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Evaluating the Societal Impact of Using Drones to Support Urban Upgrading Projects

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Abstract: Unmanned Aerial Vehicles (UAVs), or drones, have been gaining enormous popularity for many applications including informal settlement upgrading. Although UAVs can be used to efficiently collect highly detailed geospatial information, there are concerns regarding the ethical implications of its usage and the potential misuse of data. The aim of this study is therefore to evaluate the societal impacts of using UAVs for informal settlement mapping through two case studies in Eastern Africa. We discuss how the geospatial information they provide is beneficial from a technical perspective and analyze how the use of UAVs can be aligned with the values of: participation, empowerment, accountability, transparency, and equity. The local concept of privacy is investigated by asking citizens of the informal settlements to identify objects appearing in UAV images which they consider to be sensitive or private. As such, our research is an explicit example of how to increase citizen participation in the discussion of geospatial data security and privacy issues over urban areas and provides a framework of strategies illustrating how such issues can be addressed.

Keywords: Unmanned Aerial Vehicles (UAVs); urban planning; informal settlements; social impact; privacy

1. Introduction

Rapidly growing urban populations and an inability to meet affordable housing needs are some of the driving factors behind the emergence of informal settlements worldwide. It is estimated that 881 million people were living in slums in 2014, which corresponds to 29.7% of the urban population at that time [1]. This proportion may be much higher nationally, as estimates of the urban population living in slum areas reaches 77% in Tanzania and 96% in Rwanda [2]. The need of improving these conditions is considered one of the main challenges in urban development [3] and is a prominent issue on many urban agendas [4–7]. The current paradigm regarding urban upgrading projects encourages in situ upgrading which aims to improve the living conditions within a neighborhood itself [1,7,8] through the improvement of the physical infrastructure [9], while advocating effective participation of the local community [10]. The design of these infrastructural improvements, as well as urban governance in general [11], requires geospatial information [7,8,12]. This geospatial information generally consists of elements such as terrain elevation, building footprints, roads, drainage, powerlines, water pipelines, land use, services, parcels, and administrative boundaries [13]. Information pertaining to natural hazards such as natural drainage, landslides, and inundated areas may also be relevant [14]. However, consistent and up-to-date geospatial information is often lacking [15], especially for informal settlements. These are sometimes excluded from official data collection [16] and often remain ‘empty spots on the map’ [17]. Although Remote Sensing has emerged as a useful tool for the provision of spatial information for informal settlement management [18], the spatial resolution provided by satellite imagery is sometimes not sufficient for e.g., the detection of individual houses, infrastructure, and details of environmental conditions.

Unmanned Aerial Vehicles (UAVs), also known as drones or Remotely Piloted Aircraft Systems (RPAS), are a potential solution for this issue. A UAV equipped with a camera can take images of the area it flies over. These images can be used to obtain detailed elevation models and orthoimagery. UAVs have been gaining enormous popularity for many applications, from recreational uses by hobbyists to serving as a genuine data collection tool by businesses and local governments. Some projections estimate the global commercial UAV market to have a value of seven billion dollars in 2020 [19]. Recently, there have been a number of projects using UAVs for mapping informal settlements including in Rwanda [13], Tanzania [20], Uruguay [21], and Albania [22].

The main motivation for the use of UAVs in urban upgrading projects is the perceived utility of the geospatial information that they obtain. It is important to understand the range of (technical) benefits of this geospatial information as it is a strong driver behind the deployment of UAVs and therefore provides context to the social impact analysis. We distinguish three categories which describe how UAVs can provide geospatial data to support urban upgrading projects (Table 1). The first category is data which can be directly derived from UAV imagery. Objects such as roads and building footprints may be first digitized over imagery in the office, and later updated and verified during field visits. Satellite imagery or outdated aerial imagery is often used as a basis for digitization, but having access to recent UAV imagery may greatly speed up both the digitization and the field verification [13]. The second category refers to spatial information for which the UAV imagery by itself cannot be used as a complete and accurate data source, but may be (partially) derived from the UAV data. This refers to the attributes of larger objects, such as identifying housing material which may be visible in some of the original UAV images. It also refers to objects which are relatively small (lamp posts) or sometimes lie below other objects (drains that run below covers or under roads). Other information can be derived from UAV data, but require advanced processing (e.g., the number of stories in each building can be approximated from the height difference between the ground and roofs) or local knowledge (e.g., water distribution points may be recognized by the piles of uniform water containers outside the building). Geospatial information in this second category can generally be used to support informed decision making when supplemented by additional data sources, advanced processing or local knowledge, but cannot by itself be used to provide the completeness and accuracy required for mapping. The local context greatly influences whether a certain type of information falls into the first (i.e., is clearly visible in the UAV data) or second category. Finally, the third category is geospatial data which cannot be identified from the UAV imagery. This can be 'invisible' data such as administrative boundaries which are social constructs and have no physical representation or information which may have a physical representation but are not visible in the UAV imagery, such as population counts.

Table 1. Examples of geospatial information derivable from UAV images.

