Integrating Participatory and Technology-Driven Mapping in Namibia's Informal Settlement Upgrading

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Key Words: Community Based Organisation, Participatory Mapping, Informal Settlement Upgrading, Tenure Security, Municipal Policies

SUMMARY

The growth of informal settlements highlights the urgent need for affordable housing amidst challenges faced by local authorities in providing land at scale. Innovative approaches to mapping and upgrading informal settlements in a participatory manner have the potential to scale up these efforts and meet the needs of informal settlement communities for secure tenure and improved access to basic services. Through a series of case studies on tools, techniques, and approaches, we demonstrate what has proven effective in the Namibian context, identify areas for improvement, and outline strategies for scaling up these solutions. Drawing from experience in non-governmental organisations, community-based organisations, and academia, we focus on mapping technology, identifying the most efficient and cost-effective methods for mapping informal settlements. For over 30 years, community participation has emerged as the most successful approach to upgrading informal settlements, yet it remains the least adopted. Advancements in land survey have introduced unmanned aerial vehicles (UAVs) for mapping, which are crucial for identifying the status of informal settlements and supporting participatory designs of new settlement layouts. In this study, we compare various methods for aerial data capture, postprocessing, and participatory mapping platforms to support informal settlement mapping. A comparison of mapping approaches reveals that photogrammetry and lidar surveys offer distinct benefits, and the choice of approach depends on available budgets, skills, and capacity of local and national governments. This research indicates that scaling up informal settlement upgrading faces governance issues and limited institutionalisation of lessons learned from collaborative projects.

A collaborative approach to scaling up land and housing delivery would benefit from applying lessons from successful case studies and improving upon areas where scaling was limited due to technology, funding, or political willingness.

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1. INTRODUCTION

Informal settlement communities have been mapping their communities for over 30 years, an activity that has acted as a catalyst for improving living conditions. Researchers have identified various reasons mapping has been beneficial, one mainly is that mapping highlights the living conditions of households in the settlement and creates awareness about the environment (Livengood & Kunte, 2012). In addition, it can unite the residents and support advocacy work for securing land tenure security (Jamie Lundine et al., 2012). One of the most well mapped slums in the world is Kibera, in Nairobi- the settlement was actively mapped by professionals and communities members, and resulted in creating improved visibility and accessibility of information, and awareness about the settlement (Hagen, 2011). This provided a platform for stakeholders and communities to view the area not , only as a planning challenge, but also an area that has opportunities and is a living space for many residents in Nairobi. The Map of Kibera is available on OpenStreetMap and can be accessed at any time. There is now advancement in mapping of informal settlements using machine learning and remote sensing which can contribute to planning for informal settlements. Recent studies are focusing on looking at understanding expansion and growth of settlements(Yanet et al., 2025).

Detection of informal settlements can be achieved through image classification from free satellite images, which provides an essential tool for urban planners to use to inform urban planning. Detection of informal settlement in the form of using satellite images provides the physical geography of informal settlements. Ground truthing is still important as it adds an additional layer of value and wealth of information for informal settlement households. This truthing can be combined with the use of handheld GPS devices and additional population data input from informal settlement residents.

Drone mapping of informal settlements has become popular. This is because it allows for rapid and cost-effective data collection (Barnes et al., 2015). The resulting images also support ground truthing and enhance enumerations and mapping efforts. Advancements in mapping informal settlements demonstrate the availability of tools, technology and approaches that can facilitate upgrading at scale. Informal settlements neighbourhoods are permanent parts of urban areas in developing countries , but mapping alone isn't sufficient. It needs to be an active process involving the communities living there. Transformation happens when those affected are engaged and can contribute to scaling up upgrading.

This paper explores informal settlement upgrading broadly and specifically focuses on UAV mapping. It also provides background on the Shack Dwellers Federation's work and their participatory approach to upgrading informal settlements using open-source tools.

2. MATERIALS AND METHODS

This study involved a qualitative analysis of mapping methods and a compilation of knowledge from leading partitioners mapping of informal settlement and upgrading in Namibia. It also summarised information gathered by the Shack Dwellers Federation of Namibia on savings for land tenure security. The Shack Dwellers Federation (SDFN) is a local community-based organisation in Namibia supported by the Namibia Housing Action Group (NHAG), a national non-governmental organisation. Their work spans over 30 years and focuses on mobilising communities to improve tenure security and secure affordable adequate housing.

