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RESEARCH ARTICLE

Place-based landscape services and potential of participatory spatial planning in multifunctional rural landscapes in Southern highlands, Tanzania

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Abstract

Context Local scale assessments of ecosystem/landscape services in Africa are insufficient and lack relevance in landscape management. Also, few studies have explored the potential benefits of PGIS/PPGIS approaches for landscape management and stewardship among the participating stakeholders.

Objectives Our aim is (1) to establish an understanding of the realization of landscape services at the local scale across three multifunctional rural landscapes in Tanzania through PGIS/PPGIS approaches and (2) to create an understanding of these approaches' potential to support participatory spatial planning.

Methods Semi-structured surveys (n = 313) including participatory mapping of provisioning and cultural landscape services were organised to characterise their spatial patterns. The survey results were shared with the communities (n = 97) in workshops where services were ranked and the participants interviewed about their map-reading capacity, personal learning experiences, and their ability to use maps to express opinions.

Results The most abundant landscape services are sites for social gatherings and cultivation. The spatial patterns of provisioning services are realizations of human benefits from the patterns of the biophysical landscape. Overall, cultural landscape services show clustering and small spatial extent (except aesthetics). The PGIS/PPGIS approach allows for local-level, spatially specific discussions between stakeholders. The visual power of maps and satellite images is particularly emphasised.

Conclusion In the data-scarce context common in the Global South, the participatory mapping of landscape services has the potential to advance understanding of the benefits that the landscape has for the local communities and how this information, when mapped spatially, can be integrated with local-level planning practices.

Keywords Africa · Ecosystem services · Landscape services · Land use planning · PGIS · Participatory mapping

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Introduction

The ecosystem service framework has gained ground as an integrated framework with which to study the relations between ecosystems and people and to guide decision making towards sustainability (Millennium Ecosystem Assestment 2005). Specific challenges within ecosystem service management are related to rural communities in the Global South, where people depend on a diverse pool of natural resources for their livelihood and are particularly vulnerable to ecosystem degradation (Folke et al. 2002; Newton et al. 2016). Poverty, the conversion of forests to agricultural land and reliance on wood-based energy are globally recognised bottlenecks behind land changes (Brink and Eva 2009). On a broader scale, external socio-economic changes drive transitions, but on a local scale, the interlinked socio-ecological processes trigger land use changes. These closely relate to the values and preferences that people set on different land use choices and strategies (Lambin and Meyfroidt 2010) and their landscape stewardship strategies to support human well-being and enhance ecological resilience (Chapin et al. 2010). The ecosystem service framework aims to address the complex dynamics, interactions, resilience, and adaption of landscape structure–function-benefit chains in socio-ecological systems and the decoupling of the natural and human dimensions of land use (Opdam 2013; Schröter et al. 2014). To address this challenge, landscape services has been suggested as a specification to the concept of ecosystem services to be used in the analysis of these flows from the landscape into provisioning and cultural benefits and to be applied in community-based transdisciplinary, collaborative spatial planning and decision making (Termorshuizen and Opdam 2009).

In the assessment of landscape services, a focus on place is especially important to reveal the actual spatial connections and relationship between people and their surrounding biophysical landscape (Fagerholm et al. 2012). Participatory mapping is a powerful tool with which to grasp the socio-cultural realities of communities, regions, landscapes, and ecosystems in a place-based manner (Ryan 2011; Pánek 2016). Since the early 2000s, participatory mapping has increased in popularity in connection with the use of geographic information systems (GIS), under the terms Participatory GIS (PGIS) and Public Participation GIS (PPGIS), and has successfully engaged both the general public and individual stakeholders to identify and document a range of ecosystem and landscape services that originate in place-based local knowledge (Brown and Fagerholm 2015). Such a socio-cultural ecosystem service assessment approach is a successful way to identify spatial patterns, flows, synergies, trade-offs and the potential for extrapolation and upscaling of ecosystem services for the people that derive and demand (e.g. Palomo et al. 2013; Plieninger et al. 2019). The relevance of local communities' knowledge for ecosystem service assessment has also been highlighted by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (Turnhout et al. 2012). The studies have, however, mostly occurred in the Global North and only a few studies have applied PGIS/PPGIS approaches for mapping ecosystem services in the Global South (e.g. Fagerholm and Käyhkö 2009; Fagerholm et al. 2012; Ramirez-Gomez et al. 2013, 2015; Ricaurte et al. 2014). A recent review (Wangai et al. 2016) of ecosystem services in the context of Africa also shows an over-reliance on monetary valuation and a few participatory, local-scale assessments of multiple ecosystem services. The review points out that most published assessments are insufficient for applications in local-level landscape management.

Participatory processes are globally promoted to support democracy and decentralised environmental and natural resource management (Beierle 2002; Reed 2008) with claimed normative, substantive and instrumental benefits (Blackstock et al. 2007). Bringing in spatial information and technologies to capture stakeholders' place-based knowledge and values in participatory decision-making processes is being increasingly adopted through PGIS/PPGIS approaches (Bourgoin et al. 2012; Eilola et al. 2014). To date, however, there have been few studies exploring the potential benefits that PGIS/PPGIS approaches could bring to ecosystem/landscape service management and land stewardship for the participating communities and stakeholders (Brown and Fagerholm 2015). Tsai et al. (2013) addressed the evaluation of empowerment by highlighting that PPGIS involves the mutual transfer of knowledge, capabilities and power of all stakeholders within environmental management. Further, participatory 3D modelling has been evaluated as a socially engaging and user-friendly approach

to enhance ecosystem service assessments in decision making (Ramirez-Gomez et al. 2017). Studies have not, however, addressed the potential of PGIS/PPGIS for capacity-building of individuals and society at large to understand, argument and learn from various interests and perspectives or for enhancing communication through the use of maps to express opinions.

In data-scarce contexts, such as in Sub-Saharan countries including Tanzania, the potential of place-based knowledge of landscape services generated through stakeholders' participation would, hence, be important: (1) for data generation at the local scale and to fill scientific knowledge gaps of landscape services through socio-cultural assessment approaches, (2) to increase communities' and stakeholders' involvement and capacities in understanding land use and related values in the local landscapes, and (3) to advance an understanding of landscape services' (operationalised as landscape practices and values) links to land use, land stewardship and potential for land management and decision-making (Pagella and Sinclair 2014; Paudyal et al. 2015; Ramirez-Gomez et al. 2015). Thus, the aim of this paper is to establish a practical understanding of the realization of provisioning and cultural landscape services at local scales in the Southern Highlands, Tanzania, through PGIS/PPGIS approaches and to create an understanding of the potential of these approaches to support participatory spatial planning and land stewardship. The study is linked to the Village Land Use Planning (VLUP) in Tanzania where spatially sensitive participation and management of landscape services have the potential to be operationalised. The detailed objectives of the paper are:

1. to characterise (describe, prioritise and explore the spatial patterns) of place-based landscape services as perceived by local communities across three multifunctional rural landscapes, and
2. to evaluate the potential of PGIS/PPGIS approach to support understanding, argumentation and learning among community stakeholders and in relation to land use planning and landscape stewardship.

