GROUND TRUTHING: STUDYING PERI-URBANIZATION AND LAND-BASED LIVELIHOODS IN MANKWENG AND ITS ENVIRONS (LIMPOPO, SOUTH AFRICA)

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KEY WORDS: Former homeland, Ground truth, WorldView-3, Peri-urban, Land use/cover, Informants.

ABSTRACT:

Peri-urbanization is often referred to as a transition zone following either an urban-rural gradient or an inner and outer peri-urban zone. Contrary to these notions and linked to its history in a former homeland, peri-urbanization in Mankweng appears as a complex and erratic process in reaction to shifting livelihoods, in-migration, and climate change. The process of ground truth for the study was designed by accommodating a combination of remote sensing images of WorldView-3 for the densely, vastly changing populated area (200 km^2) and of Sentinel-2 for the overall study area of 400 km^2. For the purpose of intensive data gathering, 16 plus three additional sites were selected in the area covered with the very high-resolution imagery as well as transect drives in the rural part. The study sites were selected and well distributed based on specific parameters such as building density, home garden size, road type with the goal of better interpreting what can be distinguished on the imagery and what influences land-based livelihoods. Additional information was gathered from informants during the ground truth through open questions and informal discussions. A solid knowledge of the land uses and land cover, including housing structures, agricultural practices, and challenges of land-based subsistence, was attained. The results revealed influential change drivers, settlement structure types, distinct development patterns, changes in traditional land-based livelihood specifically in terms of agriculture in the region and indicators for a functional zoning of the area. The ground truth provides a thorough basis for the object-based image analysis of the 200 km^2 peri-urban area being next.

1. INTRODUCTION

Peri-urban regions of expanding cities present a highly dynamic landscape with multifarious socio-economic systems, land use patterns, and functions, thereby posing a significant spatial planning challenge in the present times (Karg et al., 2019; Nilsson et al., 2013). In the case of South Africa, the peri-urbanization landscape transformation is intrinsically linked to a complex interplay of post-apartheid political and economic factors (Smith, 2015). To tackle the complex, ever-changing nature of peri-urban areas, there is a pressing need for advanced technologies and techniques to ensure efficient and effective spatial planning. Remote sensing has demonstrated remarkable potential as a tool for the study of peri-urban landscapes, with multiple use cases showing its efficacy in identifying settlement structures, land use covers, and spatial drivers that contribute to the rapid urbanization and transformation of such areas (Addo, 2010; Kemeling, 2001). However, to augment the accuracy of remote sensing techniques, it is crucial to complement them with ground truth data. Ground truth data provides a critical reference point for interpreting satellite imagery, and it helps in the understanding of the context of land-based livelihoods, farming practices, and settlement structures (Dinis et al., 2010; Kedar et al., 2020). In the present study, our objective is to develop a typology of settlements for sustainable livelihood scenarios in peri-urban areas using very high-resolution (VHR) imagery as a starting point. Developing a ground truthing methodology was essential for fully visually interpreting the satellite imagery and for gaining insight into the contexts of land use and settlement structures. The study approach adopted is to offer rich knowledge and understanding of the peri-urban landscape under study.

2. STUDY AREA

The study area selected for the WoPedyP research project (https://www.imm.hs-karlsruhe.de/WoPedyP/), targeting four designated study sites, is situated in Limpopo province, approximately 40 km east of Polokwane. The ground truthing activities were carried out in the peri-urban and rural outskirts of Mankweng, covering an area of 400 km^2, characterized by hills (rocky outcrops, known as 'koppies') amidst mostly flat terrain. Mankweng is a region located in one of South Africa's former homelands, which developed around the University of Limpopo (McCusker & Ramudzuli, 2007) from 1959 onwards. Settlement development accelerated with the end of the apartheid with peri-urban settlements stretching south and north of the two roads which travers the area west to east (Figure 1). Agriculture in the area is predominantly monocropping, with maize being the dominant crop (Makgoba et al., 2021), and some occasional cultivation of other crops during the wet season, such as leafy greens (known as 'morogo'), carrots, sweet potatoes, cowpeas, and lemons (Sekgobela, 2019). The region is home to communal agricultural land use, locally known as 'mashemo', and encompasses also grasslands, shrubs, trees, as well as the Turfloop Nature Reserve. Mankweng and its surroundings have a semi-arid climate (BSk in the Köppen climatic classification) with the highest precipitation occurring during the summer months from October to March (Rwanga, 2017).

