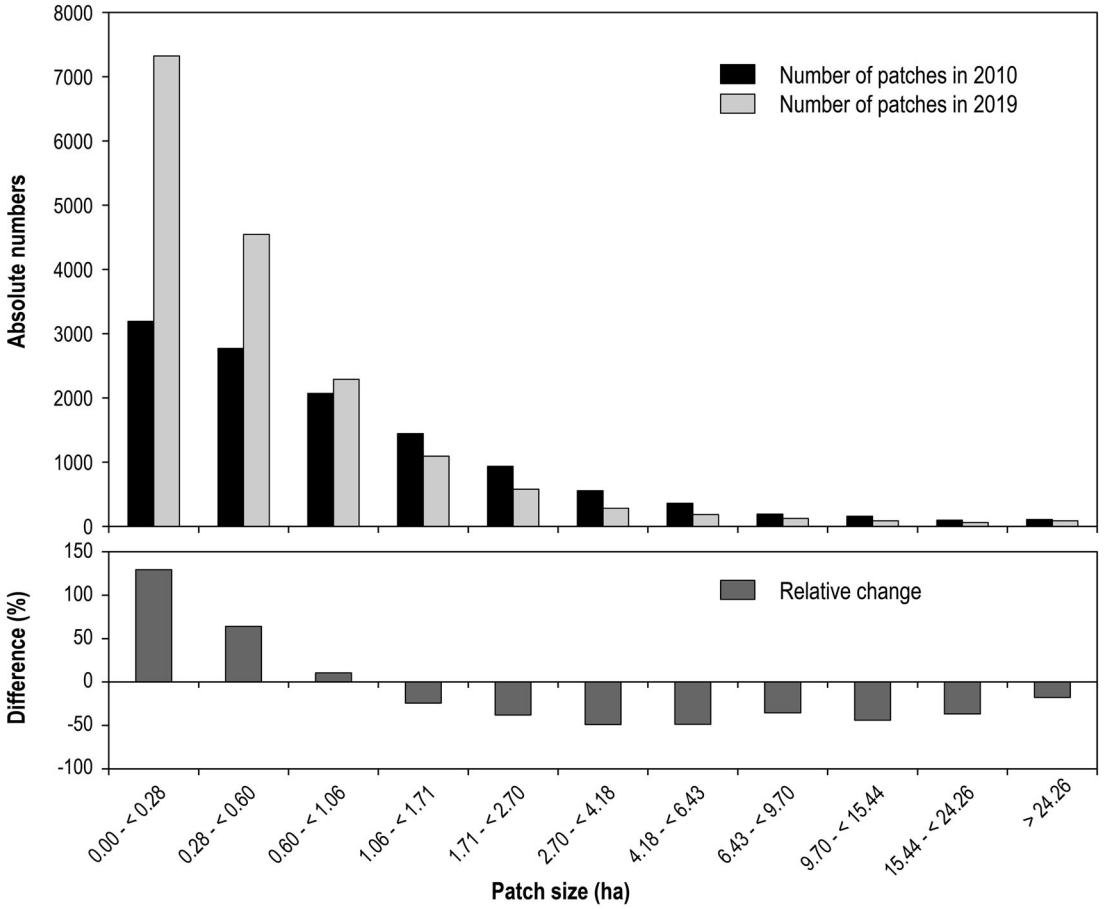


Figure 4 *Agricultural patch size distribution in absolute numbers (top) and relative changes (bottom) between 2010 and 2019, as analyzed in the focus area.*

greenhouse complex is located in a densely populated urban ward close to the urban center on a former industrial zone. Cut flowers are the main products. Newer greenhouse projects, additionally, cultivate high-value horticulture products like perishable vegetables and herbs. Type 4 farms are owned by strongly capitalized, professional, often multinational companies that mainly produce for export, supermarkets, and regional markets.

Agricultural Land Use Dynamics in Nakuru's Urban and Peri-Urban Areas

In this section, we first outline the spatiotemporal dynamics of patch size distributions and changes between 2010 and 2019. We then summarize changes across the four identified UPA land use types.[6]

Based on the focus area, in Figure 4 the size distribution of agricultural patches for 2010 and 2019 and relative changes as a function of their patch size are illustrated.[7] Whereas the number of smaller patches strongly increased, the number of patches larger than 1.06 ha decreased. The smallest patches show especially high rates of expansion, as the number of agricultural patches smaller than 0.6 ha almost doubled. Patches ranging in size between 2.70 ha and 4.18 ha presented the highest rates of decrease (–49.0 percent). The mean patch size decreased from 1.83 ha in 2010 to 1.02 ha in 2019. Thus, urban and peri-urban areas around Nakuru are subject to increasing land fragmentation that, according to our analysis, especially occurs in areas with higher densities of residential and industrial build-up (see also Figure 5B[8]). Although urban and peri-urban land fragmentation has been addressed (e.g., Padgham, Jabbour, and Dietrich 2015), patch size dynamics in East Africa have not been analyzed in any detail. Thus, patch size differentiation shown in Figure 4 already shows that UPA transformations differ based on their spatial characteristics. The following sections take a closer look at these differences among UPA types.