Directly Derived from UAV Data	Partially or Indirectly Derived from UAV Data	Not Derived from UAV Data
Buildings	Attribute information (construction material, number of floors)	Administrative boundaries
Roads	Utilities	Population count
Vegetation	Land use	Household income
Elevation	Solid waste dump sites	

Although UAVs have great potential for the provision of geospatial information in upgrading projects [13], there are concerns regarding the ethical implications of their usage [23] and the potential misuse of data [24]. Privacy is often stated as a concern as UAVs may infringe on: *privacy of location* when individuals can be identified and located in the UAV images, *privacy of behavior* in a private space without being monitored by others, *privacy of space* as information is revealed regarding private areas such as back yards, *privacy of association* regarding group membership and affiliations, and *privacy of data and image* regarding the control of persons over images in which they are present [25]. The perceptions of the local population [26] are also a concern. Especially when flying over marginalized communities, it is important to notify citizens of the purpose of data collection, the rights to access, data processing and distribution [27]. The lack of a unified policy framework directing such practices leaves much of the responsibility to industry self-regulation, which may not sufficiently protect these marginalized communities [28].

However, the existence of such a 'unified' framework is questionable due to two specific challenges. Firstly, the ethical use of UAVs is dependent on the application for which it is used [29]. For example, one ethical concern is inadvertently capturing imagery of persons or privates spaces. This risk is higher when using UAVs for real estate applications than pipeline monitoring [30]. Especially in the case of the latter, ethical UAV operations can aim to avoid the inadvertent collection of persons in their data, but when using UAVs to videotape concerts for example this is unavoidable. On the other hand, as crowds at a concert are in a public space anyway, a "chilling effect" of being observed by the UAV will be limited [30]. For journalism, context (e.g., what is the reason why a protesting crowd captured by UAV imagery is protesting?) and conflict of interest (e.g., should footage of potentially conflicting activities be turned over to law enforcement?) are important ethical concerns [24]. These examples clearly illustrate how ethics are dependent on the application.

Secondly, the concept of sensitive information or privacy may vary amongst people, groups, and cultures [15]. For example, a study of the privacy awareness behavior of almost 200,000 Facebook users from 30 countries showed a strong correlation with cultural dimensions, even when corrected for socio-economic indicators [31]. In another example, a European study of seven countries indicated that younger age groups have a lower privacy concern but higher data protective behavior than older groups [32]. At a policy level, research has related Hofstede's concepts of "collectivist" and high "power distance" national cultures with a reluctance to implement open data initiatives [33].

These challenges suggest a need to use a case-by-case method to weigh the infringement of (mainly individual) moral rights and ethical values against the assumed common good achieved through the use of UAVs for data acquisition and provision [24]. Such qualitative research is important for the ethical usage of UAVs, but also to promote the continuation of similar efforts in the future [26]. Previous studies have made efforts towards the development of conceptual framework, for example an analysis of six different emerging technologies identified seven different concepts of privacy [25]. This enables other studies to focus on a single aspect of privacy, such as the effect of the surveillance capability of UAVs on the behavior privacy [28]. Still, there is a lack of empirical knowledge investigating ethical concerns [26]. One comprehensive study in Europe provides an overview of the perceptions and practices of industry, regulators and civil society [29]. Another study in Tanzania focused on the perceptions and concerns of various private and public parties regarding the usage of UAVs for mapping purposes [34], but does not analyze in detail the privacy concerns of the image products obtained from these flights and their potential distribution.

The aim of this study is therefore to evaluate societal impacts of using UAVs for informal settlement mapping through two case studies in Eastern Africa. In analyzing their social impacts, we define 'ethical usage' of UAVs as the extent to which their use is aligned with the values of: participation, empowerment, accountability and transparency, and equity, as these values are characteristic of global policy frameworks regarding urban upgrading projects and urban governance in general. Specific emphasis is given to identifying if the local communities consider any of the objects captured by the UAV imagery to be sensitive.

The remainder of the manuscript is organized as follows. Section 2 provides background information of the two case study areas and UAV acquisitions and describes the questionnaires used to interview the residents. Section 3 summarizes and interprets the results of these questionnaires. In Section 4, these results are further interpreted by discussing the relations between UAV image acquisition to the values of privacy, empowerment, accountability, transparency, equity, and participation. Finally, Section 5 draws conclusions from these observations and analyses.

2. Materials and Methods

We utilize a comparative case study approach to compare the use and impact of UAV imagery for mapping impoverished settlements in two projects: an urban upgrading project in Kigali, Rwanda and a participatory mapping program aimed at improving urban resilience in Dar es Salaam, Tanzania. The projects have several similarities. In both cases, the deployment of the UAVs was not initiated by the residents, but rather by external institutions (the University of Twente in Kigali, and The World Bank in Dar es Salaam) in conjunction with the local governments. As far as the authors are aware, this was the first utilization of UAVs for mapping purposes over both locations. The maps derived from the imagery could be sensitive as, in both locations, some residents could be subject to displacement. In Kigali, some residents may be displaced to make space for new roads or other infrastructure. In Dar es Salaam, many residents of houses that are located on river floodplains are threatened with displacement.

However, there are also some key differences between both case studies. The maps in Kigali were created by (foreign) engineering consultants and the local government, whereas a participatory mapping approach was adopted in Dar es Salaam. The distribution of the soft copies of the orthophoto mosaics and derived geospatial data was limited to the official project partners in Kigali, whereas in the case of Dar es Salaam they are freely accessible for the public through OpenStreetMap and a webportal (ramanihuria.org). The social context of both areas also differs, causing differences in the physical appearance of the informal settlements in the imagery as well as the local interpretation of objects and their significance by the residents. In the following section, both case studies are described in more detail.