The paper concludes with a discussion of the implications of participatory mapping for a landscape service assessment both for scientific understanding and for participatory spatial planning in the context of the Global South.

Methods

Study areas

As is the case in most areas within rural Tanzania, the Southern Highlands region suffers from severe land management problems related to poverty, population growth, settlement and agricultural expansion, and overuse of forest resources (Mango and Kalenzi 2011). These driving forces of change relate to the complex, interdependent dynamics of biophysical, social, economic and cultural factors triggering land use changes at the local scales. Even though the region is a target of extensive land investment schemes in both the agriculture and forestry sectors (Milder et al. 2013; Private Forestry Program 2015), over 60% of the population faces poverty (UNDP 2015). The three study areas of this research represent rural villages with different landscape characteristics in the Southern Highlands region (Fig. 1). The villages of Iboya (I) and Lulanzi (L) are undulating mosaic landscapes of highland agriculture and forestry; Iboya is more peripheral than Lulanzi. Tungamalenga (T) is a flat grassland-woodland mosaic landscape located in the proximity of Ruaha National Park (Table S1). The livelihoods are typically based on a mixture of subsistence agriculture in addition to the minimum income from the sale of agricultural products and casual labour in agriculture and forestry.

Land use planning at the village level in Tanzania is decentralised, which provides the communities with the possibility to plan and manage their village land through a Village Land Use Plan (VLUP) (The United Republic of Tanzania 2007). The planning process aims to foster local landscape stewardship and sustainable land management. Establishment of a VLUP in a village is facilitated by a multidisciplinary team of district officials and involves a publically elected village council and Village Land Use Management Committee with regard to balanced gender representativeness. Based on the land legislation, the village assembly has the final decision-making mandate in the VLUP process. The planning activities include the participatory mapping of existing land use and the development of a community action plan that targets actions to address local socio-economic and environmental challenges. These activities culminate in proposed future land use mapping as the basis for a VLUP map and establishment of land use bylaws for

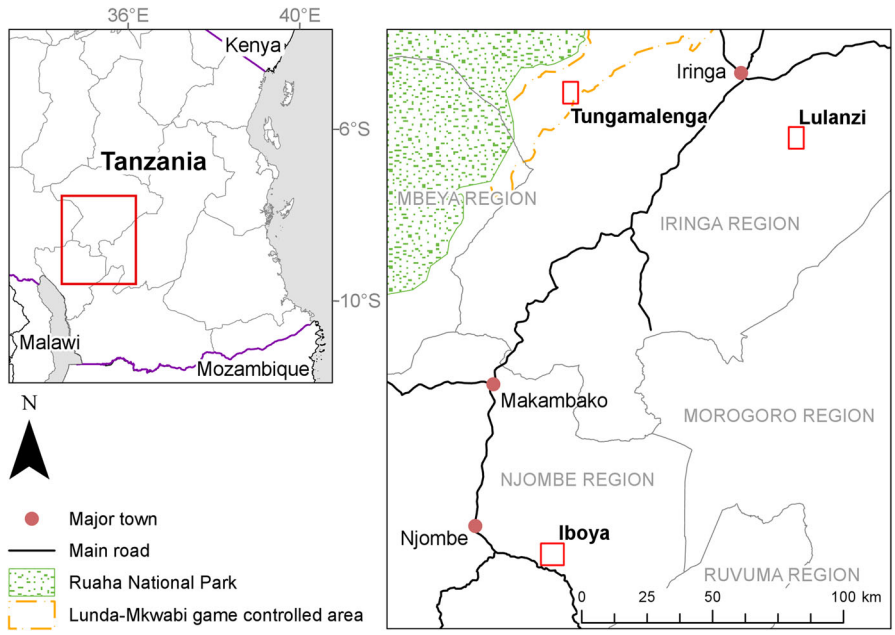

Fig. 1 Tungamalenga, Lulanzi and Iboya villages in Southern Highlands, Tanzania

the coming 10 years (National Land Use Planning Commission 2013). The process relies on tedious field work mapping as only few spatial data sets are available (namely topographic maps from the 1960s and 1970s and a national survey of village boundaries). The villages of Iboya and Tungamalenga have very recent VLUP, (Iboya was established in 2014 with funding from a Finnish forestry development project. Tungamalenga was established in 2015 in the course of Wildlife Management Area planning). At the time of this research, Lulanzi was in the process of requesting revisions to its VLUP.

Participatory mapping and landscape service typology

Conceptually, participatory mapping communicates assigned values (i.e. the judgement regarding the worth of objects such as places, ecosystems and species (McIntyre et al. 2008; Seymour et al. 2010; Van Riper and Kyle 2014; Ives and Kendal 2014). It focuses on the place-based, personal perspective that emerges from both everyday embodied experiences and accumulated knowledge (Ingold 1993; Williams and Patterson 1996; Stephenson 2008; Fagerholm et al. 2019). For the participatory mapping of landscape services, we developed a typology that follows ecosystem and landscape service typologies (e.g. Brown and Reed 2000; de Groot et al. 2002; Millennium Ecosystem Assestment 2005; Raymond et al. 2009; Vallés-Planells et al. 2014). The landscape service typology was also discussed with the Tanzanian members of the research team and based on previous experience on mapping landscape services in Tanzania (Fagerholm and Käyhkö 2009; Fagerholm et al. 2012). It aims to capture the everyday tangible and intangible benefits obtained from the landscape among the local communities and, therefore, focuses on provisioning and cultural services. Each service is addressed through operationalised landscape service benefits (Table 1). For the provisioning services (food, raw materials, fuel, and water), the benefits include, for example, cultivation, domestic animal keeping, and firewood collection. For cultural services (social relations, religious and spiritual values, culture and heritage values, and aesthetic value) the benefits include, for example, sites for social interaction and aesthetic places.

Data collection

Semi-structured surveys including participatory mapping were organised in the study villages in February–March 2016. The survey targeted community inhabitants. Sampling was spatially designed to cover different parts of the villages and the informants were

Table 1 The provisioning and cultural landscape services and their benefits in the context of Southern Highlands, Tanzania

Landscape service	Landscape service benefit
Provisioning	
Food	Cultivation
	Keeping domestic animals
	Beekeeping
	Collection of wild food
	Hunting wild animals
Fuel	Cutting/collecting firewood or wood for charcoal
Raw materials	Tree planting
	Extraction of natural building materials
	Collecting handicraft and natural medicine materials
Water	Fresh water source
Cultural	
Social relations	Sites for social gatherings
Religious and spiritual values	Religious or sacred places
Culture and heritage values	Sites for traditional practices, local culture or historical value
Aesthetic value	Beautiful, attractive place

contacted by the village executive officer following the gender and age structure of the recent census (National Bureau of Statistics Tanzania 2017). Afterwards, representativeness of the sample was estimated using ward- and district-level statistics on age and gender distribution (National Bureau of Statistics Tanzania 2017) as a proxy due to the lack of detailed village-level socio-demographic statistics. The informant sample represents the population in the area rather well in terms of age and gender, showing mostly less than a 10% deviation from the census (Table S2). The sample shows, on average, a 21.0% higher share of men between the ages of 45-65 compared to their proportion in the census statistics, particularly due to their large share in Lulanzi. In Iboya, both men and women between the ages of 20–44 are 20.3% and 19.4%, respectively, more represented in the informant sample than in the census.