Spatiotemporal changes for all four agricultural land use types are presented in Figure 5. Increasing fragmentation of agricultural land (illustrated

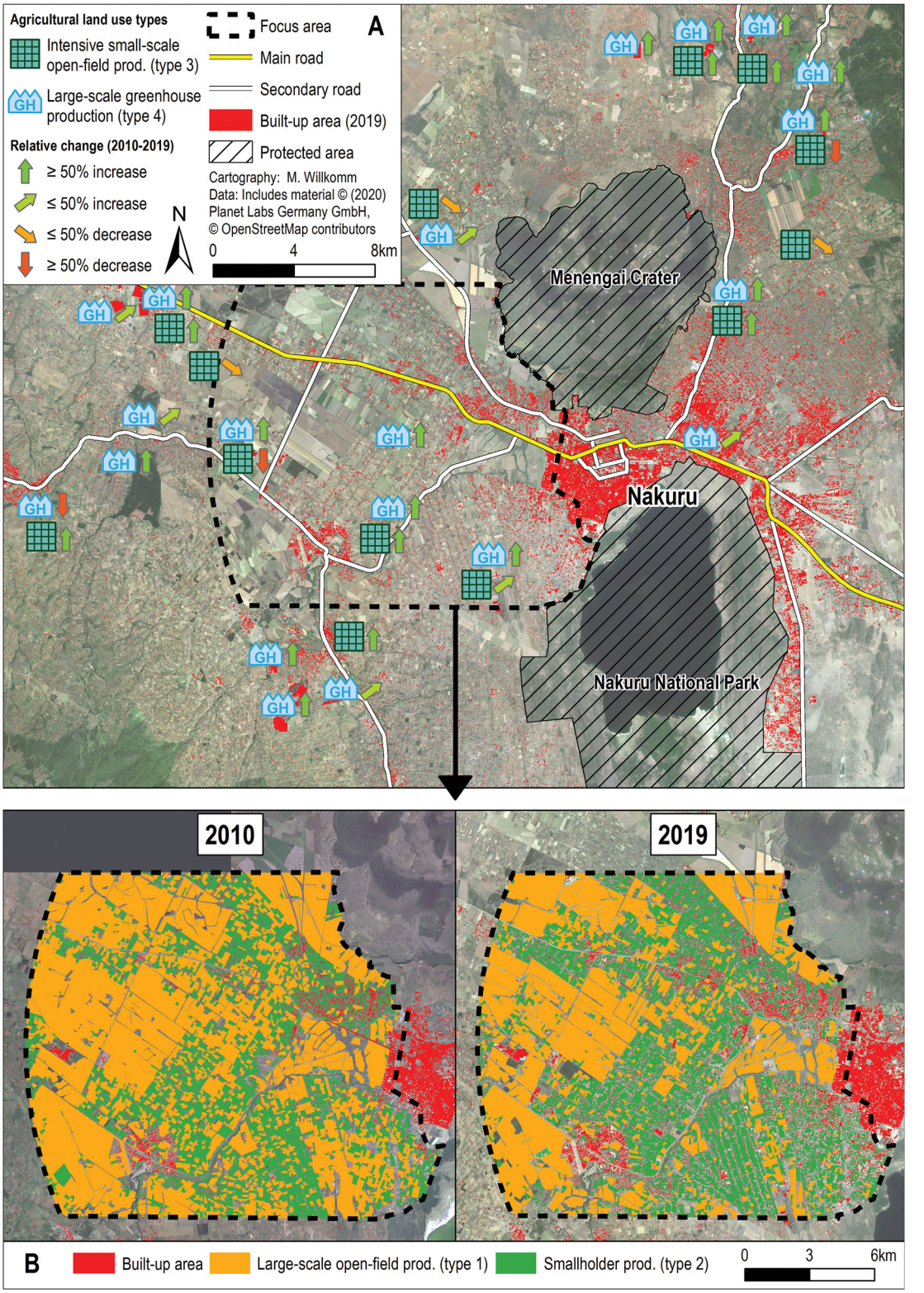


Figure 5 *Spatiotemporal dynamics of the four agricultural land use types between 2010 and 2019: (A) Changes in Types 3 and 4 in the study area; (B) Changes in Types 1 and 2 in the focus area.*

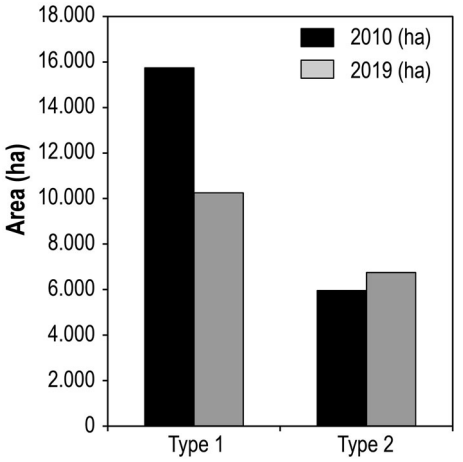


Figure 6 *Absolute changes in area of the identified agricultural land use Types 1 and 2 (derived from the focus area).*

