Defining the Peri-Urban: A Multidimensional Characterization of Spatio-Temporal Land Use along an Urban–Rural Gradient in Dar es Salaam, Tanzania

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Abstract: Highly dynamic peri-urban areas, particularly in the Global South, face many challenges including a lack of infrastructure, ownership conflicts, land degradation, and sustainable food production. This study aims to assess spatial land use characteristics and processes in peri-urban areas using the case of Dar es Salaam, Tanzania. A mixed-method approach was applied, consisting of expert interviews and spatial data analysis, on a local scale along an urban–rural gradient. Expert interviews were conducted during a field study and analyzed regarding the characteristics and processes of peri-urban land development. A GIS-based analysis of land use patterns was applied using satellite imagery and Open Street Map data to identify a number of variables, such as building density and proximity to environmental features. Results show specific patterns of land use indicators, which can be decreasing (e.g., house density), increasing (e.g., tree coverage), static (e.g., house size), or randomly distributed (e.g., distance to river), along a peri-urban gradient. Key findings identify lack of service structures and access to public transport as major challenges for the population of peri-urban areas. The combination of qualitative expert interviews and metrics-based quantitative spatial pattern analysis contributes to improved understanding of the patterns and processes in peri-urban land use changes.

Keywords: urban–rural gradient; peri-urban; spatial analysis; GIS; metrics; indicators

1. Introduction

With increasing urbanization and over half of the world's population living in cities, urban areas and their inhabitants face many challenges, including socio-economic and ecological changes [1]. Urban growth spreading into peri-urban areas is a key driver of unsustainable development [2], and in Sub-Saharan Africa, local and regional governments face difficulties in monitoring and addressing urban expansion. Significant demographic pressure is expected in Dar es Salaam, for example, where approximately 226,000 new urban dwellers are expected annually [1]. Dar es Salaam has exceeded Nairobi as Eastern Africa's largest city. Urban food security is critical and contributes to the increasing pressure on peri-urban areas that are important for urban food provision and undergo the transition from agricultural lands into residential areas [3,4]. In the less-developed world, urbanization surpasses all other uses for land adjacent to the city, including prime croplands [5].

The ways in which nations define what is urban and what is rural can vary significantly; the boundaries of urban settlements are not as clearly defined as the administrative delimitations [6]. Doan and Oduro [7] introduced the village magnet hypothesis, whereby peri-urban development appears to be attracted to pre-existing villages that already have basic levels of critical services. Hence, they often become the nuclei of fast-growing, densely

populated pockets. However, Dar es Salaam has also developed along highways and major roads, as per the Ribbon hypothesis [7]. Peri-urban areas are lacking a precise definition and a comprehensive approach or framework: the terminology remains vague with a variety of definitions (e.g., urban–rural interface, fringe, continuum, periphery, outskirts, hinterland, edgelands) [8–13]. Some studies describe the peri-urban as a type of land use or a land use dynamic, functioning as a "divide" between city and countryside (the urban fringe theory) [8,14]. Others refer to it as the dynamic and fast transformation of rural land into urban land (the sprawl approach) [15,16]. According to Ravetz et al. [17], peri-urban areas are often understood to be mixed areas under an urban influence but with a rural morphology from a European perspective, whereby in the Global South, the "peri-urban interface" relates to newly urbanized zones at the fringes of cities. In light of enhancing sustainable development of (urban) areas, peri-urban zones play a critical role at a global level [18]. Due to the complex characteristics of peri-urban areas, studies have addressed multiple dimensions of spatial change, mobility, identity, and economic activities [19,20]. Approaches describing and defining the urban–rural interface range from focusing on morphology and land use characteristics to socio-economic or cultural transitions [9,20–22]. Although the dynamics and characteristics of peri-urban areas and processes might be regionally specific [23,24], conceptual models of patterns and dynamic trends can be applied independently from regional specifics. Globally, a substantial amount of studies particularly trends to incorporating spatial metrics and analysis to develop such concepts [25–28]. However, the understanding and conceptualization of processes in studies with, e.g., European focus have usually limited transferability to regions of the GS [23].

The inherent complexity of the peri-urban areas puts the traditional duality of rural vs. urban areas in question [29]. Laband et al. [9] emphasize that the urban–rural dichotomy is still deeply embedded in the field and suggests a more open discussion and the eventual adoption of a continuum or gradient approach. Pryor [30] previously described the peri-urban as a landscape phenomenon, in which the fringe varies between cities and over time. The peri-urban is mainly characterized as a hybrid transitional zone, combining urban and rural conditions [31], forming a new type of multi-functional territory [2].

According to Nilsson [2], there are common features wherever peri-urban areas are found, such as a relatively low population density (by urban standards), scattered settlements, high dependence on transport for commuting, fragmented communities, and lack of spatial governance. Particularly in the context of Africa, studies often refer to the importance of urban fringe agriculture and rural linkages [9,31]. According to Chirisa et al. [32], the problem of conceptualizing the peri-urban interface has been implicit in development policy studies in developing countries for several decades. More recently, attention has been focused on the emergence of formal and informal land markets and the related land-use changes in peri-urban areas [29]. Studies with spatial reference to Dar es Salaam mainly focus on urban expansion along the urban–rural gradient, in relation to agriculture, transport, and policies [33–39].