The surveys preceded a meeting in which the research team and the village leaders became familiar with the satellite image map used in the mapping and the survey schedule was agreed upon. The surveys were facilitated by a 4–6 person team of researchers from Finland and Tanzania, but the surveys were conducted in Swahili by Tanzanians. The survey started with socio-demographic background questions (age, marital status, household size, livelihood sources, and relationship to the area) and an orientation to the satellite image map including locating the respondent's home. Then followed survey questions related to provisioning landscape services and mapping related landscape service benefits, followed by cultural services and their mapping. The survey ended with more sensitive socio-demographic questions on the level of education and household income. The survey was tested with ten informants after which small adaptations were made. Mapping was performed on the most recent satellite image map (mosaicked 2012–14 high-resolution Google Earth images, scale 1:7500, print size A0 (in L, T) or 1.5 × A0 (in I)) using different-coloured wooden beads (1–2 cm in diameter). Respondents were encouraged to map as many places for each benefit as they preferred. In order to transfer the locations of mapped places to digital format, the points were digitised in the field into a database in GIS. For practical reasons, place descriptions and background questions were manually noted during the survey and later inserted to this database.

The initial results were shared with the communities in workshops in March 2017 that were targeted to reach 20% of the survey participants. The aims of these workshops were multiple: to share the results in a reflective discussion, impart the local knowledge that was collected, build the capacity among community members regarding the use of the landscape and resources, deepen the interpretation of results, and rank landscape service benefits. In each village, two workshops were organised where satellite image maps

overlaid with the places mapped by the survey respondents were interpreted and discussed in groups of women, men and community experts (village council members variably including the village chairperson and the village executive officer). Workshops started with a joint introduction where the contents of the maps were explained. Landscape service maps (print size A0 or 1.5 × A0) were also visually compared with VLUP maps (print size A3) in the villages of Iboya and Tungamalenga (up-to-date VLUP not existing in Lulanzi). The main topics of discussion were shared between the groups. Each group was then asked to rank the importance of landscape service benefits from the perspective of life and the well-being of the community separately for provisioning and cultural services. The workshop facilitators, consisting of three researchers, made observations within the workshop and the main topics of discussions by taking notes.

After the group work, each participant was individually interviewed to ask about map-reading capacity (Do you think it was easy to understand the information on the maps that were used in the group discussion? [response options included yes/to some extent/no)], personal learning experiences [Do you feel that you personally learned or discovered something new during the previous discussion around the maps? (response options included yes/to some extent/no) What did you learn/discover? (open response)], and the usability of maps to express opinions (Do you think that the use of maps allows you to better communicate and share your opinion? [response options included yes/to some extent/no) Why or why not? (open response)]. These questions were chosen based on the established criteria related to the effective participation and participatory spatial planning (McCall and Minang 2005; McCall and Dunn 2012; Eilola et al. 2014). Only three themes were included in order to keep the interview effort concise for the workshop participants.

Analysis

Descriptive statistics were calculated to characterise the survey informant sample, mapped landscape service benefits and workshop interview responses in MSExcel and SPSS24. Two-tailed independent samples *t* test and Kruskall–Wallis H tests were performed to determine possible differences in the number of mapped landscape service benefits (provisioning, cultural and all) between the groups of informant background variables. As post hoc analysis for the H tests pairwise comparisons were performed using Dunn's (1964) procedure with a Bonferroni correction for multiple comparisons. Adjusted p-values are presented. In addition, Kappa values were calculated to measure the level of agreement in landscape service benefit ranking between groups and villages (Cohen 1960).

Spatial analysis was performed with ArcGIS10.5 and QGIS2.18.4. For spatial analysis, the study area was defined using the minimum bounding convex of all the service points in each village. The spatial arrangement of the mapped landscape service benefits was studied with nearest neighbour statistics (NN) to explore random distribution and clustering (Ebdon 1985). NN statistics measures the average Euclidian distance between each point and its nearest neighbours and divides this with the average distance in a hypothetical randomly distributed point layer within the analysis area. An NN ratio below 1 exhibits spatial clustering. The analysis excluded benefits with less than 30 mapped points. The distance between mapped points and respondent home locations were calculated and visualised as the relative cumulative distance for cross-site comparison. Spatial extent and intensity of landscape service benefits were analysed by creating Kernel density surfaces (Brown and Fagerholm 2015). The Kernel density estimation was calculated with a 200 m output cell size and adjusted search radii for different landscape service benefits. Based on the mapping accuracy of each landscape service benefit (the average accuracy, 200 m, was estimated based on a mapping scale of 1:7500 and beads that varied in size from 75 to 150 m), the estimated actual spatial extent of each benefit and exploration of the peaks of spatial autocorrelation with the Incremental Spatial autocorrelation tool that calculates Moran's I values for different distances, the search radius was chosen as 300, 400 or 500 m (Table S4).

Cross tabulation with Chi square tests were applied and the standardised adjusted residuals were explored to identify significant associations in the workshop interview responses. Content analysis through coding key words and identifying themes that link to or explain the data was performed for the observations and discussions from the workshops (Zolkafli et al. 2017).

Results

Informants

In total, 313 residents in the three villages (I: 79, L: 95 and T: 139) responded to the survey; approximately half of them were male and half were female (Table 2). Middle-aged (20–44 years old) was the most represented age class with a share of 56.5%. Households are typically large with 4–6 persons (48.9%, mean ± SD 5.2 ± 2.7, min 1, max 21), particularly in Lulanzi where 31.6% of households

Table 2 Characteristics of survey respondents as a relative proportion (%) in all villages and for Iboya, Lulanzi and Tungamalenga