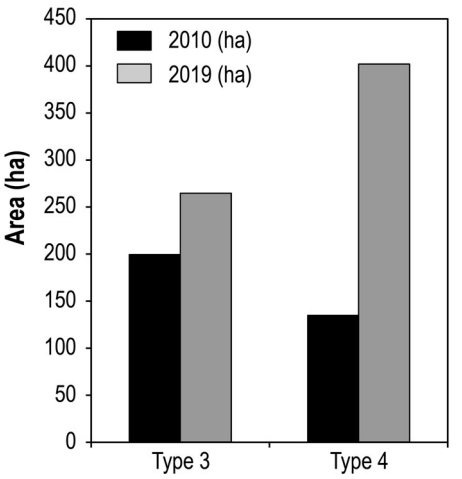


Figure 7 *Absolute changes in area of the identified agricultural land use Types 3 and 4 (derived from the study area).*

earlier) indicates a shift from large-scale open field production to smallholder production. Indeed, as shown in Figure 6, the total area of Type 1 production decreased by approximately one third between 2010 and 2019. In total, 6296.34 ha of land shifted from large-scale open-field production to another type of land use by 2019, whereas only 806.91 ha were newly classified as Type 1. In contrast to this total reduction, the total area of land devoted to smallholder production increased from 5,958 ha in 2010 to 6,751 ha in 2019. The formation of new Type 2 agricultural areas is consistent with increasing land fragmentation described earlier, as 87.9 percent (3261.71 ha) of new smallholder production areas were classified as large-scale open-field production in 2010. At the same time, 49 percent of 2010 smallholder production areas disappeared by 2019 and were replaced with other land uses. As also reported by Willkomm, Follmann, and Dannenberg (2019), former smallholder areas in particular were replaced by new residential and industrial build-up (see also Figure 5B).

As illustrated in Figure 5A and Figure 7, Type 3 and Type 4 expanded in area. The total area of intensive small-scale open-field production increased by about one third (2010, 199.5 ha; 2019, 264.6 ha), and the area of large-scale greenhouse production almost tripled (2010, 134.9 ha; 2019, 402.1 ha). The growing importance of these particular types indicates increasing intensification of UPA in Nakuru, which is a dynamic that has not been reported in the literature. In some cases, we observed that Type 3 appears as an intermediate stage in the process of intensification, as about 10 percent of these areas were transformed into large-scale greenhouse production (Type 4), whereas others were newly developed.

Land Use Dynamics as Processes of Replacement, Fragmentation, and Intensification

Our analysis shows that the four identified types of agricultural land use are affected in different degrees and ways by three main processes: replacement, fragmentation, and intensification. In Figure 8, these processes and their dominating connections to the agricultural land use types are highlighted. In this section, we describe in detail how far the processes affect the agricultural types, and discuss the drivers identified based on our qualitative interviews.

As expected, the replacement of agricultural areas particularly applies to the type of smallholder production located close to urban settlements (Figure 5B). As smallholder production implies relatively low added value compared to other land uses, such as residential and industrial use (Drechsel and Dongus 2010), it is mainly replaced by built-up land (cf. Cobbinah, Gaisie, and Owusu-Amponsah 2015). As shown by Willkomm, Follmann, and Dannenberg (2019), the increase in Nakuru's population has led to a massive expansion of built-up areas. Although detailed official statistics are not available, our interviews with farmers, planners, and local experts reported highly competitive land markets and increasing land use pressure. For example, an officer from the Ministry of Agriculture stated: "Urban growth is a threat for poor farmers. Some people sell their land and move to the rural areas for farming … . Others find other jobs in town" (Interview, Nakuru, March 2016). In the case of farmers with greater capital, by contrast, we observed that smallholder production closer to urban settlements is also practiced as an interim usage before further residential and industrial development takes place. This strategy helps to secure land and can also be found in other East African