3. MAPPING INFORMAL SETTLEMENTS USING UAVs

UAV generated images can address critical limitations in availing timely images for informal settlement mapping. Images collected can provide a spatial resolution of 2-5cm (Ground Sample Distance) enabling identification of individual structures, boundary features, informal pathways, and other planning features capabilities essential for household enumeration, layout planning, and cadastral applications. Temporal resolution constitutes another critical advantage. Informal settlements have dynamic spatial characteristics, with continuous construction, demolition, and modification of structures. UAV surveys provide up to date images that can be used with planning activities, contrasting with satellite imagery that may be 6-12 months outdated. This temporal accuracy ensures planning decisions reflect current conditions rather than obsolete spatial configurations. Positional accuracy of 5-10cm (horizontal and vertical) when properly implemented enables precise layout planning, infrastructure design, and can potentially be used for cadastral applications. This accuracy exceeds Google Earth imagery, which typically exhibits 6–10m discrepancies in Namibian contexts due to both image inaccuracy and coordinate transformation limitations between WGS84 and local coordinate systems. Orthophotos offer benefits for informal settlement communities. This study demonstrates how they can be effectively integrated into workflows for upgrading these communities.

3.1. Planning Workflow Integration

Orthophotos enable multiple planning activities:

- **Household Registration:** Visual identification and digitization of dwelling units for enumeration , supporting community engagement and participatory planning processes.
- Layout Design: Precise delineation of existing structures, roads, and open spaces enables optimal plot configuration while minimizing structural relocations. Design accuracy directly translates to reduced implementation conflicts and community acceptance.
- **Infrastructure Planning:** Identification of existing water points, drainage patterns, electricity connections, and road networks informs infrastructure upgrading strategies and cost estimation.
- **Topographic Modelling:** Digital terrain models and contour maps enable engineering design for roads, stormwater management, and utility networks. Accurate terrain modelling proves particularly critical for low-gradient informal settlements where minor elevation differences significantly impact drainage design.
- **Cadastral Planning:** High accuracy orthophotos enable layout planning at cadastral precision, ensuring survey beacons placed during implementation correspond with planned plot boundaries. This alignment eliminates costly resurveys, layout modifications and structure relocations during formalization processes.

There is an interest on national level to map informal settlements using LiDAR technology for mapping informal settlements. This is specified in the Namibia governing party SWAPO's Implementation manifesto, as the Decent living: Land and Housing and Sanitation priority Area. The government aims to allocate N$ 2.5 billion formalising 50% of all informal settlements by 2029 , a portion of the funds will be for the commissioning of Aerial Lidar Surveys for mapping and profiling informal settlements(SWAPO, 2025, p. 33). To apply this technology to over 200 informal settlements we need to delve into the characteristics of LiDAR technology and its possible application for informal settlements.

3.2.LiDAR Technology Comparison

Light Detection and Ranging (LiDAR) technology addresses specific photogrammetric limitations through direct laser scanning rather than indirect optical imaging:

Vegetation Penetration and Bare-Earth Modelling: Multiple lasers return per emitted pulse enable modelling of vegetation and underlying ground surfaces. This capability proves essential for forested areas or settlements with substantial tree cover where photogrammetry generates only canopy surface models. Classification algorithms separate ground returns from vegetation, buildings, and other above-ground features, generating accurate digital terrain models even in areas with thick grass or dense vegetation. This capability ensures reliable contour generation for engineering applications regardless of vegetation conditions.

Infrastructure Detection: LiDAR reliably detects overhead power lines, telecommunications cables, and other linear infrastructure invisible or ambiguous in optical imagery. This capability supports utility planning and conflict identification during infrastructure upgrading.

However, LiDAR systems cost substantially more than photogrammetric UAVs (NAD 600,000+ versus NAD 90,000), generate massive datasets requiring specialized processing capabilities, and produce monochrome point clouds without inherent colour information. Photogrammetric systems collect RGB imagery, enabling both terrain modelling and orthophoto generation from a single survey. Hybrid systems mounting both LiDAR and optical cameras on a single platform represent optimal solutions for complex environments but at premium cost points.