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https://doi.org/10.5194/isprs-archives-XLVIII-M-1-2023-241-2023

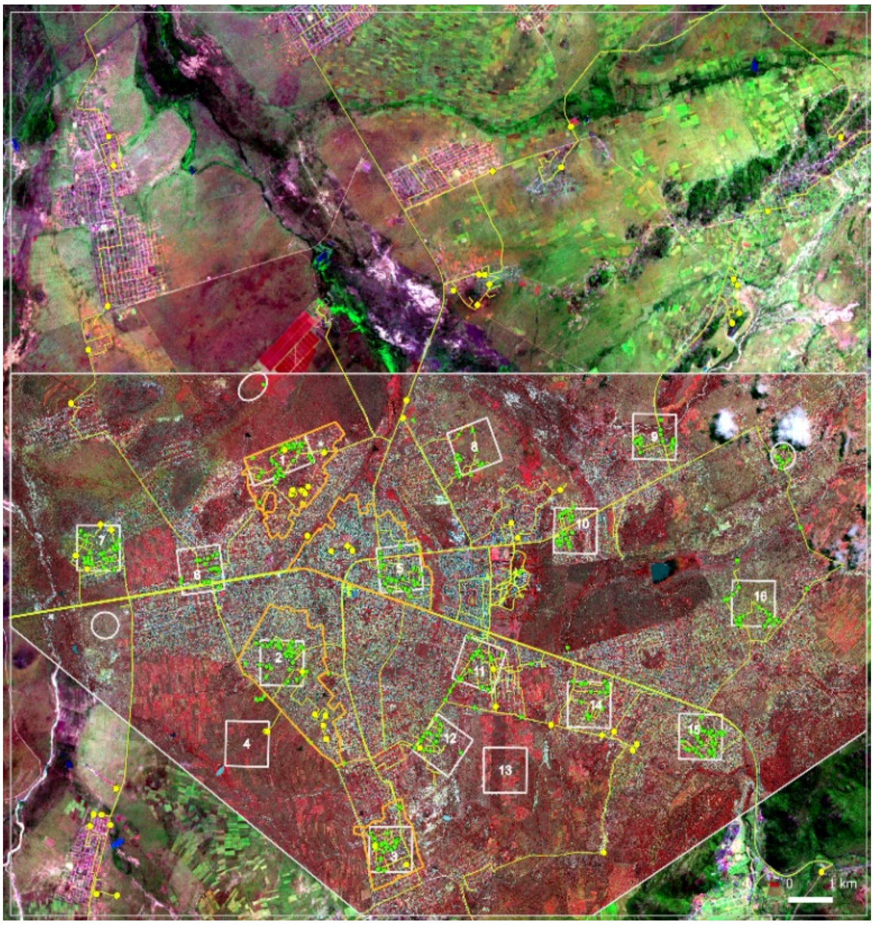

Figure 1: Study area (-23.90 Lat, 29.72 Long) with the four WoPedyP study sites (orange), ground truth sites delineated by square or circular polygons (white), ground truth points (green from 1st visit, yellow from 2nd visit) and tracks (yellow) overlaid on WorldView-3 (20 March 2022; bands 7,5,3) and Sentinel-2 (11 April 2021; bands 10,7,2) imagery.

3. MATERIALS AND METHODS

Sentinel-2 imagery (11 Apr 2021, Level-2a) is used for visualizing the overall study area of 400 km^2. Out of the 13 stacked bands, bands 10 (SWIR), 7 (Red Edge) and 2 (Blue) are used in the false colour composite for during ground truth. WorldView-3 (20 Mar 2022, Level-2) is utilized for the coverage of the peri-urban area of Mankweng and surroundings. Out of the eight bands, bands 7 (Near-IR), 5 (Red) and 3 (Green) are used as colour composite. The image composites were created to distinguish between settlement structure types in the study area (Figure 1). For image processing, *ERDAS IMAGINE 2022* and *ArcGIS Pro 2.9* were used. *ODKCollect*, in combination with *Kobo-Toolbox,* served as data collection tool in the field, which allows for form-based data collection (Cai et al., 2017). *OSMAnd* was used for navigation to the predetermined ground truth sites and points, while *OSMTracker* for daily route logging.

The project's ground truth procedure can be broadly divided into four phases: prerequisite research, lab preparations, fieldwork, and post-analysis of ground truth (Lübker & Schaab, 2008a). Prerequisite research included a literature review on the region’s geography. Relevant geodata sets and demographical datasets were pooled for adding to the spatial understanding of the area (Openshaw, 1997). WorldView-3 satellite imagery had to be acquired. Based on previous comparison studies and a review of the literature on PAN sharpening approaches, Tu et al. (2012) and Belfiore et al. (2016) determined IHS as the method most suited for WorldView-3 imagery. For our study the PAN sharpening approaches of NNDiffuse Resolution Merge, HPF Resolution Merge, Subtractive Resolution Merge, and Modified IHS Resolution Merge were run on a subset of the WorldView-3 image data (cp. Lübker & Schaab, 2008b). Finally, the Modified IHS Resolution Merge algorithm was chosen as the best for the WorldView-3 scene. The result was visually acceptable and minimized unwanted artefacts in the image that were causing pixel dissolution due to high reflectance values (Wang et al., 2021).