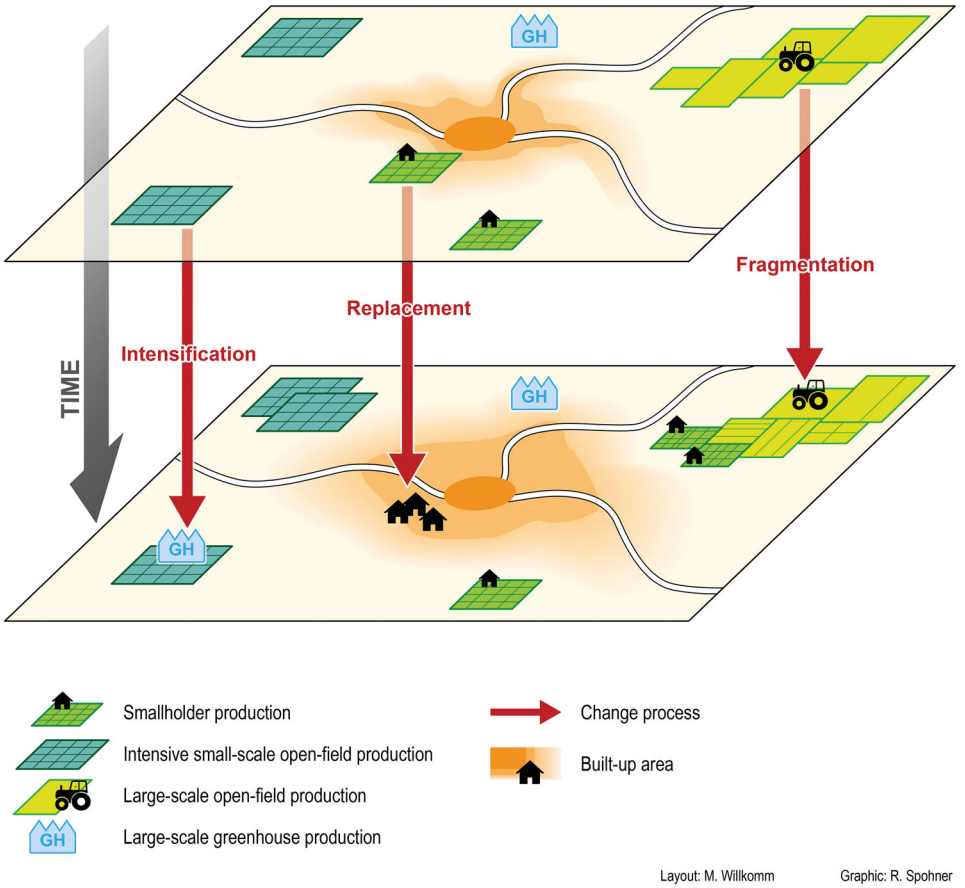


Figure 8 *Typical distributions of the four agricultural land use types and their dominating processes of replacement, fragmentation, and intensification.*

cities (e.g., Owens 2016). Our interviews, as well as recent literature (Holden and Otsuka 2014; Schlesinger, Munishi, and Drescher 2015; Kleemann et al. 2017), however, indicate that the allocation of land is often more complex, as it depends on land tenure regimes, sociocultural norms, and local policy regulations. In this context, the particular history of Nakuru also needs to be considered as part of the former White Highlands with its large farms owned by European settlers followed by subsequent, conflict-ridden processes of postcolonial land redistribution (Kanyinga 2009; Boone 2012). Those large farms around Nakuru reveal the spatial legacy of the colonial past. Smallholders explained that their lands had been part of large white settler farms before they were bought by them (or their ancestors), and then divided among cooperative and family members between the 1960s and 1980s. Today, the fragmentation of land ownership can be partly attributed to the division of inherited family estates as well as land speculation (Interview, Ministry of Lands, Housing and Physical Planning, Nakuru, February 2019), but these processes were not the focus of this study. Further studies might be useful at this point.

The second process detected is the fragmentation of agricultural land, which implies a reduction in agricultural patch sizes and, thus, a particular shift from large-scale open-field production to smallholder production. We identified two different causes for such fragmentation: (1) land subdivision in the course of urbanization, and (2) the subdivision of large-scale open fields (Type 1) into smaller patches (< 2 ha) for the cultivation of high-value cash crops.

Most important, land fragmentation is a consequence of ongoing urbanization and transformation into built-up areas (see Hidding and Teunissen 2002). Our analysis of satellite imagery revealed that land subdivision particularly occurs close to expanding settlements. In these sites, not only do smallholders leave or convert their land (see earlier), but owners of large-scale open-field production sites also subdivide parts of their land to sell as smaller parcels. A statement from the manager of a large-scale farm was typical: "Last year, … we sold 5

acres of land to a developer. This one is now selling single plots for residential [use]" (Interview, farm manager conducting large-scale open-field production, Njoro, February 2019). As a result, smallholder production is established on these smaller plots, either before residential or industrial development begins, or in the form of kitchen gardens. This kind of land fragmentation is typical of urbanization and has been identified globally (Keys, Wentz, and Redman 2007; Li et al. 2017).

Additionally, in the case of large-scale open field production (Type 1), the fragmentation of larger patches is also a result of a shift to high-value cash crops typically cultivated on smaller patches. Managers of larger farms in peri-urban areas recognize promising markets especially for fresh horticultural products, as indicated by one farm manager who used irrigation: "Particularly in the dry season, … you can make good money with cabbage" (Interview, farm manager conducting large-scale open-field production, Bahati, February 2019). The cultivation of these products is usually more capital, labor, and land intensive, as they are produced on patches smaller than those used for staple crops like wheat. Whereas Li et al. (2017) suggested that "fragmentation has long been considered to be a barrier for cultivation" (222), the fragmentation of large-scale farming land can also imply a form of agricultural intensification linked to shifting crop markets. In the case of smallholder production, however, the cultivation of high-value crops might be a strategy to avoid displacement and fragmentation. Yet, only those farmers with access to some capital are able to invest in, and profit from, high-value crops.