Although the majority of peri-urban research has focused on the global North (Europe and North America), Nilsson et al. [2] has emphasized the arising global challenges of peri-urbanization, particularly in the Global South (GS). A number of studies have investigated the land use dynamics of African cities and peri-urban regions [3,4,24,36,40], as well as the challenges posed by rapid urbanization, particularly food insecurity or land degradation [41] and the spatial patterns of informal growth and interdependencies of city centers and peri-urban settlements [36]. However, there is a lack of information on the characteristics of the spatio-temporal processes of the peri-urban: these data are urgently needed for an improved understanding, particularly for cities in the GS [42].

Previous studies have included spatial indicators, such as land cover, access to public transport, road density, distance to roads, building density, or travel time [3,6,39,43]. Developing strategies to understand and monitor these changes are also in line with the Sustainable Development Goals [44]. The city of Dar es Salaam in Tanzania is committed to the development of sustainable cities and communities under the Sustainable Development Goals. The need for ongoing research for understanding characteristics and processes, in combination with analyzing land use change, is crucial in peri-urban areas, particularly in the GS, where population numbers and urbanization is rapidly increasing. This rapid population growth drives urban expansion, with unregulated development leading to challenges in regulation, control, and monitoring.

The aim of this study is to characterize the patterns and underlying processes of the spatio-temporal dynamics of the peri-urban area in the GS. We identify and analyses indicators using a gradient approach in order to answer the following questions: (1) What are spatio-temporal characteristics and patterns of peri-urban areas? (2) How can dynamics along a peri-urban gradient be generalized and conceptualized? While we show the processes along a case-study specific peri-urban gradient, the methodology and conceptual conclusions may be transferred to other regions. The case of Dar es Salaam is investigated, with the focus on a peri-urban gradient in the Msongola ward. An urban–rural gradient was chosen that includes the former peri-urban and more urbanized areas, as well as sparsely populated areas within the Dar es Salaam region representing different stages of peri-urbanization with heterogeneous spatial and temporal dynamics.

We followed a workflow of combining qualitative and quantitative approaches. In particular, we conducted expert interviews to explore characteristics and processes within the peri-urban followed by spatial pattern analysis of a selected set of characteristics quantified through indicators including socio-economic and environmental indicators. Finally, we propose trends of dynamics to generalize peri-urban characteristics and processes.

2. Methodology

2.1. Study Area

Dar es Salaam was selected for this study because it is one of the most rapidly growing East African cities, with a population of 4,364,541 in 2012 (last census) to projected 5,017,294 in 2017 [45,46]. The city is located on the eastern side of Africa, bordered by the Indian Ocean (Figure 1). Since its independence (1961), Dar es Salaam has been the dominant business and industrial center of Tanzania [38]. It has a radial structure and grows outwards following the main infrastructure lines of the water supply, electricity and major roads [33]. Since the 1970s, the city has been growing rapidly without adequate planning and enforcement regulations [47]. The majority of unplanned settlements in the urban periphery lack service infrastructures. Msongola ward, within the Ilala district of the Dar es Salaam region, was chosen as the case study area (Figure 1). The ward represents a peri-urban gradient, with a rapidly growing population (2002: 7268; 2012: 24.461), a relatively low population density (2012: $3762/km^2$) [45], and a change in characteristics from urbanized residential zones to rural areas in the periphery. The administrative area of $65 \ km^2$ was overlaid by a hexagonal grid (cell size $1 \ km^2$), resulting in an extended study area of $98 \ km^2$.
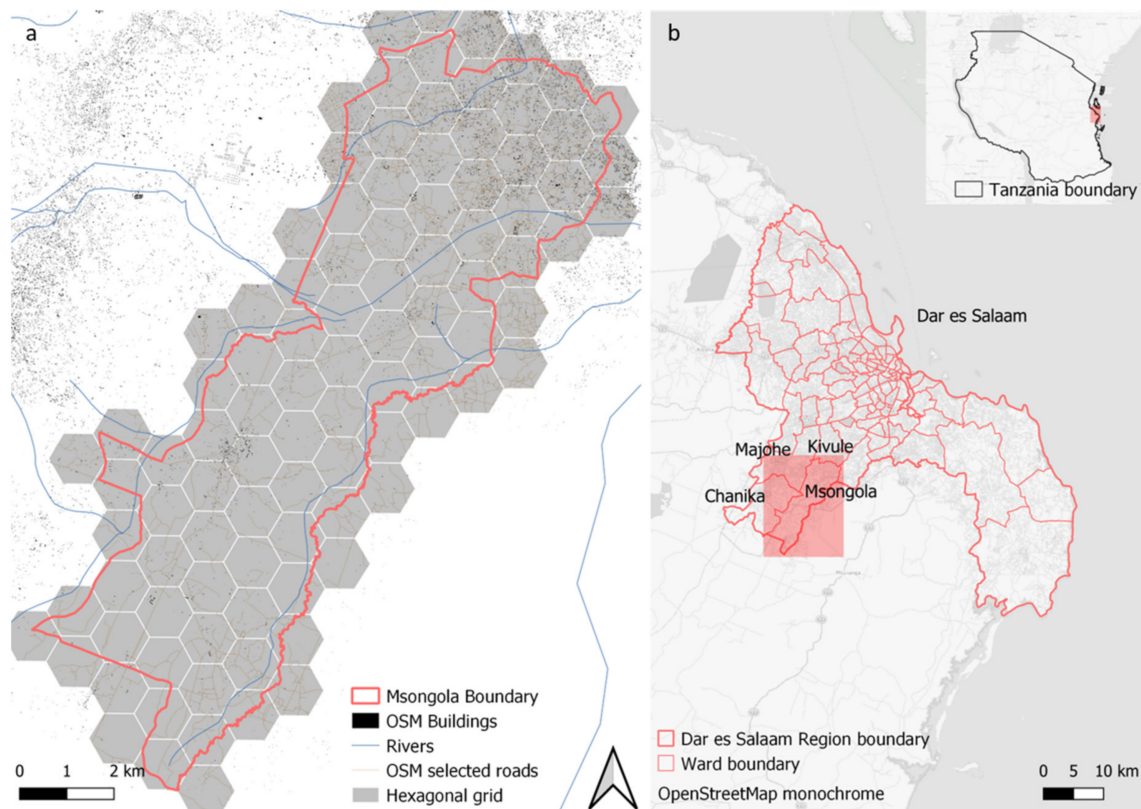
Figure 1. Study region of Dar es Salaam with (**a**) Msongola ward details with data including rivers, roads, and buildings and hexagonal grid overlay and (**b**) Location of Msongola ward in the city of Dar es Salaam.