Site selection prior to ground truthing serves as an optimization step for efficient ground truthing (Hegarty-Craver et al., 2020). It helps with the goal of better interpreting what can be distinguished on the imagery, for identifying the region's land cover, and for understanding the land-based livelihoods in this former homeland area. The actual ground truthing was done in two parts, at first intensively in areas with WorldView-3 image coverage and later in the more rural areas with Sentinel-2 coverage. To conduct the ground truth in the area of WorldView-3 coverage, a total of 16 ground truth sites were selected with a square area of 1 km^2 each (Figure 1), except for site 1 which is rectangular in shape due to the need to fit within the demarcated WoPedyP study site, and further three circular sites for covering additional aspects of ground truth. The 16 sites were selected with the main intention of identifying settlement structure types. Here, 15 variables specific to the peri-urban landscape guided the selection (cp. Lübker & Schaab, 2008a) The variables considered were: arrangement of parcels, parcel size, size of main house, location of main house, building density, type of dwelling and roof, parcel boundary demarcation, road type, size and type of agricultural plot, type of main crop, plot layout of mashemo, abundance of trees, other natural vegetation, and other land use/cover (LUC). A preliminary zoning was conducted to identify the unique settlement structures in the study area and to ensure that all were covered by the placement of the 16 sites. The sites are therefore representative and reflect the strong heterogeneity of the area covered by the WorldView-3 image data.

In addition to selecting the ground truth sites, prior selection of points aids in improved data gathering and correlation later (Joyce, 1977). A total of 261 points of 18 distinct LUC classes, reflecting mainly vegetation and land cover types, crops, and settlement structure components, were marked inside the ground truth sites on the WorldView-3 data to serve as a basis for the field survey (Bhatt et al., 2018). In light of the subsequently placed Object-based Image Analysis (OBIA) categorization, a complete LUC classification scheme was designed and implemented, annotations added of what additional details to capture, and maps of the ground truth sites and points created (Maktav et al., 2020). Finding a suitable smartphone-based survey application for the ground truth is important. The application was chosen with anticipated challenges in mind, such as the ability to work in offline conditions, to help with navigation, a decent bandwidth requirement for uploading the collected points to a server, the customizing of forms for point collection, and the function of adding the WorldView-3 imagery as background layer (Manandhar et al., 2010). For planning of time in the field, a routing to the ground truth sites was calculated based on the OpenStreetMap road network (Hegarty-Craver et al., 2020).

Approximately 40 questions were formulated for addressing potential informants to better comprehend the livelihood of the region, including the dependency on natural resources, the accessibility of services, the age of settlements, agricultural practices, changes in crop yield, variations in rainfall throughout the years, crop diseases, and particularly land-based livelihoods in the area. It included also the roles of the traditional and municipal authorities. The combination of gathering local knowledge while reading the remote sensing data was employed to obtain contextually relevant data and to gain a comprehensive understanding of the factors driving land use change, as recommended by Hoover et al. (2017). In the first stage of ground truthing, 16 plus three predetermined locations in the peri-urban area and covered by WorldView-3 imagery were targeted and data was collected over a period of 17 days (23 Jun – 16 Jul 2022). In the second stage (31 Aug – 02 Sep & 09–16 Sep 2022), transect drives were conducted to cover the remaining 200 km^2 of more rural area over a period of eleven days. During both stages (Figure 1), field assistants assisted with tasks such as capturing photographs and their compass directions, to help with navigation, translation, administering the questions, and recording all information collected in the *ODKcollect* mobile application, a booklet or on the printed maps.

Table 1: Ground truth efforts: number of points captured and number of informants spoken to per site. For location of sites see Figure 1.

