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Research Paper

A bird's eye view of my village – Developing participatory geospatial methodology for local level land use planning in the Southern Highlands of Tanzania

Salla Eilola[a,*], Niina Käyhkö[a], Andrew Ferdinands[b], Nora Fagerholm[a]

[a] Geography Division, Department of Geography and Geology, University of Turku, Finland
[b] Private Forestry Programme, Tanzania

A B S T R A C T

Despite the large number of participatory mapping and participatory geographical information system (PGIS) applications developed since the 1990s, few studies have utilized participatory mapping in formal planning processes. Evidence is needed regarding their practical applicability in rural land use planning in the Global South and their effectiveness in decision-making in formal planning processes. In this paper, we present participatory mapping and planning methodology that we have co-developed for official village land use planning processes in Tanzania and assess the method's influence on spatial data quality as well as deliberation and spatial understanding and learning among the participants. We describe 11 literature-based criteria for integrating participatory mapping into spatial planning processes and use them in our assessment. The assessment includes analysis of village land use plan (VLUP) maps and observations as well as interviews and group discussions with participants and facilitators of the planning process. We show that the participatory mapping method with georeferenced images is a powerful tool to capture local spatial knowledge from a wide range of stakeholders and increase the quality of and confidence in spatial planning. As a visual aid, the georeferenced image supports deliberation and detailed examination of the landscape, enhancing spatial understanding and learning about the village landscape. Apart from generating local spatial data, we show that the participatory geospatial method supports the decision-making capacity of participants, which is important for the effectiveness of the method in formal land use planning processes.

1. Introduction

Despite the development of a large number of participatory mapping and participatory geographical information system (PGIS) applications since the 1990s, there exists only few studies, which have utilized participatory mapping in formal planning processes (Brown & Kyttä, 2014). Often official planning processes are not designed to engage the public in more than a consultancy role, and planners may lack the skills or means to utilize the collected participatory information in planning practice (Brown, 2012; McLain et al., 2013; Pietilä & Fagerholm, 2018). Evaluation of participatory mapping has usually focused on the mapping tools and data instead of their influence on outcomes of participatory processes. Thus, there is little evidence regarding the effectiveness of participatory mapping in land use decision-making in formal planning processes (Brown & Kyttä, 2014, 2018). The relevance and usability of participatory mapping technologies for decision-making and planners is an urgent research agenda. For example, FAO (Ziadat, Bunning, & De Pauw, 2017) has recently reported concerns about the lack of adequacy of planning tools, knowledge and skills available to decision-makers at various scales regardless of the huge technological advances in geospatial tools, data management and communications.

Many countries of the Global South lack spatial data on biophysical and socioeconomic landscape characteristics to act as a basis for spatial planning. Participatory geospatial technologies have significant potential in capturing such knowledge from the local land users (Brown & Fagerholm, 2015; Ramirez-Gomez, Brown, Verweij, & Boot, 2016). For example, the African Landscape Action Plan (2014) and several initiatives (e.g. the African Forest Landscape Restoration Initiative [AFR100] and African Resilient Landscapes Initiative [ARLI]) emphasize participatory designs and integration of knowledge systems to better understand and manage multifunctional landscapes of the continent. Development of applicable participatory mapping methods that integrate local knowledge into planning and support spatial decision-making is needed.

Participatory geospatial technologies make the complexities and dynamics of landscape and resource uses easier to capture and consider in local level planning (Brown & Kyttä, 2014; Jankowski, 2009). Participatory mapping can be done in various ways, ranging from ephemeral non-scale maps to analog and digital geospatial techniques, all of which serve different purposes. In spatial planning, the accuracy of mapped information is important, and georeferenced map outputs

* Corresponding author at: Geography Division, Department of Geography and Geology, University of Turku, 20014 Turku, Finland.
E-mail addresses: skeilo@utu.fi (S. Eilola), niina.kayhko@utu.fi (N. Käyhkö), nora.fagerholm@utu.fi (N. Fagerholm).

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are required (Corbett, 2009). Collecting local knowledge in a scale-map form enables more informed spatial planning processes in which background map data (e.g. roads, infrastructure, water bodies) and participatory collected data (e.g. land use activities, landscape values, important local areas) can be integrated in GIS for more reliable and transparent decision-making (Brown & Kyttä, 2014; Craig, Harris, & Weiner, 2002; Fisher et al., 2017). Better spatial data and map quality ensure local knowledge is held credible in the formal planning process and compatible with other spatial datasets and planning tools (Brown, Weber, & de Bie, 2015; Kahila-Tani, 2015). The advantages of participatory mapping in spatial planning do not only apply to data generation (Brown & Kyttä, 2014) but also to inclusiveness and community capacity-building. For example, Zolkafli, Brown, and Liu (2017) showed in a case study from Malaysia that participatory mapping methods enhance residents' learning about the landscape and planning processes, providing them with better abilities to discuss concerns and needs in their living environments.

For geospatial technologies to fit the Global South and local context (Schlossberg & Shuford, 2005), solutions need to be innovative in terms of some basic prerequisites, such as electricity, internet connectivity or digital geospatial data; they must also accommodate participants with little previous exposure to these technologies. Furthermore, planners and practitioners struggling with financial and institutional obstacles to innovation (Valencia-Sandoval, Flanders, & Kozak, 2010), should be involved in designing participatory methods to increase the methods' adoptability. Involving practitioners also means that one does not have to reinvent the wheel but can improve existing practices, which may help practitioners to be more receptive to change. Here, close interaction and co-development between researchers and practitioners is key, which has been highlighted by researchers of public-sector innovation (Bason, 2018; Torfing, 2016).

This study addresses the need for participatory mapping methods that increase spatial data quality, inclusiveness and local decision-making capacity in real-life planning processes in the Global South. Our study has two objectives. First, we co-develop a more effective participatory mapping methodology with planning practitioners for official village land use planning processes in Tanzania. Second, we assess how the co-developed participatory mapping method influences the quality of the produced spatial data, inclusiveness and deliberation during planning and spatial understanding and learning among participants. The co-development of a method for an official planning process was made possible through our long collaboration in Tanzania and a request by the Tanzanian planning authority to develop their practice.

2. Material and methods

2.1. Research design

Our research consisted of four phases forming an adaptive cycle of activities in which each research phase fed information into the next phase (Fig. 1). The research team included members of the partnering organizations; university researchers, community development and GIS staff of the development cooperation project; and staff of a Tanzanian non-governmental organization (NGO) specializing in participatory facilitation. The team (henceforth referred to as "we") worked with district planning officials, who are the official VLUP planning facilitators and therefore the main end-users of the developed participatory mapping methodology and capable of assessing it based on their practical experience. In first phase, we studied the existing planning policy and practice and worked with the district planning officials to identify limitations (Fig. 1: Phase A). In the second and third phases, we collaborated with planning officials to co-develop and test the participatory mapping methodology (Fig. 1: Phases B and C). In the fourth phase, we assessed the co-developed mapping method against context-specific criteria for quality spatial data and literature-based criteria for effective participation and good practices in PGIS (Fig. 1: Phase D).