2.1. Case Study I—Kigali, Rwanda

After a city-wide inventory of the status of informal settlements in Kigali, the Agatare neighborhood was selected by national, municipal, and district authorities to serve as a pilot project for urban upgrading projects [35]. The project employed a participatory approach to identify key issues in the neighborhood and propose infrastructural improvements. The methodology developed during this pilot project will serve to develop upgrading guidelines nation-wide [7]. The project area is roughly 86 ha, with an estimated 3977 households and 18,914 individuals at the time of the pilot project [35]. Field investigations indicated that approximately 24% of respondents have a member in the household who works in the formal sector such as government of NGOs, whereas 27% of the household are employed informally (vendors, mechanics, construction, etc.). Roughly 40% of the households had an income of less than 100 euros per month at the time [31].

During the pilot study in May/June 2015, UAV imagery was acquired over the project area through a collaboration of the University of Twente—Faculty ITC and the City of Kigali One Stop Center (CoK-OSC). The UAV was a DJI Phantom 2 Vision+ quadcopter (i.e., a rotary-wing UAV with four rotors). Eighty-nine flights were made in total, taking more than 15,000 images. These images were then processed to obtain an orthomosaic with a spatial resolution of 3 cm. More information regarding the UAV flights and data processing can be found in [36]. Local village officials were notified when UAV flights would take place over their neighborhoods, with the idea that they would be able to further notify the residents of the area and answer any concerns they might have.

The raw UAV data and point clouds remain in the hands of the organization executing the UAV flights (University of Twente/Faculty ITC). The orthomosaic was provided to the CoK-OSC, and has been used by various consultants to support the design of interventions in subsequent stages of the upgrading project. Consultants of the upgrading project in Kigali described how the UAV imagery was beneficial for: reducing the time needed to collect data, providing previously unavailable information (such as solid waste accumulation sites), improving field work efficiency, designing more appropriate infrastructure interventions, communication between stakeholders, and mitigating expropriation [13]. Printed hardcopies of the UAV orthomosaic at scale of approximately 1:1000 overlaid with vector layers representing the planned project interventions and administrative boundaries, were also provided to the local sector offices by the CoK-OSC, where they are used by local officials and residents when discussing upgrading or general development issues.

2.2. Case Study II—Dar es Salaam, Tanzania

Ramani Huria is a large-scale community mapping project in Dar es Salaam, funded by The World Bank and the United Kingdom's Department for International Development (DFID) under the Tanzanian Urban Resilience Program. Its objective is to improve urban resilience to flooding by providing accurate spatial information to support planning decisions. The project started with the mapping of the Tandale Ward in 2015. In 2017, the project was scaled up with the intent of mapping the entire city of Dar es Salaam. Local university students are mobilized to digitize buildings and urban infrastructure from imagery, which is then refined and populated with detailed attribute information in the field through the engagement of community members. One important aspect of the community outreach is their involvement in mapping areas prone to flooding.

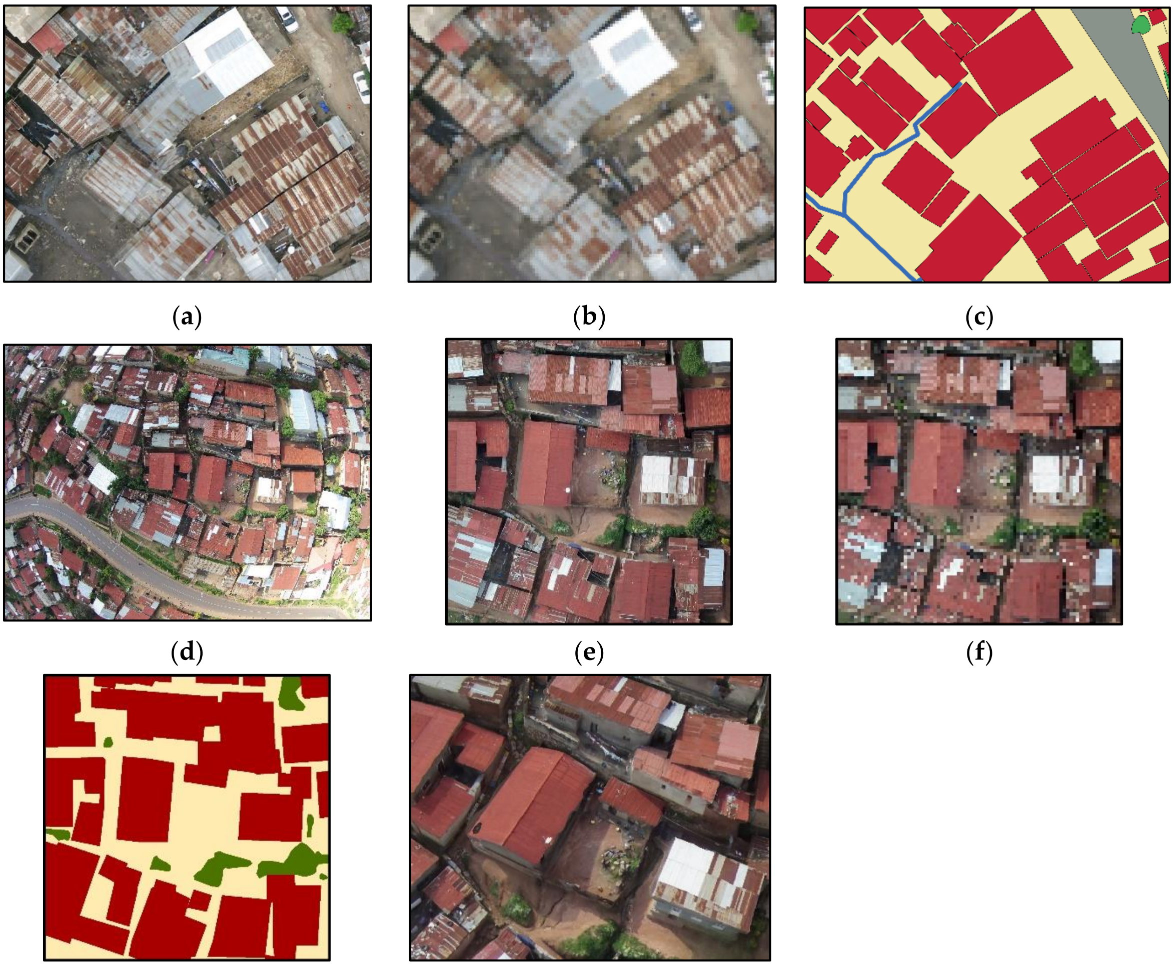
To support the mapping process, UAV flights were conducted over a large part of the city in 2015 using a Sensefly eBee. The images were processed to obtain orthomosaics with a spatial resolution of 5 cm. The orthomosaics were published online by the Tanzania Open Data Initiative. Vector layers of buildings, roads, drainage, and inundated areas are published in OpenStreetMap. An atlas was made which translates the Ramani Huria data into three maps for each ward: general topographic, drainage, and potential inundation. Local ward offices were also provided with printed maps of their ward and copies of the atlas.

