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Exploring value-landscape associations in the Tanzanian Southern Highlands

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Many decisions in land use management are made without sufficient local knowledge. The ecosystem service framework has brought attention to the relationships between humans and nature by conceptualizing how ecosystem functions are identified as different benefits for local communities. Through place-based participation locations of landscape benefits are mapped. These locations can be combined with the underlying physical landscape structures to define value-landscape associations that help to understand how ecosystem functions are turned to human benefits in different socio-ecological contexts.

In this thesis I studied value-landscape associations in Iboya, Lulanzi and Tungamalenga villages in the Tanzanian Southern Highlands. Information on the landscape values of the communities was collected in a participatory mapping campaign and further spatially analyzed to map spatial distribution. I collected information on the landscape structure via visual interpretation methods and calculated landscape indices to describe the physical village landscapes. Based on the available data I calculated statistical analyses to define value-landscape associations.

The physical landscapes in Iboya and Lulanzi are characterized by heterogeneity while in Tungamalenga the landscape is more homogenous. In all villages landscape heterogeneity tended to be higher near the settlements. The trends in value distribution are similar between villages as cultural values are concentrated at the settlement areas and provisioning values show a more scattered pattern in the landscape. Important areas of value co-existence were identified at central settlements and certain forested areas. The general value-landscape associations in all the villages are very practical as for example wild food is collected from forested areas. The value-landscape associations indicated that growth in landscape heterogeneity results in higher value richness and diversity in Iboya and Tungamalenga while in Lulanzi the relationship is not as strong. The study highlights that the realization of value-landscape associations are sensitive to the local scale practices and the wider socio-ecological context. Therefore, the created information can be useful for the local-scale land use management in the villages.

KEYWORDS: Landscape, Landscape services, ecosystem services, participatory mapping, value-landscape associations, value-transfer, Tanzania

TURUN YLIOPISTO
Matemaattis-luonnontieteellinen tiedekunta
Maantieteen ja geologian laitos

ARKI, VESA: Maisema-arvojen ja maiseman rakenteen välisten yhteyksien tarkastelu Tansanian eteläisellä ylänköalueella

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Usein maankäyttöön liittyvien päätösten tekemiseen ei ole tarjolla riittävää tietoa paikallisen tason rakenteista. Ekosysteemifunktioiden tuottamia hyötyjä paikallisille yhteisöille voidaan kuitenkin tarkastella ekosysteemipalveluviitekehyksen kautta. Esimerkiksi maisema-arvojen sijainnit voidaan kartoittaa paikkaperustaisen osallistamisen avulla ja yhdistämällä nämä sijainnit fyysistä maisemaa kuvaavan aineiston kanssa on mahdollista tarkastella näiden välisiä yhteyksiä. Tämä tarkastelu luo lisäymmärrystä siitä, miten ekosysteemifunktiot muotoutuvat hyödyiksi erilaisissa sosio-ekologisissa konteksteissa.

Tässä tutkielmassa tarkastelen maisema-arvojen ja maiseman rakenteen välisiä yhteyksiä Iboyan, Lulazin ja Tungamalenga kylissä Tansanian eteläisellä ylänköalueella. Tietoa maisema-arvoista ja niiden sijainneista kerättiin osallistavien paikkatietomenetelmien avulla ja tietoa analysoitiin maisema-arvojen spatiaalisen jakauman kartoittamiseksi. Tietoa maiseman rakenteesta kerättiin visuaalisten kuvantulkintamenetelmien avulla. Tuotettujen aineistojen avulla tarkasteltiin maisema-arvojen ja maiseman rakenteen välisiä yhteyksiä käyttäen tilastollisia menetelmiä.

Iboyassa ja Lulanzissa maisemarakenne on heterogeeninen, kun taas Tungamalengassa rakenne on homogeenisempi. Kaikissa kylissä asutusaluetta ympäröivä alue on rakenteeltaan heterogeenisempää kuin muu maisema. Maisema-arvojen alueelliset jakaumat kylissä ovat yleisellä tasolla samankaltaisia. Kulttuuripalvelut keskittyvät asutusalueella ja tuotantopalvelut ovat levittäytyneet ympäri maisemaa. Maisema-arvojen keskittymiä havaittiin keskeisimmissä asutusaluissa ja tietyissä metsäpeitteisissä alueissa. Maisema-arvojen ja maiseman rakenteen väliset yhteydet ovat kaikissa kylissä luonteeltaan käytännöllisiä, esimerkiksi luonnonvaraisia ruokakasveja kerättiin metsäpeitteisiltä alueilta. Maiseman rakenteen heterogeenisyyden ja maisema-arvojen monimuotoisuuden välillä havaittiin positiivinen yhteys Iboyassa ja Tungamalengassa, mutta Lulanzissa yhteys ei ollut merkittävä. Tutkimustulokset osoittavat, että maisema-arvojen ja maiseman rakenteen väliset yhteydet ovat riippuvaisia paikallisista tason käytännöistä ja suuremman mittakaavaan sosio-ekologisesta kontekstista. Tämän perusteella yhteyksistä tuotettu informaatio voi olla hyödyllistä paikallisen tason maankäytön suunnittelussa.

ASIASANAT: Maisema, Maisemapalvelu, ekosysteemipalvelu, osallistava kartoitus, value-landscape association, value-transfer, Tansania

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1. Introduction

The Earth's ecosystems provide a large variety of different services that people rely on for their material and cultural well-being (MA 2005; Fisher et al. 2009). Changes made to the environment have improved the well-being of people around the world by increasing provision of some services such as food and timber, but has come at the cost of degradation of many other services (MA 2005). The concept of ecosystem services (ES) was created with the goal of bringing attention to the benefits people receive from the environment and creating discussion on how can they be better managed and valued. Although there is no one consensus on the definition of ES, central to many of them is that ecosystem functions that are created by the biophysical structures and processes (de Groot et al. 2002) only become services when they are directly or indirectly valued by humans (Haines-Young & Potschin 2010; Fisher et al. 2009; Termorshuizen & Opdam 2009).

The concept of landscape services has been developed as a specification to ecosystem services (Termorshuizen and Opdam 2009). It puts more emphasis on the issues of spatial pattern-process relationships and is considered to better capture the experiences of stakeholders. The concept takes the discussion into the local landscape scale where the participation of people into landscape management needs to happen (Fagerholm et al. 2012). The focus on spatial pattern-process relationships highlights that the distribution of services in a landscape is not only determined by physical landscape components, but also by their spatial patterns and relationships with human communities (Fang et al. 2015). The Landscape services are then considered as products of social-ecological landscape systems where the creation and valuation of the services is defined by the social and ecological processes of that system (Reyers et al. 2013). The embeddedness of services into the socio-ecological context will likely create different human-nature relationships based on the land use practices and people's perceptions and values related to the landscape (Fagerholm et al. 2013). In practice this will lead to different spatial distributions of services in the landscape.

From the management perspective, this is problematic as it indicates that all locations within a landscape are not equally important for the provision of landscape services (Burkhard et al. 2012b). At present many management decisions, especially in developing countries, are made without sufficient knowledge (Opdam et al. 2013) and in many cases, there is a lack of information on the provision, flows and valuation of many landscape services (Carpenter et al. 2006). To better integrate landscape services in to management and decision-making, further information on the service values of the communities and their connections to physical landscape structures need to be quantified (de Groot et al. 2010). These value-landscape association are used to identify place specific service utilization practices and important landscape elements related to them.

Participatory mapping methods can produce spatially explicit maps of the landscape value distribution (Brown 2005) and have a good capacity to fill in the knowledge caps in areas where information is lacking (Ramirez-Gomes et al. 2015). Participation of communities is important because most expert based evaluations are not likely to identify the benefits received by the local stakeholder (Fagerholm et al. 2012). While place-based stakeholder knowledge on landscape service practices and valuation can be relatively efficiently collected through participatory mapping, the applicability to regional decision-making is limited due to implementation costs.

In practice the mapping of ecosystem services is done with the use indicator data that works as a proxy of landscape service distribution. Unfortunately, the associations of the indicator data with services are often “unknown or based on general assumptions” (Gulickx et al. 2013). Knowledge on site-specific associations with different landscape characteristics is central to determining reliable indicators and proxies that describe the value-landscape associations that are embedded in the socio-ecological context of the area (Ostrom 2009). Connecting the local-scale primary information collected in participatory mapping campaigns with landscape characteristics data enables the definition of proxies that are based on the quantified value-landscape associations. Suitable proxies can then enable the estimation of service distribution in locations where primary data is not available through spatial value-transfer (Brown et al. 2015).

Most studies that focus on the value-landscape associations are done in the developed countries (Brown et al. 2013) and little information is available from the African context. Doing research in different socio-cultural and ecological context will create new knowledge on the associations between ecosystem service and physical landscape characteristics (Brown et al 2015). Few studies have been unable to produce accurate information for local scale management and decision-making in Africa as most of studies on ecosystem services have focused on the national or regional scales (Wangai et al. 2016).

The landscape services that the village communities in Tanzanian receive from the surrounding environment are under constant pressure from population growth, increasing pressure on land use, land fragmentation, deforestation, environmental degradation, insecurity of land tenure and growth in land use conflicts (Kangalawe & Lyimo 2010; Mango & Kalezi 2011). The degradation of the services endangers the present and future well-being of the communities that heavily rely on the natural resources for their livelihoods and everyday activities (Mango &

Kalezi 2011; Schaafsma et al. 2014). Knowledge on the value-landscape associations and the important landscape elements can support sustainable land use management in the villages and in the region as it helps to estimate how modifying the landscape can possibly add or lower the received value (Termorshuizen & Opdam 2009).

In this thesis, I use participatory data collected in a mapping campaign in three villages in the Tanzanian Southern Highlands to analyze the spatial distribution of cultural and provisioning services and to examine the spatial associations between service indicators and the underlying landscape characteristics (i.e. value-landscape associations). The data collection was done as part of the SUSLAND -research project (2014–2018). The different socio-ecological contexts of the village within the Southern Highlands enable the assessment of the possible effects that the context might have on the value-landscape associations at the local scale. The suitability of the produced knowledge for spatial-value transfer application is also estimated from the perspective of possible generalization errors (Eigenbrod et al. 2010b).

The main objective of this thesis is to study value-landscape associations in the Tanzanian Southern Highlands village landscapes using geospatial mapping and modelling methods under socio-ecological and landscape services frameworks. I this thesis, I will map and model both landscape service distribution of the local communities and physical landscape structures of the villages, and combine these into value-landscape associations, which are tested and developed to understand how landscape structures and functions establish into human benefits. I will discuss the applicability of the methodology, used methods and results for land use planning and management.

2. Theory

2.1 Landscapes as multifunctional socio-ecological systems

The study of social-ecological systems (SES) arises from the general systems theory which is focused on studying the whole or wholeness of a system (Berkes et al. 2003). This view emphasizes that understanding the central properties of the parts of the system cannot be done without understanding the interactions between these parts which means that the focus should be on how the parts operate together and not only on the individual parts. Fischer et al. (2015) see social-ecological systems as consisting of interdependent systems of ecological and social components that are connected in different scales (Figure 1). Berkes and Folke (1998: 4) define the two components as follows: the social component is constructed of "property rights, land and resource tenure systems, systems of knowledge pertinent to environment and resources, and world views and ethics concerning environment and resources". The ecological component they define in a conventional ecological sense as the natural environment. They continue by stating that the separation of these two systems is "artificial and arbitrary" and instead emphasize the integrated concept of humans-in-nature by focusing on social-ecological systems.

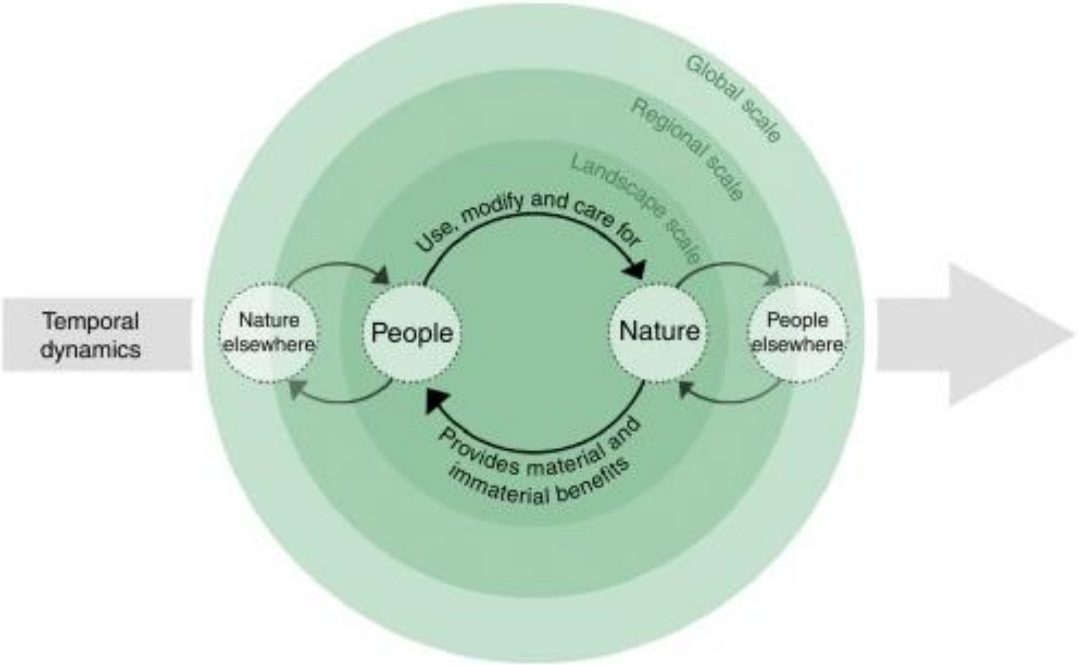


Figure 1. Fischer et al. (2015) provide an analytical framework as figure to guide the thinking on social-ecological systems and their functioning.

The social and ecological components can be separated from each other but interact to produce the outcomes at the level of the whole SES (Ostrom 2009). The components have many unique properties that are not strictly connected to either of them but emerge from the interaction between them (Liu et al. 2007). Therefore, people are an integral part of the environment in two ways: by shaping it through their actions and by being dependent on the services for their wellbeing and development (Fischer et al. 2015).

Landscapes have been studied in multiple disciplines which has created many definitions and a variety of concepts related to their study (Farina 2006: 4). In practice definitions often focus on either the physical characteristics of the landscape or the relationships between people and landscape (Fang et al. 2015). According to Farina (2006: 8) landscapes consist of material and immaterial entities. The material entity focuses on the physical context and the immaterial or cognitive entity brings focus to subjective reality that is experienced by all organism and how these experiences are integrated with the physical properties of a landscape. In this thesis the landscape is approached from the perspective of humans as the organism that experiences and acts in the landscape.