Name of ground truth site	Planned no of points	Points captured 1st + 2nd visit	Informants 1st + 2nd visit
Nchechane (1)	28 (19)	38 + 14	14 + 6
Nobody (2)	31 (28)	45 + 5	17 + 8
Ramogale (3)	16 (22)	42 + 2	19 + -
Ga-Mothabo mashemo (4)	8 (0)	4 + 2	5 + -
Mankweng Unit F (5)	28 (24)	32 + 3	12 + 10
Total Nobody (6)	23 (18)	20 + -	6 + -
Morongoa (7)	25 (20)	25 + 5	10 + 7
Seckline (8)	16 (8)	18 + 2	15 + -
Ga-Kama (9)	23 (12)	15 + -	7 + -
Iraq & Thabang (10)	17 (14)	23 + 3	8 + -
Ga-Makanye (11)	19 (16)	27 + 2	ca 7 + -
Makanye Extension & Magowa (12)	19 (12)	19 + 1	13 + -
Makanye mashemo (13)	18 (0)	1 + -	2 + -
Mentz Moshongo (14)	27 (14)	23 + 4	5 + 7
Matshelapata (15)	28 (31)	40 + -	9 + -
Mamabolo Village (16)	25 (17)	26 + -	12 + -
Tshware (Misc1)	9 (6)	7 + -	7 + -
Mothibaskraal (Misc2)	5 (0)	0 + -	3 + -
University Farm (Misc3)	3 (0)	2 + -	1 + -
Larger study area	-	- + 28	- + 14
Σ	**368**	**478**	**ca 225**

() no of points captured of those initially planned

The post-analysis of the ground truth data is a crucial step in the research process (Zhang et al., 2016). It was conducted to ensure accuracy and relevance of the collected data. It involved daily data cleaning and sorting to verify the correct locating of the data points. This step proved important for enhancing the visual interpretation of the WorldView-3 imagery, i.e. the learning process of reading the VHR satellite imagery. The photographs taken in the field were also organized and archived appropriately to facilitate future analysis.

4. RESULTS OF THE GROUND TRUTHING

4.1 Ground truth efforts

The study involved two separate field visits, which were 17 and 11 days long, respectively, for a total of 28 days of fieldwork. An overall distance of approximately 700 km were covered during these visits, by car and on foot, in order to collect data in the field. The primary goal of the ground truthing efforts was to check features in the field and to gather additional information in order to add meaning to the findings from remote sensing data. In total, 478 points were captured and ca 225 informants were spoken to. The local names for the various ground truth sites (mostly villages) were collected to provide further context. Table 1 gives a summary on the ground truthing efforts in comparison to the number of points originally planned to visit.

4.2 Hierarchical LUC classification scheme

The LUC classification scheme initially developed was based on research literature and the preliminary visual interpretation of the WorldView-3 satellite data. However, the ground truthing process revealed some shortcomings in the initial interpretation, such as e.g. the omission of wetlands. As a result, the LUC classification scheme was revised to better reflect area-specific classes. The revised scheme (Table 2) includes additional agricultural crops, fruit trees, and other classes relevant to land-based livelihoods. Overall, seven classes were removed, and ten added. Some of these 56 classes (belonging to 9 hyper-classes) may not be detectable from the WorldView-3 satellite imagery due to its acquisition towards the end of the raining season.

4.3 Zoning of settlements

Prior to placing the ground truth sites, a zoning of settlement structure types was created. This was based on knowledge from the literature as well as the preliminary visual image interpretation of the WorldView-3 imagery. The settlement structure types were visually grouped distinguishing differences in building densities, building alignment, and other typical feature arrangements and patterns. Eleven zones were highlighted on the VHR imagery. With a thorough understanding of the settlement types based on details as gathered from informants and with the ground perspective in mind, this number reduced to eight. Both zoning approaches can be seen in Figure 2.

Table 2: Hierarchical LUC classification scheme, updated post ground truthing.

Homestead (Roof of building)	**Agriculture**
Metal roof	Maize
Concrete roof ^{x}	Sorghum ^{x}
Sheet roof ^{x}	Wheat ^{x}
Slate/tile roof $^{+}$	Beans
Thatched roof $^{+}$	Beetroots
Unfinished roof $^{+}$	Cabbage
Homestead (Purpose of building)	Carrots
Occupied dwelling	Chillies $^{+}$
Vacant dwelling	Cowpeas
Cattle shed	Groundnuts
Garage shed	Lettuce
Plot boundaries	Onions
Fence	Spinach
Wall	Tomatoes
Hedge ^{x}	Fruit tree(s) ^{x}
Miscellaneous LC in settlement	Avocado $^{+}$
Pavement	Lemon $^{+}$
Grass meadow	Mango $^{+}$
Unused land	Orange $^{+}$
Other (urban) LU	Fallow land
Car park	Burnt area
Cemetery	Other
Dumpsite	**Roads**
Mining $^{+}$	Tarmac road
Erosion $^{+}$	Paved road ^{x}
Golf club	Dirt road
Industry	**Natural vegetation**
Bare ground	Forest
Kraal $^{+}$	Bushland
Water bodies	Shrubland
Stream	Rangeland
Dry riverbed	Grassland
Natural pond	Single tree(s)
Water dam	Outcrop
Water tank (closed)	
Wetland $^{+}$	

