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Associations between local land use/land cover and place-based landscape service patterns in rural Tanzania

Vesa Arki[a], Joni Koskikala[a,*], Nora Fagerholm[a], Danielson Kisanga[b], Niina Käyhkö[a]

[a] Department of Geography and Geology, University of Turku, 20014, Finland
[b] Department of Geography, University of Dar es Salaam, Tanzania, P.O. Box 35051, Dar es Salaam, Tanzania

ABSTRACT

Securing reliable flows of landscape services is a vital prerequisite for sustaining well-being, especially in the rural Global South, where livelihoods of local communities are dependent on the surrounding village landscapes. To support sustainable landscape development strategies, increased understanding is needed on how landscape services are associated with physical landscapes. In this paper, we studied how place-based landscape services are spatially associated with local land use/land cover (LULC) patterns in three rural villages in the Southern Highlands of Tanzania. We mapped the spatial distribution of eight provisioning and one cultural landscape service indicators through participatory mapping and identified their associations with the local LULC patterns using chi-square residual and correlation analysis. Based on our results, LULC patterns are significantly associated with landscape service patterns. Although local realities and interactions have created unique association patterns, some commonalities were found in all villages. This suggests that spatial information on LULC patterns could be used as a proxy for landscape service patterns at broader scales.

1. Introduction

There is a landscape sustainability challenge in many parts of the world, and concern is increasing that landscapes may lose their potential to deliver services for people (MA, 2005). Land use changes, declining biodiversity, climate change and degradation of forests, soils and water bodies threaten landscapes' overall capacity to deliver human benefits (Haddeland et al., 2014; Porter et al., 2014; Gibbs and Salmon, 2015; Sloan and Sayer, 2015). Unfortunately, vulnerability to and impacts of these processes are felt especially in the rural communities of the Global South, where additional pressures emerge from rapid population growth, poverty, overuse of natural resources and unregulated development of infrastructure and settlements (Fisher et al., 2011; Parnell and Walawege, 2011; Nkonya et al., 2016; Lambin and Meyfroidt, 2010; IPBES, 2018). We need to increase our understanding of how the coupled natural and cultural systems interact and evolve through time and how the physical living environment translates to explicit human benefits. Such knowledge is especially vital at the local scale to help in the sustainable management of service provision, but also to help us understand and predict how services are perceived, realized and valued at broader scales (Gulickx et al., 2013; Brown et al., 2015; Ramirez-Gomez et al., 2015; Nowak and Grunewald, 2018).

The ecosystem service framework is a comprehensive and integrative framework to study the associations between ecosystems and humans to guide sustainable management (MA, 2005, Carpenter et al., 2009). It enables us to study the complex dynamics, interactions and resilience of landscape systems, where linkages between physical landscape properties, different system functions and human benefits are put in focus (Haines-Young and Potschin, 2009). Landscape services bring beneficial specificity to the concept of ecosystem services when we focus on the perceived flow of services from the physical and cultural living environment at the local landscape scale (Termorshuizen and Opdam, 2009; Fagerholm et al., 2012; Bastian et al., 2014). The concept emphasizes that the provision of services is context-sensitive and that a focus on place is especially important to reveal the actual spatial connections and relationships between residents and their surrounding landscapes (Fang et al., 2015). Therefore, landscape service patterns can be seen as a realized flow of services from the cultural and natural systems and the complex interactions between them.

There is a wealth of studies concerning spatial mapping and modelling of ecosystem services in different landscapes (Seppelt et al., 2011; Egoh et al., 2012; Martinez-Harms and Balvanera, 2012; Crossman et al., 2013; Malinga et al., 2015; Wangai et al., 2016). However, a major knowledge gap remains when it comes to local landscape systems in rapidly developing societies. While numerous studies in the Global North show us a strong relationship between land use/land cover (LULC) patterns and ecosystem services (Haines-Young, 2009; Schulp and Alkemade, 2011; Seppelt et al., 2011; Martinez-Harms and Balvanera, 2012; Crossman et al., 2013), it is not that well-known how multifunctional and often fragmented landscapes in the Global South

* Corresponding author at: University of Turku, Department of Geography and Geology, 20014 Turku, Finland.
E-mail address: jonkosk@utu.fi (J. Koskikala).

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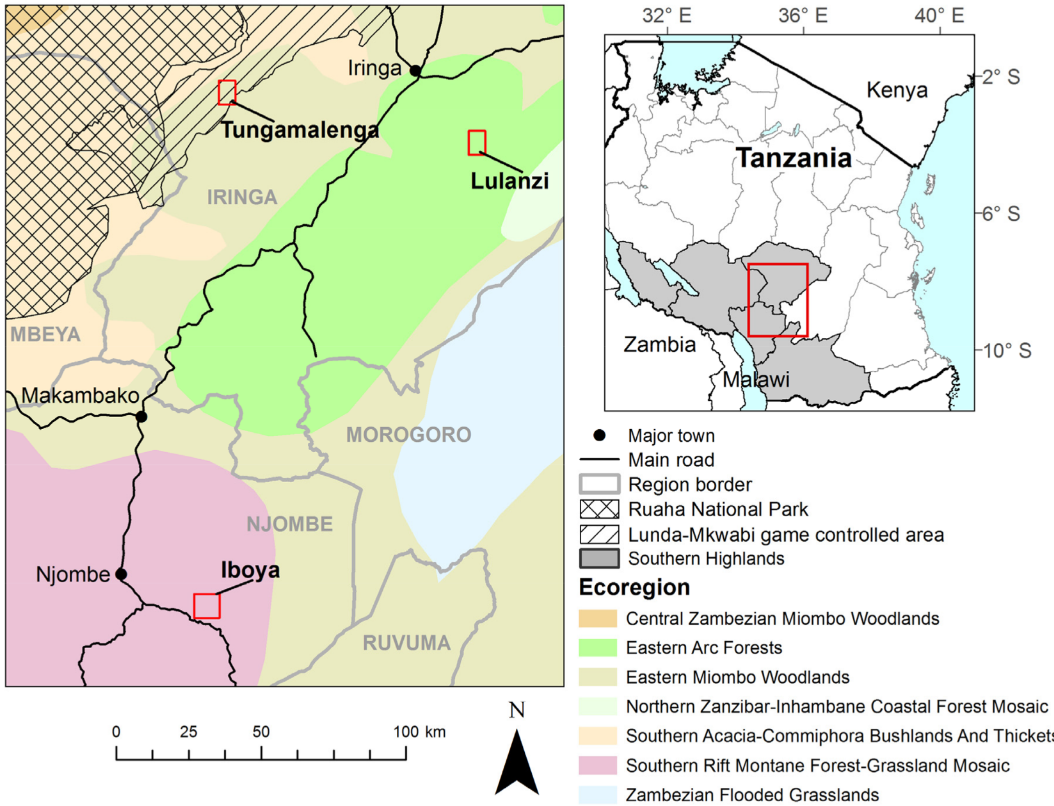

Fig. 1. The three study villages (Iboya, Lulanzi and Tungamalenga) are located in rural and relatively remote areas in the Tanzanian Southern Highlands.

come to yield multiple human benefits (Vrebos et al., 2015; Palomo et al., 2018). Such information is crucial prior to using, for example, regional or global LULC data or satellite imagery-derived indices as proxies in ecosystem service assessments in different parts of the world (Lu et al., 2015; Sarvajayakesavalu, 2015; Malmborg et al., 2018).

Spatial information on landscape and service patterns is often limited in availability or suffers from poor quality, especially at the local scale in a rural context of the Global South (Wangai et al., 2016). In cases where data availability is scarce and practices of how people value and use the land are unknown, participatory mapping approaches are useful, providing powerful solutions to generate place-based information on how services produce perceived benefits at a local scale (Ramirez-Gomez et al., 2013; Fagerholm et al., 2012; Damastuti and de Groot, 2018). These approaches enable local communities to be involved in the data generation, and thus they increase the quality and contextual relevance of the mapping data. When local spatial information on landscape services is linked with physical landscape data, they together enable estimations of service distributions over the whole landscape (Potschin and Haines-Young, 2013; Brown et al., 2015). These integrated, spatially explicit service databases enable mapping and modelling of associations between place-based landscape services and local landscapes. They increase our understanding of service flows in landscapes and contribute to transferring values throughout similar areas (Troy and Wilson, 2006; Sherrouse et al., 2011; Brown and Brabyn, 2012b; Sherrouse and Semmens, 2014; Brown et al., 2015). However, the functionality of the integration depends on the quality and extent of the available data on the physical landscape, as well as on its relevance in terms of generating and upholding the services important to the local community.

Recent studies have shown that in multifunctional and heterogeneous landscapes, service flows are not that explicitly linked with certain LULC types (Fagerholm et al., 2013; Gulickx et al., 2013; Sinare et al., 2016; Malmborg et al., 2018). In such cases, a landscape approach that corresponds to the perceptions of the local people is more sensitive to the role of spatial heterogeneity for the service pattern within the landscape (Verburg et al., 2009). Such a community-powered approach can reveal important associations between landscapes and service patterns that help us to understand the function of the landscapes for the communities (Dawson and Martin, 2015). Therefore, to increase our understanding of service patterns in multifunctional landscapes, more empirical evidence is needed that focuses on the overall service pool of local communities and is sensitive to the landscape context (Pagella and Sinclair, 2014; Ramirez-Gomez et al., 2015; Lamy et al., 2016).