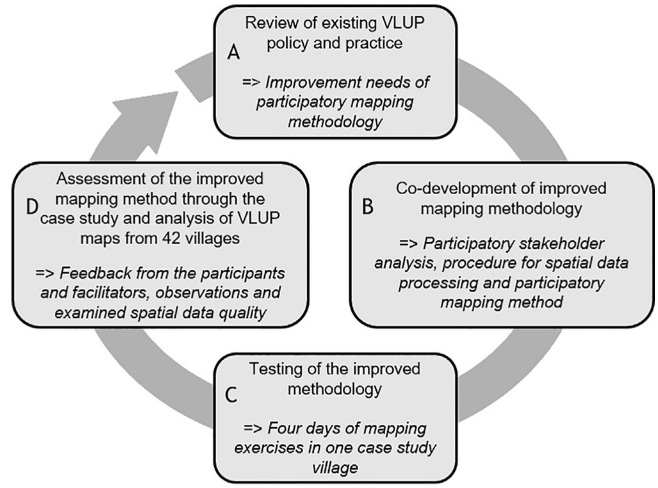

Fig. 1. The overall research design with four phases A) existing situation review, B) improved methodology co-development, C) testing, and D) improvement assessment.

2.2. Village land use planning policy and practice in Tanzania and improvement needs

In Tanzania, village land use plans (VLUPs) are prepared for village administrative area for 10 years at a time. Land use planning and management legislation sets communities as the main planners and managers of their village land (Village Land Act no. 5 of 1999 and Land Use Planning Act no. 6 of 2007). Village councils have executive responsibilities and work with other popularly selected community representatives to prepare plans while the village assemblies, composed of all village inhabitants over the age of 18, hold the final decision-making power through a majority vote. The role of district planning officials is to facilitate the process. Mapping current village land use and planning future land use allocation are essential parts of the planning process. The establishment of VLUPs since the enactment of the Village Land Act of 1999 has been slow (OECD, 2013); approximately 13% (1640 out of 12,545) of villages have a VLUP (S. Nindi, National Land Use Planning Commission, personal communication, June 2017). While expanding the coverage of VLUPs in the country is urgent, finding cost-effective ways to speed up the planning process without undermining stakeholder participation and the quality of plans is crucial.

This study was conducted in the Njombe region of the Southern Highlands of Tanzania. The Highlands consist predominantly of farming communities with hilly landscapes and village sizes ranging from approximately 1500 ha to as large as 200,000 ha. The region is under increasing land pressure due to commercial agriculture and plantation forestry, which left unchecked undermine the ecological and social integrity of the area. In the Southern Highlands, Hart et al. (2014) report challenges in establishing plans due to low prioritization and subsequent lack of resources for planning at the district and national levels. Most of the VLUPs are funded by international donors and facilitated by local or international NGOs (Hart et al., 2014). Dependence on external funding coupled with illegal land transactions, insecure tenure arrangements and a long history of central planning and insufficient skills regarding participatory planning exert further challenges to participation (Hart et al., 2014; Kaswamila & Songorwa, 2009; Lerise, 2000; Walwa, 2017).

In this study, the external funder and district officials were involved in the co-development and testing of the participatory mapping and planning methodology. The funder was a bilateral development cooperation project, which establishes VLUPs with the aim of identifying land for community forest plantations in villages of the Southern Highlands. To study the policy environment, we conducted a policy

	Identified improvement needs	Research institute	Development project (funder)	NGO	District planning authority	
A	Higher quality spatial data	x	x		x	Process itself and its tangible and immediate outputs - Possible to assess
B	Wider representation and inclusive deliberation in the process	x	x	x	x	
C	Capacity development in village level decision-making	x		x	x	
D	More socially and environmentally informed decisions	x	x	x	x	
E	Individual and social learning	x				
F	Social capital development	x		x		Less-tangible long term outcomes
G	Trust building	x	x			
H	Fostering of innovative future developments			x		

	Topics in the assessment	Assessment criteria	Means of verification
a	Quality of the produced spatial data	1. Amount of mapped information content 2. Amount and variation in mapped land use categories 3. Richness of mapped land use area information 4. Level of cartographic detail	Spatial data sets of 42 VLUP maps
b	Inclusiveness and deliberation in decision-making	5. Participatory mapping method supports inclusive participation and accommodates wider participation 6. The spatial data and techniques used are affordable and technically accessible 7. The participatory mapping method supports deliberation and expression of views 8. The participatory mapping method enhances shared understanding of issues and land features under discussion 9. The process produces informed decisions that are acceptable to majority	Interviews and group discussions with participants and facilitators, observations
c	Spatial understanding and learning	10. Participatory mapping method supports individual and collective learning 11. Spatial data and participatory mapping method increase understanding of land use characteristics, complexity and multifunctionality	
	Not assessed in the study		

Fig. 2. Identified improvement needs in the VLUP process emphasized by each partnering organization, selected topics in the improved method assessment, assessment criteria and means of verification.

review of Guidelines for Village Land Use Planning, Administration and Management of 2013, the Land Use Planning Act of 2007 and the Village Land Act of 1999 (Fig. 1: Phase A). We studied the existing VLUP planning practice through discussions and needs assessment with the district planning officials as well as assessment of the existing VLUP maps and spatial data from the Southern Highlands. We also identified and made explicit the varying interests and motivations of each involved organization, which has been encouraged by Hassenforder, Pittock, Barreteau, Daniell, and Ferrand (2016) when evaluating participatory processes. We held formal and informal discussions with the district facilitation teams of six districts and relevant staff of the partnering organizations during two visits to the area in February and August 2015. The review yielded several critical needs for methodological improvements and limitations of existing practice, which were highlighted by the collaborating organizations (Fig. 2, A–H).

2.3. Co-development and testing of mapping methodology

After examining the existing policy and practice, we began the co-development of an improved methodology in collaboration with the district planning officials of the six districts (Fig. 1: Phase B). The design focused on improvements in spatial data quality and inclusive participation, followed official VLUP guidelines of 2013 and was intended to fit the technological context. The partnering organizations held different priorities for community empowerment and quality data collection; the developed mapping methodology is a compromise between these objectives (Fig. 2, A–H). The methodology that we co-developed consists of 1) a participatory stakeholder analysis, 2) a procedure for obtaining, processing and digitizing spatial data for and from participatory mapping and 3) a participatory mapping method utilizing high-resolution satellite image printouts. Details of the methodology and a comparison to existing practices are described in Table 1 and Fig. 3. Staff of the development project and district planning officials tested and refined the use of satellite image with village representatives during the co-development phase.