2.2. Data

The following open-source data was used: Open Street Map (OSM) and remote sensing images from Sentinel 2 [48,49]. OSM can be accessed and used for free by anyone and for any purpose, which makes it a viable data source when availability and access to geoinformation is limited [50]. Considering the lack of digitalization within the study area, the (2018) building footprints were completed manually using JOSM software, based on remote sensing image tiles with a high resolution (2018 MapBox). Incomplete buildings, i.e., (brick) wall structures were included in the digitalization, as far as possible with the level of detail used (zoom factor 18). The digitized data was uploaded and made publicly available via OSM. Other datasets from OSM included roads and waterways (accessed 2018). Roads were selected, while pathways or tracks were excluded due to their unsuitability for vehicles, except motorcycles. Waterways were supplemented by river data from ICPAC Geoportal [51]. Land cover data derived from Sentinel 2, supplied as a prototype land cover map (2016) by the European Space Agency (ESA) [49], was analyzed for tree coverage by extracting the tree cover area. To generate up-to-date information on land cover, remote sensing is one of the most effective techniques available [48,49]. Data was then used for calculating metrics on a local scale to investigate small-scale land use patterns in peri-urban areas.

2.3. Expert Interviews

In-depth expert interviews provide qualitative data where quantitative information is not available [43]; however, studies focusing solely on interviews often lack an understanding of the interdependencies between human behavior and spatial configuration, such as the effect of the distance to roads, markets, or the suitability of a location for house construction. Consequently, linking analytical approaches, e.g., remote sensing-based land-use observations with human behavior, is necessary to understand the complexity of

human–environment interactions [43]. In-depth expert interviews, field visits, and photo documentaries were used to identify peri-urban land use characteristics, processes, and challenges. Expert interviews with officials from Ilala municipality were conducted from August 2017 to October 2017. "Experts" are defined as people with extensive knowledge and experience regarding land use planning in the study region. Six in-depth interviews were conducted, at ministerial, municipal, and ward administrative levels. The interviewees included persons involved in planning, research, and community development and an executive ward officer. Following an open interview guideline (Appendix B), interviewees were asked about characteristics and changes in the study area, planning strategies and regulation, the role of different institutions and actors, and the challenges and perception of peri-urban development. Employing open questions, additional topics were discussed depending on the interviewees field of expertise. Each interview took between 30 and 120 min depending on the expertise of the interviewee and the level of detail of the answers (a list of interview dates and expert functions are shown in Table A1). Interviews were transcribed and analyzed in a qualitative content analysis according to Mayring [52], followed by inductive category development by adjusting categories including subsuming and formulating new categories. Results were qualitatively interpreted and complemented by a coarse quantitative analysis, e.g., word frequency to approximate importance of categories. Information derived from expert-interviews was supplemented by the analysis of secondary documents, such as the Dar es Salaam Master Plan (in development, 2018 draft version), the Land Act and Village Land Act (1999), and the National Human Settlements Development Policy (2000).

2.4. Spatial Pattern Analysis along a Peri-Urban Gradient

The selection of characteristics derived from literature and expert interviews was subsequently analyzed using a gradient approach with increasing distance to the city center. We identified spatial indicators for those characteristics and applied a spatial pattern analysis, using the datasets explained above. The following indicators were selected based on previous studies [9,53] and the results of the qualitative expert interviews and field visits: number, size, and density of building structures, road length, and Euclidean distance to roads, river (valleys), and the city center. Following Birch et al. [54], a hexagonal grid-based approach was chosen to cover the entire study area in a more systematic way than administrative boundaries. All variables were subsequently averaged for each hexagonal cell (1 km^2 area) as mean values (Table 1).

Table 1. Indicators calculated for spatial pattern analysis.

Variable	Indicator for	Data Source	Processing (1 km^2 Grid Cells)
Land Cover/Use			
House Density	Urban density and proxy for population density	Open Street Map [37]	Houses per km^2
House Size	Building size	Open Street Map [37]	Mean house size per km^2
Tree Coverage	Land degradation	CCI Landcover [38]	Share of tree cover per km^2
Proximity			
Road density	Access to transport and infrastructure density	Open Street Map [37]	Road length km per km^2
Distance to city center	Proximity to city center (central business district)	Centroid central business district	Hub Distance from cell centroid
Distance to main roads	Access to transport and infrastructure density	Open Street Map [37]	Mean distance from house centroids
Distance to river	Access to water resources	ICPAC Geoportal [40]	Mean distance from house centroids

The information derived from expert interviews and the literature review were combined with the results from the spatial data analysis to suggest a generalized scheme characterizing peri-urban development, including environmental (including land cover and proximity to features), social, and economic variables.