In Tanzania, landscapes are under constant pressure from population growth, land fragmentation, deforestation, environmental degradation, insecurity of land tenure and growth in land use conflicts (Kangalawe and Lyimo, 2010; Schmitz et al., 2014). Landscape changes and the resulting degradation of vital services endanger the present and future well-being of the communities that rely on natural resources for their livelihoods and everyday activities (Mango and Kalnezi, 2011; Schaafsma et al., 2014). Many spatial ecosystem service studies in Tanzania have been conducted only at a regional scale, with focus on selected ecosystem services (Mwampamba, 2007; Elisa et al., 2011; Swetnam et al., 2011; Schaafsma et al., 2014). Thus, additional local, village-scale assessments are needed for spatially explicit understanding of landscape services and their associations with landscapes' physical patterns.

In this paper, we have studied how local landscapes provide spatially explicit services to communities in three rural villages in the Southern Highlands of Tanzania. The aim is to establish a practical understanding of an integrated landscape approach's potential for supporting sustainable landscape development. To depict the physical landscapes and the ways people use the land, we have created LULC category and LULC mosaic maps and collected place-based landscape services through participatory mapping. Through integrated spatial analyses of the landscape services perceived by the local communities and the LULC coverage, we proceed to identify the most important associations between place-based landscapes services and LULC patterns. Based on our findings, we discuss how the integrated landscape analysis advances our understanding of the association patterns in multifunctional landscapes at multiple scales. Finally, we discuss the methodological challenges and risks related to spatially explicit analysis of LULC and service patterns, especially when projected at broader scales.

2. Methods

2.1. Study area

The study was conducted in The Southern Highlands of Tanzania (Fig. 1). The Southern Highlands, located in Southwest Tanzania, are biophysically diverse, encapsulating the valuable Eastern Arc Mountains ecoregion, Southern Rift Montane Forest-Grassland Mosaic ecoregion and the Eastern and Zambezian miombo woodlands, with a diverse set-up of forests, woodlands, bushlands, grasslands and agricultural land (Olson et al., 2001; Burgess et al., 2007). Today, the area is the most important production area of grains and potatoes, and its southern and eastern parts are the main source of timber in Tanzania (Kangalawe, 2012). The Southern Highlands are a good representation of a rural region where local village landscapes change under multiple pressures from population growth, land fragmentation, deforestation and environmental degradation (Kajembe et al., 2003; Malley et al., 2009; Schaafsma et al., 2012; Green et al., 2013; Sawe et al., 2014). The government of Tanzania is promoting extensive land improvement schemes both in the agricultural and forestry sectors, and expectations are set high in terms of their future development opportunities for productivity and well-being (Milder et al., 2013; Nijbroek and Andelman, 2016; PFP, 2016).

We selected three villages representing different biophysical contexts in the region. Iboya (I, pop. 899) and Lulanzi (L, pop. 1879) are best described by landscape mosaics of agriculture, grassland and forest, located at higher altitudes in a temperate-to-cool climate and receiving high (1000 to 1600 mm) and reliable annual rainfalls (Mbubululo and Nyihirani, 2012; URT, 2013a). Lulanzi has good access to the larger markets of the regional capital Iringa, while Iboya is located on the periphery and has weak access to markets. In Tungamalenga (T, pop. 3101) the climate is semi-arid with unreliable rainfall from 500 to 600 mm annually (URT, 2013b). The landscape consists of a large wet plain, surrounded by tree-covered hills and areas of semi-open woodland. Located in the Lunda-Mkwabi game control area, Tungamalenga is the last village tourists pass by on their way to Ruaha National Park.

A mixture of subsistence-based livelihoods and the collection of natural resources are prevalent in the villages, where most of the families have multiple sources of income (Covarrubias et al., 2012). A majority of the rural population collects wood extensively from woodlands and natural and planted forests (Kangalawe and Lyimo, 2010), using it for energy, construction and charcoal production. Small-scale, low-efficiency agriculture is the main economic activity, with minor cash cropping, livestock, beekeeping, and casual labor supplementing the local economies. In Iboya and Lulanzi, sufficient and reliable rains enable the practice of forestry, and small patches of private plantations are found throughout the landscape (Koskinen et al., 2019). In the semi-arid Tungamalenga, the cultivation is concentrated in floodplains and irrigation systems built on them. Less rainfall keeps agricultural productivity relatively low outside the irrigated farms, but tourism provides additional sources of income.

2.2. Research design

Our approach for studying the associations between place-based landscape service and local LULC patterns is shown in Fig. 2. Place-based landscape service indicators (A) were collected in a participatory mapping campaign. LULC pattern analysis was initiated by digitizing LULC information of the village landscapes (B). To analyze the associations of LULC and landscape services, both datasets were spatially joined onto a grid. The grid cell size of 500 m was considered suitable due to the uncertainty in spatial accuracy of the mapped landscape service indicators. Patterns of landscape services in each grid cell were described by service metrics (C) derived from place-based landscape service indicators. To evaluate the spatial coexistence of landscape services, correlation between service category counts in each grid cell was calculated. Patterns of LULC in each grid cell were described by calculating LULC and distance metrics (D). Furthermore, the LULC and distance metrics were clustered into LULC mosaics (E). The LULC mosaics describe unique landscapes combining LULC patterns and geographical distance to village center. Thus, LULC categories and LULC mosaics describe the LULC patterns at the villages by two scales. Finally, statistical analysis of associations between landscape services and the LULC patterns were conducted. To estimate the role of spatial representation of LULC pattern for the associations, we analyzed the associations of landscape service indicators between the LULC categories and mosaics.

2.3. Landscape service pattern analysis

A Participatory mapping campaign was organized in the villages from February to March 2016. A representative sample of community members covering both sexes and all age groups was assigned to the campaign with the help of local village authorities. In total, 313 (I = 79, L = 95 & T = 139) community members participated in the mapping campaign in the three villages. Approximately half of the participants were female (I = 50.6%, L = 52.6% & T = 44.6%), and middle-aged (20–44 years old) participants were the most represented at 56.5%. All surveys were done in Swahili by Tanzanian team members. A service typology (Table 1) was designed based on previous experience with similar methods and landscapes (Fagerholm and Käyhkö, 2009; Fagerholm et al., 2012) and on consulting with the Tanzanian members of the research team. The typology aimed to capture the tangible material (provisioning) and non-material (cultural) services that local communities obtain from their everyday landscapes. Each service is addressed through a landscape service indicator. For example the provisioning service of "food" includes cultivation, livestock keeping and wild food collection. Each mapped point indicates an area where the service is utilized. In other words, the data layer describes the realized flow of services to the local communities.

During the campaign, participants individually identified and mapped provisioning and cultural landscape service indicators on very high resolution (VHR) Google Earth image prints (size A0 or 1.5 × A0, scale 1:7500) using wooden beads (1–2 cm in diameter) of different colors. The reference images were from the years 2012–2014. The mapping accuracy was estimated to be within 200 meters. The extent of each map was estimated to represent the respective villagers' area of everyday activities on a scale enabling easy identification of different landscape elements. For a more detailed methodological description of the mapping campaign, see Fagerholm et al. (2019).

The mapped points were transferred to a digital format and spatially joined to the 500 m grid for calculation of landscape service metrics. The extent of the grid was designed to cover the grid cells that spatially overlapped with the landscape service indicator points and their neighboring cells, as the service indicator location was spatially unprecise. We calculated the number of service indicator points per category, service richness (number of different services), service density (number of service indicator points in total) and service diversity (Shannon's H' diversity index (Shannon and Weaver, 1949)) to describe the spatial distribution of the landscape service indicators in each grid cell. Furthermore, to evaluate the coexistence of the services, we calculated Spearman's rank correlation coefficients (rho) between the service category counts in each grid cell.