The participatory stakeholder analysis is meant to be conducted at the beginning of the official VLUP process. The village council and other representatives, such as the school headmaster and agricultural extension officer, carry out the analysis and identify land users and social groups in the village as stakeholders of the VLUP, then present them to the village assembly for comments and approval. Subsequently, each stakeholder group is represented in the VLUP process by a representative nominated by the village assembly. Participatory mapping is done on a high-resolution satellite image printout produced by the district planning officials. The selected representatives of stakeholder groups map current and future land uses in exercises that last two to six hours depending on the village size, land use complexity and possible land conflicts. At the beginning, the participants collectively list all the current land uses and resources that they wish to map and delineate these features on the satellite image printouts as areas and points. The mapping is done in two separate groups, and then the participants jointly compare both maps in terms of their differences and similarities and combine them into one map. In the future land use mapping exercise, the satellite image printout is used as a diagnostic and decision aid tool while participants evaluate land use value and tradeoffs and map how land use should be allocated in the village. GPS tracking is carried out on sites, which are impossible to identify on the image printout. Then, the sketch maps are photographed, the photographs georeferenced and the spatial information digitized to produce the digital VLUP maps. The sketch and digital maps are displayed to the village assembly for their comments and approval.

In June 2016, the co-developed methodology was ready to be tested during the official VLUP process funded by the development cooperation project, and we joined the project staff to assess its impacts in one of the project villages (Fig. 1: Phase C; Fig. 4). Carrying out the test in an official process had the advantage that the methodology was utilized and assessed in a real planning situation carrying the weight of an enforceable plan as an outcome. The test village was selected due to official VLUP process scheduling and availability of cloud-free satellite images. The size of the selected study village is 4145 ha; it has 792 inhabitants. Due to the official planning process, we controlled only the participatory mapping exercises and not elements such as inception, participant selection and schedule. Participatory stakeholder analysis was moderated by the facilitating district planning officials. The mapping exercises took four days during the 12-day VLUP planning process. In total, 39 inhabitants (25 male, 14 female) participated, of which 20–35 were present in each exercise. District facilitators observed the mapping exercises while members of our research team facilitated the mapping. After the mapping, a staff member of the development project converted the data into digital form.

2.4. Assessment of the mapping method

The assessment focused on the developed participatory mapping

Table 1
Description of existing planning practices, improved methods and their benefits.

		Existing practices	Improved methods	Benefits of improved methods
PARTICIPANT SELECTION	Selection of participants	Village council suggests 6–8 people considering the quota for women. Village assembly makes the final selection.	Village council and other village actives conduct participatory stakeholder analysis to identify different social groups in the village and suggest representatives for each group considering the quota for women. Village assembly makes the final selection.	Ensures identification of land users and social groups with different characteristics as stakeholders of the VLUP process
	Participants in mapping exercises	6–8 people, half women and all subvillages represented	More than 20 people, selected to represent all identified land user and social groups in the village	Ensures that needs and opinions of different stakeholders have a possibility to be raised directly by their representatives in the planning process
MAPPING METHOD	Sketch mapping	Land use areas are drawn on blank flipchart paper	Land use areas are marked with marker pens and stickers on a transparent plastic sheet on top of high-resolution satellite image printouts which are georeferenced	Satellite image enables comparison of mapped features with ground features, and aids delineation and examination of land uses and landscape patterns
	Spatial reference of the sketch map	No spatial reference	Spatial reference, scale 1:7500	The produced sketch maps are in scale, easily digitizable and comparable to other georeferenced data
	Working mode	One mixed group in current and proposed land use mapping activities	Two groups in current land use mapping (village leaders and vulnerable social groups), one mixed group in future land use mapping	In well-thought separate groups power relations are easier to manage and participants feel likely more comfortable to participate than in one mixed group
	Information mapped	The land use categories listed in the 2013 VLUP guideline	Land use categories listed in the 2013 VLUP guideline and possibility to map sites of resources, environmental degradation and land use problems, seasonal changes and cultural and historical values	The spatial information is mapped in more detail and is more semantically accurate
	Sketch map used in future land use planning discussions	Current land use sketch map on the flipchart paper	Current land use sketch map on the satellite image printout	Current land use sketch map on satellite image supports discussion and estimation of area sizes and distances to assist in land allocation decisions
	Display of maps in village assembly meeting	Land use sketch maps on the flipchart paper	Land use sketch maps on the satellite image printout	Sketch maps on satellite image allow assembly to assess whether the land use area delineations are acceptably delineated by comparing mapped features to ground features
SPATIAL DATA PROCESSING	Reliance on GPS data	High reliance, while most areas outside settlements and roads have to be tracked to get spatial reference	Low reliance, while tracking is only needed for areas and places which were impossible to see and identify in the satellite image	Satellite image reduces need for field tracking and allows more reliable mapping of areas which are inaccessible for GPS tracking
	Converting sketch maps into GIS data and VLUP maps	District GIS expert digitizes land use areas from the non-georeferenced sketch map using the available GPS points from the field	District GIS expert digitizes land use areas from georeferenced photographs of the sketch maps drawn on satellite image printout	Georeferenced background image ensures better location and semantic accuracy of local land use data.