Unlike studies by Kuusaana and Eledi (2015) and Cobbinah, Gaisie, and Owusu-Amponsah (2015), which identified replacement and fragmentation of UPA as the predominant trends, our findings indicate persistence and intensification of UPA under certain conditions. In particular, our results show a strong expansion of intensive forms of UPA (Types 3 and 4), the transformation of large areas of Type 3 into Type 4 production (where the latter is the most intensive type), and several cases of intensifying smallholder production. Our field visits to Type 3 and Type 4 farms have shown that they are typically owned by larger companies, and mainly produced for highly commercialized value chains, including regional markets, supermarkets, and export. Farmers reported that they benefit from growing demand for horticultural products, as explained by a large-scale greenhouse farm manager: "Compared to the smaller farmers around, we are able to produce larger amounts in a reliable way all year round. And the demand is high. … Most of our produce is for export, but since a few years we also sell to supermarket companies" (Interview, farm manager conducting large-scale greenhouse production, Solai, February 2019). According to Satterthwaite, McGranahan, and Tacoli (2010), this is due to a growing urban population and changing consumption patterns, especially increased demand for high-quality food from a growing urban middle class. Our analysis of spatial dynamics for UPA Types 3 and 4 reveals that expansion particularly takes place in the outer fringes of peri-urban areas (15–25 km from the town center; Figure 5), where land use pressure is lower than in areas with higher building density. Nevertheless, these farmers emphasize that they benefit from the proximity to Nakuru by marketing their products and by obtaining inputs and labor from the city.

In addition to the intensification of the market-oriented UPA types, a number of smallholder farmers (especially those with greater capital) have also intensified their production, sometimes resulting in a shift from Type 2 to Type 3. As described by Lerner and Eakin (2011) and Pribadi and Pauleit (2015), this kind of intensification is connected to rising market potential, among other factors. In this context, future research could address questions of how smallholders build up capital to serve this market potential.

More detailed understanding of processes of replacement, fragmentation, and intensification can inform policymakers seeking to identify and promote specific types of UPA (e.g., in the form of support for intensified small-scale production), as well as to regulate UPA in certain locations. Our analysis shows that different types of UPA follow different development trajectories under certain circumstances. These findings can serve planners as they decide how to foster and better govern different forms of UPA in the future. This is particularly important as UPA continues to serve important food supply functions, despite being under increasing land use pressure.

Conclusion

This study characterizes spatiotemporal transformations of UPA in Nakuru, which might offer further insights for other East African cities. We detected four agricultural land use types shaping Nakuru's peri-urban areas. Although the dominant narrative suggests a general replacement of UPA, this study has shown that the dynamics of UPA are more complex. Replacement also occurs in Nakuru, but different kinds of agricultural fragmentation and intensification simultaneously coexist, as well. The intensification of UPA Types 3 and 4 has been identified in the proliferation of capital-intensive agrobusinesses, which are heavily investing in farming equipment (including greenhouses and irrigation techniques), gradual transitions away from staple crops in larger fields to labor-intensive vegetable production on smaller patches, and increasing agricultural investments among some smallholders.

Although the abandonment of smallholder patches closer to the urban center can be traced to increasing competition for land, the growing demand for perishable products in different markets has also fostered the intensification of other forms of UPA. For urban households, moreover, agriculture is still of high cultural importance and is easily accessible. Our analysis shows that a high-resolution focus on types of agricultural land use can offer a better lens through which to illustrate and understand ongoing UPA dynamics in East Africa. These dynamics are often based on complex interactions (e.g., farmer's market integration) that need to be addressed in future research. Nevertheless, our results contribute to detailed typological approaches by identifying important spatial and temporal dimensions of UPA, which have implications for planners concerned with land use dynamics in rapidly changing peri-urban environments. ■

Acknowledgments

The authors would like to thank Planet and DLR for providing RapidEye satellite imagery for this study. We are also grateful to the three anonymous reviewers for helpful discussions and constructive comments on earlier versions of this article. In addition, a special thanks goes to all local farmers and experts who participated in this research. Thank you also to George Owuor (Egerton University), Gilbert Nduru (Karatina University), Florence Opondo (Laikipidia University), the Global South Studies Center (University of Cologne), and the IPaK-programme (DAAD) for their valuable support during fieldwork.

Funding

Funded by the German Research Foundation (DFG) through the collaborative research center "Future Rural Africa", funding code TRR 228/1. This article includes material © (2020) Planet Labs Germany GmbH. All rights reserved. Data provided on behalf of the German Aerospace Center (DLR) through funding of the German Federal Ministry for Economic Affairs and Energy.

ORCID

Alexander Follmann http://orcid.org/0000-0002-4727-4346
Peter Dannenberg http://orcid.org/0000-0002-4159-6635

Notes

[1] The extent of the study area is based on RapidEye data availability.