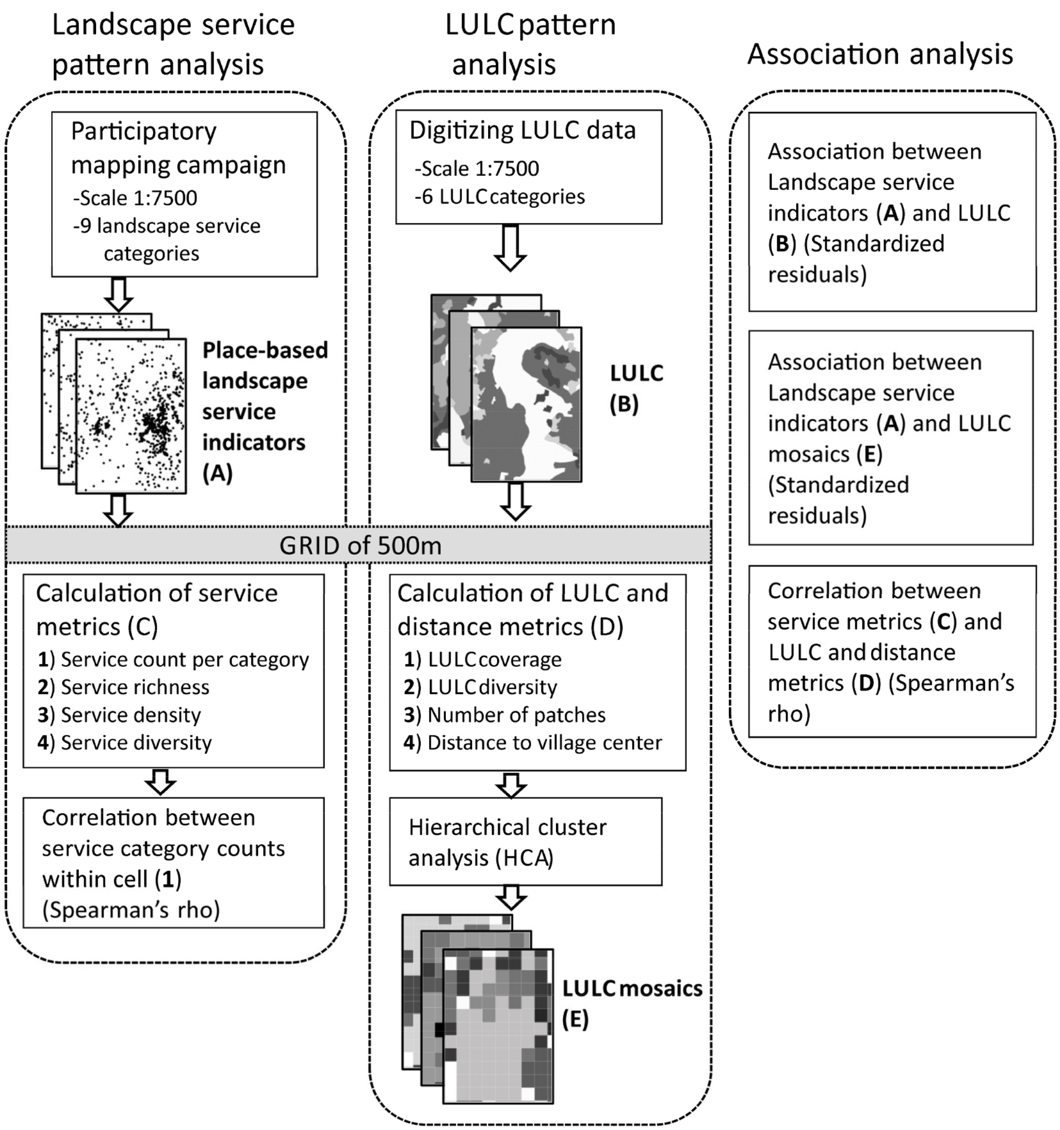

Fig. 2. Research design consists of landscape service, physical landscape and association analysis. In the figure, Spearman's rho refers to Spearman's rank correlation coefficient.

2.4. LULC pattern analysis

LULC maps for each of the three villages were created through visual interpretation of VHR images and digitization of the LULC polygons at the scale of 1:7500, corresponding to the scale of the participatory mapping. LULC categories were designed based on field experience. We used six LULC categories (Fig. 3) to cover the physical variations within the village landscapes. The LULC polygons were spatially joined with the 500 m grid, and LULC coverage, LULC diversity (Shannon's H' diversity index) and numbers of patches (NP) were calculated for each grid cell as indicators of LULC metrics.

A hierarchical cluster analysis (HCA) was run to statistically define

Table 1
Landscape services and descriptions of the eight provisioning and one cultural landscape service indicator mapped during the campaign.

Landscape service	Landscape service indicator	Description
Provisioning		
Food	Cultivation	Cultivation of crops (e.g. maize, rice and vegetables), including home gardens.
	Livestock keeping	Domestic animals (e.g. chickens, cows and goats) herding and husbandry.
	Wild food collection	Collection of wild foods (e.g. fruits, vegetables and mushrooms).
Fuel	Firewood and charcoal collection	Collection of firewood and wood for charcoal making.
Raw materials	Tree planting	Tree planting for forestry, fences and other types of planting.
	Building material collection	Extraction of natural building materials (e.g. wood, grass and soil).
	Handicrafts and traditional medicine collection	Collection of material for handicrafts and ingredients for traditional medicine.
Water	Fresh water source	Natural or human-made (e.g. well, pipe) source of water.
Cultural		
Aesthetic value	Beautiful, attractive sites	Landscape elements that are considered aesthetic in natural and built environments.

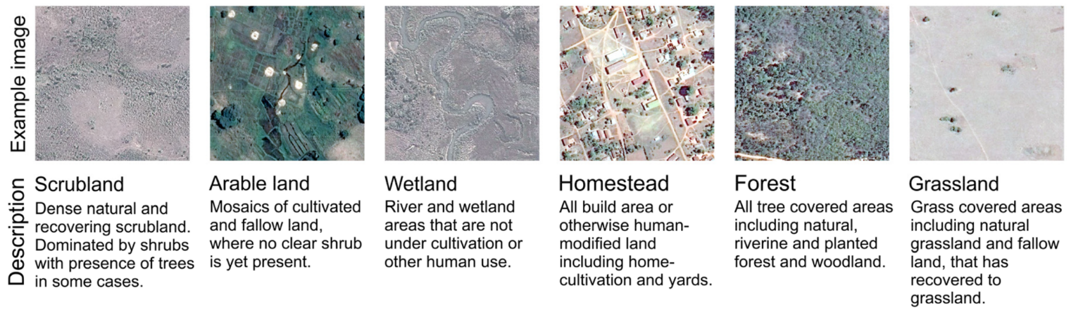

Fig. 3. Example images and descriptions of the land use and land cover (LULC) categories used in creating the LULC maps. Satellite images from Google Earth © Google.

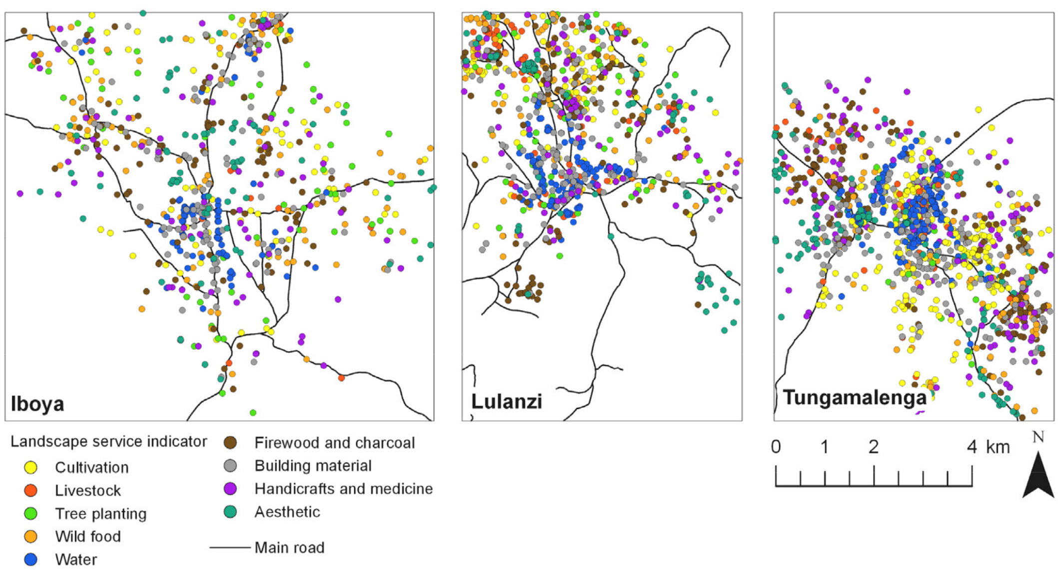

Fig. 4. Landscape service indicator points identified in the participatory mapping campaign.

LULC mosaics, characterizing the LULC pattern in each grid cell. The LULC mosaics were calculated based on the LULC metrics. Furthermore, we included distance to village center, as accessibility was estimated to affect service utilization. Before running the analysis, we normalized the variables on a scale of 0–1 to enable comparison between different measurement units. The analysis was conducted with squared Euclidean distance with Ward's agglomeration method (Ward Jr. 1963), and it was run multiple times with different numbers of clusters; a suitable amount of cluster profiles was selected based on the field experience. To characterize the identified cluster profiles, descriptive statistics (box plots, means and standard deviations) for the LULC metrics were calculated.

2.5. Analyzing spatial associations between place-based landscape services and LULC patterns

We analyzed 1) associations between the landscape service indicators and LULC categories and 2) associations between landscape service indicators and LULC mosaics based on chi-square statistics and cross tabulations with standardized residuals (see for example Brown and Brabyn, 2012a; Brown et al., 2014; Hausner et al., 2015). The chi-square test of independence determines whether there are significant associations between the variables. The standardized residuals are calculated by subtracting the expected number of service indicators in each LULC category or LULC mosaic from the observed number and then dividing the difference by the standard error of the residual. The standardized residuals indicate how many standard deviations above or below the observed number is from the expected number. The assumption is that the deviations between the realized and expected counts indicate associations between service indicators and different LULC categories or mosaics (Brown et al., 2015). Thus, the method assumes equal suitability for services throughout the LULC category or mosaic. When upscaling the LULC into LULC mosaics, the method can especially emphasize unreliable associations, since a single landscape element (LULC patch) with high service density may cause high residual (i.e., strong association) for the entire LULC mosaic. To recognize such cases, we identified and investigated the spatial associations of grid cells from each LULC mosaic deemed to be statistical outliers in terms of service density.