3. Results

3.1. Peri-Urban Characteristics and Processes

The majority of interviewees stated that their primary definition of peri-urban is based on the distance to the city center (central business district). This is in line with the Tanzanian Land Act of 1999 that defines peri-urban areas as "those located within a radius of 10 km outside the boundaries of an urban or semi built-up area, which may be prescribed by the Minister for Lands, Housing, and Human Settlements Development" [55]. The definition based on distance seems straight forward; it does not account for the boundary of an urban area or a semi-built-up area, which, unlike administrative entities (regional, districts, wards, mtaa[1] areas, etc.), is evolving and shifting as towns and cities expand. In the Dar es Salaam Master Plan (guideline for urban land use development and zoning) [57], the peri-urban is the target location for settlements, infrastructures, and areas of preservation of croplands in the urban fringe.

Furthermore, infrastructure conditions characterize the peri-urban, especially the limited access to roads and public transport. Access to roads is limited, not only by availability, but also by road quality. Most of the roads are gravel; tarmac roads are rare, except major routes connecting municipalities. Transport infrastructure depends on decision makers (ward administration) and the priorities set by the Tanzania Rural and Urban Roads Authorities. Roads are built on demand and small access roads are built after the construction of houses (Interviewee #4).

In Dar es Salaam, development of houses primarily takes place along major roads, with land prices increasing with proximity to major roads, but also with the possibility to include shops that provide income (Interviewees #1 and #3). Transport mostly requires private cars, since public transport is not well developed. Citizens of DSM mostly rely on Daladala (small buses), Bajaj (three-wheeled motorized vehicles), and Bodaboda (motorcycle taxis); however, bus stops are only established if an (undefined) threshold of population is reached. Thus, motorcycle taxis are the most common mean of transport in the peri-urban, also because they can commute on smaller access streets or pathways.

According to all interviewees, and in accordance with the literature, the peri-urban is additionally characterized by a lack of service structures for water (Figure 2) and electricity, as well as schools, hospitals, and dispensaries. The exemplary water storage tank, shown in Figure 2, was a community project in Msongola ward: land is often "donated" from one or more owners for the construction of roads or service buildings (Interviewee #6).

"Most of the peri urban area [have] poor infrastructure, especially roads. And in urban area[s] there [area the requirements of] poor people. Basic needs, especially hospital[s], clean water, even electricity. Even schools. Especially government and private schools are [lacking] in peripheral areas. " (Interviewee #2).

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[1] Wards can be sub-divided into urban wards, "mtaa" (Kiswahili for streets) [56].

Figure 2. Example of an elevated water storage tank as a water supply system (photo: Saskia Wolff 2017).

The main reason for ongoing land use changes, mainly from agricultural to residential use, is that urban dwellers move to more remote peri-urban areas because of cheaper land prices and the desire to own property instead of renting (Interviewees #2, #4, and #5). Other pull factors include the possibility for agriculture and the lower crime rates than in urban centers (Interviewee #6). If a farmer sells their property, the land is first divided and sold in small sections. Therefore, trees are cleared from the land, except some isolated trees (e.g., cashew or coconut nut) (Figure 3) that do not require maintenance and are often used as property boundary marking.

"... *These were the areas which were formerly very green, and used as the lands of the city. Food production was [done] in these areas. Now people moving in are clearing the green area, they clear the trees, [so there is] no more land for farming. It is only residential. So, it is [...] transforming them into urban [areas]. Even [if] there had been natural resources found in those areas, they are no longer there. It is only houses, houses, houses.*" (Interviewee #6).

Figure 3. Single trees between residential plots that remained after clearance of the area for house development (photo: Saskia Wolff 2017).

Agricultural activity changes from large to small-scale: it is concentrated within the river valleys and limited to vegetable production. These small plots are mainly managed by women whose families either own or rent the plots. Potential land buyers are middle to high income and can afford to commute between the peri-urban and their place of work, usually in the city center. Land ownership often remains unclear, and land can be sold more than once to multiple owners, resulting in shifting property boundaries and conflicts of ownership. Characteristic structures of these conflicts are unfinished brick houses, marking the owners right to a piece of land (Figure 4). This is also due to nonexistent or unfeasible planning hierarchy and strategies; however, local planning authorities interviewed in this study state the necessity for those strategies to come from a regional governmental

level. These strategies include customized and context-specific planning "to make sure [peri-urban areas] are not going back to where they come from and being a replica of urban areas, which are informalizing" (Interviewee #6). In Dar es Salaam, local authorities of the wards organize themselves with the help of citizens, in a demand-based system; for example, when certain population thresholds are reached. This includes the development of new Daladala stops, schools, and health facilities, which are then implemented with the help of the superordinate authorities, i.e., the ward and city administration.

> *"Yes, there is a challenge [. . .] and issues [with] urban planning. Some [urban settlements] are planned and others are built without any plan so as time goes on, the issues of urban planning become[s] difficult."* (Interviewee #5).

Figure 4. Unfinished cement block wall house structure, which often remain unfinished due to conflicts about land ownership (photo: Saskia Wolff 2017).