For informal settlement applications, LiDAR proves necessary in fewer than 10% of cases. Typical informal settlements exhibit minimal vegetation cover and relatively open spatial structure, conditions under which photogrammetry performs optimally. LiDAR becomes essential only in scenarios involving dense tree cover, thick grass obscuring ground surface, or requirements for detailed vertical infrastructure mapping. To capture images using UAVs in Namibia, there are important legal and institutional requirements according to the Namibian Civil Aviation Authority.

3.3. Namibian Regulatory Framework for Use of UAVs

Namibian Civil Aviation Authority regulations classify drones as Remotely Piloted Vehicles (RPVs), implementing comprehensive operational controls(Republic of Namibia, 2020). Legal operation requires:

- **RPV Pilot License:** Requires completion of approved training program (NAD 28,000), Restricted Radio Telephony license (NAD 5,000), Class 3 medical certificate, and English language proficiency certification. Total licensing cost approximates NAD 40,000 with two-year validity requiring renewal.
- **Aircraft Registration:** Individual UAV registration with Namibia Civil Aviation Authority (NAD 1,000 per aircraft).
- **Third-Party Insurance:** Third Party Liability insurance covering potential damages from UAV operations (NAD 2,000+ annually depending on coverage limits and operational profile).
- **Letter of Approval (RLA):** Annual operational authorization for professional survey operations (NAD 4,500). Individual flight approvals may be required for operations in restricted airspace or populated areas.

General operational restrictions include Maximum altitude of 46 meters (150 feet) in uncontrolled airspace. Minimum 9.3-kilometre (5 nautical mile) distance from aerodromes without authorization. There is prohibition over populated areas without specific approval and over private property without landowner consent. There is absolute prohibition in national parks and game reserves without special authorization.

These regulatory requirements ensure operational safety and liability management but impose substantial cost barriers (NAD 50,000+ initial investment) and administrative overhead on practitioners. Regulatory compliance represents a necessary precondition for professional survey activities and quality assurance in cadastral or engineering applications.

3.4.Integration with Cadastral Systems

UAV photogrammetry demonstrates increasing potential for cadastral applications, though current practice remains primarily planning-focused rather than survey-grade cadastral:

Sectional Title Applications: High-resolution orthophotos enable precise building outline digitization for sectional title diagram preparation. Buildings captured before roof installation allow direct corner point identification, enabling rapid sectional plan development when combined with conventional surveying.

Layout Planning: Cadastral precision orthophotos enable layout planning ensuring survey beacons placed during implementation correspond precisely with planned boundaries. This alignment eliminates costly resurveys, layout modifications and structure relocations during formalization.

Flexible Land Tenure Systems (Republic of Namibia, 2012) for Land Hold Plan Development: Current practice employs UAV orthophotos for land hold planning, though without formal survey record retention. Regulatory modifications enabling land hold plan upgrading to general plans without resurvey would enhance efficiency, provided original surveys-maintained survey-grade accuracy and documentation standards.

Formal adoption of UAV based cadastral surveys in Namibia will require established quality assurance protocols, accuracy standards and survey regulations for photogrammetric survey methods several jurisdictions internationally have implemented such frameworks, providing potential models for Namibian adoption pending regulatory development and professional consensus on standards and survey regulations.

The choice of approach depends on available budgets, skills, and capacity of local and national governments. Scaling up informal settlement upgrading faces governance issues and limited institutionalisation of lessons learned from collaborative projects. The use of UAVs adds value to the work of the Shack Dwellers Federation of Namibia for securing land tenure and upgrading informal settlements.

4. SECURING LAND TENURE THROUGH COMMUNITY SAVING GROUPS

The Shack Dwellers Federation of Namibia (SDFN), with technical support from the Namibia Housing Action Group (NHAG), supports low-income families to build ultra-low-cost houses in Namibia. The main goal is to help poor households access secure land tenure and decent housing at an affordable cost. Communities are affiliated to the Slum Dwellers Internation, which has communities with saving schemes in over 30 countries. The saving scheme approach has been in place to promote community trust and the collective capacity to management finances for the improvement of living conditions(Muller & Mitlin, 2007). Support for housing development is secured through development cooperation agencies, local, and national government.