Defining landscapes as social-ecological systems (SES) enables a holistic approach where all elements of a landscape receive their significance only in relation to the other elements (Antorp 2000). Termorshuizen & Opdam (2009) view landscapes as multifunctional social-ecological systems, which implies “that the functioning of landscapes is the result of the interaction between physical structures, which are the basis for natural processes, and human actions”. These interactions between the social and ecological components in a landscape always function in the context defined by the regional and global scale actions and other temporal dynamics (Fischer et al. 2015).

SESs and landscapes are defined as dynamic entities that are continually changing (Liu et al. 2007) and the changes are caused by the present and past interactions between the parts of the system (Fagerholm et al. 2013). This means that the changes in human actions and ecological features are highly connected and affect the development of each other (Bürgi and Russell 2001). From this perspective defining landscapes as SES provides a useful analytical framework “for understanding the interlinked dynamics of environmental and societal change” (Fischer et al. 2015). The dynamic nature, characterized by spatiotemporal landscape heterogeneity, interdependencies of the different social and cultural actions and the cross- and multiscale feedbacks between them makes it difficult to predict how the SES will be realized as a landscape (Alessa et al. 2008).

2.2 Landscape ecology

The conceptualization of landscapes as SES requires a study approach that enables the combination of the social and ecological components (Ostrom 2009). Landscape ecology as a scientific discipline unites multiple perspectives on landscapes to better understand different aspects of them (Wu 2013a). The landscape ecological perspective can integrate the study of both the human and natural components of multifunctional landscape systems to gain a better understanding of the system as a whole. Landscape ecology can be defined as a subdiscipline of ecology that studies how landscape structure, which describes the landscape pattern and its properties, affects the processes that determine the quantity and distribution of organisms in a range of different scales (Wu 2013a). Quite often the focus has been on the natural environment and human-actions are just seen as one component of the whole or the role of humans has been reduced to a driver of change among other drivers (Bürgi and Russell 2001).

Emphasis is on the interaction the environment and society in space and time between and how does this interaction result in different landscape structures (Bürgi and Russell 2001). Haines-Young (2006: 106–107) argues that understanding how landscape structure is created is equally important to understanding how does pattern affects process. They note that especially in landscapes characterized by human activities, present and past land management practices have influenced the construction of the pattern we see now. Land use management is defined from this perspective as deliberative human activities that can affect landscape structure and functions and the services that they potentially provide (Termorshuizen & Opdam 2009). Therefore, understanding the past and present phases of the generation of a landscape is important to their management (Haines-Young 2006).

The practices and principles of landscape ecology are underpinned by spatial heterogeneity (Wu 2013a). Spatial heterogeneity creates the basis for landscape structure and has two components: the amount and size of different elements and the spatial configuration of these elements (Fahrig 2006: 4; Crow 2006: 202). These components are named composition and configuration. Usually it is difficult to make generalizations of landscape structures because they have little significance in themselves (Haines-Young 2006: 104). They are only significant when considering them in the socio-ecological context of the study area, which means that conclusions drawn from any study tend to be specific to the geographical location.

The goal of landscape ecology is to achieve landscape sustainability (Wu 2013a). A sustainable landscape (structure) can be defined as a landscape that sustainably provides ecosystem services while recognizing societal needs and respecting societal values (Nassauer & Opdam 2008). In practice, it can be challenging to identify whether a landscape is sustainable or not, because there are multiple definitions of sustainability and the term sustainability is inherently context-dependent, and the context is always multifaceted including cultural, social, political and spatial aspects which leaves much room for different interpretation (Wu (2013b).

Wu (2013b) states that all the aspects of sustainability can be integrated into one holistic approach by looking at the landscape context. Because of this the knowledge gained on the interaction between the pattern-process dynamics should be combined with human knowledge to understand how are the two connected and developed together (Opdam et al. 2013). To be relative for the society and sustainable land use management, the knowledge on human values and behavior and the human-nature relationships needs to be connected to the knowledge of physical landscape structure and functioning (pattern-process) (Figure 2) (Termorshuizen & Opdam 2009; Opdam et al. 2013). This knowledge is central to understanding the dynamics of social-ecological systems and how the systems can be sustained to provide benefits to future generations (Potschin & Haines-Young 2006).

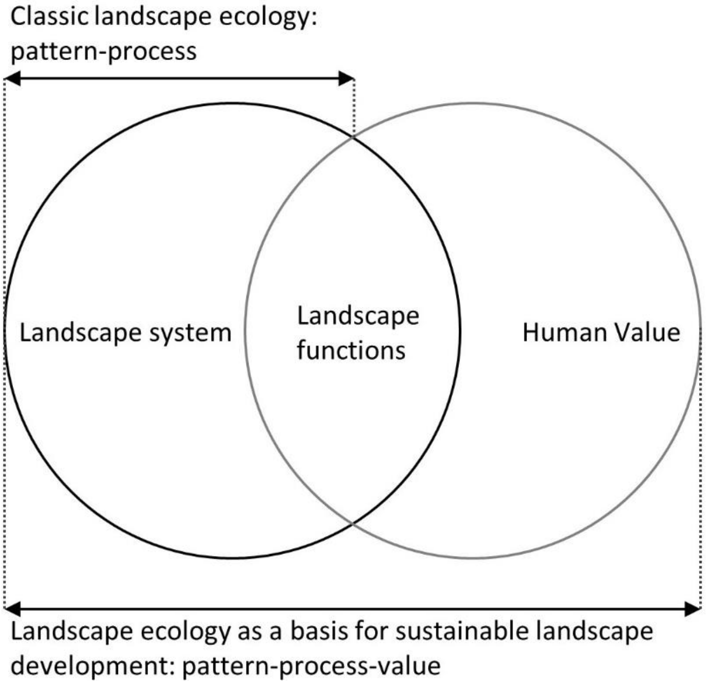


Figure 2. The pattern-process framework of landscape ecology can be connected to human valuation to emphasize the human-landscape relationships. Figure adapted from Termorshuizen & Opdam (2009).

2.3 Landscape service framework

A commonly used definition for ecosystem services is that of the Millennium Ecosystem Assessment (MA 2005): “the benefits people obtain from ecosystems”. This definition is embedded into the conceptual framework of ecosystem services presented in the assessment that states that “people are integral parts of ecosystems and that a dynamic interaction exists between them and other parts of ecosystems, with the changing human condition driving, both directly and indirectly, changes in ecosystems and thereby causing changes in human well-being”. Defining ecosystem services this way takes into consideration both services that are created naturally (e.g. carbon storage) and those that are created by systems managed by people (e.g. recreation opportunities) (Bennet et al. 2009). Other definitions only include things that are strictly ecological phenomena excluding the human component of the service creation (Fisher et al. 2009).

Regardless of whether the services are considered to be only ecological phenomena or not, central to many of the definitions is that for a landscape function to become a service it needs to be valued by people (Fisher et al. 2009; Termorshuizen & Opdam 2009). Haines-Young & Potschin (2010) present the service cascade as conceptualization of the different components of service production and valuation that are central to the concept of ecosystem services (Figure 4). The cascade identifies the biophysical structures and processes that create the functions, services and eventual benefits that people receive. The functions are defined as properties of an ecosystem that people can find useful instead of all properties of the ecosystem in question. Whether a function provides a benefit or not is decided by the value that people give to the service that the function provides. In the figure slow passage of water is presented as an example of a function that can provide flood protection as a service. The functions are then seen as intermediates between ecosystem processes and services (de Groot et al. 2010).

The terms ecosystem “value” and “benefit” are often conflated in the literature as they are closely related: ecosystem services are the benefits people obtain from ecosystems, while ecosystem values are measures of how important ecosystem services are to people (Brown et al 2016). Although the final products provided by ecosystems are presented as things valued by people, it is important not to forget the other biophysical process and structures that enable the service creation (Haines-Young & Potschin 2010). From this perspective, the definition of services should include services that are not directly perceived and valued by people (Costanza 2008).

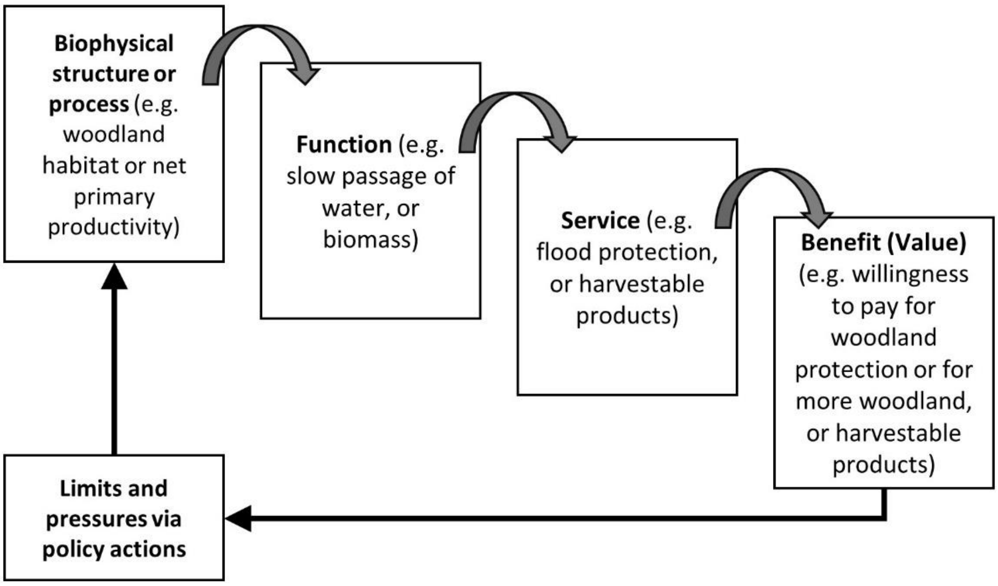


Figure 4. Service cascade adapted from Haines-Young & Potschin (2010) presenting the conceptual framework for the relationship biophysical structure and processes, ecosystem functions and human valuation as services. Within this framework the whole process should be sensitive spatial and temporal dimensions that specify the cascade.

As noted by Jones et al. (2016) the separation of functions and beneficiaries creates a distinction between potential ecosystem services and realized ecosystem services that are used by people (Figure 3). They point out that the potential service supply and user demand might not always match which can cause situations of potential unused supply or unmet demand. The service functions continue to exist when there is no people to benefit from them (Termorshuizen & Opdam 2009) and could potentially provide services in the future.

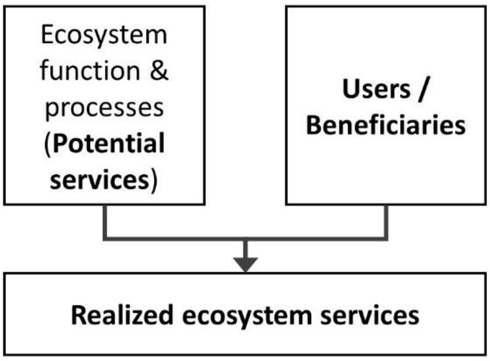


Figure 3. Description of realized ecosystem services adapted by Jones et al. (2016) emphasising the central role of people as beneficiaries from services.

The concept of landscape services has been presented by Termorshuizen & Opdam (2009) as a specification to ecosystem services. The conceptual landscape service framework defines landscapes as multifunctional systems (previously used by e.g. de Groot 2006) and seeks to connect the pattern-process paradigm of landscape ecology with the social systems where people make decision about the management of the landscape. The landscape service framework creates a window through which services that are used in a landscape can be conceptualised and studied with empirical methods. Termorshuizen and Opdam (2009) provide three arguments why in some cases the concept of landscape services should be preferred over ecosystem services. First they argue that the landscape service concept highlights the importance of the relationship between spatial pattern and processes in creating services whereas the concept ecosystem services focuses on the functional relationship between ecosystem components. The concept expresses a stronger connection to the spatial aspects by using landscapes as spatial reference units (Bastian et al. 2014) and has been favoured for its ability to better integrate spatial aspects into research (Fang et al. 2015).

The second argument is that landscape services works better when trying to capture the views and everyday activities of local stakeholders, which makes more suitable for collaborative land use management. Termorshuizen and Opdam state that the concept of ecosystem can sometimes be more associated with ”large-scale, natural processes and conservation instead of with human habitat, cultural patterns, and development” where landscape supports a more integrative view of linking people’s perception of space and actions in space with the physical character of the landscape (Bastian et al. 2014). Fagerholm et al. (2012) argue that the local landscape scale perspective enables the identification of connections between the everyday realities of participants and the surrounding landscape characteristics. For example, they support the use of landscape concept when the goal is to achieve sustainable landscape development because it gives local scale relevance to the experiences and actions of the stakeholders, which are embedded in their everyday landscapes.

The third argument state that landscape is a broader concept that has the capacity of unifying different disciplines under it, whereas according to Termorshuizen and Opdam (2009), the concept of ecosystem is primarily associated with ecological functions. This perspective is important when considering the use of the concept in land use management which requires knowledge from both the physical and cultural landscape that is often created by different scientific disciplines.

Whether the focus is on ecosystem or landscape services, it is important to conceptualize the complexity of the provision of different services into service typologies to make them more easily approachable to both science and decision-making. The MA (2005) classifies the services as provisioning (e.g. food, water, timber), regulating (e.g. water quality, climate), cultural (e.g. aesthetic, religious) and supporting services (e.g. soil formation, photosynthesis). This classification or a modification of it has been used in many studies although there are multiple other classifications. Some argue that the selected classification should be based on the study area context as the social and ecological properties and services that are provided and valued vary between areas (Fisher et al. 2009). Costanza (2008) supports this approach and argues that there are many useful ways to classify ecosystem services that are all suitable for different social-ecological contexts which are created by the complexity of the real world. The multitude of different classification typologies can cause very concrete challenges. Fisher et al. (2009) for example argue that even if the service classification is not suitable for all research purposes, there should be a clear and consistent definition of what ecosystem services are. This could enable comparison of services in different contexts, but as noted by Burkhard et al. (2012a) the definition of a common classification framework is challenging because of the context specific and question-dependent nature of ecosystem service studies.

When landscapes are defined as constructions of SES (Termorshuizen & Opdam 2009) they can be seen to have the capacity to provide a variety of different functions that are created by the social and ecological structures and processes (de Groot et al. 2002). According to Reyers et al. (2013) the SES approach to ecosystem services emphasizes how the social and ecological structures and processes are valued as services, how the bundles of services are formed and how do the benefits flow from functions to people. Having knowledge on these issues is central to understanding changes in human well-being and how does the service utilization and valuation influence the management of the SES. The changes in the management of SES can affect the different social and ecological factors that produce the services in the first place (Reyers et al. 2013).