$^{+}$ indicates classes that were added, ^{x} those eliminated

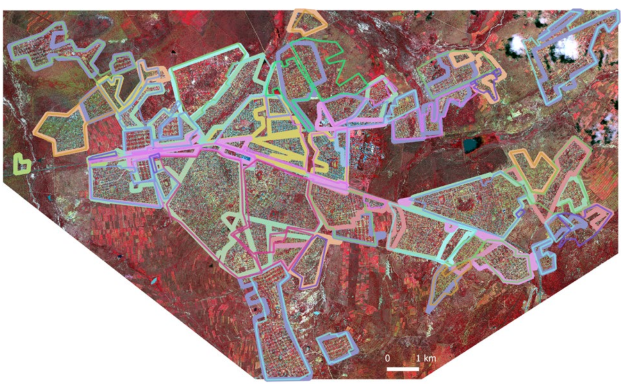

Figure 2: Zoning pre and post ground truth: Initial zoning pre ground truth considered eleven narrow zones indicated by thicker lines, while the zoning post ground truth contains eight broader zones shown by thinner lines.

4.4 Conceptual timeline of settlement development

Based on the field visits and WorldView-3 image interpretation, a conceptual timeline of settlement development was developed. Figure 3 demonstrates this progression of settlements from the first transformation of mashemo land to the stage of structured settlements as observed in the WorldView-3 imagery. The timeline's objective is to show how the area evolves through time, from the initial makeshift tin shacks to the creation of larger, permanent, and orderly houses. The following are the stages of peri-urbanization: In the mashemos (a) the Traditional Authorities (TA) allocate land as stands for residential dwellings. The stands may or may not be cultivated at the time of allocation. In the first stage of construction (b), temporary shacks with tin walls and roofing are built on the designated stands. Demarcated by fences, the TA gives the residents Permission To Occupy (PTO) which is considered to be an informal right to land (Polokwane Local Municipality, 2022). These stands must remain unoccupied for more than a year before residents can move in. Services are absent at this stage of settlement growth. Plenty of bare ground is typically observed around the metal shacks and some agriculture may be present. Occupants of these shacks are seen to take up piece jobs, with a majority being unemployed. It was observed that some shacks at this stage are rented out. In the next stage of settlement development, there is a densification of the shacks (c), but amenities such as water, electricity, and sanitation remain scarce. The bare ground around the home structures is decreasing and only a little amount of original agriculture is remaining. A massive boom in construction can be seen, including many unfinished roofs of larger structures. Occupants at this stage are either seen taking up seasonal piece jobs or traveling to Polokwane for jobs. In the third stage of settlement growth, a significant level of diversification (d) can be recognized. Communities consist of mixed constructions, including still some shacks and many more permanent, larger residences. At this stage, both bare ground and home gardens around the house are relatively limited, but in some cases more fruit trees can be seen and partial provision of services can be noted. At this point, the settlements are identified as ‘less-formal’ by the municipal authority (Polokwane Local Municipality, 2022).

Regularization of the settlements (dito) occurs later on (e). At this stage, housing structures exhibit a distinct pattern, as evidenced by the alignment of the settlements to the roads. Housing looks more orderly, with tiled roofs and concrete walls, and a good number of houses have municipal approval. The bare area around the home may be cemented or have grass meadows surrounding it. Home gardens are not apparent, although more fruit trees can be observed across the land. The services of electricity, water, and sanitation are more easily accessible in the settlement and the residents tend to have regular occupations.

The Mankweng region features two additional distinct types of settlement shown as special cases in Figure 3: (f) Mankweng itself experienced a rapid and unpredictable expansion and development, influenced by its proximity to the university and administration offices (McCusker & Ramudzuli, 2007). It looks rather planned and has the most stable service provision. Due to the housing density, there are no home gardens and this suburban area has a dynamic student and migrant population. Villagization settlements (g), the result of the betterment scheme during apartheid (De Wet, 1991), exhibits a higher dependence on mashemo. Ground truthing indicates that the population in these villages consists primarily of older individuals. They have their home gardens and access to services, although limited.