SDFN members are organised and negotiate for land access through support from NHAG. For housing development to take place, local authorities allocate affordable land. Once land is allocated, SDFN members pay for the land using their own savings, supported by loans from the Twahangana Fund. The Twahangana Fund is a revolving development fund managed by SDFN to support housing and land development. Access to affordable land remains one of the biggest challenges facing shack dwellers in Namibia. Currently, about 40.2 % of urban households in live in informal housing(Namibia Statistics Agency (NSA), 2024)., This situation makes it difficult for the country to fully address its housing crisis unless land access for low-income households is improved.

The approach of the SDFN provides a proven approach that can help communities meet the basic housing needs through community savings groups. These groups are formed in different regions of Namibia and include both women and men. Members save small amounts of money regularly, which helps them qualify for land and housing loans. SDFN members manage the construction of their own houses with technical guidance from NHAG. This community-led approach significantly reduces costs compared to contractor-driven housing projects. The cost of installing basic services (water, sewerage, or septic tanks) is approximately N$7,700 per household.

The average cost of constructing a house is N$40,000 for SDFN members. Houses are built with cement bricks and usually consist of two rooms, covering 34 square metres, with the option to extend up to 80 square metres. Almost all houses built by SDFN members have access to water and sanitation. Active participation by community members plays a major role in reducing c construction costs. To date, SDFN members have built more than 8,000 houses, making SDFN the largest low-cost housing initiative in Namibia. Community savings are a strong foundation of the SDFN model. To date, savings groups have collectively saved more than N$40 million. The Government of Namibia has contributed N$176,855,139.31 towards supporting land servicing and housing development. These combined contributions demonstrate the strength of partnerships between communities and government (Figure1)

Jan 2025 saving report							
REGION	nunber of groups	Members	Male	Female	Savings	6 months saving	land
ERONGO	226	6775	2375	4400	7,132,002.35	979,786.70	7,752,060.20
HARDAP	11	212	53	159	202,169.75	147,093.68	
KARAS	79	2768	743	2025	961,953.95	176,801.00	7,785.70
KAVANGO EAST	28	956	240	716	657,475.10	184,364.75	
KAVANGO WEST	26	438	120	318	488,182.32	69,292.00	
KHOMAS	141	6458	2956	3502	3,069,928.45	103,835.70	4,039,558.40
KUNENE	37	1940	926	1014	296,039.05	71,274.90	
OHANGWENA	40	729	158	571	1,680,064.80	733,337.30	
OMAHEKE	40	1105	283	822	849,133.87	259,855.85	425,013.63
OMUSATI	60	1516	295	1221	3,634,673.75	829,949.40	
OSHANA	78	1849	379	1470	4,217,575.23	855,307.45	0.00
OSHIKOTO	66	1396	307	1089	2,591,462.25	531,033.40	
OTJOZONDJUPA	59	1055	295	760	1,553,229.73	226,414.11	
ZAMBEZI	59	2032	499	1533	526,833.87	164,228.87	85,920.85
Total	950	29229	9629	19600	27,860,724.47	5,332,575.11	12,310,338.78
tota saving+land					40,171,063.25		

Figure 1 2025 members saving reports source: NHAG

The main opportunities include a strong community savings culture that enables low-income households to contribute financially and take ownership of their housing development, a proven low-cost and community-driven housing model that reduces construction costs while building local skills, and existing partnerships with local authorities, NHAG, and government, which create a solid foundation for scaling up affordable housing and secure land tenure initiatives. Scaling up land tenure security and affordable housing is possible if land access is improved and support to savings groups is strengthened.

The major lessons are that community savings empower low-income households by giving them financial control, and ownership. Secure land tenure is essential for long-term and sustainable housing development, community-led construction significantly reduces costs while building local skills, and strong partnerships between communities, NGOs, and government

The main challenges include the limited availability of affordable and serviced land, slow land allocation processes by some local authorities, and rising construction material costs, all of which delay housing development and increase the overall cost of providing affordable housing. Access to secure affordable and adequate housing is also supproted through participatory mapping and planning approaches, which seek to enage all community members within informal settlements(Delgado et al., 2020).

5. PARTICIPATORY MAPPING- THE CASE OF THE SHACK DWELLERS FEDERATION OF NAMIBIA

Mapping is an essential aspect of the informal settlement upgrading process, as it offers an understanding of the settlement and serves as the basis for the final layout planning, which used in re-blocking (Figure 2). Re-blocking is a participatory process that involves the community reorganizing the location of their structures according to a regularized layout, that is often approved by the local authority. Through relocking roads are planned and scrapped and households each settles on a measured land parcel with some agreed upon recognition and protection against eviction. This often comes in the form of a certificate of occupation or regurgitant of land occupation. The certificate will often have the structure number, location of shack and details of household occupants.