In the SES thinking all services used and valued by people are embedded in the interaction between the social and ecological components that define the whole system (Ostrom 2009). From the perspective of landscape services the interest lies in understanding how does the interaction between the two components affect service provision and use in different areas and scales. This view emphasises the need to understand how the human-nature interactions produce services (Carpenter et al. 2009). Because of the complexity of SES it is then likely that in different contexts the human-nature relationships create different land uses and individual perceptions and values attached to landscapes (Fagerholm et al. 2013).

From the perspective of SES it is likely that landscapes will be multifunctional. The multifunctional landscape concept describes the capacity of landscapes or landscape elements to provide multiple different land uses and related functions (de Groot 2006) which can be valued as multiple services. The multifunctionality of landscapes can lead to possible trade-offs or synergies between the services depending of the interactions between landscape functions (De Groot et al. 2010). The interactions can be defined as situations where the provision or utilization of a service affects the provision of another service. Trade-offs in ecosystem services are situations where the provision of one service increases while another service declines while synergies are situations where two or more ecosystem services all either decline or increase (Bennet et al. 2009).

Multifunctional landscape services are mostly realized in practice through land use decisions. Lambin & Meyfroidt (2010) describe two fundamental forces that influence the land use decision. First, the socio-ecological forces function at the local scale and are endogenous to the area where the transitions are happening (e.g. concrete actions and land use decision made by people). The focus on the local scale is important as in this scale people can make concrete decision on how to better manage the service use and provision (Bennet et al. 2009). Second, the socio-economic forces are exogenous forces that are born in a larger scale (e.g. national or global) and do not directly change the local landscapes. These socio-economic forces can be, for example changes in urbanization or new technology innovations. Differentiating these two and understanding their possible consequences is important when defining land use management activities.

2.4 Geospatial analysis of physical landscape structure

As noted by Syrbe and Walz (2012) the spatial arrangement of landscape elements significantly defines the generation of services and their potential valuation. This indicates a need for considering the spatial structure of landscapes in service assessments. The focus on the interactions between pattern and process in landscape ecology has created a need for methods that describe and quantify landscape structure (Turner et al. 2001: 93). To quantify structure the landscape is often reduced to a matrix of patches, where a patch is defined as a continuous area that is different from its surroundings. There are multiple different definitions on what can be considered continuous the most common answer being neighboring cells in a raster data set (Turner et al. 2001: 106). The use of Geographical information systems (GIS) methods is a common approach to the empirical study of landscape structure. To analyze landscape pattern with GIS methods information on the complex physical reality of landscapes needs to be reduced to spatial data that describes important properties and structure of landscapes. In practice this is often done with the use of land use and land cover LULC data. The selected LULC classification will strongly affect the results of the pattern analysis (Turner et al. 2001: 101). A suitable classification with a suitable level of aggregation on information must be selected so that it will match the research objectives and perform in all the different landscapes under study.

As mentioned, landscape structure is created by spatial heterogeneity and it has two components: composition and configuration (Figure 5) (Lamy et al 2016). The two components can be quantified by using landscape indices (Turner et al. 2001). Composition indices are often non-spatial and produce descriptions on landscape properties such as land cover richness (i.e. the number of different cover types) and evenness (the proportion of cover types in relation to others) (Fahrig et al. 2011). Configuration indices are focused on the spatial pattern of patches in the landscape and the interest lies in the size and shape of the patches and their locations in relation to each other (e.g. shape and fragmentation) (Lamy et al. 2016). Rutledge (2003) argues that the usefulness of indices lies in their capacity to describe and compare spatial patterns of landscapes. They also state that some indices consistently relate to specific ecological processes and could be important to understanding pattern-process relationships in the area.

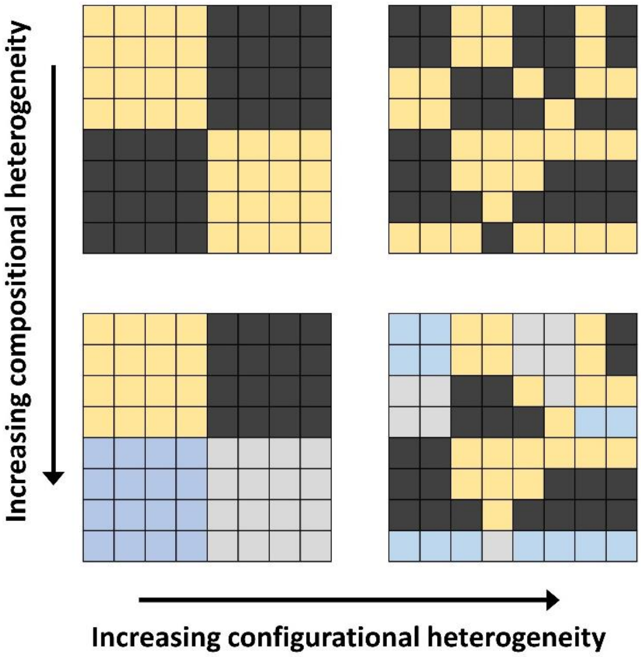


Figure 5. The two main components of spatial heterogeneity (composition and configuration) are presented on the vertical and horizontal axes. The colors indicate different LULC classes. Compositional heterogeneity is increased by the number and/or evenness of cover types and the configurational heterogeneity by the increasing complexity of the spatial pattern. Figure adapted from Fahrig et al. (2011).

When studying landscape structure, the spatial and temporal scales of the processes, or more precisely the grain and extent need to be defined (

Figure 6) (Turner et al. 2001 102–103) because the results are often sensitive to scale and the possible effects of changing the scale are difficult to detect (Farina 2006: 98). Turner et al. (2001: 102–103) define grain and extent as follows. Grain refers to the resolution of the data being used which often is the grid cell-size. When grain size grows objects and rare LULCs lose their importance and the borders between different covers become less precise. Extent refers to the size of the study area and can also affect the results independently of the grain size by for example changing the relative proportion of land covers within the study area.

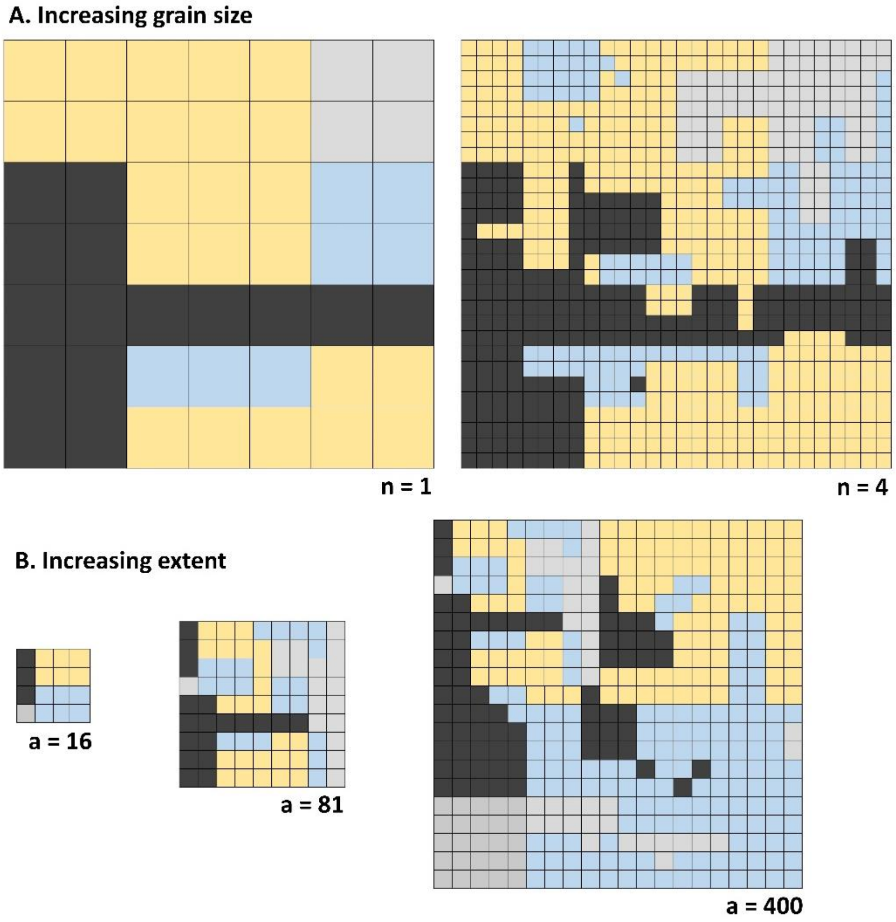


Figure 6. Presentation of the two components of spatial scale (A) grain and (B) extent. (n) indicates the number of cells aggregated to from the new data and (a) the total area. The different colors of the cells indicate different land covers. Figure adapted from Turner et al. (1989).

Another approach to analyzing landscape structure is provided by the gradient concept where the landscape is modelled through continuous surfaces (e.g. elevation or soil texture) instead of categorical patches. According to McGarical & Cushman (2005) the definition of patches as bounded categories in the patch-mosaic model ignores all further heterogeneity in the landscape or the heterogeneity is considered to be irrelevant for the study. The gradient approach is more suitable in some cases as it preserves the spatial heterogeneity of the environmental variables, removes the subjectivity of defining boundaries for patches and cut-points for categories and enables the landscape structure information to be directly associated with other continuous data sets (McGarical & Cushman 2005). McCarigal et al. (2009) present an approach for quantifying the gradient structure with the use of surface metrics and argue that some of these metrics are capable of highlighting issues that landscape indices are not able to reach. The surface metrics have spatial (horizontal and vertical variability in the surface) and non-spatial components (only vertical variability). The non-spatial metrics measure landscape composition, not configuration, whereas the spatial approach describes the distribution or arrangement of high and low values within the extent. McCarigal et al. (2009) also argue that gradients are sensitive to grain and extent and are multivariate which indicates that they need multiple metrics to describe them.

In the end, multiple landscape indices correlate with each other and often provide inessential information (Rutledge 2003). The use of indices should be approached carefully to avoid misinterpretation. The use of any indices should be based on verified relationships between process and pattern that the selected index describes, or their usefulness for understanding the pattern-process relationships is minor (Li & Wu 2004). The inability of the indices to consistently produce useful information on the pattern-process relationships for simple processes makes it highly unlikely that their use would be beneficial when trying to understand complex processes (Rutlegde 2003). Even when the relationships between process and pattern can be verified, it is difficult to form general assumptions on landscape structure through the use of the indices because the observed relationships are often specific to a certain system or location (Haines-Young 2006).

2.5 Participatory mapping of place-based services

Participatory Geographic Information Systems (PGIS) or Public Participatory Geographic Information Systems (PPGIS) are spatial research methods that aim to produce primary information on different topics from the subjective experiences of stakeholders. To achieve this, according to Fagerholm & Käyhkö (2009), the methods “combine community participation with the use of digital geospatial techniques and enable the collection, storage and analysis of stakeholder data in a geographical form”. For practical reasons, from here on I will refer to PGIS methods as participatory mapping. In practice the exact definition of participatory mapping depends on the application, aims and information needs of the research in question (Fagerholm & Käyhkö 2009). This open definition has led to multiple different ways of application (Brown & Kyttä 2014). The focus in this chapter is in applications where local non-expert stakeholders are engaged in identifying and valuing landscape services. Other studies have also engaged a variety of experts (e.g. Palomo et al. 2013) or participants interested in environmental management (e.g. Bryan et al. 2010) to identify and value services.

In participatory mapping of landscape services individuals indicate spatially explicit benefits from landscapes and can include a component of service valuation (Brown & Fagerholm 2015). This approach assumes that not all areas are equally valued by people and by using these methods the important locations and their related attributes can be identified. In landscape service research, multiple empirical studies have shown that participants can identify ecosystem and landscape benefits using participatory mapping methods (e.g. Brown et al. 2005; Bryan et al. 2010; Fagerholm et al. 2016). However, the ability of non-expert participants to identify all of the different landscape services should be viewed critically. Brown et al. (2016) for example state that identifying regulating and supporting services requires in-depth knowledge on the biophysical processes in the study area which is rarely possessed by the participants. In these cases, the participation of a smaller sample of experts of the topic could produce more accurate information (Brown & Fagerholm 2015).

Place-based landscape value mapping is especially useful as it enables the identification of spatially-explicit locations where the landscape properties are suitable for a function to exist and contribute to well-being (Brown et al. 2015). The identified benefits are considered indicators of place relationships between people and the surrounding landscape (Fagerholm et al. 2012) and they link perceived landscape values directly to the physical landscape (Brown et al. 2013). In practice, as argued by Brown et al. (2012), service maps produced via participation provide "a medium for integrating social and ecological aspects of ecosystem service management".

In practice, the values, knowledge and experiences of participants have been mapped with three methods: points, polygons or predefined areas (e.g. administrative boundaries). The latter of the three options is heavily restricted by the availability of suitable data sets for boundaries and often studies use either points or polygons. In their comparison of the two methods, Brown and Pullar (2012) note that the challenge with points is that most of the mapped attributes are in reality larger than the size of the point and therefore require a method of spatial aggregation to get spatial coverage. On the other hand, for polygons defining precise borders can be problematic. For polygons it is more likely that the method overestimates the amount of significant areas, as for points the size of significant areas is more likely to be underestimated. They also note that it can be easier for the participants to identify points instead of polygons, but that the usage of points comes with the burden of collecting a larger sample to achieve a comparative spatial coverage to using polygons. In both cases it is important to note that place-based values are always dependent on the scale which they are mapped. Depending on the mapping scale some features of the landscape may or may not be identifiable and the intended feature of the landscape pointed out by a participant might not be visible in the background map (Brown et al. 2013). It is also likely that different services indicate very different scale features of the landscape.

The need for local scale mapping is highlighted by Fagerholm et al. (2012) when they state that landscape service mapping needs to be sensitive to space and place experienced by the participant. According to them, conducting the mapping at the local scale enables us to better capture stakeholders' experiences and spatially explicitly define the benefits they gain from the surrounding environment. Most often land use decisions are also made at the local or regional scales and understanding the social values of the services at these scales can have most influence on land use related decision-making (Brown et al. 2013). From a developing world perspective, participatory mapping methods are useful in cases where data availability is limited, because with them information on local stakeholder knowledge and usage of landscape services can be relatively efficiently collected (Paydual et al. 2015). In addition to data collection, participation can support the communities so that their voice will be heard at the official management processes by including indigenous and local knowledge into decision-making (Ramirez-Gomes et al. 2015). Simultaneously they can lower the capacity differences between the local stakeholders and the administrative level and enhance capacity-building and empowerment (Fagerholm et al. 2012). The methods give the opportunity to include and empower marginalized parts of the populations by participating them in situations where access to the necessary technology is usually limited (Brown 2011).