Peri-urban areas function as a dynamic continuum for people, goods, and services, linking these areas to the city center. The characteristics of the peri-urban areas need to be determined by incorporating an environmental, socio-economic, and political framework. To assess and describe the peri-urban, the following set of indicators can be used (Figure 5):
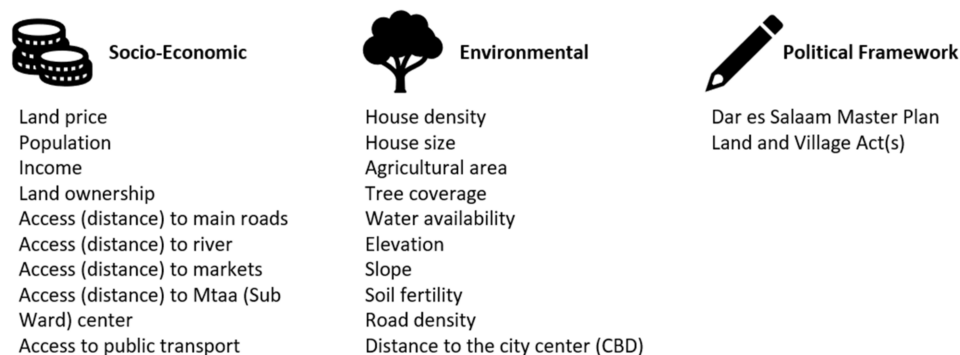

Figure 5. Set of indicators to characterize the peri-urban, with regard to sustainability pillars. Socioeconomic indicators include social and economic indicators, as well as accessibility; environmental includes ecological factors and conditions including land cover; the political framework refers to planning guidelines of land development.

3.2. Spatial Patterns along a Peri-Urban Gradient

For the selected set of the identified indicators (Figure 5, Table 1), spatial patterns on the peri-urban gradient were analyzed on a 1 km^2 hexagonal grid of the Msongola ward. These included housing density, mean house size, tree coverage, road density, distance to central business district (CBD), mean distance to main road from buildings, and mean

distance to river from buildings. One characteristic per category is illustrated in the maps in Figure 6 and a scatter diagram of dependence to distance from the city center in Figure 7.
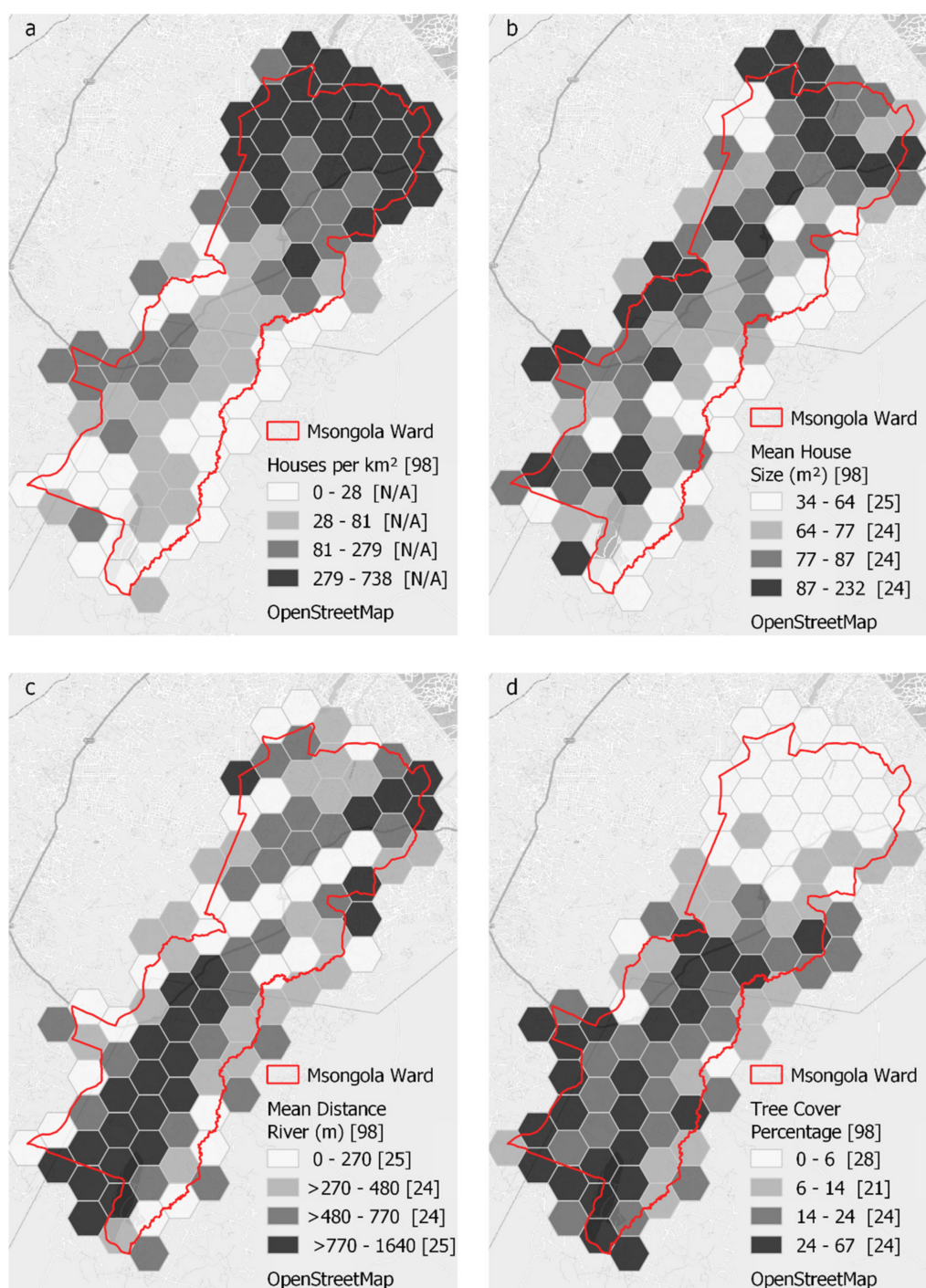