	All	Iboya	Lulanzi	Tungamalenga
Total	100.0	100.0	100.0	100.0
Gender	*(n = 313)*	*(n = 79)*	*(n = 95)*	*(n = 139)*
Male	51.4	49.4	47.4	55.4
Female	48.6	50.6	52.6	44.6
Age category	*(n = 313)*	*(n = 79)*	*(n = 95)*	*(n = 139)*
13–19 yrs	14.4	10.1	13.7	17.3
20–44 yrs	56.5	65.8	48.4	56.8
45–64 yrs	21.7	20.3	30.5	16.5
65 yrs or over	7.3	3.8	7.4	9.4
Household size	*(n = 313)*	*(n = 79)*	*(n = 95)*	*(n = 139)*
1	4.2	8.9	0.0	4.3
2–3	21.4	27.8	12.6	23.7
4–6	48.9	46.8	55.8	45.3
More than 6	25.6	16.5	31.6	26.6
Income sources	*(n = 313)*	*(n = 79)*	*(n = 95)*	*(n = 139)*
Cultivation	82.7	73.4	91.6	82.0
Keeping domestic animals	41.2	25.3	67.4	32.4
Casual labour	28.4	45.6	21.1	23.7
Small-scale business	25.9	22.8	37.9	19.4
Forestry	12.5	32.9	13.7	0.0
Charcoal sale/and firewood sale	2.6	7.6	0.0	1.4
Other	22.7	16.5	24.2	25.2
Monthly income/pers.	*(n = 299)*	*(n = 77)*	*(n = 94)*	*(n = 128)*
< 100,000 TSH	38.8	37.7	31.9	44.5
100,000–300,000 TSH	53.8	53.2	60.6	49.2
300,001–500,000 TSH	5.4	5.2	6.4	4.7
Over 500,000 TSH	2.0	3.9	1.1	1.6
Education	*(n = 311)*	*(n = 79)*	*(n = 95)*	*(n = 137)*
No formal education	9.0	5.1	13.7	8.0
Elementary education	68.5	75.9	60.0	70.1
Secondary education	20.6	16.5	23.2	21.2
Diploma	1.3	1.3	3.2	0.0
University	0.6	1.3	0.0	0.7
Years lived in village	*(n = 313)*	*(n = 79)*	*(n = 95)*	*(n = 139)*
1–5	8.0	10.1	4.2	9.4
6–10	6.1	2.5	1.1	11.5
11–20	30.4	35.4	22.1	33.1
21–60	53.4	49.4	69.5	44.6
61–100	2.2	2.5	3.2	1.4

Columns total to 100% except income sources, which denotes the relative share of persons involved in a specific activity

consist of more than six persons. Multiple livelihood activities are typical in the villages and almost everyone (93.3%) cultivates land. In addition, 49.5% have domestic animals and 12.8% are involved in small-scale business and have other sources of living such as casual labour, carpentry and handicrafts (38.3%). Particularly in Lulanzi and Tungamalenga, income sources among respondents are heavily dependent on agriculture. In Iboya, income sources are more diversified with 45.6% of people involved in casual labour (Table 2). The majority of respondents (53.8%) estimate their monthly income between 100,000–500,000 Tanzanian shillings (100,000 TSH was the equivalent of 45.8 USD in March 2016, www.poundsterlinglive.com). Elementary education is typical among the respondents (68.5%), every fifth (20.6%) has secondary education and every tenth (9.0%) does not have any schooling. Most of the people have lived 20–60 years in the village (53.4%, mean ± SD 26.0 ± 15.1, min 1, max 78).

Characteristics of landscape services

Place-based landscape services and their importance ranking

In total, 313 respondents mapped 6117 landscape service benefits, on average (mean ± SD) 18.4 ± 5.1 places (min 7, max 34). Provisioning landscape services indicate 65.0% of places and 35.0% cultural services. Most landscape services were mapped by the majority: more than 80% of informants (Fig. 2, lines). Tree planting shows largest variation and was more prominently identified in Iboya and Lulanzi than in Tungamalenga (I: 83.5%, L: 87.4%, T: 20.9%).

The majority are sites related to social interaction (21.7%, 4.2 ± 1.7 places/informant) (Fig. 2, bars), which are typically meeting places (42.3%), wedding or burial sites (22.2% and 21.6%, respectively) or sites for practicing sports (11.5%). Out of the mapped sites, 12.1% are field locations with 2.4 ± 1.0 mapped fields per respondent where maize (38.9%) is most commonly cultivated. Almost fifth (19.8%) of the mapped fields are gardens located at home. These most frequently mapped benefits are followed by sites for extraction of building materials (10.0% of mapped sites, 1.3 ± 1.0 places/informant), fresh water sources (9.6%, 0.8 ± 0.8), wood for firewood and charcoal (8.4%, 1.0 ± 0.9), and wild food collection (7.2%, 0.6 ± 0.7) (Fig. 2, bars). Building materials mainly consist of soil or wood extraction (36.3% and 30.9%, respectively). The extraction of wood to be used as firewood is much more common than extracting it for charcoal production (88.0% vs. 4.1%). Mushrooms and wild fruits are the most commonly collected wild food resources (28.4, 15.0 and 12.8%, respectively). Out of cultural services, the second most mapped are religious or sacred places (6.4% of mapped sites,

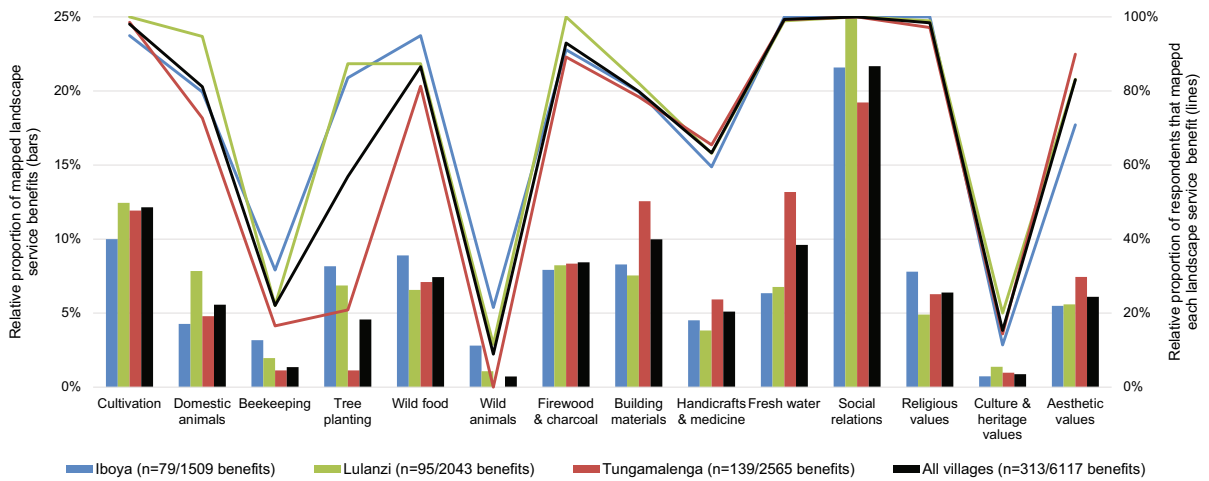

Fig. 2 Relative proportion (%) of mapped places (bars) and relative proportion (%) of respondents that mapped each landscape service benefit (lines) in Iboya, Lulanzi and all villages together. The numbers in brackets identify the amount of informants (n) and number of mapped landscape service benefits. Wild animals were not included in the survey in Tungamalenga

Table 3 Ranking the importance (1 = most important, 10 = least important) of landscape service benefits from the perspective of life and well-being within the community