2.6 Geospatial analysis of value-landscape associations

Mapping of landscape services is important because all areas are not equally suitable for the supply of services in spatially heterogeneous landscapes, as different ecosystems provide different functions depending on their structures and process (Burkhard et al. 2012b). A central motivation behind these methods is the usefulness of the maps for ecosystem related management and decision-making (Martinez-Harms & Balvanera 2012). Eigenbrod et al. (2010a) divides ecosystem service mapping methods in to two categories with two subcategories based on data availability: (1) methods that have at least some primary data on ecosystem services from the study area, further divided into maps based on representative sampling in the study area (e.g. regression models) and modelled surfaces based on some primary data (e.g. extrapolation methods or value-transfer) and (2) methods without any primary data, divided into land cover based proxies (e.g. based on expert knowledge) and modelled surfaces based on a priori information (e.g. assumed causal relationships). The examples in the brackets are from Martinez-Harms & Balvanera (2012). Willemen et al. (2008) note that these analyses are by definition data-driven and the scale and accuracy of the analysis is based on the used data.

To map ecosystem services either primary information on service distribution in the area is needed or indicator data needs to be used to estimate the presence of services. In practice, primary information on landscape services is rarely collected and proxy-based approaches are more often applied (Eigenbord et al. 2010). Out of the proxy-based approaches that rely on primary data, spatial value transfer methods have been commonly used and are the focus of this thesis as well. Value-transfer uses empirically defined associations as proxies of service distribution in an area where service data is not available (Troy & Wilson 2006). According to Martinez-Harms & Balvanera (2010), these methods are based on non-representative sampling of the study area and should therefore be separated from the regression methods which should be favored when having a spatially representative sample. In this context, proxies are defined as estimations made on the presence and/or provisioning capacity of landscape services without having primary information from that specific area, based on causal associations of the services with properties of the landscape (e.g. LULC) that are used as indicators of service capacity.

An indicator can be defined as a data set that describes the biophysical conditions, socio-economic conditions or spatial characteristics (accessibility) of the study area (Willemen et al. 2012) that are assumed or known to have a causal relationship with the provisioning capacity of services in that area. In practice, a variety of indicator data is needed, as according to Burkhard et al. (2012b), the capacity of an individual ecosystem to provide services is linked to the natural conditions (e.g. land cover, soil conditions and climate) and human activities (especially land use). They continue by stating that having accurate data in suitable resolution on all of the different aspects would enable the comprehensive estimation of the service provision capacity.

The selection of indicators should be done with sufficient knowledge on the mapped services and their associations with the indicator data. It is for example likely that there is so much variability in landscapes that the spatial distribution of a single service cannot be explained by a single indicator and that different services will associate with different indicators even when they are estimated within the same landscape (Gulickx et al. 2013). Verhagen et al. (2016) note that a common challenge is that indicators for mapping ecosystem services do not often take landscape configuration into account and mostly focus on landscape composition. They state that this can be a challenge because the heterogeneity of landscapes can directly and indirectly affect the service provisioning capacity of landscapes.

A relatively popular method for landscape service mapping by collecting primary information is participatory mapping. Participatory mapping as a direct ecosystem mapping method can produce spatially-explicit primary information on service distribution. The indicated service locations (points) represent, as Brown et al. 2015 puts it, “a spatial area of ecosystem value and can be combined with other proximate points to provide a spatial estimate of the ecosystem value area". A key assumption for these methods, as for all place-based methods, is that context matters on how services are valued, demanded and used (Potschin & Haines-Young 2013). Because of the spatially-explicit nature of the participatory data, it can be used to look at the spatially underlying biophysical and social structures and processes in the service locations. Based on this assumption the participatory information can be integrated into the service cascade presented by Haines-Young and Potschin (2010) to create a conceptual guideline for exploring associations in a landscape context (Figure 7).

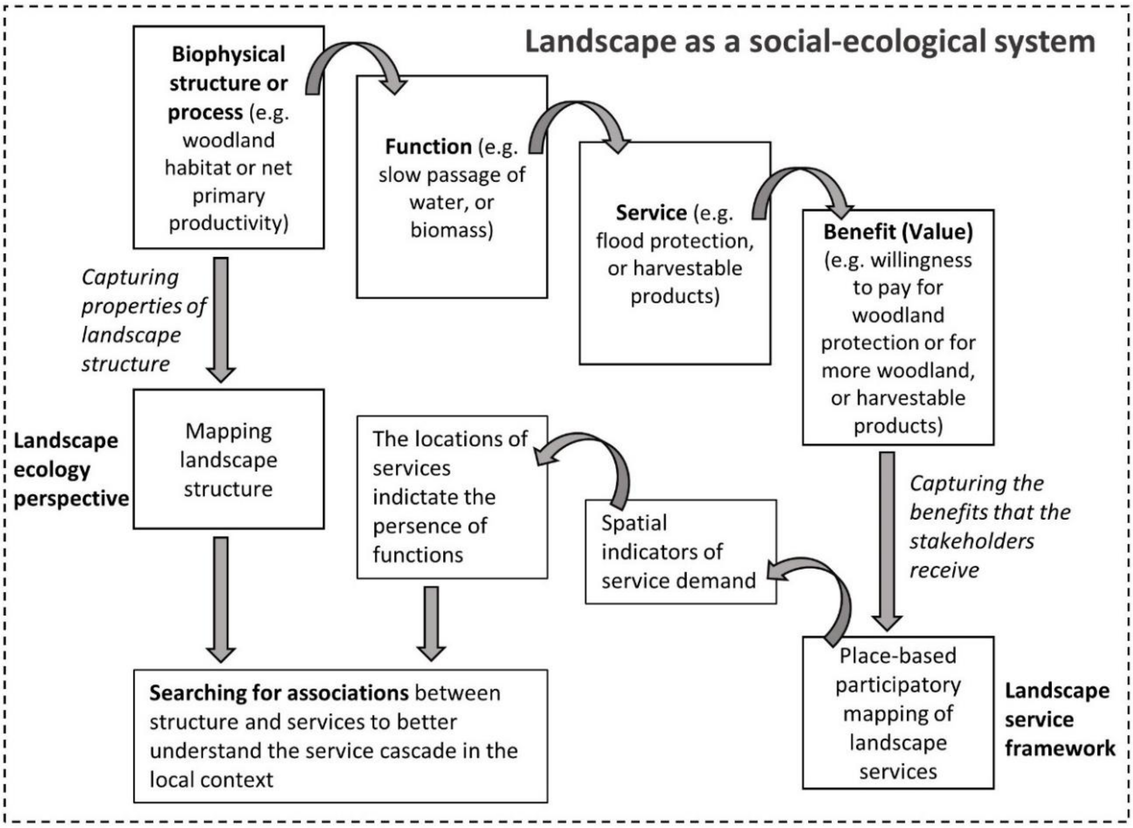


Figure 7. By incorporating place-based participatory mapping of landscapes and mapping of landscape structure in to the service cascade figure by Haines-Youg and Potschin (2009) to visualize the framework for exploring value-landscape associations. From this perspective the biophysical structures and processes should be complemented with social and economic structures and processes.

The conceptualization is created from the perspective of the landscape service framework presented by Termorshuizen & Opdam (2009) which emphasize the connections between humans and the landscape. As noted the production and utilization of all landscape services are embedded in landscapes which are constructed by the social-ecological processes of the landscape system. Through participatory mapping we can identify these human-service relationships and quantify their spatial distribution in the study landscape. From the biophysical structure and process perspective, the pattern-process framework of landscape ecology provides a way to empirically study the landscape composition and configuration that is expected to be associated with mapped landscape services.

The indicated locations of ecosystem functions are valued as benefits which creates a desire to understand, explain and predict these associations between landscape values and underlying physical landscape functions and structures (Brown et al. 2015). Therefore, as noted by Brown & Fagerholm (2015), a logical next step for participatory mapping studies is to quantify empirical associations between mapped service points and physical landscape characteristics to extrapolate the results to areas where no primary data exist. These value-landscape associations (term used by Brown & Brabyn 2012a), can then be used for spatial benefit or value transfer (e.g. Brown & Brabyn 2012b; Sherrouse & Semmens 2014; Brown et al. 2016). LULC data is most commonly used as an indicator because of its widespread availability (Eigenbrod et al. 2010a). In some cases, indicators can be directly derived from the LULC data such as built environment for residential area function (Willemen et al. 2008) but unfortunately this not always the case. The addition of further data on the landscape properties can better take into consideration the "spatial and temporal heterogeneities of landscape features and values" (Burkhard et al. 2009).

The central challenge for value-transfer methods is the possible generalization errors (Plummer 2009). Generalization errors can be divided into three main components (Eigenbrod et al. 2010b): (1) uniformity error is caused by the assumption that the value of a landscape service is constant across an indicator data category (e.g. LULC class), (2) sampling error is caused by a biased sample of primary information and (3) regionalization error is caused by the unrepresentativeness of the primary data collection area of the regions as a whole. The use of LULC especially is prone to uniformity error when used as a proxy. A single LULC class can have multiple different ecosystems or functional characteristics in it (Troy & Wilson 2006) and it is impossible to know for sure with which characteristics the service is associated with. The thematic and spatial generalizations of the LULC data can therefore have major effects on the accuracy of the results (Burkhard et al. 2009).

To overcome some of these challenges, research has applied a variety of different methods and data sources to identify more precise associations. All of the presented studies have used points to identify service locations. Brown & Brabyn (2012a; 2012b) used landscape characterization data to define associations to six landscape components (landform, land cover, infrastructure, water, dominant land cover and water views) and transfer values on a regional scale. The classification creates a typology that enables the identification of both univariate (service associated with a single landscape component) and multivariate (service associated with multiple components) associations between services and physical landscape features.

The associations between landscape services and land use and nature conservation data has also been studied to identify important value-land use associations for decision-making. For example, Hausner et al. (2015) studied the association of ecosystem services with land tenure and protected areas and Brown et al. (2014) associated cultural and social ecosystem values with public land types (e.g. state forests or historical/cultural areas) and nature conservation categories (e.g. sustainable use area or habitat/special area). These studies have shown that studying land use preferences with the help of participatory data can bring new insight in to the valuation of different land tenure, protected and public land types.

In practice, most of the studies on value-landscape associations have used categorical indicator data to define spatial associations. The use of standardized residuals has been widely applied to study the association between point data and categorical data sets (e.g. Brown et al. 2014; Hausner et al. 2015). Some studies have also taken into consideration the proportional spatial coverage of the categories in the study area to highlight small scale associations with areas with low area coverage (e.g. Brown & Brabyn 2012a; Brown et al. 2015). According to Brown et al. (2012) the identified significant relationships of services with categorical data can indicate the suitability of the data to be used as a proxy.

Another presented method is to use a set of categorical and continuous indicator data describing different landscape properties (elevation, slope, distance to water, distance to roads, land cover and landforms) together with the Social Values for Ecosystem Services (SolVES) GIS tool to map services and to identify value-landscape associations (e.g. Sherrouse et al. 2011; 2014; Sherrouse & Semmens 2014). According to Sherrouse et al. (2014), The SolVES tool provides three core functionalities: (1) the generation of social value-maps, (2) the modelling of associations between values and the underlying landscape structures and (3) using the models for value transfer. In other words it provides a nonmonetary spatially explicit estimate of service valuation in the desired study area.

The SolVES model has been criticized by Brown et al (2015) who have stated that a limiting factor to the feasibility of the model is the choice of the environmental data sets that are used to describe the physical landscape. They argue that the basic descriptors used in the SolVES studies such as elevation or distance to road are too general to describe the causal association of service locations with the surrounding environment. They can therefore have a limited capacity to "illuminate the structure – function – value chain" that can be connected to the place-based values (Brown et al. 2013). The same concern is highlighted by Sherrouse et al. (2011) when they point the need for more quantitative and qualitative variables to be used in regression analysis. SolVES as a method can help in solving this challenge as it can incorporate also other data sets than the ones used in the studies so far, including social data (Sherrouse & Semmens 2014). In any mapping method the selection of the indicators is crucial as they represent the linkages between the landscape services and the pattern-process relationship (Ungaro et al. 2014) and therefore the precision of the results relies on the suitability of the indicators in the study context.

There are some challenges related to searching for associations with participatory mapping data. First and most importantly the value-transfer method requires the associations between landscape values and the physical landscape properties to be valid and reliable (Brown et al. 2015). At the same time, participatory mapping as a place-based method is highly context dependent and is faced with the challenge of generalizing the achieved results to other contexts as they are designed to collect information on how different people or groups see, use, value and live in a certain place (Potschin & Haines-Young 2013). It is then likely that variation in both human perceptions of landscape benefits and the diversity of physical landscape structure will create different associations in different contexts (Brown et al. 2013).

Despite these challenges participating local stakeholders is essential as expert evaluations (e.g. Burkhard et al. 2009) or proxy data on landscape services cannot reach all the landscape benefits identified by the stakeholder (Fagerholm et al. 2012). Information collected at the local scale is rarely used in ecosystem service mapping although it can link the livelihood practices and local perspectives to the surrounding landscapes (Sinare et al. 2016) and explain associations between the benefits and the surrounding landscape. Understanding these associations will help to make better decision as it gives information on how modifying the elements of the landscape can add or lower the received value (Termorshuizen & Opdam 2009). For any method of service mapping to be as accurate as possible the biophysical and socio-economic context should match between the areas where empirical models or a priori rules were defined and where the proxies are planned to be used (Troy & Wilson 2006). This is especially likely for cultural ecosystem services that are seen to be highly context specific (Eigenbrod et al. 2016). The consideration of the social-ecological context is further challenged by the possible mismatches between scales of services and the indicator data, for example on the local scale services that are valued as benefits can be dependent on regional or local scale social or ecological processes that can affect local service demand (Carpenter et al. 2006).

2.7 Key concepts of the thesis

As noted by Bennet et al. (2009) in the ecosystem service research concepts have multiple definitions by different users. In this thesis I will be using the following key concepts as defined.

Following the landscape service framework by Termorshuizen & Opdam (2009) **landscape values** a specification of ecosystem values. They are defined as “contributions of landscapes and landscape elements to human well-being” (Bastian et al. 2014). This definition includes values that are produced naturally and in systems managed by people (Bennet et al. 2009). The services that are valued can be material and/or immaterial and are directly or indirectly valued by people as benefits (Costanza 2008; Fagerholm et al. 2012). In practice landscape value is used to refer to the services that people obtain from the landscape as benefits. From the SES perspective all services used and valued by people are seen to be embedded in the interaction between the social and ecological components of the whole system (Ostrom 2009).

Landscape is a multifunctional **social-ecological system (SES)** consisting of ecological and social components that interact to produce the landscape. (Ostrom 2009; Termorshuizen & Opdam 2009). Socio-ecological context describes the realization of the system in an area. **Multifunctionality** is the capacity of a landscape or a landscape element to provide multiple different land uses and related values (de Groot 2006) where a landscape element refers to a clearly identifiable area or feature of the landscape, for example a forest or a river.