Figure 6. Maps of peri-urban spatial characteristics in four categories: (**a**) decreasing with distance to city center, (**b**) constant, (**c**) random, and (**d**) increasing with distance to city center (central business district).
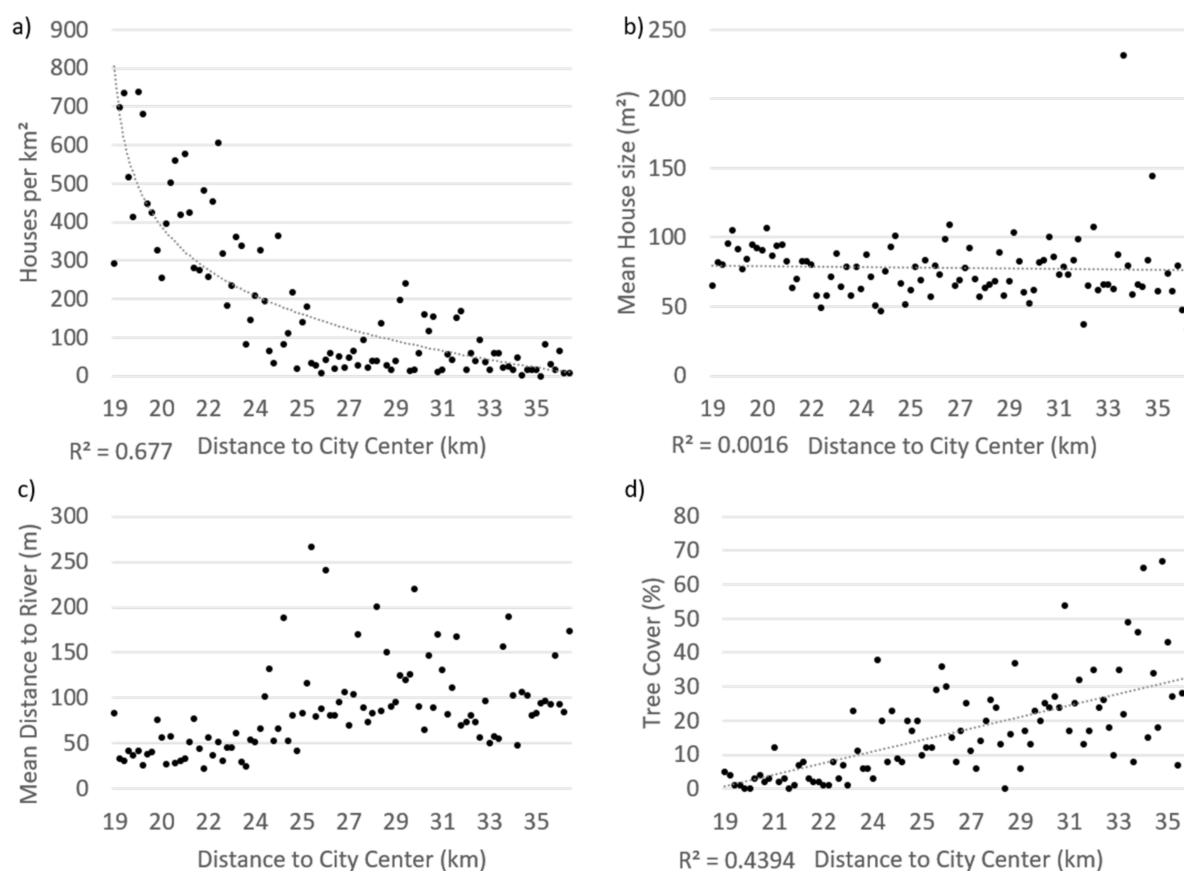
Figure 7. Distribution of values along a peri-urban gradient with trend lines for the following categories (**a**) decreasing houses per km^2 with distance to city center, (**b**) constant house size, (**c**) random mean distance to river (m), and (**d**) increasing tree cover (%) with distance to city center.

Houses per km^2 (i.e., one grid cell) showed a strongly decreasing trend with increasing distance from the city center, with a maximum value of 738/km^2 at 20 km distance and a minimum of 0/km^2 at 35 km distance (Figure 7a). On the contrary, tree coverage increases, with highest value of 67% of the cell area at 35 km distance and a minimum of 0% at 20 km distance. Areas with lower housing density show higher tree coverage. The random distribution of values, e.g., mean distance to river (Figure 7c), is due to natural landforms resulting in an unpredictable distribution of values. The mean distance to a river (from buildings) ranges from 22 to 267 m (Figure 7c). Mean house size remain constant with increasing distance to city center ranging from 34 to 232 m^2, with a mean house size of 78 m^2 (Figure 7b). The spatial patterns are in line with the statements from the expert interviews. The decreasing house density with increasing distance to the city center illustrates the availability of space for house development for cheap prices. Increasing tree coverage along the gradient area is connected to the clearance of plots, and former farm area, in order to build houses. This clearance of former large-scale agricultural areas leads to limited availability of agricultural land, which is concentrated in river valleys. As a consequence, some dwellers have to rent agricultural plots from other landowners in the river area. Hence, the spatial distribution of mean distance to rivers results in a rather random pattern but with a majority of grid cells showing values below 100 m. Preferably, houses are built in close distance to river valleys. The changes in spatial patterns on the peri-urban gradient can be differentiated into four categories: increasing or decreasing (with distance to city center), constant/no change, and random (unpredictable) (Figure 8).
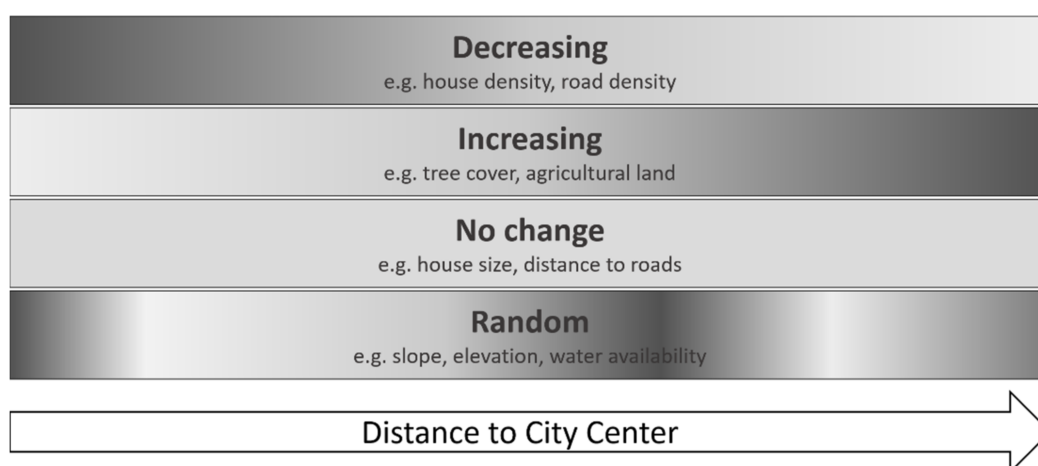
Figure 8. Spatial dynamics of characteristics on a perio-urban gradient.