	Iboya				Lulanzi				Tungamalenga				All, mean			
Service	Women	Men	Experts	Mean	Women	Men	Experts	Mean	Women	Men	Experts	Mean	Women	Men	Experts	Total
Provisioning																
Cultivation	2	2	2	2.0	2	1	2	1.7	2	1	2	1.7	2.0	1.3	2.0	1.8
Domestic animals	4	4	7	5.0	5	4	5	4.7	7	4	6	5.7	5.3	4.0	6.0	5.1
Beekeeping	6	9	9	8.0	8	8	9	8.3	8	9	7	8.0	7.3	8.7	8.3	8.1
Wild food	9	8	10	9.0	9	7	8	8.0	9	8	8	8.3	9.0	7.7	8.7	8.4
Wild animals	10	7	8	8.3	10	10	10	10.0	10	10	10	10.0	10.0	9.0	9.3	9.4
Tree planting	3	3	3	3.0	3	3	3	3.0	5	5	5	5.0	3.7	3.7	3.7	3.7
Building materials	5	6	6	5.7	6	5	4	5.0	6	6	4	5.3	5.7	5.7	4.7	5.3
Handicraft & medicine	8	10	5	7.7	7	9	7	7.7	4	7	9	6.7	6.3	8.7	7.0	7.3
Firewood & charcoal	7	5	4	5.3	4	6	6	5.3	3	3	3	3.0	4.7	4.7	4.3	4.6
Fresh water	1	1	1	1.0	1	2	1	1.3	1	2	1	1.3	1.0	1.7	1.0	1.2
Cultural																
Social relations	1	1	1	1.0	1	1	1	1.0	1	1	1	1.0	1.0	1.0	1.0	1.0
Religious and spiritual values	3	3	2	2.7	2	2	2	2.0	2	2	2	2.0	2.3	2.3	2.0	2.2
Culture and heritage values	4	2	3	3.0	4	4	4	4.0	4	3	4	3.7	4.0	3.0	3.7	3.6
Aesthetic values	2	4	4	3.3	3	3	3	3.0	3	4	3	3.3	2.7	3.7	3.3	3.2
Participants total	8	5	M:10 W:3		11	10	M:9 W:2		18	23	M:5 W:1		37	38	M:24 W:6	

The two most important services in each category are highlighted. The ranking exercise was done separately for provisioning and cultural services in the workshops in groups of women (W), men (M) and experts

0.5 ± 0.5 places/informant) indicating churches and sites for ritual services, and beautiful places (6.1%, 0.8 ± 0.7). All other services receive less than a 5.6% share of the total amount of mapped sites for landscape service benefits (Fig. 2, bars). Out of these, hunting wild animals, sites for culture and heritage values and beekeeping are indicated only amongst 0.7, 0.9 and 1.4% of mapped sites (1.6 ± 0.6, 1.1 ± 0.4 and 1.2 ± 1.1 mapped sites per informant, respectively) and are also among the least frequently mapped benefits by respondents (Fig. 2, lines).

Men mapped, on average, statistically significantly more places than women (number of all mapped places 20.6 ± 5.67 vs. 18.4 ± 5.1 for men (n = 161) and women (n = 152), respectively [t(311) = 3.519, $p = 0.000$], provisioning 13.3 ± 4.3 vs. 12.1 ± 3.8 (t(311) = 0.009, $p = 0.000$) and cultural 7.3 ± 2.0 vs. 6.3 ± 2.1 [t(311) = 4.305, $p = 0.000$)]. Between age groups, the number of mapped cultural services are statistically significantly different ($X^2(3) = 8.492$, $p = 0.037$) and differences occur in the median number of mapped points between 13 and 19 years of age (n = 45, median = 6) and 20–44 years of age (n = 177, median = 7) ($p = 0.039$). Similarly, in relation to income groups, differences were observed for cultural services ($X^2(2) = 5.465$, $p = 0.065$) but post hoc analysis did not reveal statistically significant pairwise comparisons. When looking at the length of residence, the number of mapped places are statistically significantly different between groups for both provisioning ($X^2(3) = 8.070$, p = 0.018), cultural ($X^2(3) = 11.821$, p = 0.003) and the total number of mapped landscape services ($X^2(3) = 12.642$, p = 0.002). Those who have lived in the village for a shorter time (0–10 years, n = 44, median 16.5 points for all, 11 for provisioning and 6 for cultural services) mapped less points in comparison to those who have lived there a longer time [more than 20 years, n = 174, median 20 points for all ($p = 0.001$), 11 for provisioning ($p = 0.015$) and 7 for cultural ($p = 0.004$)]. The household size or level of education did not affect the number of mapped landscape service benefits.

The results of the group ranking exercise from the workshops show that, overall, the most important landscape service benefits for the life and well-being of the communities are sites for water sources (total mean rank 1.2) and cultivation (1.8) for provisioning services and sites for social gatherings (1.0), followed by religious and sacred places (2.2) for cultural services (Table 3). Groups of women, men and experts are rather uniform in their opinions, particularly for the most important services. However, in Iboya and Tungamalenga the overall rankings of women to men (I and T: Kappa value 0.356***) and experts (I: Kappa value 0.195*) show only fair or poor agreement, Table S3). Between the villages, the rankings of different groups show mostly fair or poor agreement (Kappa values < 0.4) and a difference is seen, particularly in relation to tree planting playing a less significant role in Tungamalenga (mean rank I:3.0, L:3.0 vs. T:5.0).

Spatial patterns of landscape services

Mapped landscape service benefits are most abundant around the village centres and influenced by the accessibility through the road networks and neighbouring villages (Fig. 3). A larger spatial extent and lower spatial intensity (Kernel density) is observed for provisioning than cultural service (Fig. 3, Table S4). Iboya, the largest study area, has the largest spatial extent (828-3769 ha) for provisioning services compared to the other two villages (580–2772 ha). The spatial clustering of landscape service benefits show similar patterns in all the villages (Table S5). The three most clustered benefits are sites for social gatherings (I: NN ratio 0.18, Z − 28.19***, L: NN ratio 0.15, Z − 36.76***, T: NN ratio 0.17, Z − 35.18***), followed by either water sources or religious or sacred places (Table S5).

Cultural services are generally found closer to homes than provisioning services (mean ± SD distance from home 1090 ± 1007 m and 1389 ± 1186 m respectively). However, the shortest mean distances are observed for water sources (54–87% of points within 400 m from home, mean ± SD 434 ± 424 m) and keeping domestic animals (chickens, guinea pigs and goats) at home (67–87% of points within 400 m distance from home, mean ± SD 551 ± 1095 m, Fig. S1). With respect to the provisioning services of cultivation, wild food collection, cutting/collecting firewood or wood for charcoal and extraction of building materials, the cumulative distances show a similar trend with informants in Iboya mapping these provisioning service benefits closest to home and in Tungamalenga the furthest.