Finally, to support association analyses, we studied the correlation between service metrics and LULC metrics properties. We calculated two sets of spatial associations: (1) between service category counts and distance to village center in each grid cell, and (2) between three landscape service metrics (richness, density and diversity) and four LULC metrics (LULC coverage, LULC diversity, NP and distance to village center). Spearman's rank correlation coefficients (rho) were selected to indicate the relationship because of the non-normal distribution of the variables.

3. Results

3.1. Place-based landscape services in the villages

The participants mapped 4176 landscape service indicator points (I = 972, L = 1360 & T = 1844) (Fig. 4). Central provisioning services, such as cultivation (17.6%), building material (14.5%), water (14.1%)

Table 2
Distances of landscape service indicators to village center. The village distance column shows the Spearman’s rank correlation coefficients between service indicators and the distance. Correlations significant at the 0.01 level are bolded.

	Iboya			Lulanzi			Tungamalenga		
	Distance	SD	Village distance	Distance	SD	Village distance	Distance	SD	Village distance
Cultivation	2052	1340	−0.089	2042	1099	−0.051	1401	883	**−0.561****
Livestock	1371	1306	−0.151	1634	1155	**−0.266****	795	790	**−0.375****
Tree planting	2870	1027	*0.165**	1934	955	**−0.278****	909	837	**−0.410****
Wild food	2773	1183	−0.001	2932	958	*0.208**	2447	799	0.007
Water	1037	1042	**−0.428****	1033	487	**−0.542****	725	441	**−0.655****
Firewood and charcoal	2441	1014	**−0.206****	2546	819	−0.010	2356	750	−0.029
Building material	1803	1291	**−0.312****	1817	1040	**−0.251****	1484	955	**−0.540****
Handicrafts and medicine	2537	1181	−0.096	2265	1011	−0.027	2127	969	−0.163
Aesthetic	2144	1242	*−0.183**	2825	699	**0.270****	1560	1270	−0.019

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

and firewood and charcoal (12.4%), were mapped most often. The rest of the services were less often or less consistently mapped in all villages. For example, livestock services were more often mapped in Lulanzi than in Iboya or Tungamalenga, and tree planting was rarely mapped in Tungamalenga compared to Iboya and Lulanzi.

The distribution of place-based landscape services has distinctive patterns in the village landscapes (Fig. 4, Table 2). In Iboya, the services are most spread out, which is also shown by the high variation in the service distances to the village center. In Tungamalenga, the services are on average located nearest to the settlements and clustered in certain areas. Nevertheless, the general service patterns are relatively similar between the villages. Livestock and water service indicators, which have negative correlation with village distance, were clustered near the village centers. Wild food, firewood and charcoal, and handicrafts and medicine are located farther away in the village landscapes, showing weaker correlations with village distance.

Some of the landscape services have spatial coexistence in the village landscape, as indicated by the correlation analyses between service categories (Table 3). Two coexisting service groups are present in all three villages. The first group contains wild food, firewood and charcoal and handicrafts and medicine, while the second group includes cultivation, water and livestock. In Tungamalenga, these two groups are more diverged, meaning the services spatially coexist mostly with other services in the same group. The spatial patterns of landscape service indicator categories are more mixed in Lulanzi and Iboya, which is also shown by more abundant coexistence across all services (i.e., higher number of positive correlations). For example, cultivation is widely correlated with multiple services in Iboya and Lulanzi, whereas in Tungamalenga, associations of cultivation with wild food, firewood and charcoal and handicrafts and medicine are negative. Building material spatially coexists with both of the service groups described above due to the spatial characteristics of the resources (wood, soil, grass) collected

Table 3
Spearman's rank correlations of landscape service indicator categories in the grid cells. Correlations significant at the 0.01 level are bolded.

	Cultivation	Livestock	Tree planting	Wild food	Water	Firewood and charcoal	Building material	Handicrafts and medicine
Iboya								
Livestock	**0.342****							
Tree planting	**0.262****	0.134						
Wild food	**0.278****	0.071	**0.347****					
Water	**0.272****	**0.395****	0.032	−0.013				
Firewood and charcoal	0.180*	0.062	**0.289****	**0.314****	0.039			
Building material	**0.392****	**0.426****	**0.256****	**0.297****	**0.388****	**0.263****		
Handicrafts and medicine	0.142	0.116	**0.213****	**0.217****	0.012	0.169*	0.193*	
Aesthetic	−0.137	0.038	−0.177*	−0.045	0.054	−0.140	0.057	−0.012
Lulanzi								
Livestock	**0.567****							
Tree planting	**0.543****	**0.541****						
Wild food	**0.534****	**0.258****	**0.385****					
Water	**0.400****	**0.630****	**0.391****	0.041				
Firewood and charcoal	0.212*	0.049	**0.279****	**0.247****	−0.085			
Building material	**0.565****	**0.549****	**0.586****	**0.261****	**0.441****	**0.254****		
Handicrafts and medicine	**0.354****	**0.343****	**0.335****	**0.398****	0.177	0.238*	**0.331****	
Aesthetic	−0.094	0.092	−0.136	0.077	−0.154	−0.048	−0.202*	0.076
Tungamalenga								
Livestock	0.206*							
Tree planting	**0.491****	**0.361****						
Wild food	−0.048	−0.030	0.014					
Water	**0.507****	**0.320****	**0.414****	−0.062				
Firewood and charcoal	**−0.241****	0.083	−0.138	**0.655****	−0.016			
Building material	**0.402****	**0.294****	**0.335****	**0.265****	**0.502****	**0.262****		
Handicrafts and medicine	−0.051	0.182*	0.082	**0.382****	0.164	**0.578****	**0.335****	
Aesthetic	−0.050	0.033	0.155	0.156	0.215*	0.188*	**0.240****	0.161

**Correlation is significant at the 0.01 level (2-tailed)
*Correlation is significant at the 0.05 level (2-tailed).

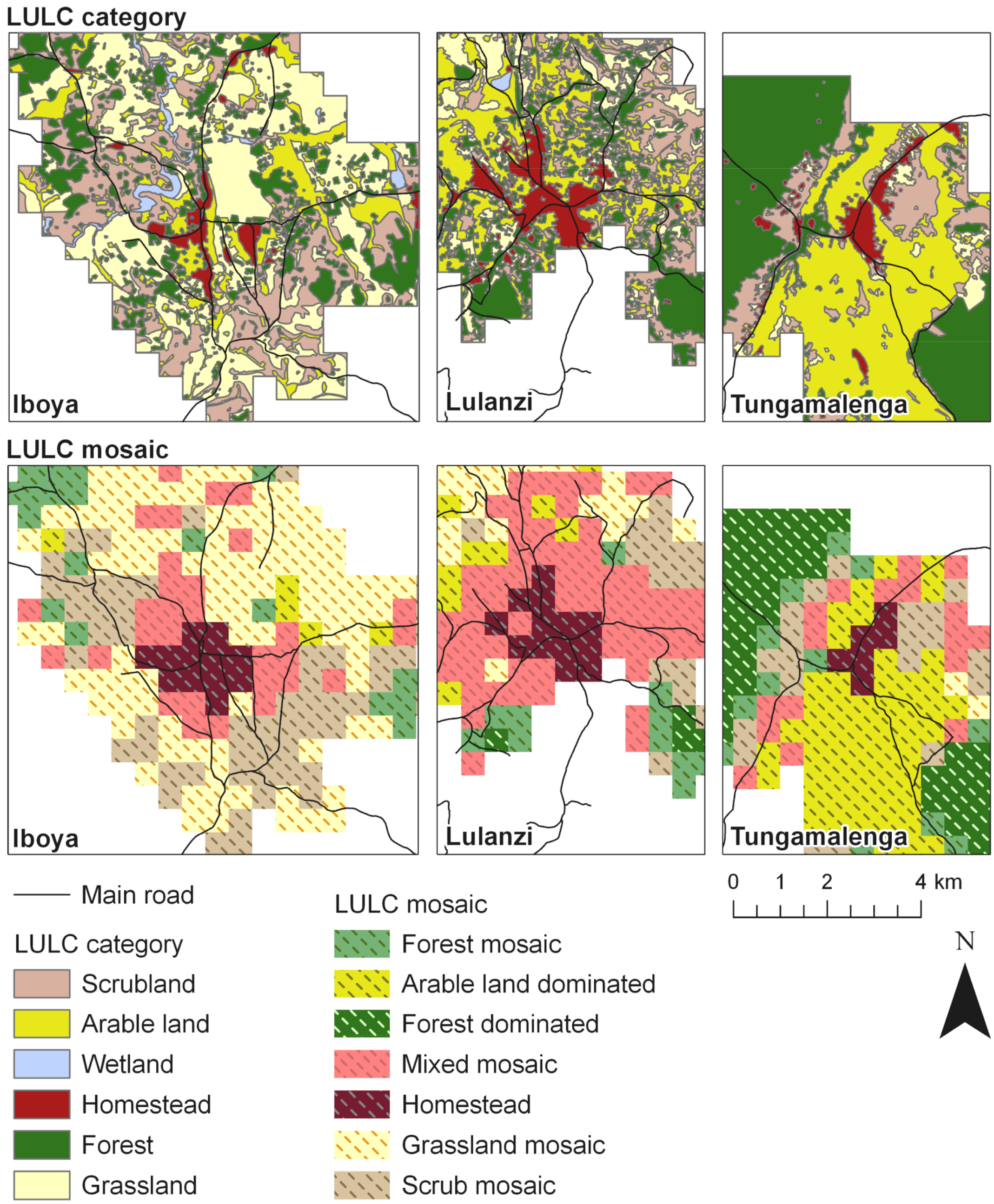

Fig. 5. LULC maps with 6 categories and the characterization of LULC pattern and geographical distance to village center with 7 LULC mosaics in the three study villages. The village landscape of Lulanzi is shared with the neighboring village of Luhindo.

within the building material service category. Aesthetic services do not seem to coexist with other landscape services in terms of their locations.