2.3. Methodology to Analyze Perceptions of the Local Community

Data on the potential social impact on the community was collected via resident questionnaires. The questionnaires consisted of two parts. The first consisted of open questions regarding residents' perceptions of the UAV flights and usefulness of the derived geospatial information. This part of the questionnaire aimed to answer the following questions:

- Citizen perceptions to the UAV flights: Did you see the UAV flights? What did you think?
- Citizen awareness of the implications of UAV flights: Have you seen other UAV flights and where? Have you seen aerial imagery before? What do you see in this example of aerial imagery?
- Citizen ability to control possibly sensitive data captured in the imagery: Were you aware the flights would take place? Are you aware of any issues being discussed at neighborhood level regarding privacy?
- The observed and perceived usage of UAV imagery and maps: Did you see the maps printed at the ward office? What were they used for and by whom? What do you think they could be used for?

The second part of the questionnaire aimed to identify which objects are considered as sensitive due to possible privacy or security concerns of the residents at various levels of abstraction (Figure 1). It showed examples of UAV orthomosaics at full resolution (i.e., 3 cm in Kigali and 5 cm in Dar es Salaam), the degraded orthomosaics downsampled to 50 cm (i.e., similar to high-resolution satellite imagery), and vector maps derived from the UAV imagery. In Kigali, the residents were also displayed a raw UAV image and a 3D mesh model. Such products were not available for Dar es Salaam. For both cities, an area of interest was selected which was representative of the settlement, and contained a clear view of resident's back yard, people, and cars. In the case of Dar es Salaam the areas also contained visible open drainage and roofless toilets. For each data format, the resident was asked to imagine that they lived in the depicted area. Then they were asked which objects or places visible in the image they would consider to be sensitive if seen by (a) their neighbors; (b) village/ward leaders; (c) other institutions; or (d) the public (i.e., published online). The intention being to investigate how privacy relates to the identity of the viewer.



(**a**) (**b**) (**c**)
(**d**) (**e**) (**f**)
(**g**) (**h**)

Figure 1. The UAV orthomosaic (**a**), blurred orthomosaic (**b**); and vector map (**c**) images used for the Dar es Salaam questionnaire and the raw UAV image (**d**); UAV orthomosaic (**e**); blurred orthomosaic (**f**); vector map (**g**); and 3D mesh (**h**) images used for the Kigali questionnaire.

In Kigali, 54 interviews (57% female) were conducted in 2017 by selecting a section of the upgrading project area and interviewing residents who were home. Interviews were conducted in the local language (Kinyarwanda) by two local students and the support of one of the authors. The interviewers had experience in conducting questionnaires and were trained regarding the purpose of the study. The area was selected as: (i) it was subject to another set of UAV flights earlier the same year so perhaps more citizens have seen the flights; and (ii) it was transected by a new road which was implemented as part of the upgrading program. Interviews were conducted during working days and hours, the same as the UAV flights, in an effort to target parts of the population which were more likely to have seen the flights.

In Dar es Salaam, a digital format of the questionnaire was developed in ODK Collect. University students used the questionnaire to interview 26 community members (39% female) who were recruited as part of the Ramani Huria community outreach activities. The interviews were again conducted during working days and hours for the same reasons stated above. The questionnaire was translated to the local language (Swahili), and interviews were conducted in the same. The students conducting the interviews had previously received extensive training in surveying and interacting with community members.

3. Results

3.1. Perceived and Actual Usage of UAV Data

Community members in both Kigali and Dar es Salaam could access the UAV products through hard copy maps distributed to local governmental offices. In Kigali, 41% of the respondents report seeing these maps at the sector offices. These maps were mainly being used by the sector officers for development, management, and explaining the Kigali City Master Plan to the local community. Only 18% of the reported cases mention to the maps being used by the general public. They mentioned using the maps for "locating" or "giving directions". However, when asked about what they thought the maps could be useful for (i.e., perceived usage of UAV data products), this proportion went up to 55%; an improvement but still quite low. However, in both cities, it is uncommon for low income residents to have access and use maps on a regular basis. Respondents in Kigali also reported that the maps could be useful for businessmen or tax and land tenure purposes.