Out of all landscape service benefits, cultural services, except aesthetic values, are the most limited

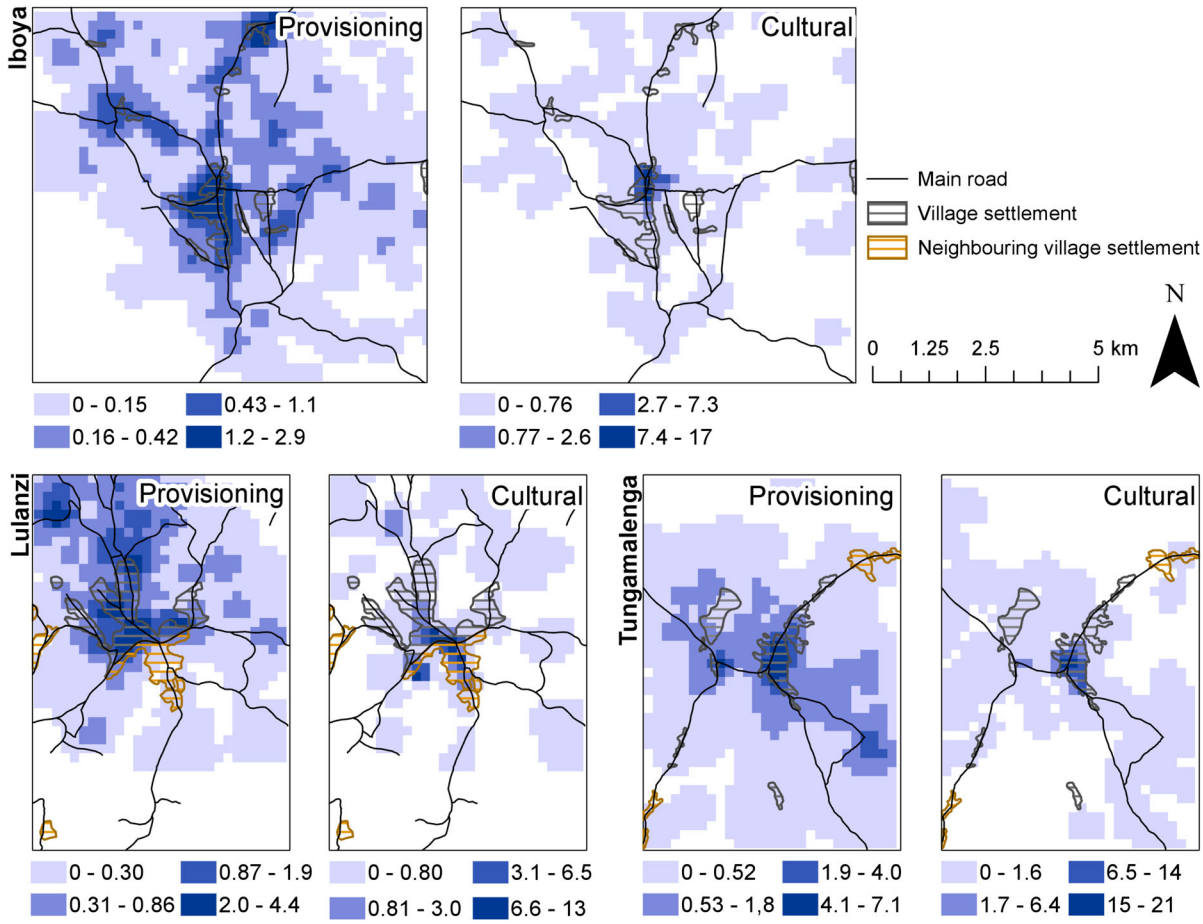

Fig. 3 Spatial intensity (points/ha, 200 m cell size) of provisioning and cultural landscape services as Kernel density surfaces for the three study areas (i.e. Iboya, Lulanzi and Tungamalenga)

in spatial extent (236–828 ha) (Fig. 3) with the mean intensity varying between 0.2 and 0.21 mapped points/ha (Table S4). Religious and sacred places have the shortest mean distance to home (mean ± SD 815 ± 4949 m, Fig. S1). In Iboya, religious and sacred places show a significantly larger extent and lower intensity values compared to the other villages (I: 828/L: 376 ha/T: 420 ha, I: 0.02/L: 0.06/T: 0.06 point density, Table S4). Cultural services (except culture and heritage values) are mapped in Tungamalenga closer to home in comparison to other villages (Fig. 4). Out of cultural services, sites for aesthetic values are mapped furthest from the informants' home (mean ± SD 2061 ± 1217) and cover 1880 ha (Kernel density surfaces) in Iboya and Tungamalenga and 1236 ha in Lulanzi. However, aesthetic values show a higher spatial intensity in Iboya compared to other villages (I:0.11/L:0.04/T:0.04) although their pattern is among the most dispersed landscape services in Iboya (NN ratio 0.67, Z − 5.47***) (Tables S4 and S5). Sites for culture and heritage values shows the most variable trends in cumulative distances across the villages (Fig. S1).

Understanding, argumentation and learning with maps

A total of 97 persons (I: 26, L: 32, T: 39) attended the workshops where maps of survey results, together with the VLUP maps, were discussed and interpreted. These participants represented 31.0% of the survey respondents. In the personal interviews, slightly over a half (58.3%) of the participants claimed it was easy to understand information presented on maps (Fig. 4).