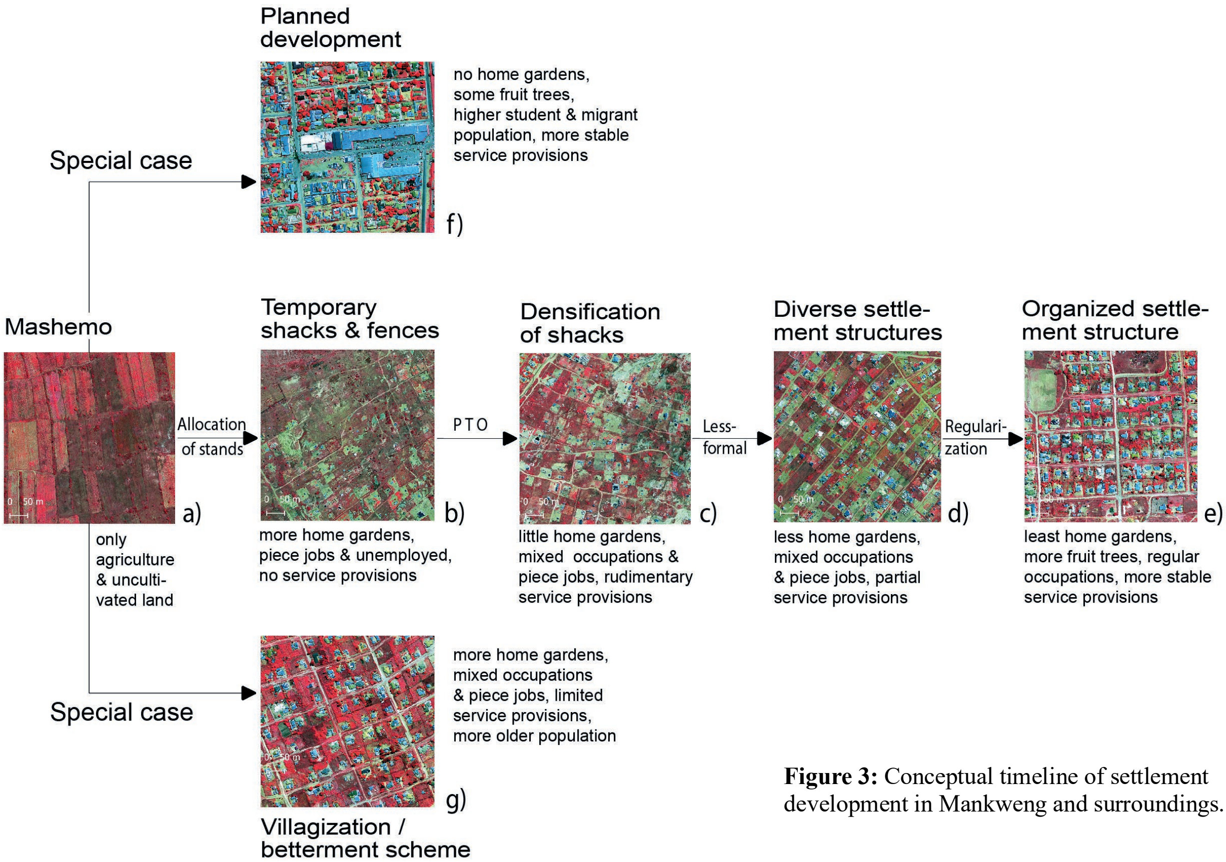

Figure 3: Conceptual timeline of settlement development in Mankweng and surroundings.

4.5 Conceptual framework of the anticipated study

The anticipated study's conceptual framework, as illustrated in Figure 4, serves to elucidate the study and is rooted in the understanding of livelihoods as obtained through ground truthing. Given the complexity of the region, the framework was designed to provide insight into the spatial and other parameters that directly or indirectly contribute to the peri-urbanization in such an unplanned and erratic manner. It neither follows the notions of an urban-rural gradient (Schlesinger, 2013) nor of an inner and outer peri-urban zone (Karg et al., 2019), but appears as a complex and erratic process in reaction to shifting livelihoods, in-migration, and climate change. Therefore, the ultimate goal of the remote sensing analysis is to comprehend the current settlement structure types. For that, the framework establishes foci and bounds for the subsequent methodical research. Besides gaining details on the current pattern of land-based activities (covering agriculture, livestock and wild natural resource use), additional understanding to add

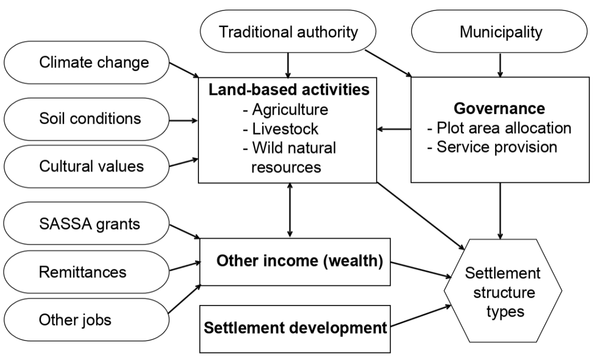

Figure 4: Conceptual framework of the research.

is related to governance (plot allocation, service provision) as well as other income sources. SASSA grants, which is social grant provision in South Africa (Lund, 2006), and remittances from relatives in cities elsewhere impact the livelihoods. Here, particular wealth can be inferred indirectly via indicators. Climate change has an overall impact but will not be explicitly studied. But for concluding on settlement structure types and associated typical livelihoods, the inclusion of a remote sensing-based time-series analysis (extending and supplementing the LUC time series of McCusker & Ramudzuli, 2007) is crucial.