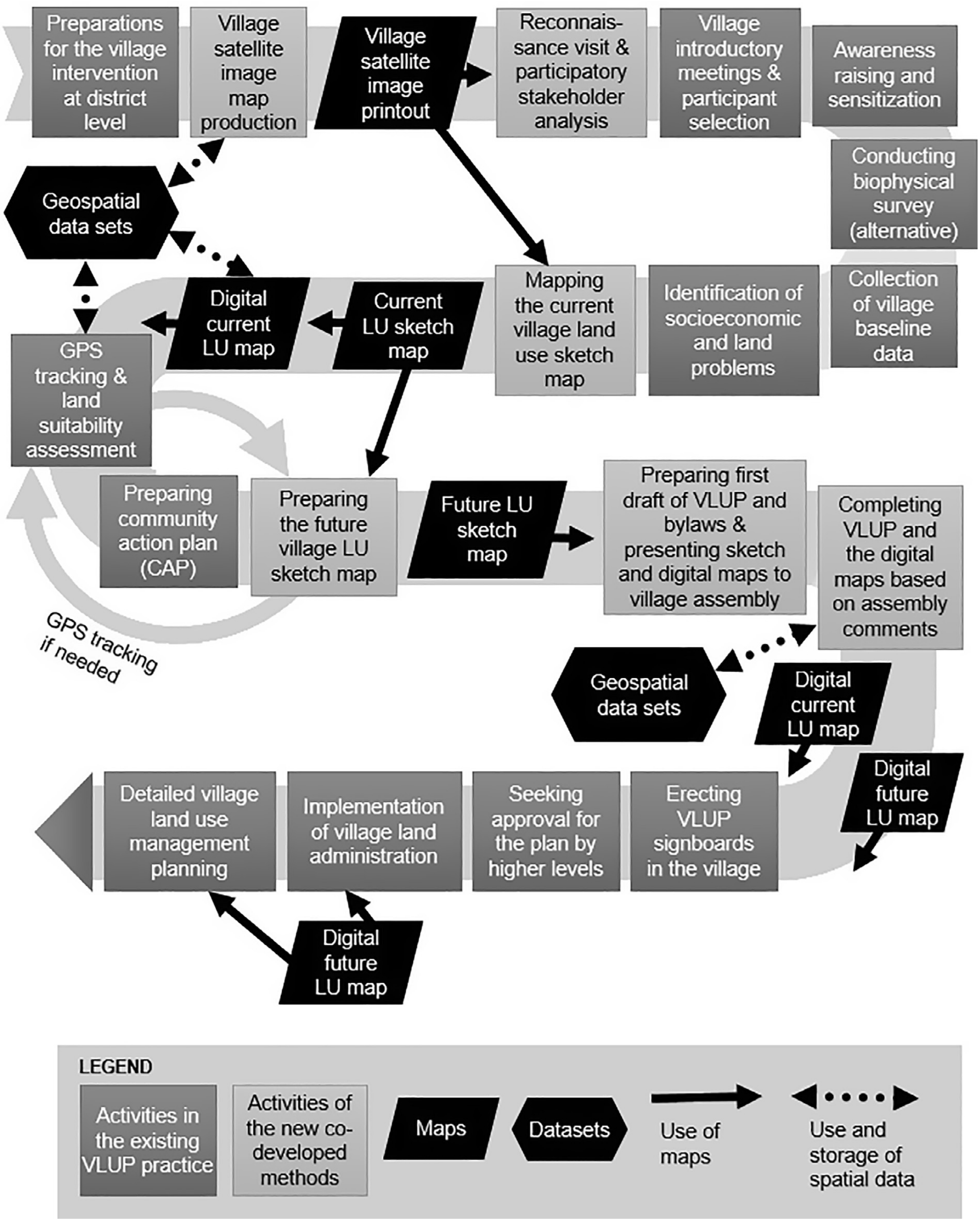

Fig. 3. The chronological order of activities in the official VLUP process and the application of improved methods and spatial data sets during the process. The light gray boxes of activities indicate when the improved methods are used and the symbols of maps, datasets and black arrows indicate the production and use of spatial data in the process.

method (Fig. 1: Phase D). We defined the topics of the assessment based on the identified improvement needs (Phase A), developed context-specific criteria for spatial data quality and elaborated the rest of the improvement needs through literature-based criteria (Fig. 2), 1–11). Some of the expected outcomes of the improvements (social capital, trust and innovative future developments) were not assessed because they are long-term outcomes, difficult to distinguish from other developments in the community and not attributable to the developed mapping method.

Spatial data quality has commonly been measured as positional accuracy (Cox, Morse, Anderson, & Marzen, 2014), logical consistency (Zolkafli et al., 2017), completeness in space and attribute or conceptual accuracy (Brown et al., 2015). Our spatial data assessment included a comparison of VLUP maps in terms of relative feature

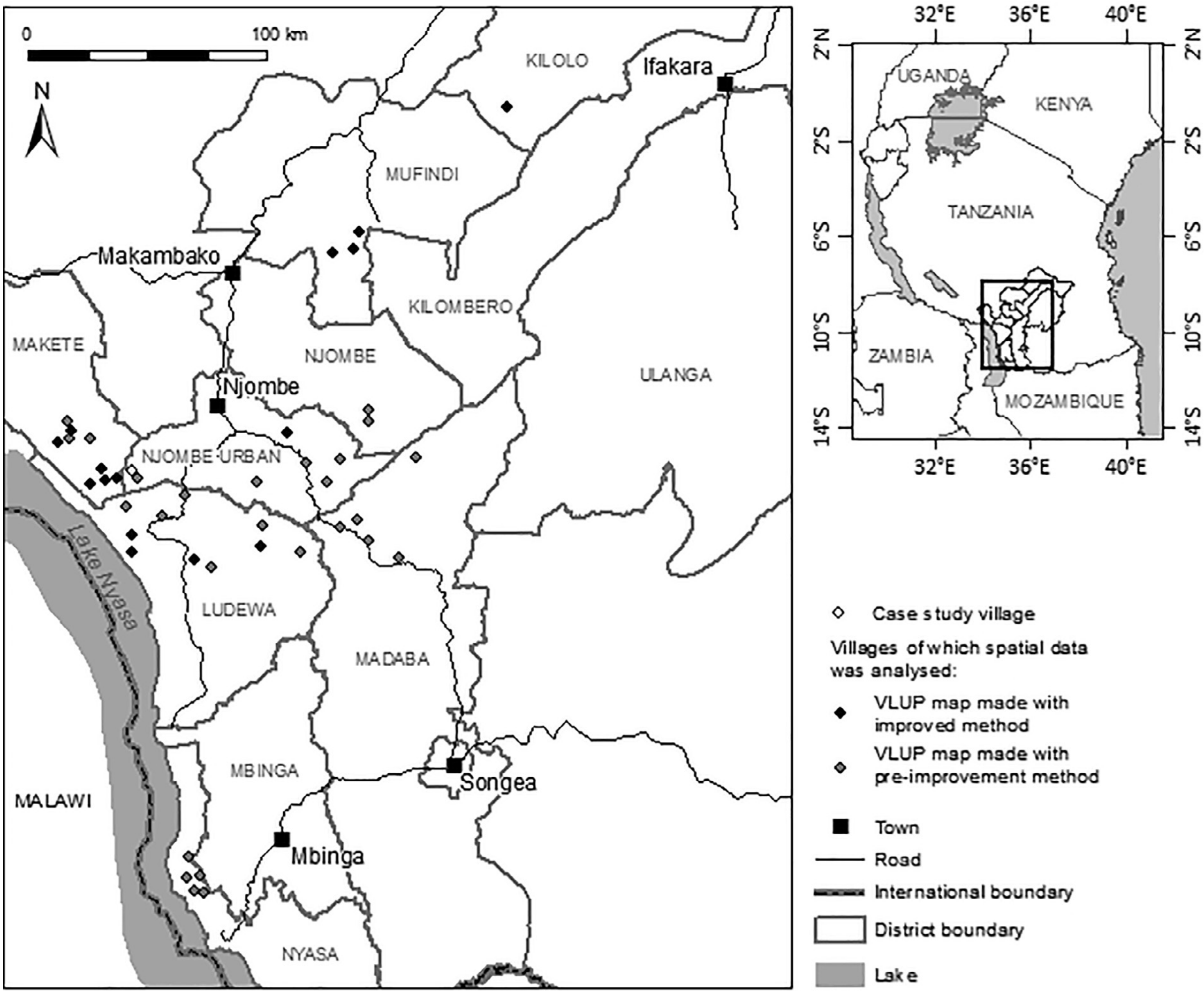

Fig. 4. Map of the Southern Highlands in Tanzania and location of case study village and the other 41 villages of which spatial VLUP data was analyzed in this study.

completeness, attribute and semantic accuracy and cartographic complexity (Senaratne, Mobasheri, Ali, Capineri, and Haklay (2017)). We applied four criteria and related indicators (in parentheses) as follows:

- Amount of mapped information content (number of all mapped features in point and polygon form) (criterion 1)
- Amount and variation of mapped land use categories (number of mapped land use categories) (criterion 2)
- Richness of mapped land use area information (number of land use areas per land use category in a village) (criterion 3)
- Level of cartographic detail (shape index and visual interpretation of land use patterns) (criterion 4).