Precise mapping of structures ensures that planning decisions are guided by the actual conditions on the ground, helping to minimize disruptions to the community. The Community Land Information Program (CLIP) (SDFN-NHAG, 2009) team is trained to collect socio-economic data and conduct settlement mapping. This training is facilitated through learning exchanges with CLIP team members from other towns and settlements that have previously undergone the upgrading process. Volunteers from the community are trained on map reading, use of handheld GPS devices and the identification of structures. Once the team becomes familiar with the maps, they can easily identify features on the ground, making the mapping process more efficient and effective (Figure 2).

Figure 2 Members orientating themselves with an aerial image print out. Source: Authors

If there is an existing layout of the external boundaries of the settlement, local authority provides this to the teams, and together with the community, the settlement is subdivided into manageable blocks for data collection and community discussions. The CLIP team carries out community-led mapping within their respective blocks. Two teams operate simultaneously in the field: one team focuses on collecting household socio-economic data, while the other team is responsible for mapping.

Figure 3 printed drone image of informal settlement in Okahandja , Namibia source: Authors

A3 printed maps are used to map each block. All numbered structures are identified and classified as either permanent or non-permanent. Permanent structures are incorporated into the layout planning process to minimize displacement during re-blocking. The mapping team is also trained to identify and record services and infrastructure within the settlement, including water points, communal toilets, and waste collection points. Social and community facilities such as schools, churches, community halls, clinics, markets, and businesses are mapped. In addition, environmentally sensitive areas, including flood-prone zones and riverbeds, are identified and recorded.

All collected spatial data were digitized and processed using QGIS (Figure 7). Before mapping, the most recent available aerial imagery was acquired. Drone imagery was preferred due to its high spatial resolution. In towns where recent imagery was unavailable, Google Earth imagery was used as an alternative base map. Once all mapped data had been digitized and verified, it was overlaid on the base map and compiled into an A0 map displaying all key features. This map was presented to the community, which was divided into groups of four to develop concept layout plans. The concept layouts were then consolidated into a single layout that incorporated community inputs. The consolidated layout was presented to the community for further consultation (Figure 4) before being submitted to the local council for approval or amendment.

Figure 4 Presentation of layout to community

During the re-blocking phase, the approved layout, together with the mapped features, was used to allocate parcels and to ensure that no parcels were allocated within flood-prone areas. Socio-economic data were linked to mapped structures in QGIS using the structure number as a unique identifier. The final dataset was handed over to the municipality, where it can serve as a local land information system to support planning and service delivery. Despite the successes of the community-led mapping approach, several challenges are often encountered during the process. One of the main challenges is the availability and quality of base imagery. While drone imagery provided high-resolution and up-to-date information, it was not always readily available due to costs in some towns. In such cases, reliance on Google Earth imagery posed limitations related to outdated information and positional accuracy. Additionally, mapping flood-prone areas relied heavily on community knowledge, which, although valuable, needed to be complemented with technical assessments to reduce risk. UAV generated orthophotos can be printed directly from Open Aerial platform (Figure 5)