[2] Based on our field mapping and previous work by Lowder, Skoet, and Raney (2016), we defined 2 ha as the threshold to demarcate large-scale open-field production from other types with smaller patches. Common threshold value problems occur in such procedures, which lead nonetheless to acceptable errors in the differentiation of Type 1 and Type 2. We offer a more differentiated view in our presentation of patch size distributions in the Results section (see Figure 4).

[3] Distance to Nakuru town center has been measured using geographic information systems (GIS). Irrigation could clearly be detected from satellite imagery in the form of dense, deep green agricultural patches and large irrigation basins installed next to the fields (we used field mapping data to validate this analysis; see also Brown and McCarty 2017). The type of agricultural products and the cultivation method were acquired through field mapping (for details see Figure 3).

[4] To validate the demarcation of the four UPA types, we used additional field mapping data. We mapped all Type 3 and Type 4 farms in the research area and achieved 100 percent accuracy, as these types can be clearly identified. For Type 1 and Type 2, we mapped around fifty Global Positioning System points each and compared them with the remotely sensed data. The overall accuracy was 91 percent for Type 1 and 86 percent for Type 2. Errors particularly occurred in the case of patches close to 2 ha in size (see note 2).

[5] In interviews with farm managers, we found that a number of Type 1 farms are managed by local institutions like universities, other educational institutions, and church-related organizations. In addition to their interest in practical training and social commitment, land ownership and commercial interests might also play a role here.

[6] Due to the fact that quantification has been applied to two different study areas (the focus area for Types 1 and 2, and the whole study area for Types 3 and 4; see Figure 1), direct comparisons between these two groups of types are not possible. This approach, however, allows for internal spatiotemporal comparisons.

[7] The patch size groups in Figure 4 have been classified using the Jenks optimization method (natural breaks), which is a data clustering method based on the distribution of absolute frequencies.

[8] The built-up areas shown in Figure 5 are based on a maximum-likelihood classification of the RapidEye imagery from 2010 and 2019.

Literature Cited

Abo-El-Wafa, H., K. Yeshitela, and S. Pauleit. 2017. Exploring the future of rural–urban connections in sub-Saharan Africa: Modelling urban expansion and its impact on food production in the Addis Ababa region. *Geografisk Tidsskrift-Danish Journal of Geography* 117 (2): 68–81. doi: 10.1080/00167223.2017.1350926.

Andersson, C. I. M., C. G. K. Chege, E. J. O. Rao, and M. Qaim. 2015. Following up on smallholder farmers and

supermarkets in Kenya. *American Journal of Agricultural Economics* 97 (4):1247–66. doi: 10.1093/ajae/aav006.

Aragrande, M., and O. Argenti. 2001. Studying food supply and distribution systems to cities in developing countries and countries in transition: Methodological and operational guide. Report DT/36-01E, Food and Agriculture Organization of the United Nations, Rome, Italy.

Asiama, S. 2006. Land accessibility and urban agriculture in Freetown. *Journal of Science and Technology (Ghana)* 25 (2):103–09. doi: 10.4314/just.v25i2.32945.

Asomani-Boateng, R. 2002. Urban cultivation in Accra: An examination of the nature, practices, problems, potentials and urban planning implications. *Habitat International* 26 (4):591–607. doi: 10.1016/S0197-3975(02)00027-9.

Bellwood-Howard, I., V. Häring, H. Karg, R. Roessler, J. Schlesinger, and M. Shakya. 2015. Characteristics of urban and peri-urban agriculture in West Africa: Results of an exploratory survey conducted in Tamale (Ghana) and Ouagadougou (Burkina Faso). Report IWMI-163, International Water Management Institute (IWMI), Colombo, Sri Lanka.

Boone, C. 2012. Land conflict and distributive politics in Kenya. *African Studies Review* 55 (1):75–103. doi: 10.1353/arw.2012.0010.

Brinkmann, K., J. Schumacher, A. Dittrich, I. Kadaore, and A. Buerkert. 2012. Analysis of landscape transformation processes in and around four West African cities over the last 50 years. *Landscape and Urban Planning* 105 (1–2):94–105. doi: 10.1016/j.landurbplan.2011.12.003.

Brown, M. E., and J. L. McCarty. 2017. Is remote sensing useful for finding and monitoring urban farms? *Applied Geography* 80 (1):23–33. doi: 10.1016/j.apgeog.2017.01.008.

Cihlar, J., and L. J. M. Jansen. 2001. From land cover to land use: A methodology for efficient land use mapping over large areas. *The Professional Geographer* 53 (2):275–89. doi: 10.1111/0033-0124.00285.

Cobbinah, P. B., E. Gaisie, and L. Owusu-Amponsah. 2015. Peri-urban morphology and indigenous livelihoods in Ghana. *Habitat International* 50 (1):120–29. doi: 10.1016/j.habitatint.2015.08.002.

Cohen, B. 2006. Urbanization in developing countries: Current trends, future projections, and key challenges for sustainability. *Technology in Society* 28 (1–2):63–80. doi: 10.1016/j.techsoc.2005.10.005.