In Dar es Salaam, only 35% of the respondents reported seeing the maps at the ward office being used, and only 11% of the reported use cases refer to usage by the general public for locating purposes. However, when asked for the perceived usage, 29% of the reported the leader using the imagery for planning purposes, 46% mentioned the public using the imagery for locating or giving directions, 33% reported using the images for map making, and 13% reported using the imagery for educational purposes.

3.2. Residents' Perceptions Regarding UAV Flights

There are two main points of community members' perceptions to UAV flights which are of interest for the current investigation. Firstly, what are the initial reactions or emotions of the community members to the UAV flights? Secondly, are the community members aware of the purpose of the flights, and the implications thereof?

According to the questionnaires, 76% of the respondents saw UAV flights in Kigali, yet only one citizen reported knowing the flights would take place. In Dar es Salaam, only 31% of the respondents saw the flights, and 12% of the respondents were aware flights would take place. Few community members reported strong negative reactions when seeing the UAVs flying. Five respondents in Kigali reported negative reactions: believing that the UAV would destroy a building, spying, and two reported fear of expropriation. In Dar es Salaam, one respondent reported feeling afraid when seeing the flights, though it is unclear why. Fortunately, most respondents who saw the UAV flights had neutral or positive reactions. In Kigali, 59% thought the drone was taking pictures, 12% thought it was for the road construction, 17% mentioned other neutral reactions (e.g., "at first we thought they were toys"), and 7% mentioned other positive reactions (e.g., "we were happy to see a plane flying over our house" and "I was amazed"). In Dar es Salaam, 25% thought the UAV was taking pictures and 63% mentioned other neutral reactions. A study in Zanzibar similarly concluded that responses of the community to the UAV flights were generally positive, even if members were previously unaware of UAVs [34].

The second question is whether community members perceived that the UAV was taking pictures or otherwise observing them. Seventy-six percent of the respondents in Kigali saw the UAV flying, and 59% of them realized that the UAV was capable of taking pictures or videos. In Dar es Salaam, 31% of the respondents saw the UAV, of which only 25% explicitly mentioned a camera. Thirty-eight percent recognized the UAV as a drone but did not specifically indicate that they were aware that it had a camera. It can be expected that as UAVs are becoming more prevalent in the general society, more community members will be aware that the UAVs flying overhead are likely to be observing them. For example, five respondents in Kigali reported seeing the use of a UAV to capture videos of the Tour du Rwanda cycling event in 2016. In Dar es Salaam, half the respondents indicated seeing UAVs elsewhere such as weddings or concerts. The connection between UAVs and aerial photography will almost certainly become more well known.

3.3. Privacy

Knowing that the UAV is observing the ground below is not the same as understanding the detail of the image products and the implications of its use for mapping. Regarding the five types of privacy discussed above, respondents did not list 'people' as being privacy sensitive even though the image samples used for the questionnaires in Kigali and Dar es Salaam were selected to include people. Upon further questioning, they reported that although the orthomosaics depicted persons, they could not be recognized and their visibility was not perceived as a cause of concern. This would indicate that *privacy of location* and *privacy of association* are not considered to be at risk in these specific locations and contexts. The *privacy of space* is relevant as the UAV images display private spaces such as backyards, which are not openly visible from the ground as the view is blocked by fences and walls. Similarly, the *privacy of behavior* is affected as objects in the backyard may shed light on the private activities performed by the household. The *privacy of data and image* is also relevant as the community members have little control over the usage of the data collected by the UAV.

Results of the questionnaires shed more light on the privacies of *space* and *behavior* in the two case studies by allowing community members to list objects which they considered to be private. The *privacy of data and image* is addressed by asking the respondents for the sensitivity of these objects for use cases by various end-users. Questionnaire responses indicate that there are substantial differences between both case studies regarding the type of objects and types of data products which were considered sensitive or private.

In Kigali, the main concern were old roofs, and 'rubbish' on roofs and in backyards (Figure 2a). Respondents did not wish these to be seen by the neighbors (13%), local leaders (11%), and other institutions (11%), whereas 24% of the respondents wouldn't like the orthomosaics showing these objects to be published online and available for the (international) public. In fact, although one respondent explicitly wished foreigners to see the old roofs, because "maybe they can provide help", in general more respondents wished to hide the dirty roofs from the foreigners more than the neighbors, local leaders, or other institutions. When further questioning queried the apparent lack of sensitivity of objects such as laundry hanging out to dry and cars in driveways, respondents answered that such behavior was 'normal' and so what would be their concern if others were to see it? With the exception of a single respondent declaring old roofs in the blurred image being considered as private, the respondents in Kigali indicated that sensitive objects were not clearly visible in the blurred orthomosaics (i.e., simulated high-resolution satellite images) or vector maps.

Further investigation of the local context can help interpret the results of the questionnaire. First, the informal settlements in Kigali generally consist of multiple households on a single plot. Therefore, backyards are generally not considered as private spaces in these areas as many unrelated people are passing by on a daily basis. This explains why many objects on display in backyards are not considered to be sensitive if their visibility is shared with a wider public through the UAV data. On the other hand, the concern with the low-quality roofing or 'rubbish' indicates that the inhabitant of that house is deviating from the social norm of cleanliness. This causes a feeling of shame, as clearly indicated by one respondent: "It is embarrassing to show everyone that your house roof is old and dirty". Another: "It may cause problems if everyone sees that the roof of my house is old." The importance of 'cleanliness' is also emphasized by the government. For example, the Mayor of Kigali stated "the development [in Rwanda] is very fast and the cleanliness is talked about the world over. Let everyone be responsible" [37]. This is reinforced by the legislation, as Article 107 of the Organic Law on Environment of 2005 states: "Any person who deposits, abandons or dumps waste [. . .] in a public or private place, is punished by a fine" [38]. As such, the high-resolution orthomosaics may be evidence documenting which houses are not meeting the development or cleanliness aspirations of the local community and government and perhaps incur fines.