Landscape ecology is a discipline that studies the interaction between landscape pattern and process (Wu 2013a). Landscape pattern is defined through the use of the concept of **landscape structure**, which refers to the composition and configuration of the landscape caused by spatial heterogeneity (Fahrig 2006: 4). The structure of the landscape is quantified through the use of landscape indices that describe the composition or configuration of the structure.

Participatory mapping is used to describe Participatory Geographic Information Systems (PGIS) that are spatial research methods that aim to produce primary information on different topics from the subjective experiences of stakeholders (Fagerholm & Käyhkö 2009). From the landscape value perspective they are seen as geospatial methods that can indicate spatially explicit locations of service values of the participants in the landscape (Brown & Fagerholm 2015). The concept of PGIS is preferred over Public Participatory Geographic Information Systems (PPGIS) in this thesis because it has been frequently used in developing country contexts and it brings more focus to the social learning and community engagement aspects (Brown & Kyttä 2014).

Landscape value mapping is defined as the process of defining the spatial distribution of landscape values in an area (Eigenbrod et al. 2010a). The definition includes both approaches that use primary data (e.g. collected via participatory mapping) and proxy-based that use either causal associations of indicator data sets with primary data from another study area or a priori information of the associations to map the distribution (Eigenbrod et al. 2010b). Distribution of values is used to refer to spatial patterns of the value points indicated by intensity, richness and diversity landscape values. **Value-transfer** is a landscape value mapping approach that uses empirically defined quantitative value-landscape association as proxies of value distribution in an area where primary value data is not available (Troy & Wilson 2006).

With **landscape-value associations** in this thesis I refer to spatial association defined between value data collected via participatory mapping and the underlying physical landscape structures described by physical landscape structure (Brown & Brabyn 2012a). **Proxies** are estimations made on the distribution of landscape values without having primary information from that specific area, based on causal associations of the values with properties of the landscape (e.g. LULC) that are used as indicators of service capacity. **An indicator** is a data set that describes the biophysical conditions, socio-economic conditions or spatial characteristics (accessibility) of the study area (Willemen et al. 2012) that are assumed or known to have a causal relationship with the provisioning capacity of services in that area.

Land use management is a set as human activities that deliberately modify the landscape through guiding people's activities and land use decisions to enhance the service provisioning capacity to be valued as benefits (Termorshuizen & Opdam 2009).

3. Study area

This research is done in Tanzanian Southern Highlands. The area is located in South to South-West Tanzania between latitudes 7° and 11.5°S and longitudes 30° and 38°E. A common definition of its extent is to include Iringa, Njombe, Mbeya, Ruvuma and Rukwa regions. This study is focused on three study villages: Iboya, Lulanzi and Tungamalenga that are located in the Iringa and Njombe regions (Figure 8). Although the population and population growth in the regions are among the smallest in the Tanzanian mainland (NBS 2013), the pressure caused by people and population growth is still a central factor guiding village land use practices.

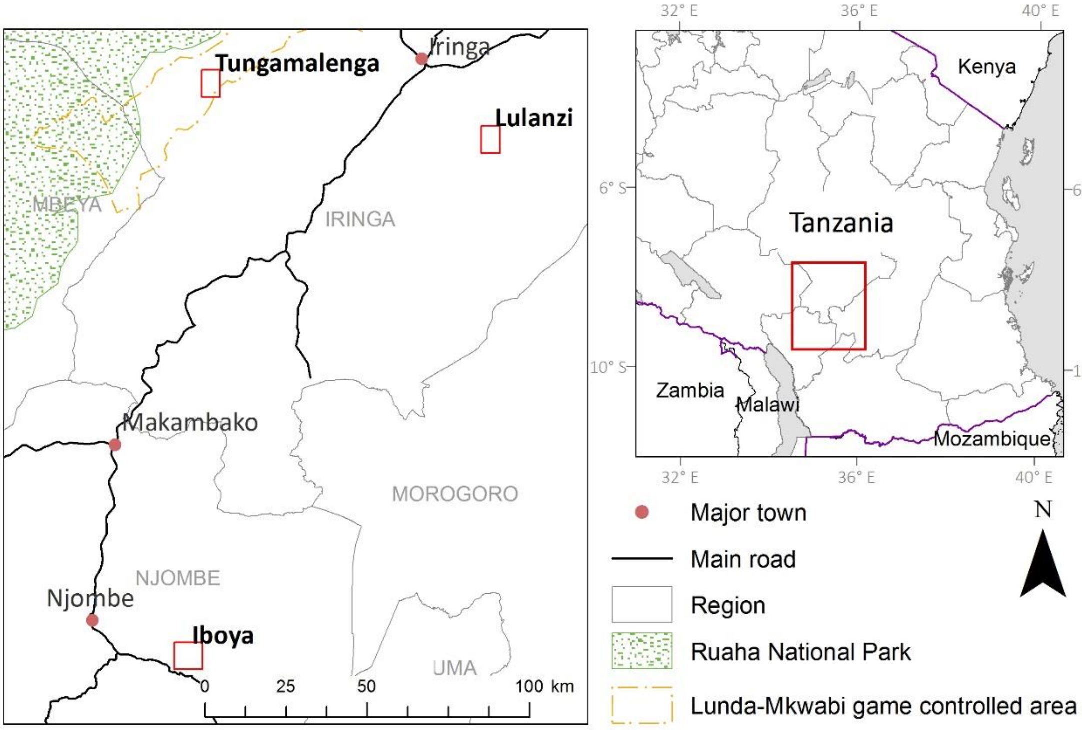


Figure 8. The three study village located within the Iringa and Njombe regions in the Tanzanian Southern Highlands. Data sources: FAO, Tazanian National Bureau of Statistics (NBS), World database of protected areas (visited 26.3.2014) and GADM database (www.gadm.com visited November 2015).

The biophysical context sets the boundaries for different livelihood practices in the villages (Table 1). The Agro-ecological zones within Southern Highlands are described as lowland, midland and highland and the classification is mostly based on annual rainfall, altitude above sea level and soil types (URT 2013 Iringa, URT 2013 Kilolo). The climate in the Southern Highlands is characterized by an annual rainy season from November to May and a dry season from June to October (URT 2012) which has led to seasonal cultivation practices. Because of the long rainy season the Southern Highlands are considered as one the most productive regions in Tanzania. The higher rains in Iboya and Lulanzi enable the practice of forestry whereas in Tungamalenga, although the soils are more productive, the unreliable rains keep agricultural productivity relatively low and leads to dependence on irrigated farms along the rivers and wetlands.

Table 1. Descriptions of the study villages the study area villages and higher hierarchy administrative areas. Data sources: Aster GDEM, WorldClim, URT 2012 and NBS Census 2012 data portal (accessed via http://www.nbs.go.tz/)

	Iboya	**Lulanzi**	**Tungamalenga**
Village population in 2012	899	1879	3101
Region/District	Njombe/Njombe Town	Iringa/Kilolo	Iringa/Iringa Rural
District population in 2012	130 223	218 130	254 032
Altitude above sea level (m)	1500 – 1900	1800 – 2200	900 – 1300
Annual rainfall (mm)	800 – 1000	1400 – 1600	400 – 600
Agro-ecological zone	Highland	Highland	Lowland

Mostly subsistence-based livelihoods are practiced in the villages with most of the people having multiple sources of income. Agriculture is commonly practiced in all three villages (73,4 – 91,6 % of people) (Table 2). The productivity of agriculture activities in Tanzania are among the lowest in Sub-Saharan Africa, mostly because of the low level of mechanization of agriculture, over-reliance on rains for precipitation and use of low-productivity animal breeds and seeds (MAFAP 2013; URT 2013). Otherwise, the different socio-ecological contexts have created different livelihood practices in the villages.

In Iboya the most common sources of income are the sale of agricultural products and casual labor in agriculture and forestry. The climate and the amount of open space makes forestry related activities common and enable the making and sale of firewood and charcoal. The forestry activities in the village are also supported by the Private Forestry Program organized between the governments of Finland and Tanzania that function in the Southern Highlands area. In Lulanzi sources of income are focused mostly on small scale business in the form of selling agricultural products and casual labor activities both in agriculture and forestry. Although the biophysical settings are suitable for forestry it is not as commonly practiced as in Iboya. Accessibility to larger markets in Kilolo and Iringa is also better than in the other villages. Tungamalenga is distinctively different from the two villages with the sources of income more related to activities in agriculture, tourism, casual labor and small scale business. The most characteristic livelihood activity in the village is the cultivation and sale of maize and rice. Because of the biophysical settings forestry cannot be practiced in the area. In Tungamalenga, there are some restrictions to wild animal hunting because of pouching practiced in the Ruaha National park. At the same time, the presence of the national park brings income in the form of tourism (URT 2013 Iringa).

Table 2. Sources of personal income within the three study villages according to the sample collected at the 2016 participatory mapping campaign.

Source of personal	**Iboya**				**Lulanzi**				**Tungamalenga**			
income (% of sample)	First	Second	Third	**Total**	First	Second	Third	**Total**	First	Second	Third	**Total**
Agriculture	39,2	20,3	13,9	**73,4**	62,1	27,4	2,1	**91,6**	69,1	12,2	0,7	**82,0**
Charcoal and firewood sale	5,1	2,5	0,0	**7,6**	0,0	0,0	0,0	**0,0**	0,0	1,4	0,0	**1,4**
Forestry	15,2	8,9	8,9	**32,9**	0,0	5,3	8,4	**13,7**	0,0	0,0	0,0	**0,0**
Livestock keeping	2,5	15,2	7,6	**25,3**	10,5	30,5	26,3	**67,4**	5,0	19,4	7,9	**32,4**
Small scale business	8,9	7,6	6,3	**22,8**	12,6	18,9	6,3	**37,9**	5,8	10,1	3,6	**19,4**
Casual labour	17,7	24,1	3,8	**45,6**	5,3	1,1	14,7	**21,1**	3,6	12,9	7,2	**23,7**
Other	10,1	3,8	2,5	**16,5**	8,4	7,4	8,4	**24,2**	9,4	10,1	5,8	**25,2**

The other subsistence-based activities that do not produce monetary income are also important for the overall well-being of the communities. Firewood is collected from the village landscape and used as the main source of energy for cooking as in most rural areas in Tanzania (URT 2013). Building materials for personal use are also often collected from the surrounding landscape, although the usage of modern materials for constructions is becoming more common in the rural areas, which lowers the stress caused by the collection of natural materials (URT 2013). The areas of Iringa and Njombe have been identified as potential areas for beekeeping, but for now activities related to it are relatively uncommon (URT 2013 Iringa; URT 2013 Kilolo).

The described livelihood practices together with the socio-ecological settings have formed quite different landscapes to the three villages at the local scale (Figure 9). In Iboya the landscape is undulating and heterogeneous with multiple small patches of land covers and uses (Figure 10). The area surrounding the settlement can be described as a grass- and cropland mosaic with patches of planted forest. The definition between grass and cultivation areas is blurry because fallow land is common. The only large and clear elements of the landscapes are the planted forest areas and the grassland area next to the village that is used for grazing. A large river runs past the village and multiple smaller streams run in the valleys between hills. Compared to the other study villages, the distance to the nearest neighboring village center is larger.

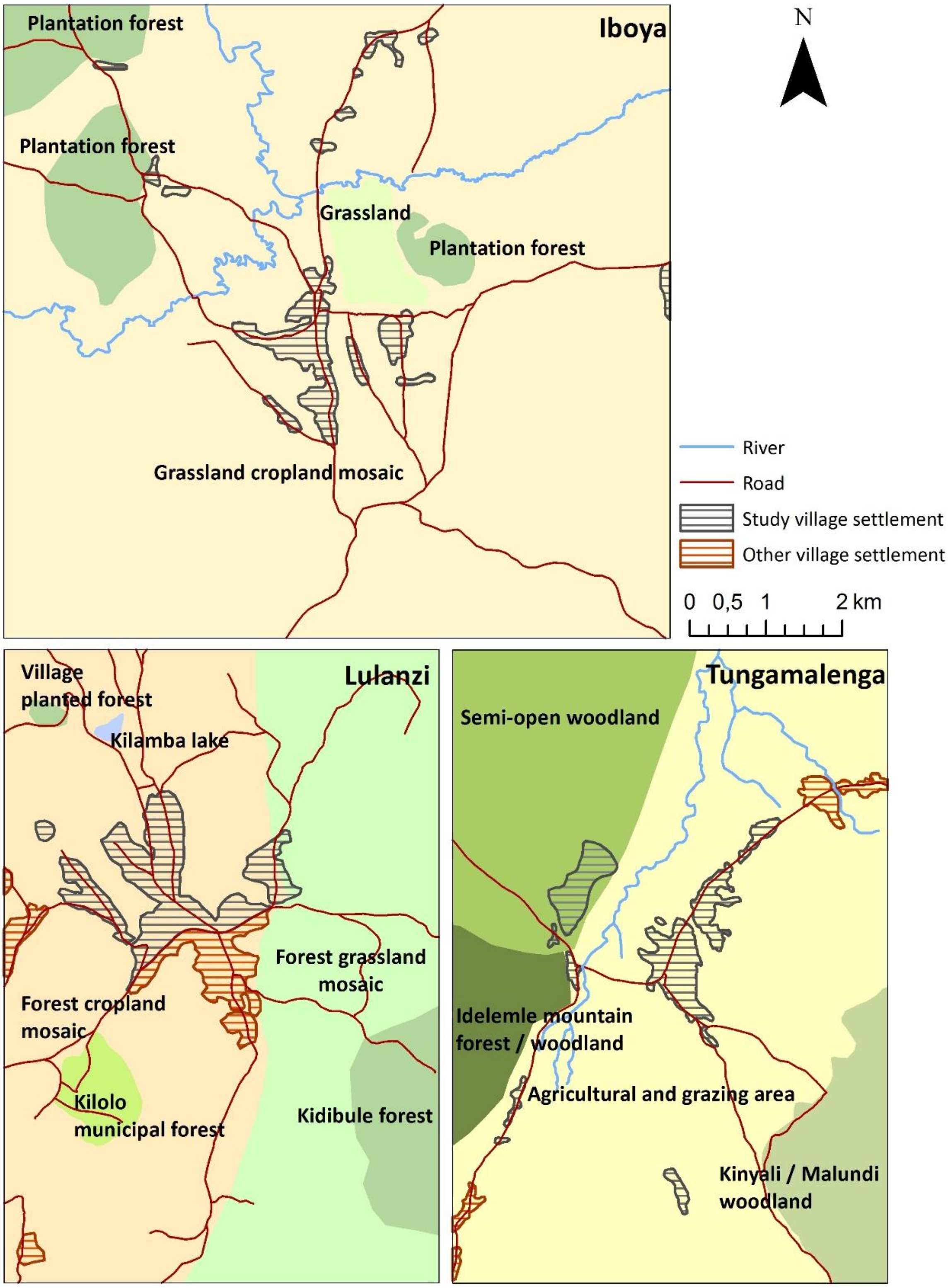


Figure 9. LULC and the most important elements of the landscapes in the three study villages. The data sets were created by digitizing the elements on top of a high-resolution Google earth satellite images (source: © Google) and should be only considered as illustrative and not spatially accurate.