4.6 LUC classes for identification in OBIA

With a framework in hand and the knowledge that the detailed, agriculture-related LUC classes (Table 2) cannot be distinguished in the WorldView-3 imagery, Table 3 provides the LUC classes, which OBIA should focus on. By defining rules, classes will go beyond broadly defined area-specific land uses and covers in order to help in quantifying information related to livelihoods. For example, building occupancy can be inferred from the presence of bare soil surrounding a home structure. Indicators for wealth of households are the roof type in combination with the presence of fruit trees, green lawns and water tanks on the compound. Areas used to harvest wild natural resources can be derived from the distribution of foot-paths leading to and along dry riverbeds and bushland. And the distinct pattern of spots seen on grassland in the imagery was identified as termite mounds, which point to former woodlands.

5. DISCUSSION

Mankweng and surroundings is characterized by the disappearance of grassland and agricultural area, and a high level of urbanization, resulting from a dramatic pattern of increasing spatial

Table 3: LUC classes aimed at in OBIA.

Vegetation	**Land uses inferred via rules**
Maize	*Farming methods:*
Tree(s)	- mashemo
Bushland	- commercial farm
Riverine vegetation	- home garden
Grassland	
Fallow	*Uses (built-up):*
Burnt area	- dwelling
Land uses	- industry
Dry riverbed	- school
Cemetery	- shed
Dumpsite	- water tank
Mining	
Roads & infrastructure	*Building occupancy:*
	- bare ground around the structure vs. overgrown with grass
Tarmac road	
Dirt road	
Footpath	*RDP houses:*
Car park	- based on roof size and shape
Other land cover	
Bare ground	*Wealth of household (indicators):*
Outcrop	- slate/tile roof
Waterbody (dam)	- fruit trees
Wetland	- greenness of lawn
Forest	- water tank(s)
Built-up	
Building:	*Kraal:*
- with metal roof	- black soil colour and closeness to house
- with slate/tile roof	
- with thatched roof	
- with unfinished roof	*Wild natural resource use:*
Compound demarcation:	- based on footpaths
- wall	*Former woodlands:*
- fence	- based on termite mounts

concentration (McCusker & Ramudzuli, 2007). The WorldView-3 imagery being used for the peri-urban part of the study area was captured on 20 March 2022 (Figure 1) with the hope to in particular also learn about the peri-urban land-based activities. One could argue that the timing of image acquisition towards the end of the rainy season was not the best, with rotation and mixed cropping during the wet season not being captured. However, cloud-free imagery was given priority. And as most of the communal agricultural land and the home gardens is used for maize planting (acc. to Dovie et al., 2007 e.g. 96% of the households), the additional information would have been only minor. Instead, the ground truthing was a combination of visually studying the area in comparison to the satellite imagery and obtaining relevant information from residents and locals of the ground truth sites (Table 1). Thus, very valuable information for complementing the image-based information and for understanding the complexity and diversity of land-based livelihoods in the area could be gained. Here, it proved sufficient to limit the VHR satellite imagery to the more diverse peri-urban area of the study site (Figure 1).

From ground truth investigation it was noted that the farming patterns in Mankweng is seen as home gardens attached to the residential property, mashemo (or community farms) and some commercial agriculture plots. Maize is the most important crop grown throughout the country and grown under diverse conditions (Baloyi, 2011). During the ground truthing, rarely diversified agriculture practices were observed in the region. As challenges, the lack of inputs such as irrigation facilities, financial aids and capacity building (cp. Oluwatayo & Rachoene, 2017) in addition to poor quality of soil, the size of land holding, crop diseases and the depleting quality of maize seeds were identified. However, these factors cannot be identified on the VHR imagery. Besides, in particular the younger population are not keen in pursuing a farming life. Cattle and poultry are prevalent in the areas ground truthed, but it is for self-subsistence only and seen as a status symbol within the community. Large cattle herds were observed more often in the rural part of the study area, which is in agreement with Puttick et al. (2014) who point to the diminishment of ranging lands. It is hoped that the census 2022 data will become available in time to complement the kraals to be detected in the WorldView-3 image (Table 2 and 3) and thus in half of the study area only.