Dannenberg, P., and G. M. Nduru. 2013. Practices in international value chains: The case of the Kenyan fruit and vegetable chain beyond the exclusion debate. *Tijdschrift Voor Economische en Sociale Geografie* 104 (1):41–56. doi: 10.1111/j.1467-9663.2012.00719.x.

Drechsel, P., and S. Dongus. 2010. Dynamics and sustainability of urban agriculture: Examples from sub-Saharan Africa. *Sustainability Science* 5 (1):69–78. doi: 10.1007/s11625-009-0097-x.

Foeken, D. W. J., and S. O. Owuor. 2008. Farming as a livelihood source for the urban poor of Nakuru, Kenya. *Geoforum* 39 (6):1978–90. doi: 10.1016/j.geoforum.2008.07.011.

Gockowski, J., J. Mbazo'o, G. Mbah, and T. Fouda Moulende. 2003. African traditional leafy vegetables and the urban and peri-urban poor. *Food Policy* 28 (3):221–35. doi: 10.1016/S0306-9192(03)00029-0.

Hidding, M. C., and A. T. J. Teunissen. 2002. Beyond fragmentation: New concepts for urban–rural development. *Landscape and Urban Planning* 58 (2–4):297–308. doi: 10.1016/S0169-2046(01)00228-6.

Holden, S. T., and K. Otsuka. 2014. The roles of land tenure reforms and land markets in the context of population growth and land use intensification in Africa. *Food Policy* 48 (1):88–97. doi: 10.1016/j.foodpol.2014.03.005.

Kanyinga, K. 2009. The legacy of the white highlands: Land rights, ethnicity and the post-2007 election violence in Kenya. *Journal of Contemporary African Studies* 27 (3):325–44. doi: 10.1080/02589000903154834.

Kenya National Bureau of Statistics. 2019. *2019 Kenya population and housing census, volume II: Distribution of population by administrative units*. Nairobi: Kenya National Bureau of Statistics.

Keys, E., E. A. Wentz, and C. L. Redman. 2007. The spatial structure of land use from 1970–2000 in the Phoenix, Arizona, metropolitan area. *The Professional Geographer* 59 (1):131–47. doi: 10.1111/j.1467-9272.2007.00596.x.

Kleemann, J., J. N. Inkoom, M. Thiel, S. Shankar, S. Lautenbach, and C. Fürst. 2017. Peri-urban land use pattern and its relation to land use planning in Ghana, West Africa. *Landscape and Urban Planning* 165 (1):280–94. doi: 10.1016/j.landurbplan.2017.02.004.

Krishnan, A. 2018. The origin and expansion of regional value chains: The case of Kenyan horticulture. *Global Networks* 18 (2):238–63. doi: 10.1111/glob.12162.

Kuusaana, E. D., and J. A. Eledi. 2015. As the city grows, where do the farmers go? Understanding peri-urbanization and food systems in Ghana—Evidence from the Tamale metropolis. *Urban Forum* 26 (4):443–65. doi: 10.1007/s12132-015-9260-x.

Lerner, A. M., and H. Eakin. 2011. An obsolete dichotomy? Rethinking the rural–urban interface in terms of food security and production in the Global South. *The Geographical Journal* 177 (4):311–20. doi: 10.1111/j.1475-4959.2010.00394.x.

Li, W., D. Wang, H. Li, and S. Liu. 2017. Urbanization-induced site condition changes of peri-urban cultivated land in the black soil region of northeast China. *Ecological Indicators* 80 (1):215–23. doi: 10.1016/j.ecolind.2017.05.038.

Lowder, S. K., J. Skoet, and T. Raney. 2016. The number, size, and distribution of farms, smallholder farms, and family farms worldwide. *World Development* 87:16–29. doi: 10.1016/j.worlddev.2015.10.041.

Macrotrends. 2019. Nakuru, Kenya population 1950–2019. Accessed October 3, 2019. https://www.macrotrends.net/cities/21712/nakuru/population.

Maxwell, D. G. 1994. Household logic of urban farming in Kampala. In *Cities feeding people: An examination on urban agriculture in East Africa*, ed. A. G. Egziabher, D. Lee-Smith, D. G. Maxwell, P. A. Memon, L. Mougeot and C. J. Sawio, 47–65. Ottawa, Canada: International Development Research Centre.

Mougeot, L. J. 2000. Urban agriculture: Definition, presence, potentials and risks. Report IDRC-31, International Development Research Centre, Ottawa, Canada.

Moustier, P., and G. Danso. 2006. Local economic development and marketing of urban produced food. In *Cities*

farming for the future, ed. R. van Veenhuizen, 171–206. Leusden, The Netherlands: IDRC and IIRR Publishing.

Moustier, P., and H. Renting. 2015. Urban agriculture and short chain food marketing in developing countries. In *Cities and agriculture: Developing resilient urban food systems*, ed. H. de Zeeuw and P. Drechsel, 121–38. London and New York: Routledge.

Orsini, F., R. Kahane, R. Nono-Womdim, and G. Gianquinto. 2013. Urban agriculture in the developing world: A review. *Agronomy for Sustainable Development* 33 (4):695–720. doi: 10.1007/s13593-013-0143-z.