3.2. LULC patterns of the villages

In Iboya, the landscape is a heterogeneous mosaic of LULC patches, its widest coverage consisting of grassland (36.4%), scrubland (23.8%) and forest (20.6%) (Table 4, Fig. 5). The LULC pattern in Lulanzi is also heterogeneous, the largest categories being arable land (27.9%), forest (24.4%) and scrubland (22.2%). A clear difference between the two villages is the homestead area, which in Lulanzi is larger and surrounded to a greater extent by small patches of different LULC categories. In Tungamalenga, the landscape is homogeneous, with an extensive arable land area (36.8%) bordered by widespread forest (38.9%). More heterogeneous land is found in small, scattered areas at the boundaries of the dominant categories.

Seven unique LULC mosaics were identified in the villages (Figs. 5 and 6). The forest mosaic (Mosaic 1) is characterized by a high coverage of forest with moderate coverage of grassland, scrubland and arable land and a small proportion of wetland and homestead. It is present in all the villages. In Iboya and Lulanzi, the forest mosaic captures a spread-out pattern of forested areas, while in Tungamalenga, it captures the borders of the larger woodlands. The arable land-dominated mosaic (Mosaic 2) depicts areas under intensive cultivation with small proportions of forest, grassland and scrubland. It is most abundant in the floodplains of Tungamalenga, while in Iboya and Lulanzi, it is present in a scattered pattern. The forest-dominated mosaic (Mosaic 3) is almost solely composed of forest coverage. It is typical in Tungamalenga, where it consists of semi-open woodlands lying further away from the settlement areas. It also captures the largest forest areas in Lulanzi. The mixed mosaic (Mosaic 4) is characterized by variety and no clear dominance in the coverage of different LULC categories, which are also

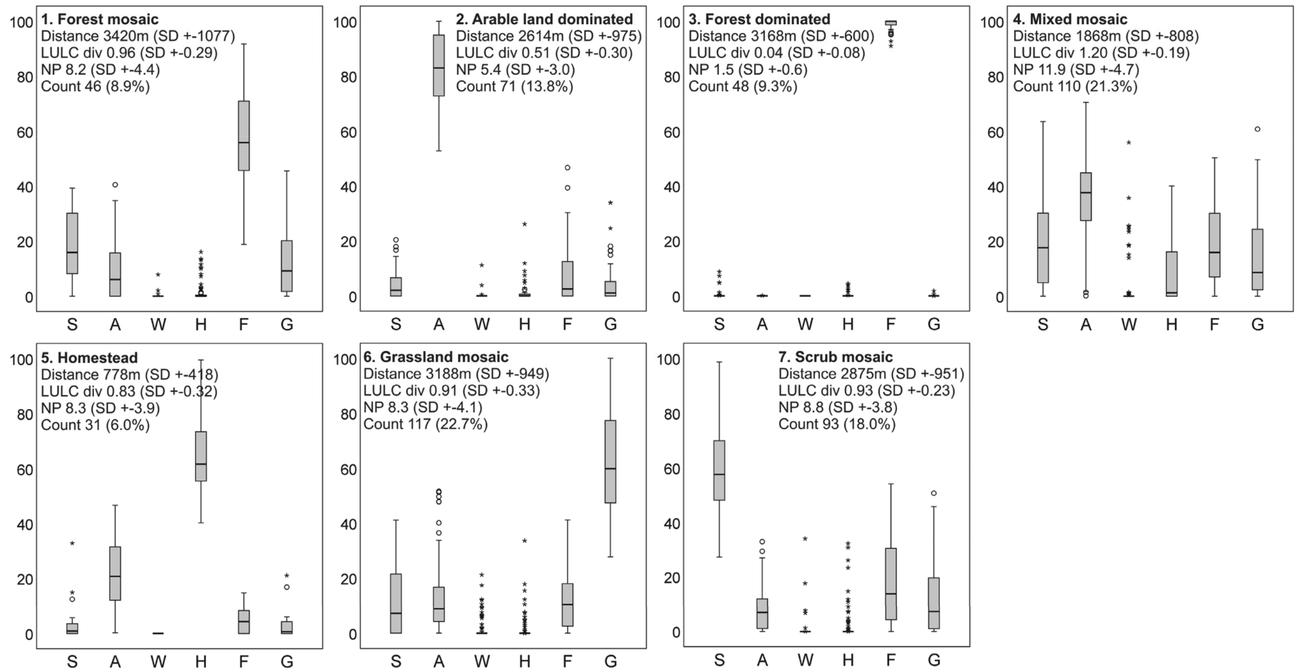

Fig. 6. Box plots depicting the dispersion of the LULC categories in the LULC mosaics. 'Distance' indicates the average distance to the village center, 'LULC div' the average Shannon's H' diversity index, 'NP' the average number of patches and 'count' the number of cells and their relative share of all cells. S = scrubland, A = arable land, W = wetland, H = homestead, F = forest, G = grassland.

shown by the highest LULC diversity and NP values. These areas are mostly located around the village settlements. The main village settlement areas and their close surroundings are captured by the homestead mosaic (Mosaic 5), which is characterized by dominance of the homestead LULC category with varying coverage of arable land (i.e., small-scale home cultivation) and forest. The grassland mosaic and scrub mosaic (Mosaics 6 and 7) have similar characteristics with a highest coverage of grassland and scrubland, respectively. They are

Table 4
Results of cross tabulations with standardized residual grouped by LULC categories (S = scrubland, A = arable land, W = wetland, H = homestead, F = forest, G = grassland). Standardized residual values lower than −2.0 (red) or higher than 2.0 (green) highlighted under- and over-representation of the landscape service indicators in the LULC categories. Especially high and low values represent cases of greater deviation from the expected counts. Coverage of each LULC category is also presented.