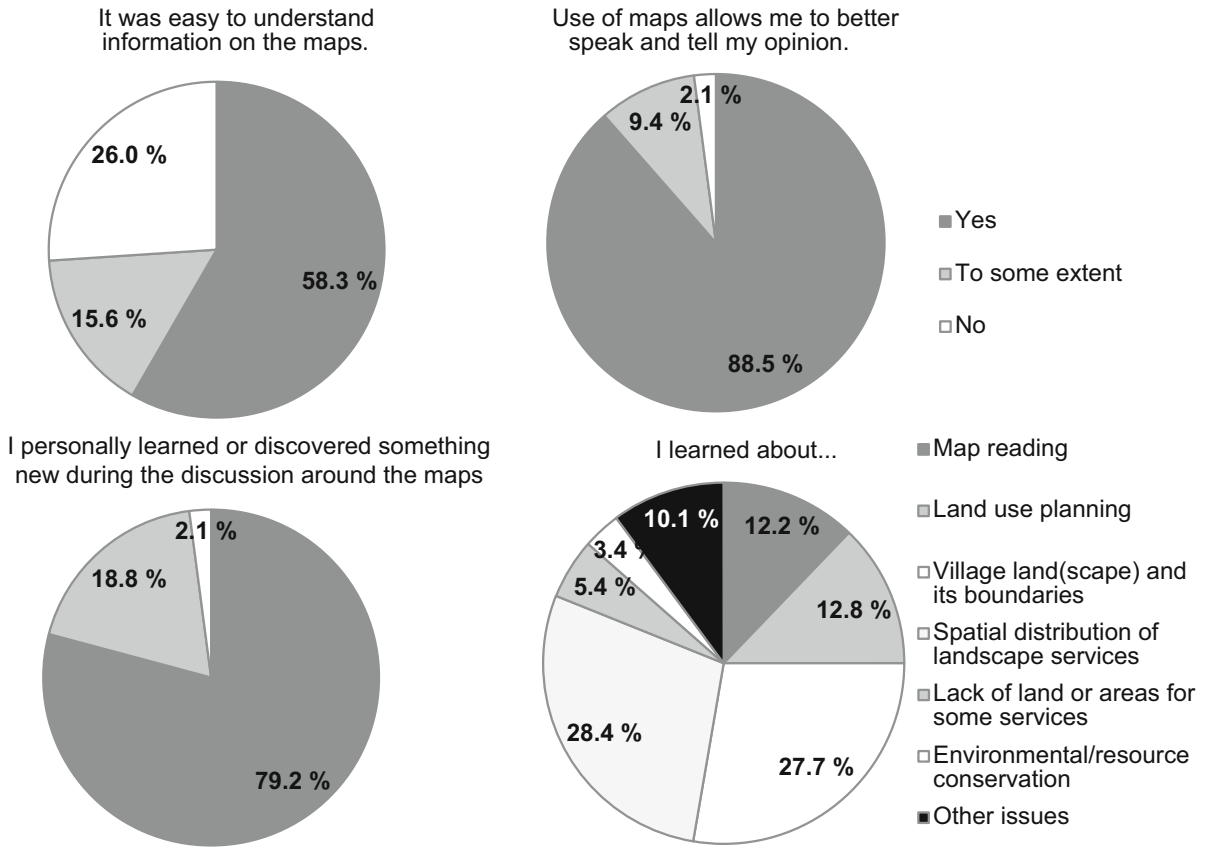

Fig. 4 Relative share of responses related to questions on understanding, argumentation and learning with maps posed to workshop participants

The majority (88.5%) said that using this type of map allowed for better argumentation and 79.2% learned or discovered something new, particularly related to the spatial distribution of landscape services, village land(scape) and its boundaries, land use planning and map reading (Fig. 4). Some differences between the groups of women, men and community experts were observed. Men found the maps easier to understand than women (yes responses 69.2% vs. 45.5%, respectively, $X^2(2, N = 96) = 7.262$, $p = 0.026$). Among villagers, 60.6% found the information presented on maps to be easy to understand, while only 53.3% of experts held the same opinion; a significant portion of them (30.0%) responded 'to some extent' ($X^2(2, N = 96) = 7.431$, $p = 0.024$). No statistically significant differences for any of the questions were observed between villages.

Enhanced argumentation with spatially explicit data is particularly related to the visual power of maps and satellite images used in the background and exemplified by the following interview quotes:

> *The satellite image helped to increase understanding because some areas are not well understood by just walking in the village. (male, 28 yrs.),*
> *Without the map I can hardly tell [anything] about the village, but through the map I could easily see everything. (female, 42 yrs., expert group),*
> *The satellite image shows things differently than other hand-drawn maps or by walking in the village. (male, 38 yrs.) and*
> *Because the map was clear and I could see everything, it triggered my mind. (female, 45 yrs., expert group).*

Documentation from discussions amongst the groups shows that maps are useful in showing use of resources and values on land from the villagers' perspective.

They are considered a good addition to VLUP maps and can be useful in developing new VLUPs and revising the existing ones. Participants from Lulanzi in particular wanted to use landscape service maps in the future VLUP process. Group discussion can also be encouraging for bringing different priorities in land and resource use and related values across genders at the front:

> *I learned to think and especially to discuss priorities with women. (male, 48 yrs., expert group),*

and effective format in collaboration:

> *A map can be used with many people at the same time so all can see and discuss. (male, 63 yrs.).*

It was also observed that, in participation applying spatial approach, skilled facilitation is essential, as was pointed out in interview quotes:

> *Facilitators helped me to understand the map and I was able to share my opinion. (male, 45 yrs.),*

> *I was taught how to read and understand the map and I was able to answer the questions (female, 40 yrs., expert group), and*

> *With the map I was able to identify areas and their resources. With the facilitators' help we could understand the village very well. (male, 59 yrs.).*

In Lulanzi, the workshop was not started effectively as participants arrived slowly, but this created an opportunity for the participants who were present to start looking at the maps amongst themselves without guidance or orientation. This opportunity created lively discussion and people explained the contents to each other.

Discussion

Participatory mapping of landscape services for science and stakeholders

Under the shortage of studies addressing the landscape and ecosystem services in Africa (Wangai et al. 2016), our study enhances an understanding of what contributions landscapes with their natural and cultural assets make to the lives of the communities in the three studied Tanzanian villages. The key place-based landscape service benefits are linked to social interaction and cultivation (cf. Fig. 2). Ranking the importance of the benefits for the life and well-being of the communities (cf. Table 3) confirms findings from other studies that show food production, firewood, and religious and spiritual values as the most prioritised benefits in rural developing communities (e.g. Muhamad et al. 2014; Paudyal et al. 2015). Hence, our results show essential differences in studies performed in the rural Global North context that highlight the role of recreational and aesthetic values alongside social interaction as key ecosystem/landscape services (e.g. Plieninger et al. 2013; Hausner et al. 2015).

The applied PGIS/PPGIS approach allowed us to map how local land use practices and values are distributed in the villages. Our results show that the spatial patterns of provisioning services are realizations of human benefits from the structure of the biophysical landscape that stress the multifunctional character of the landscapes in the context of the Southern Highlands. The scattered pattern, large spatial extent and low spatial intensity (cf. Fig. 3, Table S5) observed for the majority of provisioning landscape service benefits is a consequence of the family-based livelihood activities distributed close to resources where the daily activities happen, confirming observations from other subsistence-based communities (Fagerholm et al. 2012). The spatial patterns are explained, not only by the individual family strategies of subsistence, but also by the fact that families have different parcels of cultivation land scattered in the landscape. In Tungamalenga, cultivation is concentrated on the southwest wet plain (cf. Fig. 3) and the surrounding flat land, also highlighted by the NN analysis results (cf. Table S4). In Iboya and Lulanzi, cultivation areas outside the settlements are more evenly spread in the landscape (cf. Fig. 3). The location of these fields is essential in defining the sites where other landscape service benefits, such as wild food, firewood and building materials, which are often gathered along the route to the field or in the surroundings, are realised. It is confirmed by the similar trends for these benefits in the cumulative distance graphs (cf. Fig. S1). Hence, the uniqueness of the local landscape for the realisation of landscape

services is highlighted by the differences in these distances across the three villages.

The place-based landscape service benefits are most abundant in the village centres and they are the hot spots of landscape service co-production through human-nature interaction (Palomo et al. 2016; Fischer and Eastwood 2016), particularly in terms of cultural services. This result is in line with studies performed both in the Global South and North (e.g. Fagerholm and Käyhkö 2009; Garcia-Martin et al. 2017). Overall, cultural landscape services show clustering and small spatial extent (except aesthetics). The mostly abundantly mapped sites for social gatherings (cf. Fig. 3) highlight these shared sites' essential importance to meeting and interacting with people as fundamental to the well-being of the communities. In fact, social relationships are commonly identified as a core component of quality of life and subjective well-being (Costanza et al. 2007; Rogers et al. 2012). Although religious or sacred places and sites for social gathering show spatial clustering close to home, these cultural services are located in different areas in the villages, meaning that religious sites are different from the informal meeting places. Beautiful places are not located in the immediate vicinity of informants' home sites, but distributed in the landscape. Interestingly, a similar result was found in a cross-site comparison in rural multifunctional landscapes in Europe (Fagerholm et al. 2019), which suggests that people possibly have a tendency to value aesthetics outside the core residential areas. The variable distances from home to the sites of culture and heritage values (cf. Fig S1) are explained by the specific location of particular heritage sites (e.g. house of the first village chair in Lulanzi).