Owens, G. R. 2016. "We are not farmers": Dilemmas and prospects of residential suburban cultivators in contemporary Dar Es Salaam, Tanzania. *The Journal of Modern African Studies* 54 (3):443–67. doi: 10.1017/S0022278X16000392.

Padgham, J., J. Jabbour, and K. Dietrich. 2015. Managing change and building resilience: A multi-stressor analysis of urban and peri-urban agriculture in Africa and Asia. *Urban Climate* 12 (1):183–204. doi: 10.1016/j.uclim.2015.04.003.

Planet, L. I. 2020. Planet imagery product specifications. Accessed April 20, 2020. https://assets.planet.com/docs/Planet_Combined_Imagery_Product_Specs_letter_screen.pdf.

Pribadi, D. O., and S. Pauleit. 2015. The dynamics of peri-urban agriculture during rapid urbanization of Jabodetabek metropolitan area. *Land Use Policy* 48: 13–24. doi: 10.1016/j.landusepol.2015.05.009.

Robineau, O., and P. Dugué. 2018. A socio-geographical approach to the diversity of urban agriculture in a West African city. *Landscape and Urban Planning* 170 (1): 48–58. doi: 10.1016/j.landurbplan.2017.09.010.

Satterthwaite, D., G. McGranahan, and C. Tacoli. 2010. Urbanization and its implications for food and farming. *Philosophical Transactions of the Royal Society of London Series B: Biological Sciences* 365 (1554):2809–20. doi: 10.1098/rstb.2010.0136.

Schlesinger, J. 2013. Agriculture along the urban–rural continuum: A GIS-based analysis of spatio-temporal dynamics in two medium-sized African cities. PhD dissertation, Albert-Ludwigs-University.

Schlesinger, J., E. Munishi, and A. Drescher. 2015. Ethnicity as a determinant of agriculture in an urban setting—Evidence from Tanzania. *Geoforum* 64 (1): 138–45. doi: 10.1016/j.geoforum.2015.06.019.

Schmidt, S., W. Magigi, and B. Godfrey. 2015. The organization of urban agriculture: Farmer associations and urbanization in Tanzania. *Cities* 42 (Part B):153–59. doi: 10.1016/j.cities.2014.05.013.

Simon, D., D. McGregor, and K. Nsiah-Gyabaah. 2004. The changing urban–rural interface of African cities: Definitional issues and an application to Kumasi, Ghana. *Environment and Urbanization* 16 (2):235–48. doi: 10.1177/095624780401600214.

Tacoli, C., and J. Agergaard. 2017. *Urbanisation, rural transformations and food systems: The role of small towns*. London: IIED.

Thebo, A. L., P. Drechsel, and E. F. Lambin. 2014. Global assessment of urban and peri-urban agriculture: Irrigated and rainfed croplands. *Environmental Research Letters* 9 (11):114002–09.114002. doi: 10.1088/1748-9326/9/11/.

Traoré, M. T. 2012. Growing greener cities in Africa: First status report on urban and peri-urban horticulture in Africa. Report FAO-2012, Food and Agriculture Organization of the United Nations, Rome, Italy.

UN-Habitat. 2014. *The state of African cities 2014: Re-imagining sustainable urban transitions*. Nairobi, Kenya: UN-Habitat.

Willkomm, M., A. Follmann, and P. Dannenberg. 2019. Rule-based, hierarchical land use and land cover classification of urban and peri-urban agriculture in data-poor regions with RapidEye satellite imagery: A case study of Nakuru, Kenya. *Journal of Applied Remote Sensing* 13 (1): 1–19. doi: 10.1117/1.JRS.13.016517.

Zezza, A., and L. Tasciotti. 2010. Urban agriculture, poverty, and food security: Empirical evidence from a sample of developing countries. *Food Policy* 35 (4):265–73. doi: 10.1016/j.foodpol.2010.04.007.

MAXIMILIAN WILLKOMM is a PhD student at the Institute of Geography, University of Cologne, Albertus-Magnus-Platz, 50923 Cologne, Germany. E-mail: willkomm@smail.uni-koeln.de. His research interests include urban and economic geography, agricultural transformations, and remote sensing and GIS application in these fields. His PhD project explores the understanding of urban and peri-urban agriculture under rapid urban growth in East Africa.

ALEXANDER FOLLMANN is Researcher and Lecturer at the Institute of Geography and the Global South Studies Center, University of Cologne, Albertus-Magnus-Platz, 50923 Cologne, Germany. E-mail: a.follmann@uni-koeln.de. His research interests include urban and economic geography, human–environment interaction, and peri-urban dynamics.

PETER DANNENBERG is a Professor of Urban and Regional Development at the Institute of Geography and the Global South Studies Center at the University of Cologne, Albertus-Magnus-Platz 50923 Cologne, Germany. E-mail: p.dannenberg@uni-koeln.de. His research interests include economic geography, transformation processes, dynamics of globalization, and related regional impacts.