We analyzed 42 VLUP maps, of which 16 were produced with the improved method presented in this paper and 26 were produced with a previous method that utilized no satellite images in the mapping, hence the name "pre-improvement maps." The maps were of villages from the same geographical area as our test village (Fig. 4). The pre-improvement maps had been produced by the district officials, the National Land Use Planning Commission of Tanzania or a geospatial NGO between 2014 and 2016. The improved maps had been produced by the development project with district officials from 2016 to 2018. We obtained spatial datasets of only 27 of these VLUP maps for the analysis. Most of the digital GIS data layers of the VLUP maps required cleaning prior to analysis (deletion of overlapping and redundant polygons, for example). Shape index was chosen to indicate geometric complexity, as it omits the effect of polygon size on the index (McGarigal, 2015), and polygon sizes vary greatly in the available data sets. The shape index was calculated using ArcGIS 10 software for the land use polygons of the seven most common land use categories in the maps to ensure validity of the comparisons. We performed visual analyses of eight of the VLUP maps.

In the following, we briefly explicate principles of effective participation and good PGIS practice literature that prompted our criteria for integrating participatory mapping into planning processes. Public participation in decision-making is based on democratic ideals of meaningful and effective involvement of those affected by decisions. While in practice participation takes different forms, guiding principles for the effectiveness and quality of participation have been suggested in various instances, such as by Beierle (1999), Rowe and Frewer (2000) and more recently, the International Association for Public Participation (2014). No universally accepted principles exist, however, and evaluation criteria are often designed for a particular participatory context, thus reducing the generalizability of case studies (Rowe & Frewer, 2004). While accepting this, our assessment draws mainly from principles developed in the field of participatory mapping and PGIS, which emphasizes empowering elements of participation in line with participatory action research and aims to ensure access to and relevance of spatial technologies and data to the lay public and in decision-making.

Among the principles, inclusiveness and accessibility are common prerequisites for participatory practice (Abelson et al., 2003; Carr, Blöschl, & Loucks, 2012; Faehnle & Tyrväinen, 2013; McCall & Dunn, 2012; McCall & Minang, 2005; Rambaldi, 2010; Reed, 2008; Rowe &

Table 2
Assessment results of the spatial data quality criteria for the maps produced with improved and pre-improvement mapping methods.

	Maps made with pre-improvement method (n = 26)				Maps made with improved method (n = 16)			
	Min	Max	Ave	St dev	Min	Max	Ave	St dev
Number of mapped features (areas and points)	5	56	21,44	12,91	27	93	49,63	15,15
Number of mapped land use categories	2	9	4,84	2,03	6	9	8,06	1,06
Number of mapped land use areas per land use category in a village	1	13	1,86	1,23	1	19	4,13	1,36
	Maps made with pre-improvement method (n = 13)				Maps made with improved method (n = 14)			
Shape index* of mapped land use areas per each land use category	1,06	4,90	1,80	0,68	1,01	13,72	1,82	1,03

* McGarigal (2015)).

Frewer, 2000; Vacik et al., 2014). An important part of participatory planning is deliberation, during which participants share, listen and reflect on diverse views and knowledge as well as weigh alternatives and finally reach informed decisions (Abelson et al., 2003; Kenter, Reed, & Fazey, 2016). Participatory mapping exercises have been shown to aid in deliberation by allowing visualization and spatial evaluation of land use options and by supporting expression of views by participants of various backgrounds (Arciniegas & Janssen, 2012; McCall & Dunn, 2012). The relevance of participatory mapping as a planning support tool thus requires that the mapping exercises allow interaction among the participants and support expression of opinions when priorities and trade-offs are discussed to reach fair and implementable decisions (Abelson et al., 2003; Berkes, 2009; Carr et al., 2012; Faehnle & Tyrväinen, 2013; Laurian & Shaw, 2009; Rambaldi, 2010; Vacik et al., 2014). The extent of inclusive deliberation and agreement among participants may be used as indicators of the quality of participatory mapped information (i.e. validity-as-credibility, [Spielman, 2014; Zolkafli et al., 2017]). In this case, the participants evaluate the credibility of each other's information and mapping efforts during the collaborative mapping exercise, provided that participants are allowed to contest each other. Finally, many scholars have emphasized that participatory mapping should particularly enhance spatial understanding and offer opportunities for learning so as to contribute to local decision-making capacity and informed decisions in planning (Faehnle & Tyrväinen, 2013; McCall & Minang, 2005; Rambaldi, 2010; Reed, 2008; Vacik et al., 2014).

Based on the literature, we derived seven criteria to assess inclusiveness, deliberation and spatial understanding (see Fig. 2b and c and Annex A for detailed description of each criteria), which include:

- The participatory mapping method supports inclusive participation and accommodates wider participation (criterion 5).
- The spatial data and techniques used are affordable and technically accessible (criterion 6).
- The method supports deliberation and expression of views (criterion 7).
- The method enhances shared understanding of the issues and land features under discussion (criterion 8).
- The process produces informed decisions that are acceptable to the majority (criterion 9).
- The method supports individual and collective learning (criterion 10).
- The spatial data and participatory mapping method increase understanding of land use characteristics, complexity and multi-functionality (criterion 11).

We studied the criteria through observations, interviews and focus group discussions. The observations were done by two research team members during each mapping exercise using a list of themes: usability of the satellite image, signs of learning, inclusiveness and interaction between participants. Interviews were held with the village participants to collect informants' background information, expectations from the exercises and ex post reflections on the exercises. We interviewed 27 participants (18 male, 9 female) before the exercises and reached 21 of them and one additional participant (14 male, 8 female) after the exercises for feedback interviews. Eleven participants were interviewed after current land use mapping and 11 after future land use mapping. Group discussions focused on ex post reflections. One feedback discussion was held with 10 (6 male, 4 female) participants and one with 11 (8 male, 3 female) facilitators from the district facilitation team, development project and NGO. We held the participant group discussion after the current land use mapping exercise, and organized the facilitator group discussion after the VLUP process was finished. We analyzed the data through conventional content analysis (Flowerdew & Martin, 2005; Yin, 2011) using NVivo 10.