Figure 10. Undulating village landscape in Iboya. Maize is cultivated in the front of the image and on the other side of the large grassland area there is an accidently burned down tree plantation.

In Lulanzi (Figure 10) the heterogeneous landscape can be divided into two main landscape types: forest grassland mosaic and forest cropland mosaic. The clearest difference between the two categories is the amount of land dedicated to agriculture although fallow land is making the classification challenging. Within the heterogeneous landscape there are some larger landscape elements: the Kidibule natural forest and the Kilolo municipal forest cover large areas and the Kilamba Lake in the north is a unique feature of the area. The landscape and landforms (undulating) are otherwise quite similar to Iboya but there is no large river near the village. The surrounding landscape is shared by two villages separated by the main road in the east to south direction. Lulanzi and the now neighboring village Luhindo used to be under the same village governance, but were separated in 2015. The landscape of Tungamalenga has a clearer division of LULC than the other two villages. There are two semi-open woodland areas in the south-east and north-south and a semi-open forest/woodland area at the hill to the west (Figure 11). In between these wooded areas there is the cultivation and settlement area with lower tree coverage and a large wet plain for rice cultivation. The landscape is relatively flat and the woodland areas are mostly located at the hills surrounding the wet plains. The river Tungamalenga runs past the village and is the origin for the name of the village.

Figure 12. Settlement landscape in Lulanzi showing a combination of multiple different LULC in the central settlement area.

Figure 11. The wet plain in Tungamalenga is used for rice cultivation. The wet plain is surrounded by hills covered by semi-open forest/woodland and semi-open woodland areas.

The core settlement area in Tungamalenga is most dense and clustered of the three villages. The clearest exception is the Maasai settlement in the north-west woodland area. In Lulanzi the situation is similar but with more homestead type settlement around the dense core of the village settlement. In Iboya there are smaller homestead areas outside of the central village area. The higher population has created a landscape with more clearly defined elements near core settlement area in Tungamalenga and Lulanzi whereas in Iboya the surroundings are characterized by a more heterogeneous structure.

4. Material and methods

4.1 Research approach

In this research the objective is to explore the value-landscape associations in the Tanzanian Southern Highlands village context. To reach the objectives the research approach presented in Figure 13 was applied. The approach is divided into three separate sections: First I mapped the physical landscape structure by using a variety of different tools and methods. The availability of spatial data in the region is limited and most of the data that I used in this thesis was created either through participatory mapping or visual interpretation of satellite images. I did the largest share of the data collection work with Open Foris Collect Earth tool. I used this data to calculate indices that describe the landscape structure in the villages. The selected data sets and the methods are more precisely described in chapters 4.2 and 4.4

Second the participatory mapping of landscape values is described. This process included the mapping campaign and the spatial analyses of the distribution of landscape values in the study area which are described in chapters 4.2 and 4.4. In this thesis value intensity, richness and diversity are defined as components of the distribution.

The third step was to use the data sets to study value-landscape associations (chapter 4.5). First I explored the association between the landscape structure indices and value indices. Then I selected a set of landscape values for further analysis on the associations between individual landscape values and landscape structure. The suitability of the found associations as proxies for landscape value mapping is discussed in chapter 6.2.

All the methods of data collection and analysis are more precisely described in the following chapters. I did all the spatial analyses, if not defined otherwise, in ArcMap 10.3.1. I used IBM SPSS statistics 23 and MS excel to create descriptive statistics and to conduct the statistical analyses.

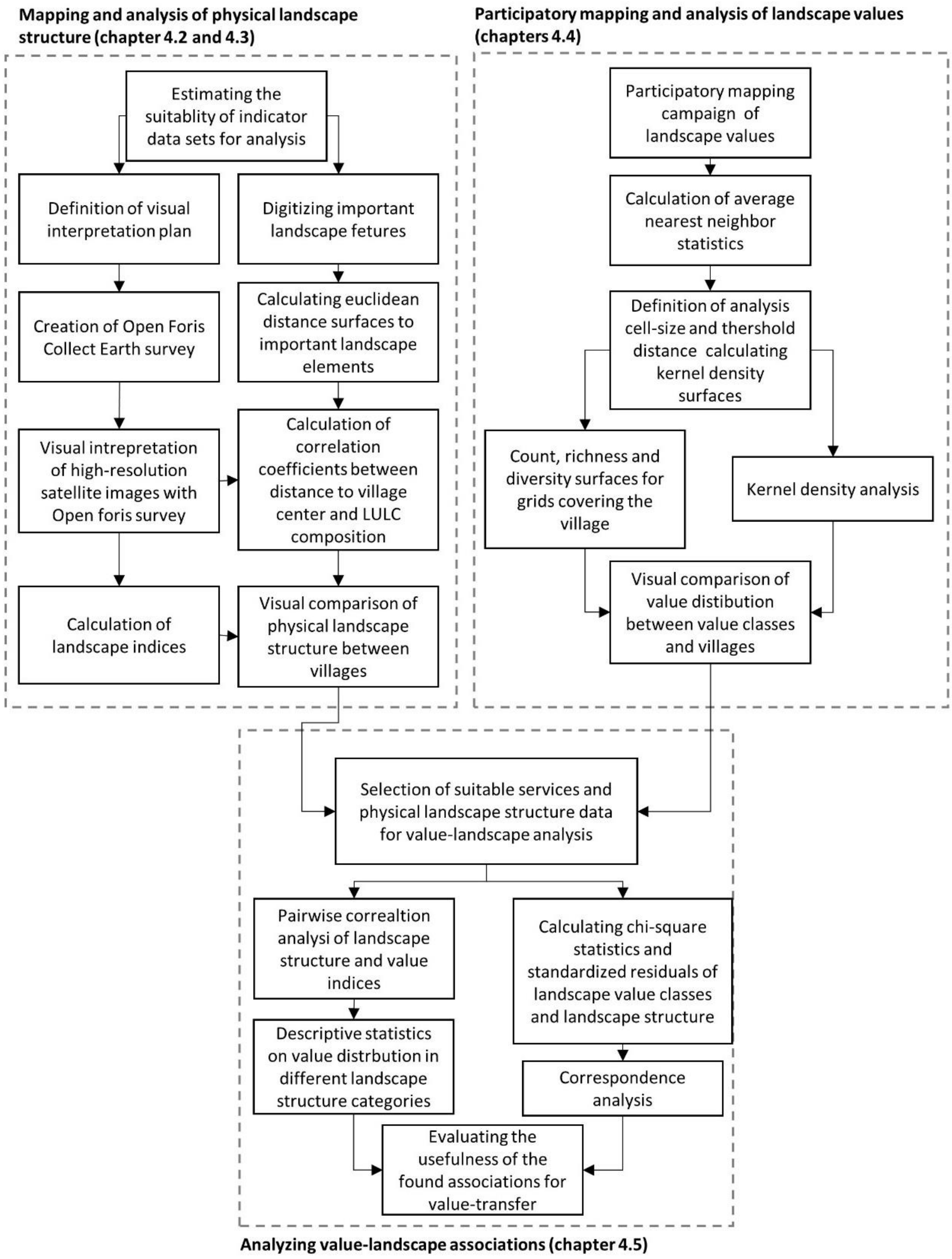


Figure 13. A flowchart of the research approach applied in this thesis to explore the value-landscape associations. The highlighted chapters describe the methods in more detail.

4.2 Materials

The data sources that I used in this thesis are described in In addition to the open data sets available online more specific data on the physical landscape structure was visually interpreted from satellite images to gain more accurate information to study the value-landscape associations. More information on the visual interpretation method can be found in chapter 4.3 and on the participatory mapping campaign in chapter 4.4

Table 3. In addition to the open data sets available online more specific data on the physical landscape structure was visually interpreted from satellite images to gain more accurate information to study the value-landscape associations. More information on the visual interpretation method can be found in chapter 4.3 and on the participatory mapping campaign in chapter 4.4

Table 3. Description of data that are used in the thesis

Data source	Description
Responses from participatory mapping campaign	313 participatory mapping surveys were conducted in the three study village between February and March 2016.
Digital globe WorldView and CNES/Astrium satellite images from Google Earth	High-resolution images with a spatial accuracy of approximately 50 centimeters. The images were used for visual interpretation and as a background map in the participatory mapping campaign.
Shuttle Radar Topography Missions (SRTM) digital elevation models (DEM)	Raster DEM with 30m resolution. The elevation and slope values and the topographic wetness index (TWI) were derived from the DEM.
Visually interpreted information on the physical landscape	Information on the physical landscape structure was collected in to grid with 500-meter cell size.

I estimated the suitability of the available data in all phases of the analyses to select the best available data for the selected approach. The selected data sets can be divided into two groups: distance data created from landscape elements and data that were visually interpreted from the satellite images (Table 4). The initial selection of data was influenced by previous studies that have spatially associated landscape values with physical landscape characteristics data. Also, the principles of landscape indices in landscape ecology were applied to select indices of landscape composition.

I divided the data sets as either suitable or unsuitable based on two criteria: The linear or point landscape elements, such as rivers, roads or solitary trees could not be used in the analyses, because either almost all or almost none of the cells in a village contained a certain landscape element making it an unsuitable indicator and because for some elements such as solitary trees and smaller roads or path it was too difficult to reliably identify the elements from the satellite image. The first problem was also faced when using distance variables to roads and streams/rivers. Because of the high topographical variability in Lulanzi and Iboya the elevation and slope were also not suitable to be used as selected cell-size for the analysis evened out the possible differences.

Table 4. Identified variables that could potentially be used for defining value-landscape associations. Variables that were selected for the value-landscape association analyses are indicated with green color. The rest could be used for the overall description of the physical landscape characteristics in the village.

	Select data sets	**Reasoning behind selected**
Character of landscape structure	**Land use and land cover (LULC) diversity and richness, patch richness** and landscape structure	The richness, diversity and patch variables were selected as they were expected to represent the heterogeneous structure of the village landscapes.
	Largest LULC, largest patch, **LULC characterization / classification, built environment classification**	LULC classes or characterizations have been commonly used by multiple studies (e.g. Brown et al. 2015). As noted by Fagerholm et al. (2012) the settlement areas are important for village landscape service provision.
	tree and scrub or grass coverage	Tree and scrub and grass coverage were thought to represent some of the core characteristics of the heterogeneous village landscapes.
Presence of important landscape elements	Paths or roads, rivers or streams, solitary trees or wood fences and tree plantations	Central landscape elements can be important indicators for values. For example Brown & Brabyn (2012) discovered that ski lifts can work as an indicator of cultural values and Van Riper & Kyle (2014) used distance to important management infrastructures in a national park. Therefore, this elements are likely to be context specific.
Distance to important landscape elements	**Euclidean distance to village center**, roads, streams/rivers and	Different studies have shown that the distance to important landscape elements can be an important indicator of service accessibility and intensity. For example distance to roads and water (Beverly et al. 2008), waterways and coastline (Sherrouse et al. 2014; Fagerholm et al. 2016) and distance to village to homes or village settlement (Fagerholm et al. 2012) have been identified and used as possible indicators.
Elevation and slope	Elevation and slope in the study area	Used as an indicator of landscape structure and landform by for example Sherrouse et al. 2011 and Sherrouse et al. 2014

For the LULC to present relevant information on the landscape structure a suitable classification needed to be defined (Table 5). The classification used in this thesis is a modification of the classification created in the National Forest Resources Monitoring and Assessment (NAFORMA) in Tanzania (MNRT 2015). I needed to modify the classification because it was not suitable for the local scale village context where the level of human influence in the landscape is extremely high and has created a highly heterogeneous structure. Also, identifying all the classes defined in NAFORMA would not have been visually possible from the satellite images. The objective of a LULC classification is to simplify reality into categorical groups by selecting and emphasizing issues that are central to the research in question. The selected classification is always subjective and is based on justified choices that will help the interpretation of the data in a way that it will help the set research objectives.

Table 5. Land use and land cover classification that is used in the study.

LULC classes	Definition
Natural forest	All natural dense forest land, including riverine forests
Planted forest	All planted forest areas. Includes all age plantations from young to mature
Scrubland	Dense natural and recovery after farming or tree planting scrubland
Semi-open woodland and/or scrubland	Natural scrubs/trees in semi-open environment, usually with grasslands and identifiable solitary trees and/or scrubs
Arable land/Farmland	Mosaics of cultivated and fallow land
Grasslands	Mosaics of natural grassland and fallow land
Homesteads	Mosaics of houses and homesteads, including surrounding grass, cultivated, fallow etc. areas
Built environment	Dense built or otherwise human-made land (e.g. parking areas or football grounds), including the surrounding grass, cultivated fallow etc. areas
Wetland	River and wetland areas that are not under cultivation
Other land	Any land use or land cover area that does not fit the other classes

To better describe the village landscapes the LULC information was used to create a simplified classification of the landscape character. This was necessary because of the very heterogeneous structure of the landscape consisting of multiple small patches of different LULC classes made the use of the LULC categories in themselves unsuitable. This was selected as the best practice to use the LULC data to create categories that describe important characteristics of the landscape and are as different from each other as possible. Principles for the characterization can be seen in Table 6

Table 6. Description of LULC classification used to simplify the information.