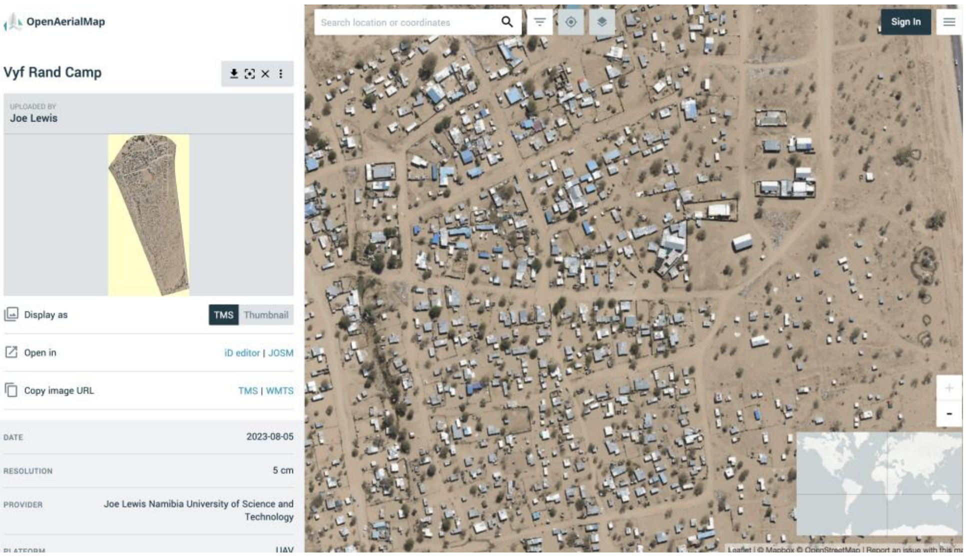

Figure 5 UAV image on Open Aerial, openly available for us Source: Open Aerial

One of the key lessons from the mapping processes is the importance of meaningful community participation. Training and involving the CLIP team ensured local ownership of the data and increased trust in the upgrading process. Communities were more willing to support re-blocking when they understood how the mapping informed layout planning. Another important lesson was the need to adapt data collection methods to local conditions and capacity. This flexible approach helped balance technical accuracy with inclusivity. Linking socio-economic data to spatial data using unique structure identifiers proved critical for creating an integrated dataset that could support long-term planning beyond the upgrading process.

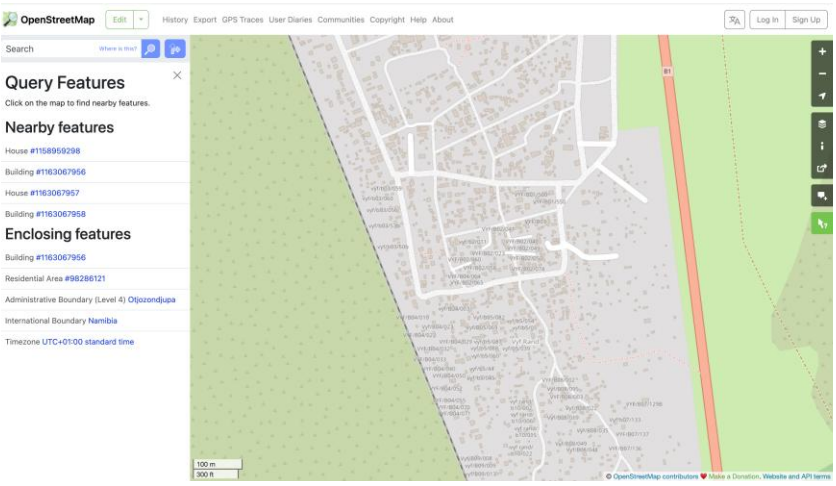

Figure 6 Informal settlement mapped on OpenStreetMap Source: OpenStreetMap

The mapping process provides several tangible and intangible benefits. Technically, it resulted in a comprehensive and verified spatial database that included structures, services, infrastructure, social facilities, and environmentally sensitive areas. This dataset directly informed layout planning and re-blocking, ensuring that permanent structures and flood-prone zones were considered, thereby minimizing displacement and risk.

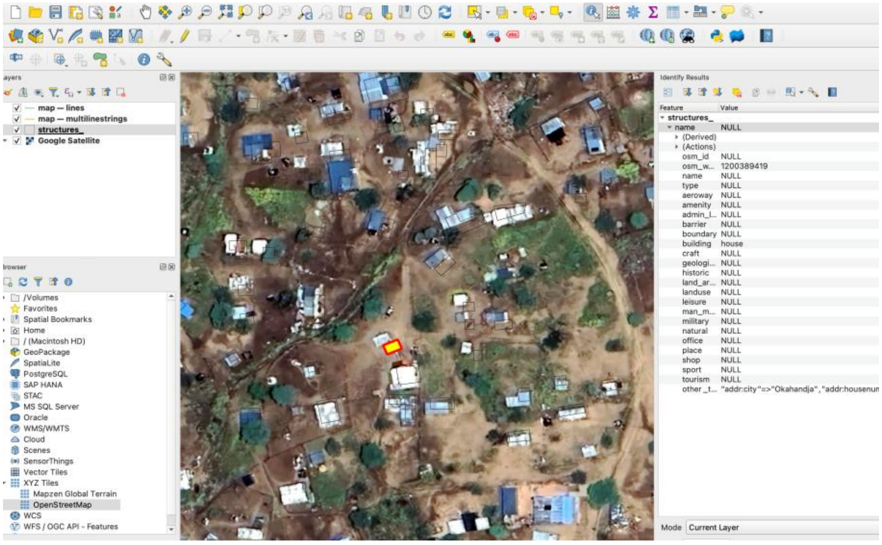

Figure 7 aerial image loaded into QGIS using Web Map Tile Service (WMTS)