3. Results

3.1. Influence on the quality of produced spatial data

There is a higher level of detail in the VLUP maps when the improved mapping method is applied (Table 2, Annex B). The maps have more than twice as many features (49.63 on average) as the maps produced with pre-improvement method (21.44) and nearly twice as many land use categories (8.06 and 4.84, respectively). The improved mapping method influenced the prevalence of certain land use categories in the maps. For example, more agricultural, grazing and land bank areas and wetlands are depicted in the maps produced with the improved method. Furthermore, it seems that the pre-improvement method favored mapping of the "mixed land use" and "settlement with agriculture" categories. On average, 4.13 land use areas per category were mapped in each village after the improvements, compared to only 1.86 prior to method modifications. The average total number of mapped land use areas in a village is much higher (32.8) in maps produced with the improved method, compared to 9.4 areas in maps produced with pre-improvement method.

The shape index does not reveal many differences in the geometric complexity of mapped land use areas (Table 2). The average shape index of areas after implementation of the improved method is 1.82, compared to 1.8 prior to improvements. Comparing shape indices of areas of different land use categories shows very little difference (Annex C). The average shape indices per land use category have little variation, although the maximum shape index values are mostly much higher in the improved maps. In visually analysing the selected maps, the increase in the level of geometric detail before and after the improvements is clear (Fig. 5). Maps made on top of high-resolution satellite images clearly show better geometric accuracy of the mapped land use areas. The improved mapping method captured the organic shapes of the land cover and land use patterns in the landscape better than drawing on the blank flipchart paper. Previously, many land use

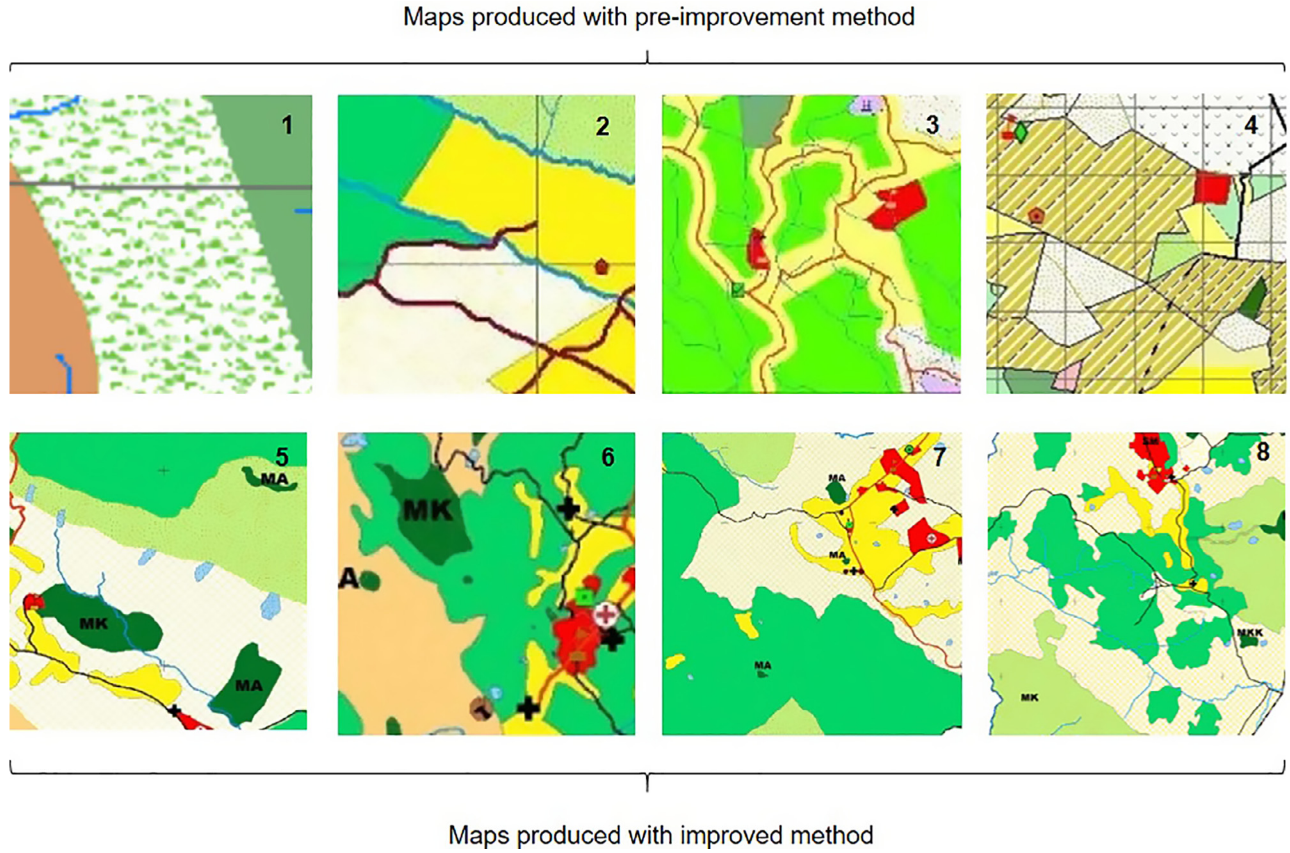

Fig. 5. Examples of visual comparison of maps of existing land use from eight different villages produced with pre-improvement (upper row) and improved methods (lower row). The comparison is done within 4000 × 4000 m cells captured from each map.

areas were expressed by harsh geometric abstractions of the land use areas, as shown, for example, on map number four in Fig. 5.

3.2. Influence on inclusiveness and deliberation during spatial decision-making

Through the participatory stakeholder analysis, more than 20 social groups were identified and represented in the planning process; among them, young women and men, elders, farmers, tree growers, disabled and HIV positive people, orphans, widows and widowers, inhabitants of all five subvillages and members of the village council. Previous planning practice did not identify social groups in the village and involved six to eight village representatives in the mapping exercises (Table 1). The age of the interviewed participants (n = 27) ranged from 22 to 62 years with an average age of 40.2 years. The interviewed participants had lived an average of 26 years (st. dev. 18.5; n = 27) in the village, and their self-perceived familiarity of the village landscape was 3.40 on average (n = 27) on a scale of 1 (I know very little) to 5 (I know it all).

Only 15% of the interviewed participants (n = 27) had used any kind of maps before, and 56% had seen but not used them. None of the participants had ever seen a satellite image, and only one had been involved in making a map of the village before. The participatory mapping situation was a new experience for them all. Almost half of the participants who were interviewed after the mapping exercises (n = 22) said they had initially difficulties in understanding the image, but the difficulties decreased with better map-reading instructions and support in reading the legend of the map (Annex A, criterion 5). In all the mapping exercises, there were a few participants who did not engage but only observed. During the feedback interviews, when each informant was asked to show a feature of interest in the image, all the informants were capable of understanding and using the image. Interviews showed that some participants required more instructions to understand and engage with the image. This was noted by both participants and facilitators during the feedback discussions. Furthermore, the facilitators noted that the use of satellite images puts the villages and districts in unequal positions in terms of access to the skills and technology required.