		Ibova (X^2: 758, p < .001)							Lulanzi (X^2: 1075, p < .001)							Tungamalenga (X^2: 819, p < .001)					
		S	A	W	H	F	G	Tot	S	A	W	H	F	G	Tot	S	A	H	F	G	Tot
Cultivation	Count	20	35	0	59	11	37	162	18	105	0	102	11	35	271	22	198	69	3	9	301
	%	12.3%	21.6%	0.0%	36.4%	6.8%	22.8%	100%	6.6%	38.7%	0.0%	37.6%	4.1%	12.9%	100%	7.3%	65.8%	22.9%	1.0%	3.0%	100%
	Residual	0.5	1.7	-2.1	3.3	-5.1	1.4		-0.8	4.6	-2.9	3.1	-7.3	1.9		-2.0	12.8	-1.4	-9.4	0.0	
Livestock	Count	2	4	0	51	2	9	68	4	23	1	90	7	24	149	4	9	91	14	2	120
	%	2.9%	5.9%	0.0%	75.0%	2.9%	13.2%	100%	2.7%	15.4%	0.7%	60.4%	4.7%	16.1%	100%	3.3%	7.5%	75.8%	11.7%	1.7%	100%
	Residual	-2.0	-2.1	-1.4	8.7	-3.9	-0.9		-2.3	-2.3	-1.7	7.6	-5.2	2.7		-2.6	-4.1	10.2	-3.9	-0.9	
Tree planting	Count	13	5	0	9	47	27	101	24	26	0	41	40	7	138	1	9	17	2	0	29
	%	12.9%	5.0%	0.0%	8.9%	46.5%	26.7%	100%	17.4%	18.8%	0.0%	29.7%	29.0%	5.1%	100%	3.4%	31.0%	58.6%	6.9%	0.0%	100%
	Residual	0.6	-2.8	-1.7	-3.0	3.5	2.0		3.9	-1.4	-2.1	0.4	0.5	-1.7		-1.2	0.4	3.2	-2.4	-0.9	
Wild food	Count	18	18	1	7	66	20	130	13	36	0	7	55	29	140	30	28	6	102	14	180
	%	13.8%	13.8%	0.8%	5.4%	50.8%	15.4%	100%	9.3%	25.7%	0.0%	5.0%	39.3%	20.7%	100%	16.7%	15.6%	3.3%	56.7%	7.8%	100%
	Residual	1.0	-0.7	-1.4	-4.3	4.9	-0.7		0.6	0.2	-2.1	-5.1	2.8	4.4		2.2	-3.0	-6.1	6.1	3.6	
Water	Count	7	58	0	28	6	9	108	6	63	0	47	21	4	141	9	90	143	96	0	338
	%	6.5%	53.7%	0.0%	25.9%	5.6%	8.3%	100%	4.3%	44.7%	0.0%	33.3%	14.9%	2.8%	100%	2.7%	26.6%	42.3%	28.4%	0.0%	100%
	Residual	-1.4	9.6	-1.7	0.5	-4.4	-2.4		-1.6	4.7	-2.1	1.2	-2.8	-2.5		-4.7	-0.2	5.3	-1.0	-3.2	
Firewood and charcoal	Count	22	5	0	4	67	23	121	12	23	0	3	133	10	181	41	22	6	133	12	214
	%	18.2%	4.1%	0.0%	3.3%	55.4%	19.0%	100%	6.6%	12.7%	0.0%	1.7%	73.5%	5.5%	100%	19.2%	10.3%	2.8%	62.1%	5.6%	100%
	Residual	2.4	-3.3	-1.8	-4.6	5.7	0.2		-0.6	-3.3	-2.4	-6.7	12.0	-1.7		3.5	-4.8	-6.8	8.0	2.2	
Building material	Count	9	15	0	56	30	23	133	7	22	0	73	42	8	152	52	100	75	86	9	322
	%	6.8%	11.3%	0.0%	42.1%	22.6%	17.3%	100%	4.6%	14.5%	0.0%	48.0%	27.6%	5.3%	100%	16.1%	31.1%	23.3%	26.7%	2.8%	100%
	Residual	-1.5	-1.4	-1.9	4.4	-1.2	-0.2		-1.5	-2.6	-2.2	4.7	0.2	-1.7		2.7	1.3	-1.4	-1.5	-0.2	
Handicrafts and medicine	Count	12	11	0	6	31	14	74	14	30	0	10	22	7	83	28	25	19	73	6	151
	%	16.2%	14.9%	0.0%	8.1%	41.9%	18.9%	100%	16.9%	36.1%	0.0%	12.0%	26.5%	8.4%	100%	18.5%	16.6%	12.6%	48.3%	4.0%	100%
	Residual	1.4	-0.3	-1.4	-2.8	2.2	0.2		2.9	2.1	-1.6	-2.7	-0.1	-0.3		2.7	-2.5	-3.4	3.7	0.7	
Aesthetic	Count	4	8	26	10	13	14	75	10	9	41	5	36	4	105	18	22	76	69	4	189
	%	5.3%	10.7%	34.7%	13.3%	17.3%	18.7%	100%	9.5%	8.6%	39.0%	4.8%	34.3%	3.8%	100%	9.5%	11.6%	40.2%	36.5%	2.1%	100%
	Residual	-1.5	-1.2	16.6	-1.8	-1.8	0.1		0.6	-3.3	21.0	-4.5	1.4	-1.9		-0.7	-4.1	3.4	1.3	-0.7	
Total	Count	107	159	27	230	273	176	972	108	337	42	378	367	128	1360	205	503	502	578	56	1844
	%	11.0%	16.4%	2.8%	23.7%	28.1%	18.1%	100%	7.9%	24.8%	3.1%	27.8%	27.0%	9.4%	100%	11.1%	27.3%	27.2%	31.3%	3.0%	100%
LULC coverage	%	23.8%	14.0%	2.0%	3.1%	20.6%	36.4%	100%	22.2%	27.9%	0.4%	9.2%	24.4%	16.0%	100%	14.9%	36.8%	5.2%	38.9%	4.2%	100%

Table 5
Spearman's rank correlation coefficients (rho) of the associations between landscape properties and the landscape service metrics within the village landscapes. Significant correlations are shown in bold. S = scrubland, A = arable land, W = wetland, H = homestead, F = forest, G = grassland.

	Service metrics	Landscape properties								
		Village distance	LULC diversity	Number of patches	S	A	W	H	F	G
Iboya	Service richness	−0.260**	0.245**	0.134	−0.216**	0.217**	−0.075	0.412**	0.130	−0.102
	Service diversity	−0.233**	0.193*	0.110	−0.156*	0.134	−0.075	0.351**	0.144	−0.100
	Service density	−0.358**	0.305**	0.186*	−0.235**	0.246**	0.006	0.455**	0.093	−0.091
Lulanzi	Service richness	−0.177	0.115	0.153	−0.166	0.263**	0.144	0.260**	−0.312**	−0.046
	Service diversity	−0.205*	0.175	0.238*	−0.089	0.246**	0.106	0.234*	−0.210*	−0.060
	Service density	−0.129	0.007	0.004	−0.286**	0.225*	0.261**	0.253**	−0.300**	−0.041
Tungamalenga	Service richness	−0.558**	0.190*	0.183*	0.138	0.079	0.006	0.246**	−0.179*	0.014
	Service diversity	−0.297**	0.067	0.034	0.067	−0.210*	−0.056	0.093	0.129	−0.050
	Service density	−0.532**	0.148	0.148	0.059	0.111	0.008	0.222*	−0.165	0.022

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

most common in Iboya and are mostly located further away from the settlement areas. In general, all three villages show high coverage of certain LULC mosaics and a scattered pattern of the rest. The arable land-dominated and forest-dominated mosaics have the lowest LULC diversity and NP and are mostly found in Tungamalenga, indicating a more homogeneous landscape pattern compared to the other villages. The three largest mosaics in Iboya and Lulanzi are grassland, scrub, and mixed mosaics.

3.3. Associations between place-based landscape service and local LULC patterns

There are clear associations between landscape services and LULC categories in all villages (Table 4). Cultivation is associated with arable land and homestead categories, and wild food, firewood and charcoal, and handicrafts and medicine with forests. These LULC categories have the capacity to provide required material resources. In general, homestead, arable land and forest categories include the most service indicators relative to their coverage, while scrubland and grassland encompass the least. In most cases, the associations are strongest in Tungamalenga.

The services are more abundant and diverse in the village centers, showing negative correlation with distance to village center (Table 5). Furthermore, an increase in the homestead LULC coverage correlates positively with all service metrics. In Iboya and Lulanzi, small-scale cultivation is practiced widely across the landscape, and its coverage indicates a diverse service utilization pattern shown by positive correlations between arable land and service metrics. In Tungamalenga, the cultivation area is large and more intensive, indicated by the negative correlation with service diversity.

The most diverse service pools are found in the homestead and mixed mosaic, encapsulating the multifunctional landscapes located in and around the village settlement areas (Table 6). The homestead mosaic captures local communities' daily activities, such as livestock keeping and home cultivation, as well as fetching water. In the mixed mosaic, multiple services coexist, but strong associations with particular services are missing. These intensive and versatile service utilization practices maintain the diverse LULC patterns close to the village center with good accessibility.

Outside the village settlements, wild food, firewood and charcoal, and handicrafts and traditional medicine are collected together by practice (Table 6). However, the associations vary more distinctively between villages. In Iboya, the landscapes are extensively used for multiple services, which is shown by the even spatial distribution of services (Fig. 4) and low residual values in the scrub and grassland mosaics, which cover the majority of the landscape. The forest mosaic is an exception where services are utilized more intensively, as shown by the higher service density and diversity. In Lulanzi, the extensive multifunctional mixed mosaic also captures the majority of the provisioning service collection activities. Additionally, the grassland mosaic has high service density and moderate associations with multiple services. Surprisingly, the largest forest areas of Lulanzi, captured by the forest-dominated mosaic, have weak associations with services. In Tungamalenga, where the service pattern is diverged, the associations are also diverged. The arable land-dominated mosaic has strong associations with cultivation and building material, while the forest-dominated mosaic is associated with wild food, firewood and charcoal, and handicrafts and medicine.

LULC pattern affects the strength of the associations (Table 6). In the more homogenous landscape of Tungamalenga, the number of significant deviations is the highest, with 22 under- and 16 over-representations (both Lulanzi and Iboya have 15 and 17 of each). Moreover, in most cases the associations are strongest in Tungamalenga and smallest in Iboya (average deviation I = 1.8, L = 2.1 & T = 2.9). The effect of the LULC pattern on the associations is further highlighted in Table 5. LULC diversity and NP correlates positively with service metrics in all villages.

There are notable differences between the associations in the villages depending on the scale of the LULC pattern representation. In Tungamalenga, where the landscape is homogeneous, the landscape service associations with LULC categories and mosaics are similar. For example, the majority of services that are associated with the forest category are found in the forested mosaics. However, in the heterogeneous landscapes of Iboya and Lulanzi, the LULC categories fail to capture the wider spatial pattern of the landscape services. In these two villages, a major share of the service indicators are found within the diverse LULC mosaics. In other words, diverse LULC mosaics capture services associations of multiple LULC categories. Therefore, the mosaics capture the wider LULC patterns and their spatial service associations in heterogeneous landscapes.