LULC classification	Description
Forest dominated	50% or over forest (natural forest, planted forest or semi-open woodland) coverage in a cell
Woodland dominated	50% or over semi-open woodland coverage in a cell
Arable land dominated	50% or over arable land coverage in a cell
Grassland dominated	50% or over grassland coverage in a cell
Built dominated	33% or over homestead or built environment coverage in a cell
Mixed mosaic	The coverage of any LULC is not 50 % or 33% for built categories or over

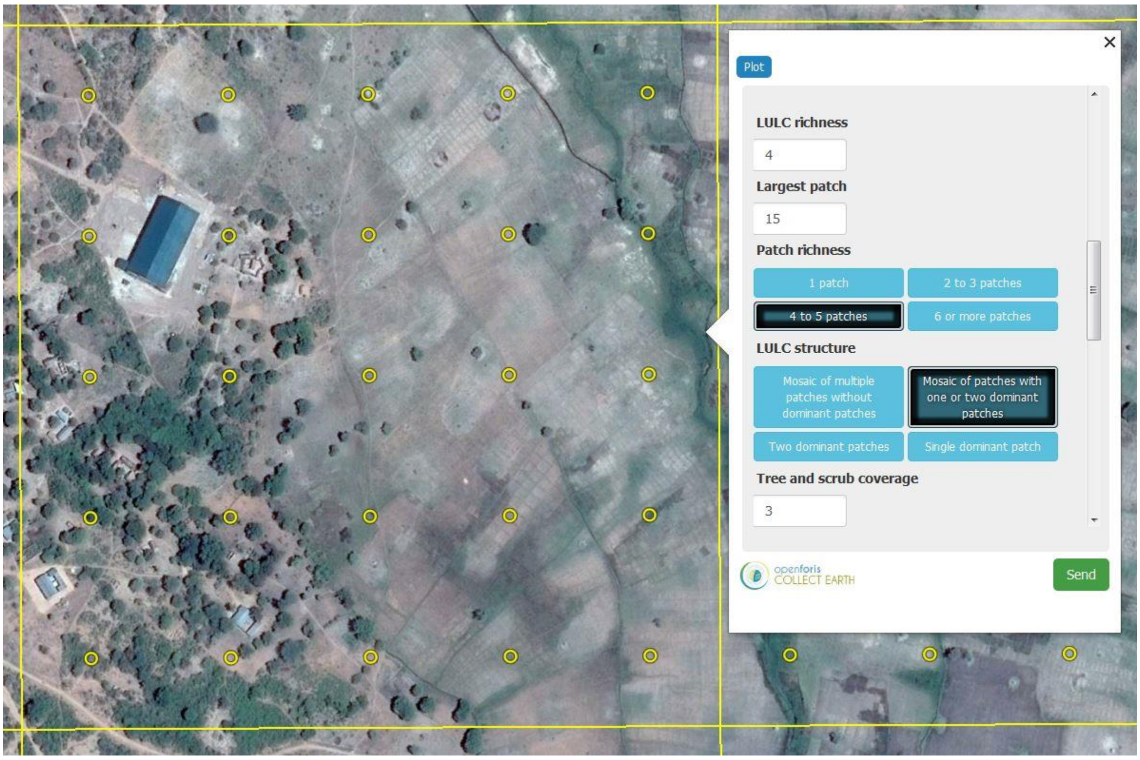
4.3 Mapping and analysis of physical landscape structure

First I defined the study area extent for the visual interpretation, which also functioned as the processing extent for physical landscape structure and association analyses. As there was no

suitable administrative border data available I used the mapped value points to define the best representation of service utilization area within the villages. Because it is very laborious to visually interpret satellite images I decided to collect information only on the value areas as the data outside of this area could not be used for the value-landscape analyses.

I defined the study area extent through the following process: I created a 500 times 500 meter grid that covered the value points. The 500 meters was selected for two reasons: (1) the size was suitable for studying the landscape scale properties (based on visual evaluation of the satellite images) and (2) using a smaller cell size would have led to a much larger number of cells which would have been practically too laborious to interpret. Next, I created a 500-meter buffer around each point to create an estimate of the area of the service utilization. Cells with 20% or less overlap with the buffered area were left out of the analysis. This resulted to 516 cells to be interpreted. Because of the different distribution of points the size of the grid is different in each village and the comparison some analysis results need to be interpreted with this restriction in mind. The study area is also different from the actual printed map that was used in the mapping campaign and I assume that the value points located at the very edge of the original mapping area entail an inherent spatial error.

In this thesis, I used visual image interpretation methods to collect useful information from unclassified satellite images. The fieldwork during the mapping campaign was important for the success of the interpretation as to achieve reliable results the interpreter must have knowledge on the geographical context image and on the object being interpreted (Campell 2008: 123). I did the interpretation with the Collect Earth tool, which is part of the Open Foris open-source software, created by the Forestry Department of the Food and Agriculture Organization (FAO) of the United Nations. Collect Earth can be used together with multiple different open satellite image sources (e.g. Google or Bing) to enable visual interpretation of high-resolution imagery. I created a customized data entry form that suited the purposes of this study and used it to collect data on the physical landscapes structure from open satellite data in Google Earth (Figure 14). The interpretation was done in each cell of the grid (wall-to-wall) covering 516 cells in the three villages. The high-resolution satellite images in Google Earth were from the years 2012 – 2014.



LULC richness: 4

Largest patch: 15

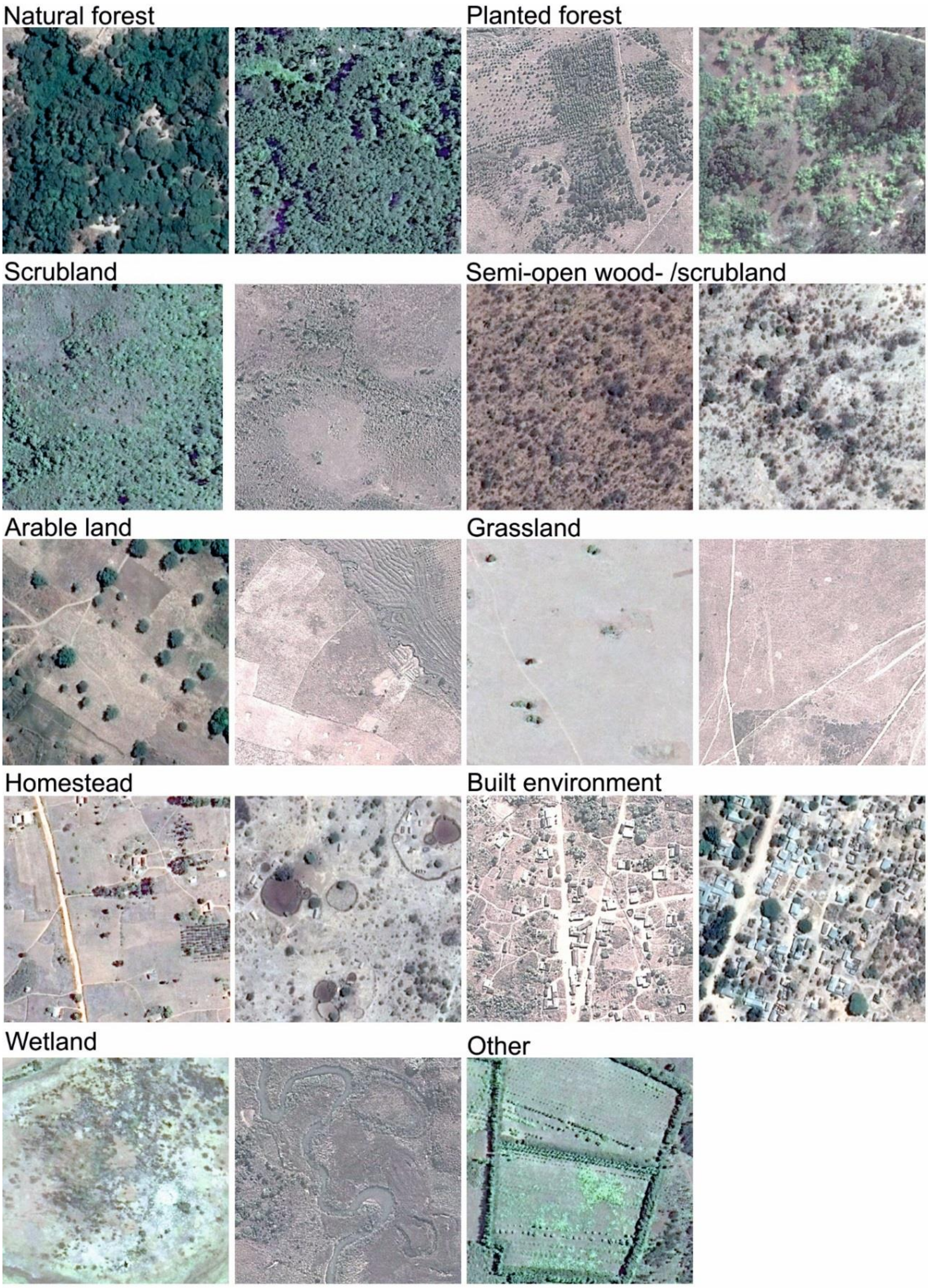
Patch richness: 1 patch · 2 to 3 patches · [✓ 4 to 5 patches] · 6 or more patches

LULC structure: Mosaic of multiple patches without dominant patches · [✓ Mosaic of patches with one or two dominant patches] · Two dominant patches · Single dominant patch

Tree and scrub coverage: 3

Figure 14. Filling in the questionnaire for a single cell in using the Collect Earth tool that runs in Google Earth. Satellite image © Google 2017.

There are two things that needed to be defined before starting the image interpretation (Lillesand et al. 2008: 204-205). First the classification system and the criteria that separates one LULC class from another. The process can be difficult as one must define at what scale and accuracy are the classes identified from each other and where to draw the line when the border between two classes is gradual (Campell 2008: 126). The possible errors caused by these challenges were minimized by defining a clear LULC classification and an interpretation plan before the process was started (Appendix 1 and Figure 15).



Natural forest

Planted forest

Scrubland

Semi-open wood- /scrubland

Arable land

Grassland

Homestead

Built environment

Wetland

Other

Figure 15. Example images of different LULC classes used to aid the interpretation work. Source: © Google 2017.

The second challenge is defining the minimum mapping unit or in other words the smallest objective that will be interpreted as an individual unit. The smaller the unit is the more precise the classification will be. To aid the mapping process I added a 25 point grid into the cells (Figure 16) and for practical reasons the minimum mapping unit was defined as one point (approximately 100 meters times 100 meters area).

Figure 16. Example of a 500 times 500 meters grid cell with the point grid that aids in the interpretation. The points were used to help define the coverage of each LULC class, define patch sizes (only horizontal or vertical connections between two points were seen as consisting of the same patch) and for defining the scrub/tree and grass coverage values. Satellite image © Google 2017.

After completing the survey, I exported the results from Collect Earth and joined them to the 500-meter grid using a common ID. I calculated landscape indices and descriptive statistics for each village and created map visualizations to compare the differences in the physical landscape structure. The indices were calculated separately for each cell and averaged for the whole village area. Landscape heterogeneity was described by calculating LULC richness (amount of different LULC in a cell (1 – 11)) and Shannon's H' diversity index values. More precise description of indices is presented in chapter 4.4.

I calculated the distance surfaces for three different landscape elements: village center, rivers and streams and main roads. The elements were digitized on top of the available high-resolution google maps images. Euclidean distance was used because it was impossible to identify all the different routes that villagers might use and because it is assumed that they will walk on these routes regardless of the slope or height differences. The distances were calculated by using the Euclidean distance tool with cell size of 100 meters to fit the cell division of the 500-meter grid and later averaged in to the 500-meter cells using the zonal statistics tool. To evaluate the possible connections of human actions with the physical landscape heterogeneity I calculated Spearman's rank correlation coefficients between distance to village center and LULC richness and diversity. See more information on the analysis method in chapter 4.5. It is important to note that the analysis only included cells with value coverage and because of this the analysis does not create a complete view on the physical landscape structure in relation to the village center but can work as a sufficient indicator for changes in the structure.

4.4 Mapping and analysis of landscape values

A more in-depth description of the participatory mapping campaign data is necessary because of the possible effects that the data collection might have on the analysis. The landscape value data was collected in a participatory mapping campaign in Iboya, Lulanzi and Tungamalenga villages between January and March 2016. The villages were selected to represent different biophysical conditions within the region. A sample that covered equally people of both sex and all age groups was collected.

The campaign was conducted in collaboration between researchers from the University of Turku Department of Geography and Geology, University of Dar-es-Salaam Department of Geography and partners from University of Iringa. The campaign is part of the Sustainability, scale relations and structure-function-benefit chains in the landscape systems of the Tanzanian Southern Highlands (SUSLAND) –research project funded by the Academy of Finland. As a part of the research team I participated in all the work phases described below, but my principal responsibilities were the production on the background maps, the planning and execution of the point digitizing method, entering the field data into a database and participating in the planning of the survey structure. All the surveys were done in Kiswahili to avoid any language barriers between the interviewer and the interviewee.

During the semi-structured surveys and mapping exercises the participants individually identified and mapped material (provisioning) and non-material (cultural) landscape benefits on a satellite image (scale 1: 7500) using different color wooden beads (approximately 10–20mm in diameter) (Figure 17). The extents of the maps were estimated to present the area of everyday activities of the stakeholders in a scale which makes it is easy for them to identify different elements. Careful attention was payed to the selection of the map used in the PGIS because it is critical to the success of the method (Brown 2005). The mapping accuracy in participatory mapping always needs to be scrutinized because it will partly define the potential for analyzing the data. The mapping process was partly guided by the interviewee to insure sufficient accuracy in the point location (Figure 18). The exact accuracy was difficult to define, because of the nature of the method of using beads. Beads create point locations, which indicate the presence of the value but the area of the landscape value can vary quite a lot from a single building to a whole forest patch.

Figure 17. During the participatory mapping campaign individuals identified landscape benefits that they receive from the environment with the help of wooden beads.

Figure 18. An example of a participants value map after identifying all of the different services. Different colors of wooden beads indicate different landscape values. Orange stickers identify important locations in the village used to help participants to navigate on the map. Satellite image © Google 2017.

As noted by Fagerholm et al. (2012) the value typologies defined in western contexts may lack some essential dimensions when applied in a completely different setting. This is why the mapping method and the landscape value typology were defined in collaboration with colleagues from the local universities with knowledge of the local context. The capacity of the participants to identify different values was also evaluated based on previous experience of working in Zanzibar, Tanzania (Fagerholm & Käyhkö 2009; Fagerholm et al. 2012). The selected typology of landscape values aims to capture both the material (provisioning) and immaterial (cultural) benefits gained from the landscape (Table 7).

Table 7. Landscape value typology used in the mapping campaign.

Value class	Value description
Provisioning values	
Cultivation	Areas for all different types of cultivation including home gardens
Livestock	Areas where livestock is kept and grazed
Beekeeping	Areas where traditional or modern beehives are used
Tree planting	Areas where trees are planted, including plantation, fences and other types of tree planting
Wild food	Areas where wild food is collected
Wild animals	Areas where wild animals are hunted
Water	Areas were water is collected
Firewood and charcoal	Areas for firewood collection and charcoal making
Building material	Areas where material for building is collected
Handicrafts and traditional medicine	Areas where material for handicrafts and ingredients for traditional medicine are collected
Cultural values	
Social	Areas where social activities are performed
Religious	Areas where religious activities are performed
Local culture	Areas that are important for local cultural reasons
Aesthetic	Areas that the participants feels are aesthetic

I used the point data collected in the mapping campaign to map landscape value distribution in the village landscapes. For these analyses, it was important to note the inherent properties of a point based participatory mapping data of landscape values to avoid possible false interpretations. As noted by Brown (2005) the landscape area associated with each point cannot be defined precisely. The assumption is that each point indicates an area, which shape and size is undetermined. I tackled this issues by creating spatial aggregations of the data to define areas of value intensity, richness and diversity. The definition of cell sizes and thresholds for different analyses are crucial for creating realistic aggregations that take into consideration the nature of the data.