The satellite image supported deliberation by helping participants express their views using the image as a visual aid and by creating shared understanding of the areas under discussion. Almost all of the interviewed participants of future mapping exercise stated that the satellite image helped in the discussions about land allocation (Annex A, criterion 7). One informant noted that the image helped people to participate in the discussion because they could use the image to express themselves. The observations show that participants used the satellite image to show their fellow participants which areas they were talking about and referred to the features on the image when explaining their arguments.

The discussion on land allocation was made detailed and concrete through use of the satellite image. The effects of satellite image in deliberative decision-making are exemplified by the following quotes:

"It [the satellite image] made the discussion easier, because we could look at everything we were discussing on it" –female representative of the village council.

"[We made a] more precise village land use plan by seeing the village accurately in the satellite image" –male representative of orphans.

The satellite image was used in discussions of land allocations in relation to area size, distance to the settlement and other land use areas and to establish which were the environmentally vulnerable areas. Several interviewed participants reflected on the difficulty of negotiating land allocation in densely populated settlements because the satellite image forced them to properly consider the location of unoccupied and free land for new land uses. They failed to find available land for a bus stand and teachers' housing and decided to negotiate with some land owners for consent to allocate their land for public use. Finally, the satellite image reduced misrepresentations and misunderstandings, as locations could be deliberated and collectively agreed upon based on the image. In the pilot village, a misplacement of the southern boundary of the village was discovered on the official boundary map. It was a result of a misunderstanding and was resolved together with the neighboring village representatives using the satellite image.

3.3. Influence on spatial understanding and learning

The satellite image increased participants' understanding of the village land area and gave them opportunity to learn about land use throughout the entire village. Most of the interviewed participants stated that they learned something new about their village area through the satellite image (Annex A, criteria 10). They mentioned learning the actual village boundaries, the existing land uses and resources and their locations in the village. Moreover, all participants stated that they learned something new about the village from their fellow participants. Participants expressed learning and increased understanding in various instances:

"[The] satellite image allowed me to know the whole village; I am a disabled person, so I cannot move around the whole village" –male representative of disabled inhabitants.

"The satellite image has widened my understanding of the village [regarding] boundaries, sources of water and uncultivated land" –male representative of a subvillage.

"I see the village future [as] more positive, because now there is good understanding of village boundaries and land use areas in the village" –male representative of village land use management committee.

Participatory mapping with a satellite image increased comprehension of the details and the bigger picture of the landscape as well as spatial and functional understanding of the land use characteristics (Annex A, criteria 10 and 11). The resulting maps depict this collectively produced understanding and knowledge. The informants in the participants' group discussion said that combining current land use maps of the two groups increased the map's accuracy and enhanced collective learning. The combining exercise acted as verification of land use area delineations and allowed for the addition of more details on the joint map. The informants of the facilitators' group discussion said that the spatial information they now have of the village is more accurate, and their understanding of the village area has increased due to the use of satellite images. They gained understanding of the village's land use characteristics, such as landscape patchiness and existence of remote, sparsely utilized land areas within village boundaries. This allowed the facilitators to advise appropriately and in more detail about future land use allocation. For example, they identified that settlement areas are sparse and widely interrupted with agricultural plots and advised villagers to promote settlement densification through the VLUP to minimize future settlement expansion.

4. Discussion

In this study, we co-developed a participatory mapping methodology that was piloted and subsequently adopted into use in a formal rural planning process in the Tanzanian Southern Highlands. We assessed the improved mapping method in terms of spatial data quality, inclusive participation of various social groups in the communities and increased learning, which are important factors in making participatory mapping exercises relevant for spatial planning. The use of georeferenced images, such as high-resolution satellite images, for a mapping background ensured that the participatory mapped information fulfilled the accuracy requirements of official spatial plans. The methodology brought together a diverse set of participants to map their experiential knowledge of the landscape, thus giving them opportunities to express themselves and learn from each other. Moreover, as a visual aid, the georeferenced images supported communication and detailed examination of the landscape during the mapping exercises, which helped discussions about future land allocations in the VLUP. In the following, we discuss the observed impacts and limitations of the co-developed method and reflect on the limitations of our method assessment.

The georeferenced image as a mapping background produced higher semantic and geometric accuracy in land use planning data as indicated by the level of detail in mapped features, land use categories and land use area delineations. Due to similar landscapes and socio-economic characteristics of the research villages, it can be assumed that the number of categories in the VLUP maps indicates the level of detail in semantics instead of differences in land use in the villages. The increased confidence of the VLUP facilitators on the quality of mapped information is an important outcome, as local knowledge and planning decisions are conveyed through maps to the higher administrative levels as binding documents. The higher detail of spatial information is due to the high-resolution georeferenced image, which allows participants to map landscape features based on their knowledge and the visual representation of the features on the image in more detail. Furthermore, since the georeferenced image allows depiction of land use planning units in relation to biophysical features in the landscape, the mapped information is more likely to reflect the real landscape characteristics than when mapped on a blank piece of paper. Because the scale of data capture affects the level of detail of the data, the mapping should always be done on a specific scale (in this case, 1:7500) to minimize the effect of scale on mapping quality. However, the image quality and the familiarity of the participants with the mapped area affect the level of detail. Thus, it can be assumed that areas of more intensive land use are mapped with more detail than areas that are less known and utilized.

The accuracy requirements of official plans and mapping exercises can limit the expression of local spatial knowledge. This is because local spatial knowledge often encompasses fuzzy boundaries, uncertain or holistic perceptions of landscape features and their symbolic meanings (McCall & Dunn, 2012; Reid & Sieber, 2019) that are not renderable to the strict conventions of official spatial data; participants may find it impossible to express their knowledge in these terms. Also, the necessity of using nationally defined land use categories prohibits participatory legend-making and risks obscuring local characteristics, diverse forms of knowledge and semantic accuracy (Rambaldi, Chambers, McCall, & Fox, 2006). Thus, the captured local knowledge is not only influenced by the mapping method but by what knowledge the VLUP policy recognizes and enables to capture.

The involvement of a larger, more diverse group of stakeholders contributes to the mapped local knowledge content and the map's credibility. Many participants in the mapping exercises, however, lacked knowledge of the entire village area and its land uses prior to the exercises, which leads to a conclusion that involving more participants does not automatically equate to more or increased diversity of local knowledge content being captured. In fact, the selection of participants is highlighted by participatory mapping scholars as a determinant of what type of content and level of accuracy can be expected of the spatial information (Brown & Kyttä, 2014; Chambers, 2006; Forrester & Cinderby, 2011). Therefore, in the developed methodology, it is important that some participants who are knowledgeable of the village landscape are purposefully selected and the involvement of a wide range of stakeholders is opted to support the legitimacy of the planning decisions and capacity-building in decision-making.