Responses in Dar es Salaam were quite different (Figure 2b). Only three respondents listed rubbish in the orthomosaic as being a sensitive object. Rather, toilets were listed as the main sensitive object in the orthomosaic. Ten of the respondents would not like these to be seen by neighbors, local leaders or the general public, and four would rather they not be seen by other institutions. It should be noted that in this case, the roofless structures housing the toilets were shadowed and so persons or objects inside these structure could not be distinguished. Yet the idea of a UAV peering into the toilets was enough to make it considered sensitive, even in the blurred orthomosaic images.

Other objects which were commonly named were wetland, drainage, and buildings (Figure 2d). Even in the vector map, 12–15% of the respondents did not want maps with these objects to be distributed. One interpretation of these results leads back to the flooding issues in the region. Flooding is a large problem in the city, and construction in the wetlands is restricted by the government. The delineation of buildings combined with the mapping of flooded areas is therefore an understandable cause of concern for the inhabitants of these buildings.

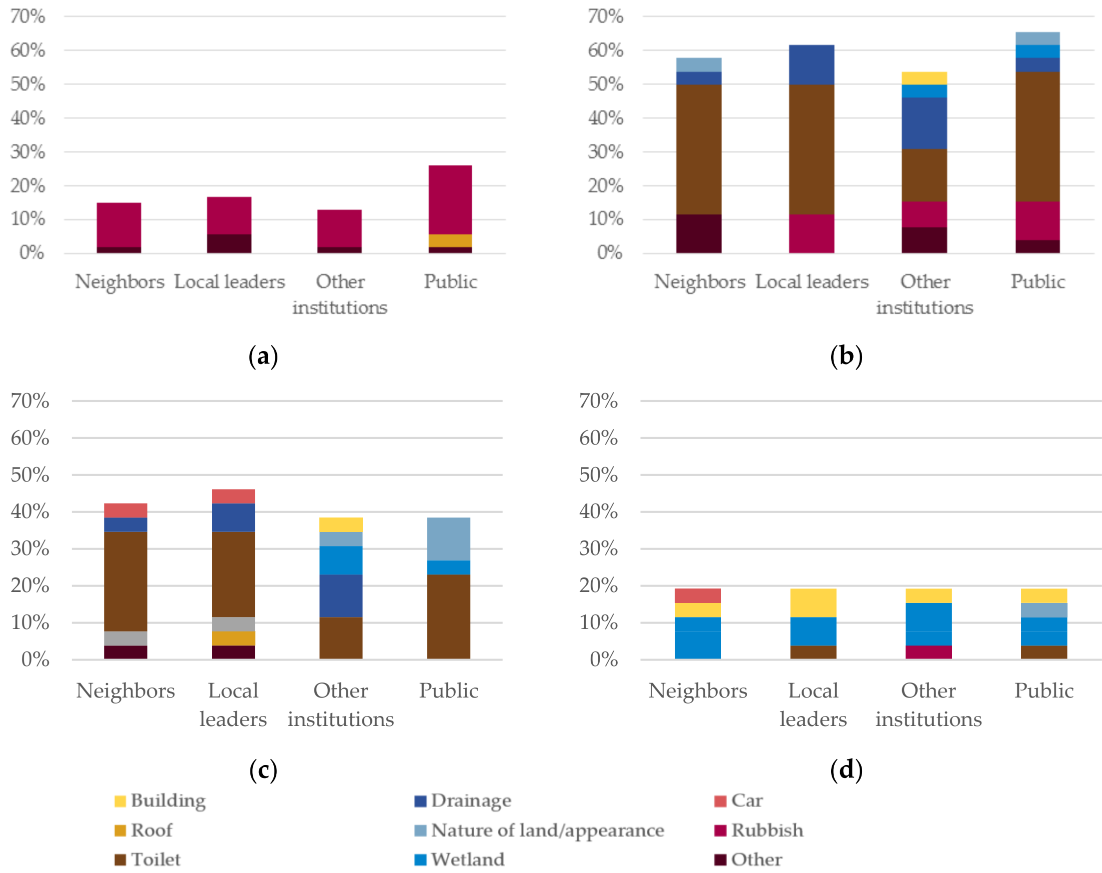


Figure 2. Percentage of questionnaire respondents considering an object visibly sensitive in: the high-resolution UAV orthomosaic in Kigali (**a**) and Dar es Salaam (**b**). The privacy sensitive objects in the blurred orthomosaic (**c**) and vector map (**d**) also provided for the Dar es Salaam case study.

4. Discussion

4.1. Privacy, Unintended Usage, Empowerment, and Trust

The results of the questionnaires illustrate the importance of local context regarding privacy issues. Both case studies appear quite similar—both are related to flying UAVs over deprived areas for mapping purposes. Yet the objects considered as private by the local communities are quite different. Some concerns regarding sensitive objects and data distribution are linked to unintended usage of the UAV data. Residents in Kigali are concerned with being confronted with 'messy' roofs and backyards and the shame associated with having such transgressions being available to the wider public. In Dar es Salaam and Kigali there are concerns regarding expropriation. These uses are not the direct motivation of the UAV mapping activities, but may be perceived as such. We identify three strategies for addressing sensitive objects in UAV data products (i) *avoidable*; (ii) *unavoidable but removable*; and (iii) *unavoidable and irremovable*, and describe how these strategies are related to the potential misuse of the data (Table 2).