Settlement structure types are vastly studied using the aid of VHR satellite imagery (e.g. Niebergall et al., 2008). Sentinel-2 imagery is widely used for studies in landcover as well as peri-urban and human settlement layer contexts (Helber et al., 2019; Phiri et al., 2020). For this present study the VHR imagery helped in identifying several housings structure types, particularly via four roof types such as slated roof, metal roof, thatched and unfinished roofs as listed in Table 2 and 3. This can be cautiously used as an identifier of household wealth in combination with other features like fruit trees, irrigated lawns and water tanks (see Table 3). Such an indirect assessment of socio-economic conditions will help in testing and strengthening the conceptual timeline of settlement development as visualized in Figure 3. However, the challenge remains that the areas are mixed in nature. Even the core peri-urban areas of Mankweng comprise of large permanent houses besides shacks of temporary materials. During the ground truthing subsidised housing, known as RDP houses, were seen clustered or scattered in the peri-urban and rural areas. These houses are hoped to be distinguished by their smaller size and simplicity in shape (Table 3). Settled areas are formally categorized as A, B, C, D and only unplanned settlements (D) without prior approval from the authorities are categorized as ‘illegal settlements’, while the term ‘less-formal’ is used for all settlements initiated by the traditional authorities (Polokwane Local Municipality, 2022). Distinguishing them based on their structure types is not easy due to their heterogeneity, especially when being built non-compliant to the formal regulations. Here the conceptual timeline (Figure 3) in combination with a time-series analysis (see Figure 4) will aid to understanding and distinguishing between settlement structure types.

The use of wild natural resources such as fuel wood, edible insects, wild herbs and wild fruits is common in many of the developing regions (Twine et al., 2003). Ward & Shackleton (2016) presented a detailed study on wild resource use along an urban-rural gradient in a place close by. In agreement to their paper, during ground truth it was seen that regardless of the economic status, the use of fuel wood collected or bought was prevalent. Despite improvements in electrification and government efforts, most South African households still rely on firewood for energy (Masekela & Semenya, 2021). Cow dung was also seen to be used in some sites. Traditional healers were found to be collecting wild herbs and plants. Seasonally, some wild edible fruits such as prickly pears are collected for sale or self-consumption. Identifying collection sites can be achieved with rule-based classification as indicated in Table 3. Sand mining has grown popular due to the increasing demand for construction in and around peri-urban regions (Malebana, 2021). Around Mankweng, illegal sand mining was seen to form an important livelihood from natural resources linked to unused mashemos and dry riverbeds, although studies state this can lead to loss of land and livelihood (Shackleton, 2020). Land degradation as a consequence, but also due to erosion, poor sanitation and illegal waste dumping, was extensively seen throughout the area. Some large garbage cans were observed in the ground truth sites, however, proper sanitation facilities are missing (Maphosa, 2017).

Services provided by the municipality in the region is notably running water and waste removal, while Eskom provides electricity. Despite the willingness of residents to pay for the above-mentioned services, there is a lack in infrastructure for providing the services (Nkoana et al., 2019). Similar challenges were found during ground truthing in multiple sites majorly categorized as 'less-formal' settlements. In certain sites, which have undergone regularization, water distribution happens bi-weekly in trucks provided by the municipality. Also private vendors were seen selling water in large cans. The influence of service provision forms an important part of settlement development (Figure 3) and was also reflected in the rezoning of the settlements (Figure 2). Only after OBIA of the World-View-3 imagery, a final zoning of the settlements of Mankweng and surroundings will be available, then thoroughly combining the remote-sensing based details with other geodatasets and the knowledge coproduced by involving informants.

6. CONCLUSION AND OUTLOOK

The findings of the ground truthing highlight the significant role that social grants, traditional farming practices, and the availability of services play in the spatial pattern which has evolved in the area and is constantly and rapidly changing. The peri-urban landscape has witnessed a reduction in dependence on land-based activities, with livelihood diversification moving away from indigenous practices, this particularly in Mankweng itself. The decline of land-based livelihoods is evident, with an increasing demand for residential areas paralleled by a decrease in farming land and in the interest to still rely on farming. Here, provision of services plays a vital role in area development and thus when identifying settlement structure types. The ground truth efforts provide a thorough basis for the subsequent OBIA of the WorldView-3 imagery and the scaling to the entire study area based on a Landsat/Sentinel-2 time series analysis. However, it has to be noted, that the analysis will only allow to provide a snapshot in time which is already out-dated, a fact which became evident during ground truth.

ACKNOWLEDGEMENTS

This work is based on the research supported wholly by the National Research Foundation of South Africa (Grant Number 136090) and the German Federal Ministry of Education and Research (Grant Number 01DG21049). The authors acknowledge the help of the student assistants Tshilidzi, Melon, Willem and the senior lab assistant Prudence who helped with translation and data collection. Special thanks to Izelque Botha for the arrangements and logistics on the ground.

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