4. Discussion

The findings from this case study of Dar es Salaam suggest that the peri-urban is a highly dynamic space with specific characteristics and processes. In particular, it is characterized by poor accessibility and a lack of service infrastructures, as determined by Kombe [36]. The urban–rural fringe, located between an urban area and the rural regions, shows a particular landscape structure that differs in land use patterns from both the urban and rural regions and is characterized by rapid development and changes over time. The quantitative findings on land use patterns, e.g., housing or road density, support earlier studies [3,6,58], showing a decreasing trend with increasing distance to the city center. Experts and legal documents primarily define the peri-urban with a focus on distance to the city center, which is even considered in the definition given in the Tanzania Land Act (1999) [55]. The consideration of peri-urban space on its own, opposed to urban or rural areas, is highlighted by many studies [33,59,60], which emphasizes that the simple dichotomy between the urban and rural must be overcome for planning and policy strategies [3,29,42]. On the other hand, Karg et al. [3] argue that planning policies are often reflected in the administrative, dichotomous entities of "urban" and "rural" that do not adequately reflect the real-world situation in many cities. However, the peri-urban is not necessarily tied to administrative boundaries or entities of an urban area [61] but is strongly linked to the urban (and the rural) by forward and backward flows of people (migration), goods (trade), and money (investment) [3,62]. Two very important factors for peri-urban development are the land price and the land tenure system. In terms of tenure, Msangi [33] noted that peri-urban areas exhibit both customary (commons may be owned by indigenous peoples or other communities with customary tenure systems, and this may be legally recognized [63]) and quasi-customary arrangements. Quasi-customary refers to land tenure arrangements where occupiers have acquired land from customary holders largely through non-customary modes such as purchasing [36]. Land acquisition is strongly linked to different actors, i.e., institutions, land owners, or local authorities [33,64]; however, this is beyond the scope of this research. Land price and actual construction of houses is influenced by different variables, including accessibility and service provision [33,65]: if a road is connected to the parcel, it becomes more expensive. This is also reflected by the decreasing road density along the peri-urban gradient: hypothetically, land price shows a similar gradual pattern. To determine accessibility, features from OSM were chosen that are suitable for vehicles; however, particularly paths and footways can be frequented by motorcycle taxis as well.

The development of peri-urban space can follow different spatial patterns. According to the Village Magnet and Ribbon theory [7] and the interviewees in this study and confirmed by the spatial data analysis, high shares of development take place around (former) village centers and major roads. This is mainly revealed through house densities per square

kilometer along the grid overlaying Msongola ward, where small agglomerations of higher building densities along major roads were identified. According to the interviewees, one major difference compared to peri-urban areas of the Global North is that the main function of buildings is residential, with rarely a mixture of purposes [2], except small commercial shops at bus stops or on the front of buildings, for example [4]. Independent from the area, studies worldwide emphasize the integration of peri-urban areas into sustainable development monitoring and planning. According to Wandl et al. [18], peri-urban areas have enormous potential to play a positive role in enhancing urban sustainability, which is in line with our interview results. Sustainable development of peri-urban areas include better-tailored planning and development of built-up areas in order to limit the transformation of open spaces [18,66]. At the same time, peri-urban areas are under increasing pressure regarding the provision of ecosystem services like recreation or food production [66]. However, a better balanced and more sustainable development requires more policy attention at the regional level and the urban–rural interface [67]. Peri-urban areas present opportunities to shape ecological networks and to foster productive economic activity [18]. For example, Magoni et al. [68] describe how innovative integrated planning has addressed multifunctionality in peri-urban areas by bringing together food production with environmental and landscape planning.