4. Discussion

In this paper we studied the associations between place-based landscape service and local LULC patterns in three Tanzanian rural villages. The results bring new insights into the landscape properties and their associated values and uses to local rural communities. The inclusion of three villages enables comparison of different and unique local landscapes, which share similar characteristics of socio-cultural environments. This is important in order to understand how the local landscapes evolve and produce benefits to local communities in different conditions. Furthermore, studying associations of services between both LULC categories and LULC mosaics brings new views on how multifunctional landscapes can be characterized and how spatial scale affects the associations. Our results show that although similar associations were identified in all villages, local realities and

Table 6

Results of cross tabulations with standardized residual grouped by LULC mosaics (FM = Forest mosaic, ALD = Arable land dominated, FD = Forest dominated, MM = Mixed mosaic, HS = Homestead, GM = Grassland mosaic, SM = Scrub mosaic). Standardized residual values lower than −2.0 (red) or higher than 2.0 (green) highlighted under- and over-representation of the landscape service indicators in the LULC mosaic. Especially high and low values represent cases of greater deviation from the expected counts. Coverage of and average service metrics in LULC mosaic are also presented.

		Iboya (X^2: 306, $p < .001$)							**Lulanzi** (X^2: 496, $p < .001$)								**Tungamalenga** (X^2: 986, $p < .001$)							
		FM	ALD	MM	HS	GM	SM	Tot	FM	ALD	FD	MM	HS	GM	SM	Tot	FM	ALD	FD	MM	HS	GM	SM	Tot
Cultivation	Count	7	4	30	54	50	17	162	1	33	0	103	88	39	7	271	3	183	0	25	77	2	11	301
	%	4.3%	2.5%	18.5%	33.3%	30.9%	10.5%	100%	0.4%	12.2%	0.0%	38.0%	32.5%	14.4%	2.6%	100%	1.0%	60.8%	0.0%	8.3%	25.6%	0.7%	3.7%	100%
	Residual	-2.5	1.1	-0.4	1.5	0.6	-0.7		-2.1	2.1	-2.0	-0.7	1.1	-0.2	-0.5		-4.0	12.0	-6.8	-0.5	-0.8	-2.0	-4.2	
Livestock	Count	4	0	13	40	11	0	68	0	1	0	41	82	21	4	149	2	10	10	2	88	0	8	120
	%	5.9%	0.0%	19.1%	58.8%	16.2%	0.0%	100%	0.0%	0.7%	0.0%	27.5%	55.0%	14.1%	2.7%	100%	1.7%	8.3%	8.3%	1.7%	73.3%	0.0%	6.7%	100%
	Residual	-1.2	-1.0	-0.1	5.0	-1.9	-2.9		-1.9	-3.3	-1.5	-2.5	5.9	-0.3	-0.3		-2.2	-3.8	-2.0	-2.7	9.4	-1.7	-1.7	
Tree planting	Count	9	4	21	8	45	14	101	2	10	0	74	37	10	5	138	1	10	0	1	17	0	0	29
	%	8.9%	4.0%	20.8%	7.9%	44.6%	13.9%	100%	1.4%	7.2%	0.0%	53.6%	26.8%	7.2%	3.6%	100%	3.4%	34.5%	0.0%	3.4%	58.6%	0.0%	0.0%	100%
	Residual	-0.6	2.1	0.2	-3.7	3.0	0.4		-0.7	-0.5	-1.5	2.4	-0.5	-2.3	0.4		-0.7	0.9	-2.1	-1.0	3.1	-0.9	-1.9	
Wild food	Count	26	0	26	12	43	23	130	4	20	0	57	9	47	3	140	14	30	63	34	2	15	22	180
	%	20.0%	0.0%	20.0%	9.2%	33.1%	17.7%	100%	2.9%	14.3%	0.0%	40.7%	6.4%	33.6%	2.1%	100%	7.8%	16.7%	35.0%	18.9%	1.1%	8.3%	12.2%	100%
	Residual	3.2	-1.4	0.1	-3.9	1.0	1.7		0.4	2.3	-1.5	0.0	-4.9	5.7	-0.6		0.3	-2.4	6.6	4.3	-6.8	5.0	0.1	
Water	Count	3	1	19	75	8	2	108	0	0	0	48	93	0	0	141	20	72	0	23	168	0	55	338
	%	2.8%	0.9%	17.6%	69.4%	7.4%	1.9%	100%	0.0%	0.0%	0.0%	34.0%	66.0%	0.0%	0.0%	100%	5.9%	21.3%	0.0%	6.8%	49.7%	0.0%	16.3%	100%
	Residual	-2.5	-0.4	-0.5	8.5	-4.1	-3.1		-1.8	-3.5	-1.5	-1.2	8.2	-4.6	-2.1		-0.8	-1.6	-7.3	-1.4	7.6	-2.9	2.3	
Firewood and charcoal	Count	21	2	28	4	39	27	121	11	24	11	84	6	40	5	181	24	21	87	33	4	16	29	214
	%	17.4%	1.7%	23.1%	3.3%	32.2%	22.3%	100%	6.1%	13.3%	6.1%	46.4%	3.3%	22.1%	2.8%	100%	11.2%	9.8%	40.7%	15.4%	1.9%	7.5%	13.6%	100%
	Residual	2.2	0.2	0.8	-5.0	0.8	3.1		3.3	2.2	4.9	1.2	-6.4	2.5	-0.2		2.3	-4.6	9.3	3.0	-7.2	4.6	0.7	
Building material	Count	16	1	28	50	30	8	133	0	17	2	58	61	10	4	152	13	104	47	31	81	5	41	322
	%	12.0%	0.8%	21.1%	37.6%	22.6%	6.0%	100%	0.0%	11.2%	1.3%	38.2%	40.1%	6.6%	2.6%	100%	4.0%	32.3%	14.6%	9.6%	25.2%	1.6%	12.7%	100%
	Residual	0.4	-0.7	0.3	2.3	-1.3	-2.1		-1.9	1.1	-0.2	-0.5	2.6	-2.7	-0.3		-2.1	2.3	-0.4	0.3	-0.9	-1.1	0.4	
Handicrafts and medicine	Count	14	0	6	10	25	19	74	1	8	1	46	14	9	4	83	14	24	51	15	18	4	25	151
	%	18.9%	0.0%	8.1%	13.5%	33.8%	25.7%	100%	1.2%	9.6%	1.2%	55.4%	16.9%	10.8%	4.8%	100%	9.3%	15.9%	33.8%	9.9%	11.9%	2.6%	16.6%	100%
	Residual	2.1	-1.0	-2.3	-2.2	0.9	3.2		-0.7	0.3	-0.2	2.1	-2.0	-1.0	0.9		1.0	-2.4	5.7	0.3	-3.7	0.1	1.6	
Aesthetic	Count	5	2	21	10	26	11	75	13	3	7	42	3	27	10	105	40	21	29	5	60	4	30	189
	%	6.7%	2.7%	28.0%	13.3%	34.7%	14.7%	100%	12.4%	2.9%	6.7%	40.0%	2.9%	25.7%	9.5%	100%	21.2%	11.1%	15.3%	2.6%	31.7%	2.1%	15.9%	100%
	Residual	-1.1	0.9	1.6	-2.3	1.0	0.5		6.7	-2.0	4.2	-0.1	-5.0	2.9	3.8		7.3	-4.0	-0.1	-3.0	1.0	-0.3	1.5	
Total	Count	105	14	192	263	277	121	972	32	116	21	553	393	203	42	1360	131	475	287	169	515	46	221	1844
	%	10.8%	1.4%	19.8%	27.1%	28.5%	12.4%	100%	2.4%	8.5%	1.5%	40.7%	28.9%	14.9%	3.1%	100%	7.1%	25.8%	15.6%	9.2%	27.9%	2.5%	12.0%	100%
Service richness	Mean	2.9	2.2	3.2	5.1	2.1	1.5		1.4	2.8	2.3	3.7	5.5	3.4	1.5		2.7	2.9	2.3	2.8	7.7	4.5	3.4	
	SD	2.6	1.6	2.4	2.0	1.8	1.7		1.2	2.9	1.0	2.5	2.8	2.1	2.1		2.3	2.1	1.8	2.6	0.5	0.7	2.5	
Service diversity	Mean	1.04	0.45	0.95	1.07	0.67	0.45		0.27	0.54	0.88	1.00	1.09	0.83	0.77		0.77	0.87	0.70	0.72	1.36	1.26	1.03	
	SD	0.67	0.51	0.59	0.37	0.52	0.49		0.42	0.43	0.60	0.59	0.54	0.43	0.54		0.62	0.62	0.46	0.58	0.16	0.01	0.67	
Service density	Mean	5.0	2.8	6.4	21.9	2.9	2.2		2.9	9.7	5.3	8.9	30.2	9.7	2.5		9.4	8.8	6.5	9.4	85.8	23.0	10.5	
	SD	7.2	2.5	7.5	21.1	3.4	3.2		3.3	13.8	4.7	10.7	28.7	13.6	4.7		14.6	9.2	10.1	14.5	48.6	9.9	17.1	
Mosaic coverage	%	9.7 %	2.3 %	13.8 %	5.5 %	43.3 %	25%	100%	7.9 %	8.6 %	2.9 %	44.3 %	9.3 %	15.0 %	12.1 %	100%	8.8 %	34.0 %	27.7 %	11.3 %	3.8 %	1.3 %	13.2 %	100%

interactions are unique. This emphasizes the importance of understanding local spatial associations in assessing the services of multifunctional landscapes.