Table 2. Categories of sensitive objects and possible strategies to address residents' concept of sensitive objects.

Sensitive Object Characteristics	Examples	Privacy Protection Strategy	Geodata Containing Objects
Avoidable	Rubbish Cars	Notify residents before flights Notify residents of image capture	None
Unavoidable but removable	Roof quality Toilets	Blur orthoimagery	Raw images
Unavoidable and irremovable	Houses in wetlands	Identify/mitigate potential misuse	All data products

Some objects which are considered sensitive are *avoidable*. For example, the sensitivity of rubbish on roofs and in back yards in Kigali. The presence of these objects in the imagery can be controlled by the local residents if they are informed the flights will take place and have an understanding of the implications of the UAV flights. From both case studies, it was clear that very few residents were aware the flights occur. Fifty-nine percent of the residents who saw the flights in Kigali realized the UAV was taking pictures or videos, though this was only 25% in Dar es Salaam. Ensuring that residents understand the observation capabilities of UAVs and when flights will take place also empower them to control which objects are visible in the UAV image. This is also the best way to protect sensitive objects against unintended uses, as they are not captured by the camera in the first place. On the other hand, it could be argued that in this case the privacy of space is improved at the cost of the privacy of behavior as the form of overt surveillance stifles illegal or discouraged behavior [28].

In other cases, the sensitive objects are *unavoidable but removable*. Their presence in the images will be difficult to control by the local residents. Here, the privacy of the residents can be controlled through blurring certain parts of the image and/or restricting the data distribution. Indeed, there are reports of operators blurring people or cars in their UAV images before distribution, but coordinated efforts are difficult due to a lack of clear guidelines [29]. The roofless toilets in Tanzania would fall into this category. This mode of respecting the privacy of the residents, however, depends on the ethical conduct of the UAV operators and requires trust between the institutions. It may also require a formal procedural check of image content to be made before public release and distribution. It has been noted that such self-regulation does not sufficiently protect the privacy of residents [28]. Limiting the distribution of data may serve to respect the privacy of the inhabitants and prevent misuse of the data for other purposes. However, the raw UAV data will likely be stored, and may therefore be (mis)used in the future for other purposes.

The third category of sensitive objects are *unavoidable and irremovable*. Their presence may be considered as private even when presented in vector format. The presence of buildings in flood-prone areas of Dar es Salaam is the most prominent example. This is the most difficult category to address, as the objects considered as private are directly related to the objects of interest for the mapping activities. Due to the scale of these objects, this is not a problem specific to the use of UAV imagery, as the data could be obtained through high-resolution satellite imagery or other participatory mapping applications. Indeed, the decision of which objects to put on a map may be a politicized decision. For example, informal settlements are sometimes purposefully excluded from official statistics [16].

4.2. Collaboration, Transparency, and Accountability

A map is politicized as there is always a person or body responsible for deciding which information is represented in the map. Once this information is categorized, it leaves little space for alternative interpretations. Imagery, however, can be interpreted in different ways. In the case of urban upgrading projects, the high-resolution imagery improved communication between stakeholders as it created a common visual format for communications. In Kigali, displaying the planned project interventions over the UAV imagery helped community members identify, locate and discuss issues in the area. Consultants could explain where planned project interventions are located and why, which improves the transparency behind the decisions of the upgrading interventions.

As the appearance of the settlement changes with time, the imagery provides concrete evidence of a previous state of the settlement. For example, when there are legal frameworks which guarantee citizens a right to compensation in case of expropriation, the image proves the existence of a dwelling, enables its size to be measured, and perhaps conveys some information on its materials and quality. Any building or plot characteristics present in the image could be used for valuation purposes. In Kenya, a community-based enumeration campaign was initiated to provide slum dwellers with documentation to give them legal protection in the case of expropriation [39]. It is easy to imagine an application where UAVs are utilized to provide such information at a larger scale.

4.3. Equity and Participation

An 'ethical usage' of UAV imagery depends not only on the mitigation of negative issues such as privacy, but also on a more equitable distribution of the benefits. Although geospatial technologies may support informed decision making regarding urban issues, it is important to ensure that those with no access to the knowledge nor the capacity to use it are not excluded [40].

Providing hard copies of the UAV imagery to local governmental offices is a successful way to return the information to community members. In Kigali, 70% of the interviewees could name a use case for the aerial imagery presented in the questionnaire. Out of these, 61% were examples of how the images could be used by businessmen or the general public. This means that 43% of the community members interviewed in Kigali could think of how the images could be useful for the general population. In Dar es Salaam, 46% of the respondents named examples of how the images could be useful for the general public. However, 13% of the respondents also indicated that the community members should be trained to use the images. It remains a question to which degree such training should accompany the distribution of the hardcopy maps to the community.

One key difference between the maps produced from the UAV imagery is *how* the map layers are generated. In Kigali, the GIS data was generated by institutions and consultants, whereas in Dar es Salaam the maps were created through Participatory GIS (PGIS) methods. The purpose of PGIS is to empower the community by providing them with control and access to spatial information [41]. For example, in Dar es Salaam it was observed that involving community members in the collection of the spatial information also increased the awareness and responsibility amongst community members regarding possible flood mitigation levels at a local level [20]. One of the main differences between PGIS and Volunteered Geographical Information (VGI) is that PGIS involves the community in the process acquiring geospatial knowledge, whereas VGI combines the data obtained by the community [42]. As UAVs become more ubiquitous and cheaper, it is feasible to imagine community-based UAV mapping campaigns. This would involve community members in the process of UAV data capture, perhaps transferring some of the benefits of PGIS to UAV workflows.