With the set of indicators and the spatial trend of the peri-urban gradient, we propose a systematic assessment and characterization of patterns and processes. These indicators are similar to those suggested by Karg et al. [3] to identify access, services, and built-up areas for peri-urban classification; these are structured according to three dimensions of sustainability: environmental, socio-economic, and policy framework. This is in-line with ongoing discussions and policy aims for achieving sustainability goals of food security (Goal 2) and inclusive, safe, resilient, and sustainable settlements (Goal 11) [44]. All dimensions and characteristics cannot be fully captured, but the results from the literature review and expert analysis reveal the most important ones on which to focus. To the best of our knowledge, this is the first time the trends in these indicators have been categorized over the peri-urban gradient. These indicators can be modified and utilized for other study areas. As studies of other regions/cities have shown, a comparative approach might reveal additional insights [15,69–71].

There are a number of uncertainties and limitations of this study. First, the focus of this research is on a specific study area and peri-urban subset in Dar es Salaam. The direct transferability of these results (i.e., spatial patterns and dynamics of specific indicators) to other areas is, therefore, limited and is also not the aim of this study. Instead, the detailed insights from this study can be used to develop a set of indicators to characterize the peri-urban. Second, due to a lack of official spatial and temporal data on land use, infrastructure, or population on a suitable spatial resolution, not all variables could be analyzed quantitatively. Alternatively, crowd-sourced OSM data was used, with additional digitalization to meet the requirements of this study. Using this kind of open-source spatial data, the quality of data cannot be guaranteed due to the type of data assessment [50]. To identify the high spatio-temporal dynamics of the peri-urban, new remote sensing datasets with high temporal resolution, such as Sentinel, offer additional possibilities for future studies to explore the dynamics in more detail. Thirdly, we relied on few expert interviews in this study and did not do a representative quantitative survey covering different administrative levels beyond the one ward. However, the aim of this paper was to explore and identify the characteristics in an initial step and, therefore, the qualitative in-depth interviews produced good results for this aim.

The results from the applied mixed-method approach for analyzing peri-urban characteristics has the advantage that information derived from the qualitative research can be incorporated into the quantitative method and that their outcomes can be compared [72]. In the analysis of indicators to assess peri-urban characteristics, methods from social science perspectives provide more information; therefore, a combination of qualitative and quantitative data analyses from natural and social sciences are applied. The methodology

draws from local community knowledge to provide background information and develops a backdrop of social relations that produce the spatial patterns of peri-urban land use [73].

5. Conclusions

In our study, we propose a conceptual identification of indicators characterizing the urban–rural interface in terms of spatio-temporal dynamics. While results and trends might differ for other study areas, the methodological set and categorization of dynamics (random, no change, increasing, decreasing) can be transferred and utilized for the characterization of peri-urban areas using a gradient approach. In Dar es Salaam, the peri-urban is characterized by socio-economic challenges including the lack of infrastructure and services, i.e., schools, hospitals, or land ownership. Environmental challenges include the clearance of vegetation, particularly trees and availability of land for large-scale agricultural cultivation. These patterns could also be identified in spatial dynamics along a peri-urban gradient, including a decreasing house density, which relates to available land and the flow of people through migration. At the same time, large scale agriculture mostly vanished and small-scale cultivation is mainly linked to river valleys. As a consequence, access to agricultural land is limited, also related to conflicts in land ownership. Many households have no property at the river but need to rent agricultural plots. The limited availability of agricultural space in peri-urban areas is critical, particularly considering its function as food production areas. In terms of sustainable transformations, the city planning of Dar es Salaam focuses on the implementation of sustainable city development goals, which is also reflected by the wish of local administrations for formalization and support by planning authorities.

In general, sub-Saharan African cities, including DSM, are growing unmonitored and without adequate urban planning [35,36,38]. Planning and policies have to address the specific dynamics and the spatio-temporal gradient in the peri-urban. The city center is closely linked to the peri-urban and needs to be considered as a continuum (of people, including transport and housing, and products, e.g., agricultural products). Particularly the provision of service infrastructures plays a decisive role and needs to be tackled in planning and political strategies. To face the continuous population increase in Dar es Salaam and other cities in the GS, providing living space and food production in a sustainable manner remains one of the major challenges. The peri-urban area, where urban and agriculture intermingle, should be the focus of future research, policies, and planning.

Appendix A

Table A1. List of interview dates and expert function.

#	Date	Function
1	12 September 2017	Town Planner
2	18 September 2017	Community Development Officer
3	20 September 2017	Executive Officer
4	20 September 2017	School Principal
5	21 September 2017	Community Development Officer
6	29 September 2017	Researcher

Appendix B. Interview Guidelines

Date:
Institution: Interviewee:

Introduction

- Introduction of project . . .
- Anonymity agreement, recording
- Function of the expert
- Current position and area of responsibility

Background

- How would you describe peri-urban areas?
- What are the characteristics and functions?
- What are challenges?

Structure and Characteristics

- What is the major structural change occurring?
- Peri-urban farms: What are specific characteristics/how are they organized?
- What is the difference to rural farms?
- What are biophysical characteristics/limitations? (natural elements)
- What are limiting/relevant socio-economic characteristics?
- How is the peri-urban connected to . . .
    - . . . rural areas?
    - . . . urban areas?

Interests and Strategies

- What are people's (farmer, residents) motivation to settle in peri-urban areas?
- Where do they come from?
- What are people's long-term plans?
- What are strategies to achieve long term plans?

Regulations and Decision Making

- Who are the relevant actors, decision makers, and authorities?
- What is the role of different institutions?
- What responsibilities do they have?
- How do actors interact?
- What are current policy and planning strategies?
- How are strategies implemented in practice?
- What are the formal/informal aspects, regulations?
- How does the city react towards the increasing population pressure and rising demand for settlements?

Perception and Opinion

- How does lifestyle, e.g., household type, affect land use decisions?
- What are future expectations, trends?
- Additional comments?

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