4.1. Associations between landscape services and LULC pattern in the villages

Based on our findings, it seems that the more diverse the landscapes are physically, the more diverse are the services associated with them at the local level. In all of the villages, the area surrounding the dense settlement is highly modified, under heavy human influence with a heterogeneous and diverse LULC pattern. At the same time, these areas hold high service diversity, reflecting their multifunctional character. Other studies conducted in a Global South context (Fagerholm et al., 2012; Sinare et al., 2016; Malmborg et al., 2018) have also reported the importance of village settlement areas and their close surroundings as service hot spots. In such heterogeneous and multifunctional landscapes, the spatial coexistence of services is related to the spatial proximity and accessibility of different LULC (i.e., the LULC pattern) rather than the presence of certain LULC categories (Fagerholm et al., 2016).

Two groups of services have shown consistent associations with specific LULC patterns in all villages. Livestock and water services were associated closely with village settlements and their surroundings. Further out from the settlements, wild food, firewood and charcoal and handicrafts and medicine were associated with forests. Forested landscapes, in particular, have been found important for service provision by numerous previous studies, regardless of the geographical context (Raudsepp-Hearne et al., 2010; Fagerholm et al., 2012; Brown and Brabyn, 2012a; Burkhard et al., 2012; Schaafsma et al., 2014; Brown et al., 2015; Paudyal et al., 2015). Such association patterns are important in understanding the synergies and trade-offs across the landscape and in designing sustainable management of heterogeneous and multifunctional landscapes (Bennet et al., 2009; Spake et al., 2017).

Different biophysical settings, livelihood practices and access to markets have evolved into different LULC patterns, influencing the strength and number of the service associations within the study villages. The associations were stronger in landscapes of more homogeneous LULC patterns, where the pattern-benefit relationship remains strong. Furthermore, in more homogeneous landscapes, the service associations between LULC categories and mosaics experience little difference, since they depict similar patterns within the landscape. Consequently, the association studies in such environments are less dependent on spatial scale. Clear associations between services and LULC mosaics were found also in more heterogeneous landscapes. However, in such landscapes, the mosaics capture the everyday living environments of the local communities where the spatial coexistence of LULC patches creates an LULC pattern—one that enables multiple activities and grants access to a variety of landscape services. Previous studies focusing on service-LULC association support these findings, reporting firm correlation in Global North landscapes with strong pattern-benefit relationship (Vihervaara et al., 2010; Burkhard et al., 2012; Brown, 2013) and weak correlation in Global South landscapes, which are often heterogeneous and multifunctional (Dawson and Martin, 2015; Sinare et al., 2016; Malmborg et al., 2018).

4.2. Challenges of the used methodology

Although the associations between the place-based landscape service and local LULC patterns can be presented with the methodology used, there are several challenges related to the quality and representativeness of the patterns and their associations. The service typology needs to be well designed to spatially match the service utilization in a given landscape. Variety within the indicator categories and the spatial scale they operate in the landscapes affect the identified associations. For example, plant species for traditional medicine vary and are collected from different environments, leading to a widely dispersed pattern of service indicator points and causing the service to have weak associations with any landscape type. Similarly, for building material, weak associations are caused by the distinctive spatial pattern of collecting clay for brick making and wood for building, both materials being mapped within the same landscape service indicator category. Thus, the spatial character and scale of landscape service indicators should already have been considered when planning the typology and mapping method, so as to enable sensible evaluation of the associations.

The variables chosen will impact the LULC mosaic generation and therefore also the associations. Both landscape composition and configuration have been related to provisioning and regulating service availability on a regional scale (Laterra et al., 2012; Lamy et al., 2016) as well as on a local one (Verhagen et al., 2016). However, empirical work connecting landscape configuration to the ecosystem service provision is still scarce and limited to a few, mainly regulating services (Eigenbrod, 2016). We mapped the everyday activities of several communities' members and studied the associations of the mapped locations at a village scale with the LULC patterns (LULC coverage, LULC diversity, NP and distance to village center). These properties can be explicitly linked to the service flows in the village landscape context.

The use of standardized residuals to identify significant associations between landscape services and LULC patterns should be examined with care. In practice, the method assumes that all areas within a category are equally suitable for a service, although this might not always be the case due to the inherent heterogeneity of the LULC categories and mosaics used. Furthermore, a single service hot spot can cause strong associations (big residual) for an entire LULC mosaic. Thus, interpreting the associations between services and LULC patterns should be done with respect to the spatial distribution of the service indicators, as the hot spots may relate not to the landscape conditions but to a single landscape element. The spatial compatibility of the service indicators and landscape types is a major prerequisite of the approach used. For instance, social and religious services are often spatially related to a single element (e.g., church) (Fagerholm et al., 2019) and would skew the associations of services with LULC patterns when one is using standardized residuals. For this reason, we did not include social or religious services in this study.

Participatory mapping is a powerful method for defining spatial distribution of landscape services, especially in areas poor in data (Ramirez-Gomez et al., 2015). However, there is no commonly defined set of best practices for the mapping, and methodologies need to be considered according to the application (Brown and Pullar, 2012; Brown and Fagerholm, 2015). In our campaign, we used wooden beads on printed satellite images, as this method had proven to work well in similar conditions previously (Fagerholm et al., 2012; Käyhkö et al., 2015). Because service indicator locations were treated as point locations, the possible inaccuracy of the mapping method and the exact spatial extent of each service point were not taken into consideration, which in effect generalizes the service location regarding the associated LULC patterns. Furthermore, although the used service typology was planned together with local experts following previous experiences working in similar contexts (Fagerholm et al., 2012), it is difficult to say whether it could capture all the important service flows for the local communities. Further emphasis should be put on context-sensitive design of surveys and service typologies that depict the local values and practices of Global South societies. For example, involving the stakeholders in defining the service typology would increase the relevance of the topic and participant engagement (Ramirez-Gomez et al., 2013; Ramirez-Gomez et al., 2015; Boeraeve et al., 2018).

4.3. Importance of understanding the sustainability challenge in the Global South

The integrated use of participatory mapping and LULC pattern analysis provides a feasible methodological set-up for generating locally relevant and holistic understanding of service and LULC patterns and their associations in multifunctional Global South landscapes. Firstly, the use of an integrated landscape approach depicts the realities in multifunctional local landscapes, helps in sustainable management of service flows and simultaneously enables comparison of different locations. Such spatial understanding is crucial for evaluating the impact of landscape change on local livelihoods and for assessing sustainable ways to use village land in development strategies operating at larger (e.g., national or regional) scales. Secondly, the participatory approach is not only a method for collecting place-based landscape services within villages, but it also enhances the participants' and whole communities' capacities to understand their surrounding landscapes and the services they use and value (Fagerholm et al., 2012; Verplanke et al., 2016). As such, a successful participatory mapping campaign increases awareness of sustainable service utilization, empowering community members to be involved in landscape management and plan future land use in their villages (Eilola et al., 2019).

On the village scale, the landscapes and service patterns are always unique due to the different biophysical conditions and socio-ecological processes—present and historical—that affect the governance of the landscapes. In practice, it is not feasible to collect spatial information on LULC patterns and service flows in every village when designing a regional plan for sustainability. Therefore, it is important for regional development strategies to recognize associations between LULC and service patterns present in villages, despite differences in biophysical and socio-cultural settings. The general conclusions of the associations presented by our study are in accordance with other studies conducted at the village level in the Global South (Fagerholm et al., 2013; Sinare et al., 2016). These notions can be used to evaluate the potential consequences of ongoing landscape changes to the service flows for local communities. An intriguing question is how these notions can be turned into contextually and spatially sensitive regional estimations of landscape service patterns, or how they can lead to valuation practices that support development of broader-scale strategies addressing regional and/or national sustainability challenges. We have demonstrated that LULC mosaics recognize multifunctional patterns and represent broadly the service patterns at local scale in different biophysical and socio-cultural settings. Such spatial information on LULC patterns could be generated through an automated approach and serve as a proxy for service patterns. However, to understand associations between landscapes and their services in different circumstances, more evidence is still needed at the local level that is sensitive to biophysical and socio-ecological contexts.

Future studies should focus on the value and best practices of service extrapolation from local-scale associations to broader scales, as the empirical evidence and value assessment of such studies are still scarce (Brown and Brabyn, 2012b; Malmborg et al., 2018). Such assessments are desperately needed in the Global South, but the challenges lie in how to collect local landscape service data and depict the dimensions of multifunctional local landscapes at a broader scale, considering the limited availability of spatial data describing LULC patterns. Growing archives of openly available remote sensing and geospatial data will increase opportunities for automated landscape classification and evaluation in the Global South (Gorelick et al., 2017). Furthermore, recent progress on high-resolution satellite image repositories and mapping applications (e.g., Google Earth, Open Foris and Open Street Map) and on mobile technologies such as smart phones enables local experts and stakeholders to be involved in the creation and use of spatial information on landscapes (Bey et al., 2016; Brown and Kyttä, 2018; Leinonen et al., 2018). Such methodological advances continue to improve opportunities to create spatially explicit and adaptable strategies for sustainable landscapes in the Global South.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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