From a social perspective, the community-led approach strengthened local capacity and empowerment. CLIP team members acquired practical skills in mapping, data collection, and spatial awareness, which can be applied in future upgrading initiatives. The participatory process also enhanced transparency and accountability, as community members could see how their inputs influenced final layouts. Institutionally, the integration of socio-economic and spatial data created a foundation for a local land information system. The handover of verified data to the municipality supports improved service delivery, land administration, and evidence-based decision-making. The process further strengthened collaboration between communities, NGOs, and local authorities. Learning exchanges between CLIP teams support cost-effective knowledge transfer and capacity building across towns and regions. The use of open-source tools such as Kobo Collect and QGIS further enhances scalability by reducing reliance on proprietary software, while allowing flexibility in imagery sources, including drone and publicly available satellite imagery.

Scaling up data collection and informal settlement upgrading

Scaling up informal settlement upgrading through mapping is essential for developing national data on informal settlements. This requires collaborative approaches and best practices in housing development like those of the SDFN . As adopting these approaches on a national level at scale will benefit all low-income communities. Engaging local communities and involving experts such as land surveyors in UAV image collection are crucial. The Revised National

Housing Policy of 2023 provides the framework for participation in upgrading. Lessons from areas like Freedom Square in Gobabis are vital for practical mapping and upgrading. Technical capacity and investment in local authority mapping hardware are also important. Finally, national governments and development agencies should prioritise continuous funding for NGO activities supporting CBOs.

CONCLUSION

Advancements in mapping informal settlements have provided stakeholders with crucial information and tools for planning and upgrading these communities using timely data. Expert support, such as from land surveyors who provide UAV images, is vital to the community process. This complements their efforts in organising and saving for tenure security. For over 30 years, informal settlement communities have been mapping their areas, which has significantly improved living conditions. To ensure data collection is both informative and supportive of community upgrades, remote data collection needs to be combined with local efforts. Light Detection and Ranging (LiDAR) technology addresses specific photogrammetric limitations by using direct laser scanning instead of indirect optical imaging. However, its use for local informal settlement upgrading requires considering the capacity of local authorities and the availability of the necessary hardware for data processing. UAV-generated images can overcome the critical limitation of timely availability for informal settlement mapping. A collaborative approach to scaling up land and housing delivery would benefit from applying lessons from successful case studies and improving upon areas where scaling was limited due to technology, funding, or political willingness

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BIOGRAPHICAL NOTES

Menare Royal Mabakeng, a PhD candidate at Namibia University of Science and Technology, focuses on land administration research. She studies how participatory data collection can support securing land tenure for residents of informal settlements. She worked with the Namibia Housing Action Group (NHAG) for over six years, coordinating technical support for community-driven data collection and supporting negotiations for informal settlement upgrading. Email: rmabakeng[at]nust.na

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Hendrina Shuunyuni-a seasoned Project Coordinator at the Namibia Housing Action Group (NHAG) with over 13 years of experience in social housing, community development, and communications, oversees project implementation, strengthens stakeholder engagement, and ensures effective documentation and communication of housing initiatives. Her master's degree in journalism and communication technology enhances her expertise in media, advocacy, and development work. She amplifies the work of the Shack Dwellers Federation of Namibia (SDFN) by securing media coverage that highlights community-led housing initiatives and policy-relevant issues. Email: hendrina[at]nhag.org.na/

Melky Namupolo is an expert in land management and GIS, with extensive experience in supporting informal settlements planning and development initiatives. He has coordinated the Community Land Information Program since 2016, facilitating spatial and socio-economic data collection and implementing upgrading projects in informal settlements across Namibia. His expertise includes land rights registration, the use of geographic information systems (GIS), urban development, and project management, all which support community-driven settlement upgrading initiatives under the SDFN and NHAG.Email: melki[at]nhag.org.na