In a review of the impact of ecosystem service knowledge on decision-making, Posner et al. (2016) found that the most important factor is the legitimacy of knowledge that is only reached by incorporating a diversity of views and the participation of different stakeholders in knowledge co-production. Therefore, in our research setting we aimed to merge the scientific contribution of increasing knowledge on landscape services with the evaluation of potential of PGIS/PPGIS approaches for participatory spatial planning. Previous studies have noted that participation applying a spatial approach and map visualisations contribute to empowerment and knowledge building (e.g. Paudyal et al. 2015; Ramirez-Gomez et al. 2015; Sinare et al. 2016), but our interest was to measure these benefits.

Although some of our workshop participants found maps to be a challenge to understand, overall we noticed that the landscape service benefit maps targeted to lay stakeholders were positively received amongst the community members (cf. Fig. 4). The PGIS/PPGIS approach allowed local-level, spatially specific discussions between stakeholders and revealed new undocumented information about the land and resources. In data-scarce contexts where people literally depend on the landscape for their livelihood, the potential of sharing such place-based knowledge is of outmost importance to advance an understanding of land use, its stewardship and planning. Although in Lulanzi we positively observed people helping each other to understand and use the maps, a general observation from the workshops is that facilitators have a crucial role in ensuring that participants understand the represented information. Being able to express opinions and learn new issues related e.g. to land use and landscape values was highly appreciated by the informants (cf. Fig. 4) and is a clear indication that a spatial approach and use of maps would be helpful in decision-making. The visual power of maps and satellite images was particularly emphasised. Valencia-Sandoval et al. (2010), Bourgoin et al. (2012), Arciniegas and Janssen (2012), and Panek and Vlok (2013) also stress the benefits of landscape visualisation tools for empowering local communities in land use planning and catalysing negotiations. Additionally, we observed that facilitated discussions in the workshops were successful for sharing views and opinions between the genders as traditionally men and women have distinct roles in Tanzanian society. Land and forest management challenges are inherently spatial and PGIS/PPGIS tools have the potential to function as a boundary object in ecosystem service management discussion (Opdam et al. 2013; Ramirez-Gomez et al. 2017). These spatial tools may bridge knowledge divides and help to achieve a fair distribution of benefits through improved visualisation and communication across stakeholder groups.

From the perspective of the local-scale planning processes, the extensive survey campaigns that were applied in this study are not, however, feasible under the limited financial and human resources of the planning authorities. Hence, we suggest a deliberative

PGIS/PPGIS approach (Palomo et al. 2014; Raymond et al. 2014) that seeks a political rather than statistical representation, such as group mapping exercises, can operationalise the participatory mapping of landscape services in land use planning. The representation of various stakeholder communities and their interests can be ensured through participatory stakeholder analysis (Reed et al. 2009) and deliberative social catchment sampling (Ernoul and Wardell-Johnson 2013). Such a deliberative approach could also be integrated to the existing land use planning processes, such as VLUP in Tanzania (Eilola et al. 2018). The decentralised planning approach of VLUP is a good opportunity for participatory mapping to guide locally relevant, informed decisions and enhance the community capacity to gather and apply information for decision-making. Landscape and ecosystem services and the benefits of nature to society would, however, need to be acknowledged by the policies guiding the local-level planning as suggested in the integrated landscape management initiatives in the Global South (Estrada-Carmona et al. 2014; Milder et al. 2014). It would also be crucial for the donating organisations, which have significant political power, to integrate these principles in natural resource management (Hart et al. 2014; Lund et al. 2017). The institutionalisation of participation by applying spatial tools is needed to support landscape stewardship and promote collaborative and bottom-up landscape governance in land use planning practice. Ultimately this has an important contribution to the empowerment of local stakeholders.

Caveats and ethics

Some methodological caveats of our study relate to sample representativeness, mapping accuracy and interview setting. Firstly, during data collection it is often challenging to follow the initially planned gender and age distribution due to on-site social dynamics in which the village leaders might express power and interest to influence the selection process (cf. McCall 2003). Our research team is, however, knowledgeable and competent to cope with this to ensure the best possible informant representativeness. Secondly, the facilitated survey approach allowed for the discussion of the correct locations of mapped places and we find this increased data quality. It is, however, possible that some uncertainty remains in point placement. Thirdly, it is possible that the positive responses to the questions related to map-reading capacity, personal learning experiences, and usability of maps to express opinions were exaggerated by the fact that facilitators did the personal interviews. However, we were concerned that the participants might not have been motivated to respond to the questions on paper after the workshop or that they lacked the capacity to read and understand the questions. Therefore, we decided not to use self-administered surveys.

Some ethical issues should also be highlighted. Our research team paid special attention for not raising false expectations within the communities, both during the surveys and the workshops. Despite the fact that a mapping process aims to create data supporting sustainable management of local resources and facilitating planning processes, there always exists the possibility that hidden conflicts can arise (Rambaldi et al. 2006; Fagerholm 2014). Our intention was not to inflame any potential conflicts, but to support constructive discussion as the workshop facilitators were informed.

Conclusions

In this study, we have mapped and characterised place-based landscape services as perceived by the local communities across three multifunctional Tanzanian rural landscapes and evaluated the potential of PGIS/PPGIS approach to support understanding, argumentation and learning among community stakeholders. Thus, our study has aimed to address the science-policy-practice gap (Ramirez-Gomez et al. 2017) by enhancing the participation of local stakeholders in the co-production of knowledge regarding landscape services while aiming to enhance the capacity of local communities to better argument their land-related choices and values in possible decision-making processes.

The PGIS/PPGIS approach allowed data generation to fill a scientific knowledge gap of place-based landscape services through a socio-cultural assessment approach. Through participatory mapping, shared interpretation and ranking of the mapped landscape service benefits, we have enhanced communities' capacities to understand how land use and landscape-related values are associated with the

residents' daily living environment; what benefits are personally important to them and which are collectively crucial and how these benefits are generally related to their biophysical environment and the development of landscape assets. We believe that this will enable local communities to better argument and explain their place-based and intimate relationship to the surrounding landscape and, thus, establish a stronger relationship and stewardship with it. In the advent of any external influences, or in the process of new development possibilities, we expect these communities to have better chances of showcasing important landscape areas and activities for the well-being of the community. We suggest the institutionalisation of participation by applying a spatial approach. In addition, the incorporation of a landscape/ecosystem service framework to land use planning is crucial. We see it operational through a deliberative participatory approach.

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