An indication of the mapping method's inclusiveness is that it accommodates participation of larger number of stakeholders and people who have no previous mapping experience. Nonetheless, not all participants actively engaged in the mapping and discussions, and proper instructions by facilitators were important. Facilitation and direct instructions have been previously shown to be crucial for method usability and spatial learning (Collins, 2018; Zolkafli et al., 2017). The georeferenced images are easier to comprehend for some than for others; visually impaired individuals and people with learning disabilities will be less able to engage with the images. Moreover, as with any participatory tools, the mapping exercises require the participants to access the venue, interact with others and feel comfortable to raise their opinions, all of which may put some in more advantageous positions than others and which facilitators have to consider in organizing and facilitating the event. Depending on the level and persistence of power asymmetry in and between communities and outside actors, mapping exercises need to be designed to support participation of marginalized groups (Corbett, 2009). In the VLUP case, facilitators mitigated power inequalities and marginalization among the participants through peer group work and skilled facilitation. Still, decision-making processes are never void of power relations (Abelson et al., 2003; Martin & Rutagarama, 2012) and facilitation may not be enough to ensure equal participation opportunities; the entire official planning system, including its funding mechanism, may require critical examination.

The positive impacts of the co-developed mapping method on expressing oneself, deliberation and spatial understanding and learning indicate that the georeferenced image acts as a boundary object enabling the development of a collective visual language among the participants and the facilitating experts during planning discussions. Conceptualizing spatial data applications as boundary objects serves to highlight their usability in deliberative planning processes (Harvey & Chrisman, 1998; Xu, Maitland, & Tomaszewski, 2015). Our results are similar to other studies that show how spatially explicit participatory mapping applications can enhance communication, awareness of different views and detection of misunderstandings and misperceptions among land actors (Arciniegas & Janssen, 2012; Fisher et al., 2017).

The substantive quality of the deliberation and planning decisions was increased, as the improved method with georeferenced image allows more detailed examination of land use areas, and participants learned to comprehend the village as a whole instead of restricted to their own everyday life environments. Spatial understanding can further be enhanced when participatory spatial data is integrated with other available datasets, which is made possible by improved spatial data quality. The development of decision-making capacity and learning among the participants could have been further emphasized if these aspects had been prioritized by all involved organizations. In the study, some of the partnering organizations emphasized data quality and output over community empowerment factors. Brown and Kyttä (2014) have described similar situations as a “tug-of-war” between the technological advances in participatory data collection and the collaborative decision-making opportunities that the technologies offer. Capacity development would have required more time for training and participant reflection during the planning process. Thus, we can say that the co-developed method improved the existing planning practice in terms of data quality, inclusiveness and learning relative to the point of departure (i.e. existing practice), but more improvement needs remain in terms of supporting local decision-making capacity throughout the planning process.

The method assessment has its limitations. The capacity of inexperienced participants and facilitators to evaluate the method may have introduced some uncertainty to the assessment. Moreover, standards of politeness and a culture of no open criticism likely influenced the feedback. The observations during exercises were our means to crosscheck feedback responses. The evidence of individual learning outcomes is based on participants’ perceptions and observations on expressions of learning or changing understanding and is thus less solid than if the participants’ initial landscape knowledge had been tested against their knowledge after the mapping exercises.

In terms of the up-scalability of the co-developed mapping method, apart from improving the quality of the participatory planning process and its outputs, this method also reduced field days and subsequently costs of the VLUP process, which is crucial for adoption in resource-poor planning contexts of the Global South. The applicability of the method has to be tested in different contexts and likely adjusted to given livelihood structures, cultural settings and environmental conditions. For example, using a georeferenced image of the administrative area of a village will not suffice to map land use of pastoral and hunter-gatherer communities, which may utilize resources seasonally on a much larger area extending to several villages and districts (ILC, 2013). In these contexts, digital and mobile participatory mapping techniques should accompany the co-developed analogue method. The policy-practice analysis informed the co-development of an appropriate methodology for Tanzanian policy, but it also showed policy improvement needs regarding sensitivity to local knowledge and special land use characteristics. This sensitivity in policy could be integrated into practice through participatory mapping methodologies that enable the definition of land use categories by participants and, moreover, if the mapping methods are further developed to identify and visualize diverse spatial knowledge of stakeholders (Elwood, 2011). The collaboration established among the Tanzanian partners during the research is meant to facilitate sharing of expertise and further co-development of the methods in the future.

In this study, a participatory planning methodology was developed for a particular formal land use planning process, namely VLUP in Tanzania, but its potential is wider. Participatory stakeholder analyses to elicit community heterogeneity are common tools for environmental management design (Reed, 2008), and participatory mapping with georeferenced images has been used in several studies with local stakeholders (see, for example, Cox et al., 2014; Fagerholm & Käyhkö, 2009; Homann, Rischkowsky, & Steinbach, 2008; Scolozzi, Schirpke, Detassis, Abdullah, & Gretter, 2015). The method’s observed impact on data quality, inclusive deliberation and perceived learning outcomes can be expected in settings where the existing planning practice lacks spatially explicit tools to engage community members and community members have little exposure to a bird’s-eye view of their living environment.

5. Conclusions

Our research addresses a concrete need to develop contextually suitable participatory mapping methods in the Global South, where information scarcity, lack of digital infrastructures and lack of effective participation hamper sustainable local level land use planning decisions (Bourgoin & Castella, 2011; Ramirez-Gomez et al., 2016). We do so by introducing an improved (but still simple and feasible) participatory mapping and planning methodology to the official local level planning process in Tanzania. Hence, our case study contributes also to the development of PGIS solutions, which engage citizens and other land users in real-life spatial planning processes (Brown & Kyttä, 2018; Valencia-Sandoval et al., 2010). We show that participatory mapping with georeferenced images is a powerful tool to capture local spatial knowledge from a wide range of stakeholders and increases the quality of and confidence on the mapped information for planning and decision-making purposes. Even though the georeferenced image is fairly self-explanatory, facilitation plays a major role in ensuring that all participants get an opportunity to actively participate. In the mapping exercises, the georeferenced image acts as a boundary object enabling a collective visual language among participants and experts and enhancing deliberation and detailed examination of the landscape. During mapping and discussion around the image, the participants experience learning about their village environment, and the aerial perspective enhances their comprehension of the village landscape as a whole. Learning and enhanced spatial understanding allow more informed and sustainable land use planning decisions to be made. The developed participatory mapping methodology shows the potential of participatory geospatial technologies in rural land use planning, especially in localities where spatial data is scarce and planning stakeholders benefit from a new, aerial perspective of the planning area.

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Appendix A–C. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.landurbplan.2019.103596.

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