4.4. Implications for Policy Development

The strategies identified in Table 2 can provide recommendations for policy development. *Avoidable* sensitive objects are closely related to residents being aware of the impending UAV activities and their implications. Relevant policy therefore falls into the realm of legislation regarding UAV flight operations and the ethical responsibility of the pilot or organization responsible for the flights. Ethical policy frameworks and practices by the UAV operators themselves can (1) ensure that citizens are aware of the operations and consequences and (2) limit the capture of unnecessary data—especially when this data is considered sensitive such as the inadvertent recording of persons. It is acknowledged that the former can be difficult in practice, in particular for large-scale UAV operations. Examples of these ethical practices are already included in UAV legislation in a number of countries [43] as well as unofficial recommendations and guidelines for UAV operators [30,44].

Unavoidable objects (both *removeable* and *irremovable*) fall into the domain of data protection and distribution policies. Good practices include ensuring securing of the data and avoiding storing unnecessary private information [30]. Cultural implications are likely to play a larger role in this group of policies compared to the operational policies discussed above. As illustrated by the two case studies presented here, the concept of which objects are considered as sensitive and which parties should have access to the data can differ greatly—even amongst seemingly similar situations. Sharing the data amongst multiple stakeholders can support the ethical values of transparency, accountability, and equity, though it is important to ensure that the voices of residents (the viewed) are incorporated in the decisions around exactly which stakeholders have access rights and what those rights entail. Due to the cultural nuances to the perceptions of data protection and sharing, it is important to include various stakeholders—especially the individuals whose persons or property is captured by the UAV data—to actively participate in the development of such policies.

5. Conclusions

The recognition of UAVs as a powerful geospatial information acquisition tool is ubiquitous. Concerns regarding their ethical usage are also on the rise. The social benefit of the high-resolution and comparatively low-cost geospatial information obtained through UAV platforms compared to more traditional methods must be weighed against social concerns such as privacy. This can be quite challenging depending on the degree to which the intentions of the mapping exercise are in conflict with objects considered as sensitive in the local context. Through an investigation of two case studies using UAVs to support urban upgrading projects, we contribute towards a better understanding of these issues and provide a framework with concrete ways of how to address them.

The use of two case studies illustrates the diversity of the concept of privacy in different contexts. You would expect similar questionnaire responses as both case studies use a UAV to map deprived areas for urban upgrading purposes in an East African context. However, the answers reveal that residents of both areas have strikingly different concepts of privacy—both regarding the objects which are considered sensitive as well as the level of abstraction in which these objects are still considered private. This underlines the importance of understanding the local context to respect the privacy.

Residents' privacy and the geospatial interests of the party collecting the UAV data do not necessarily need to cause problems. *Avoidable* objects which may be considered as private, such as rubbish on the roofs, may not necessarily be of interest for base-data collection in an informal settlement. If residents are notified of impending flights and aware that the flights imply the collection of images over their property, they have the power to move or cover these transient objects. Thus, they are empowered to control the collected data itself. Sensitive objects will not be captured in the raw data and the privacy is therefore ensured. This requires that residents understand that the UAV is collecting imagery. Although UAVs are a new technology, they are increasingly being used for various purposes; indeed the questionnaire results indicated that residents have already observed UAVs in multiple contexts. Therefore, it is expected that with time, citizens will become increasingly aware of the implications of a UAV flying over their property.

Unavoidable but removable objects which are not of specific interest to the mapping activities may be blurred in the orthoimagery before distribution. Assuming that the party conducting UAV flights bears good will and that there is trust between residents and this party, it is feasible to mitigate privacy concerns by defining guidelines for the level of abstraction and distribution. For example, toilets could be considered as sensitive in the imagery, but not in a vector map (see Figure 2). It is clear that these preferences are greatly dependent on the local context. So, how many people would need to be interviewed? How can one ensure that the respondents will feel free to express their opinions? How many individuals must present a certain view in order to sway the blurring and distribution guidelines? The practical execution of this ethical strategy is challenging, though PGIS solutions could assist.

The largest challenge is when *unavoidable and irremovable* objects of direct interest for the UAV mapping activities are those which are considered sensitive by the local population. For example, houses in wetlands may be considered sensitive even at a very high level of abstraction, such as a single point on a vector map. One could argue that, at least in these two study areas, such *unavoidable and irremovable* objects are so large that they are visible in satellite imagery anyway. As such, the sensitivity concerns are not limited to the use of UAV imagery, but rather they apply to GIS data in general. Furthermore, in the present cases, the activities are considered sensitive by the locals because they oppose local (informal or formal) norms. Still, it is important to consider how to protect the residents' concerns in such cases. One strategy is to identify likely threats of data misuse and ensuring protective governance frameworks. The potential threat of being mapped may turn into evidence for ensuring citizens' rights in the presence of protective legislative guidelines. Furthermore, the increased availability of low-cost UAVs as well as further developments towards automated and open source photogrammetric software, such as OpenDroneMap, suggest that community-driven UAV mapping activities are feasible in the future. This would truly enable citizens to reap the benefits of the high resolution geospatial data for their own purposes—although legal flights will still be regulated by national authorities.

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