First I analyzed the spatial dispersion or clustering of value points by calculating average nearest neighbor statistics. The analysis measures the Euclidean distance from each point to its nearest neighboring points (ArcGIS online, visited 5.6.2017). These values are then summed and the summed distance is compared to a theoretical random distribution of the points within the defined study area. If the distribution of the value points is clustered the analysis results in a ratio smaller than 1 with the significant Z score, indicating the amount of standard deviations that the mean is from the ratio value is (Fagerholm et al. 2012). This analysis is sensitive to the defined study area and assumes that the points are free to locate anywhere within the study area. A straightforward comparison of these values between study villages is not advised because of the different study area sizes.

Following Bryan et al. (2010), I calculated spatial indices for landscape values to identify areas of high value intensity and co-existence. I calculated count, richness and Shannon diversity values to 200 and 500-meter cell-size grids covering the study area. I defined the 200-meter cell-size as the estimated mapping accuracy. With the hardcopy map scale of 1:7500 and with the bead sizes ranging from 10–20 millimeters each bead covered an approximately 75–150 meters wide circular area. I then estimated the cell-size to be 200 meters, because although during the survey the mapping was guided by the interviewee it is unlikely that locations are as precise as the bead sizes indicate. I used the 500-meter cell-size to match the physical landscape data at the landscape scale. To calculate the indices, I spatially joined the value points to the grids.

Count indicates the total amount of all value points and richness the amount of different value classes (possible range from 1 to 14) in each cell. I calculated the Shannon's H' diversity index to estimate value diversity (Shannon & Weaver 1949). The index can estimate both the diversity and evenness of values in an area unit (Brown 2013) and it has often been used to describe the diversity of landscape values (e.g. Fagerholm & Käyhkö 2009, Fagerholm et al. 2012, Bryan et al. 2010). To further evaluate the spatial distribution of the values, I created density surfaces from the collected point data by using a quadratic kernel density function (based on Silverman 1986). The function calculates a circular curved point density surface around each point location and then sums them into a raster cell. This method has been widely applied in landscape value studies when estimating value distribution (e.g. Alessa et al. 2008; Brown & Reed 2011; Fagerholm et al. 2012; Sherrouse et al. 2011). I calculated the density surfaces for each value class and for the provisioning and cultural value categories.

The selection of the distance threshold for the kernel density analysis is critical to success of the method. There is no agreed way of defining it but quite often mapping accuracy and scale and the possible mapping error have been used to guide the selection. For example Sherrouse et al. (2011) set the cell-size to 450m to match the original mapping scales of 1:400 000 and 1:500 000. They then selected threshold distance as 10 times the cell-size (5000 meters). Alessa et al. (2008) used similar values in their study and argued that the 5000m threshold seemed to define a natural break between clusters. Brown & Pullar (2012) used a more heuristic approach based on mapping accuracy, mapping scale and an estimation of distances where points were expected to cluster. They created a range of different surfaces and selected the most suitable one based on visual evaluation. It is therefore clear that there is always a level of subjective decision-making related to selection of the cell-size and threshold.

For the selection of the distance threshold I applied a mixed definition approach that could be best compared to the one used by Brown & Pullar (2012). First I used the Incremental Spatial Autocorrelation (ISA) tool to evaluate the threshold distance where spatial clustering for each value reaches its first and maximum peak. The tool calculates spatial autocorrelation (Global Moran's I) for a set of increasing distances (ArcGIS Online Help 10.3, visited 5.6.2017). I used the first peak as the indicator as it better reflects the scale of this analysis. To calculate the ISA I needed to include a weight column in the point datasets. To gain a weight value I created a 200-meter buffer, based on the mapping scale and accuracy, around each point and calculated the amount of points of the same value class within in that distance. I selected this approach because it was able to take into consideration the element of spatial inaccuracy in the point data and therefore made the ISA results more reliable.

Next, based on visual evaluation of the value locations I visually evaluated a suitable threshold distance based on the likely mapping accuracy for each landscape value, the estimated size of the value area and the likelihood for the landscape value to exist within the threshold (Table 8). I did this evaluation by opening the point data on top of the satellite image and visually evaluating the issues above with the aid of qualitative information on the value type and characteristics (e.g. agricultural or firewood collection practices within the area).

Based on the ISA results and the visual evaluation I calculated two to three different kernel density surfaces for each landscape value and visually evaluated them to select the most suitable one. For comparison reasons, it was necessary that the selected threshold would be the same for all villages. I then made compromise based on the estimated suitable distances in the three villages, to define the final threshold distances (Table 8). For the provisioning and cultural value categories I defined the threshold as 400 meters and 300 meters as it represented the average threshold distance inside the value category. For the association analyses a kernel density layer with all the value points was calculated using a cell-size of 100 meters and distance threshold of 400 meters. The mean values from this layer was calculated into the 500-meter grid.

Table 8. The average values for the Incremental Spatial Autocorrelation (ISA) analyses and the visual evaluation. The ISA analyses was run with 100 meter intervals starting from 200 meters with 20 iterations (row standardization was not used). First peak indicate distance where spatial clustering (Global Moran's I) reached its first peak. Own evaluation indicates the distance threshold that I identified visually. Based on the first peak and my own evaluation a range of thresholds was identified for visual evaluation. The selected distances are based on this evaluation. All distances are in meters

	First peak	Own evaluation	Thresholds for visual evaluation	Selected distance
Provisioning values				
Agriculture	567	500	400 – 600	**500**
Livestock	500	467	300 – 400	**400**
Beekeeping	NA	400	400 – 500	**500**
Tree planting	333	333	300 – 500	**400**
Wild food	367	467	400 – 600	**500**
Wild animals	NA	450	400 – 600	**500**
Water	200	300	200 – 300	**300**
Firewood and charcoal	367	433	300 – 500	**400**
Building material	367	400	400 – 600	**400**
Handicrafts and traditional medicine	433	500	400 – 600	**500**
Cultural values				
Social	200	300	200 – 300	**300**
Religious	733	333	200 – 300	**300**
Local culture	NA	400	300 – 400	**400**
Aesthetic	433	433	400 – 500	**400**

4.5 Analyzing value-landscape associations

The analysis of value-landscape associations was divided into two sets of analyses. The analysis associations between spatial value indices (SVI) and the physical landscape structure is described first. After this the focus is turned to the analysis of associations between values classes and the physical landscape structure. To study the value-landscape associations for SVI I calculated value count, richness, diversity and kernel density values in the 500-meter grid. It is important to remember that these layers do not identify which values are located where and therefore cannot be used to identify landscape associations with value bundles.

I selected continuous and categorical data sets that describe the landscape structure for the analysis. LULC diversity, LULC richness and distance to village center were selected from continuous and patch richness, LULC classification and built classification from the categorical variables. To analyze the associations between SPI and the continuous data sets I calculated correlation coefficients. Because of the non-normality of landscape value distributions, I used

Spearman's rank correlation (Tomscha & Gergel 2016). For the comparison of the categorical landscape datasets I calculated descriptive statistics (mean and standard deviation) in the grid cells.

From the fourteen value classes I selected seven for value-landscape associations analysis for values classes (Table 9). I did the selection based on two criteria: (1) values with low amount of points were not selected and (2) second, based on the preliminary analysis of the value distribution, values that are highly clustered into a certain location were ruled out (e.g. religious values associate with churches). There is also a third possible source of error: some values classes included services that could have been categorized differently. For example, in the building material category there are indicators for clay collection and wood poles. I decided that these values would be included in the analysis, but that this issue would be noted when analyzing the results.

To quantify the value-landscape associations for the selected data classes I calculated cross-tabulations, chi-square statistics and standardized residuals and correspondence analyses. Similar analyses have been applied in other studies focused on the value-landscape associations (e.g. Brown & Brabyn 2012a; Fagerholm et al. 2013; Brown et al. 2015; Hausner et al. 2015). I selected categorical data set describing the landscape structure for the analysis. The data sets needed to fulfill two requirements: (1) the values within a category should be as similar as possible and (2) all categories should be as dissimilar with each other as possible. For example, tree or grass coverage is unsuitable for the analysis because it is difficult to define categories that would fulfill these requirements. Based on these requirements and the results from the landscape structure analyses I selected LULC classification and built classification for the analysis. To calculate the statistics the I spatially overlaid the landscape structure data with the value point data.

I calculated cross tabulations, chi-square statistics and standardized residuals to determine whether the amount of points differentiated significantly from the expected amount in each physical landscape character category. I calculated the chi-square test for independence to determine whether there are significant associations between the selected values and the physical landscape structure. The standardized residuals are calculated by subtracting the expected amount of values in each landscape structure category from the observed amount of values and then dividing it by the standard error of the residual (Brown & Brabyn 2012a; Hausner et al. 2015). The standardized residuals indicate how many standard deviations above or below the expected amount the observed amount is. I calculated the proportional coverage of each landscape structure category to aid the interpretation of the results.

Table 9. Description of the selection principles of landscape values for value-landscape analysis.

	Tungamalenga Amount of points	**Iboya** Amount of points	**Lulanzi** Amount of points	**Included / Not Included**
Provisioning values				
Agriculture	306	164	273	Included: It is important to note that there are a significant amount of points indicating gardens that are located at homes
Livestock	123	69	149	**Not included:** majority of the points indicate animals that are kept at participant homes
Beekeeping	29	28	26	**Not Included:** amount of points is too low
Tree planting	29	110	141	**Not Included:** Tree planting is not a common practice in Tungamalenga
Wild food	182	132	141	Included
Wild animals	NA	29	15	**Not Included:** amount of points is too low and data is not available in Tungamalenga
Water	338	109	141	Included: the points are mostly located at water sources near the village (e.g. rivers, wells)
Firewood and charcoal	214	121	181	Included
Building material	322	135	154	Included: It is important to note that there are a significant amount of points indicating clay collection, which is done at homes
Handicrafts and traditional medicine	152	75	85	Included: The amount of points is not high and the category includes a very large variety of different things being collected.
Cultural values				
Social	493	322	511	**Not included:** majority of the points indicate buildings or places within settlement areas
Religious	161	130	100	**Not included:** majority of the points indicate religious buildings
Local culture	25	9	20	**Not Included:** amount of points too low
Aesthetic	191	76	106	Included

I calculated the correspondence analysis on the select data sets to visually plot the value-landscape associations and the possible association between values or physical landscape structure categories. The correspondence analysis calculates row and column scores between nominal variables and creates normalized plots based on these scores (Hausner et al. 2015). In the plot the distance between different value classes/structure categories represents the strength of the associations. Classes/categories that are plotted close to each other are more associated than categories that farther away from each other.

5. Results

5.1 Character of physical landscape structure

The result from the visual interpretation survey done in Open Foris Collect Earth describe the village landscape structure with relatively high accuracy. The visual interpretation work covered 217 cells of 500 times 500 meters in Iboya (I), 140 in Lulanzi (L) and 159 in Tungamalenga (T). Out of these cells 71,4 % in Iboya, 78,6 % in Lulanzi and Tungamalenga had value points located in them.

The results show distinctive physical landscape differences between the three study villages (Figure 19 and Figure 20). In Iboya the LULC classes with largest coverages are grassland (45,4%), planted forest (26,5%) and arable land (13,4%) (Figure 19). In Lulanzi grassland (25,8%), arable land (25,2%), planted forest (20,4%) and scrubland (14%) were the largest categories and in Tungamlenga semi-open woodland (44,9%) and arable land (25,2%). Built environment and homestead covered a relatively small part of the cells: 1,8% and 1,9% in Iboya, 4,7% and 4,8% in Lulanzi and 4,1% and 2,8% in Tungamalenga. But in cells where they were present the coverage was much higher: between 8,6% and 16,9% for homestead 27,1% and 59,6% for built environment. Natural forest, wetland and other classes were rare in all the villages.

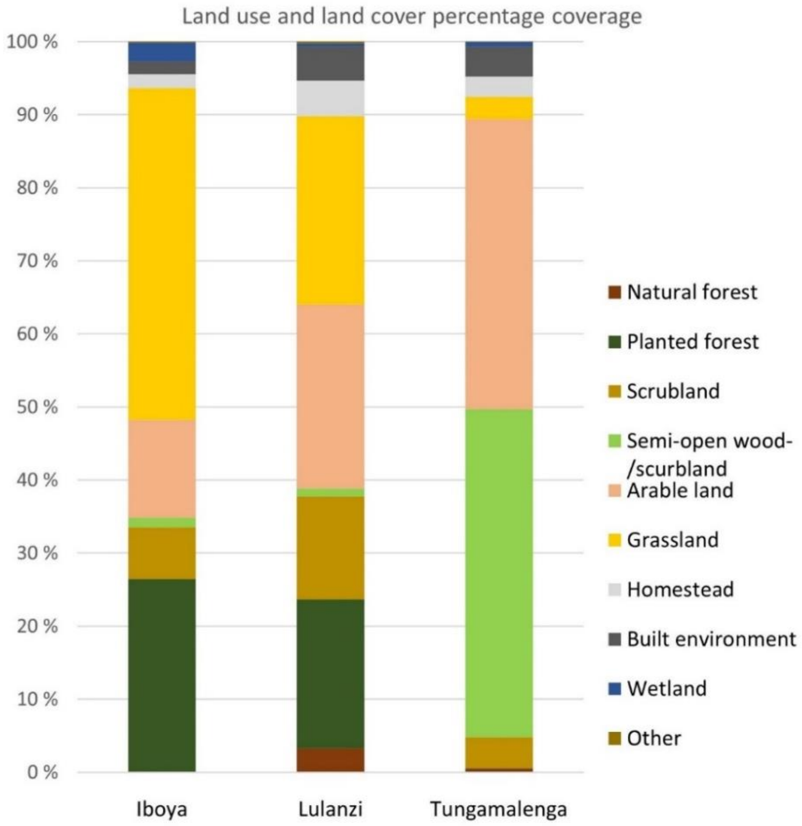


Figure 19. Proportional coverage of land use and land cover in the study villages.

The central properties of the three most common LULC in the village landscape: arable land, tree (including all tree covered LULCs) and grassland show different patterns of intensity in the villages (Figure 20). Cultivation is commonly practiced in the proximity of the settlement centers in all the villages with larger cultivation areas located around the village landscape. Outside the settlement areas arable land is scattered in the landscape in Lulanzi and Iboya and in Tungamalenga the wet plain and riverside areas have very high arable land coverage mostly caused by the reliance on irrigation.

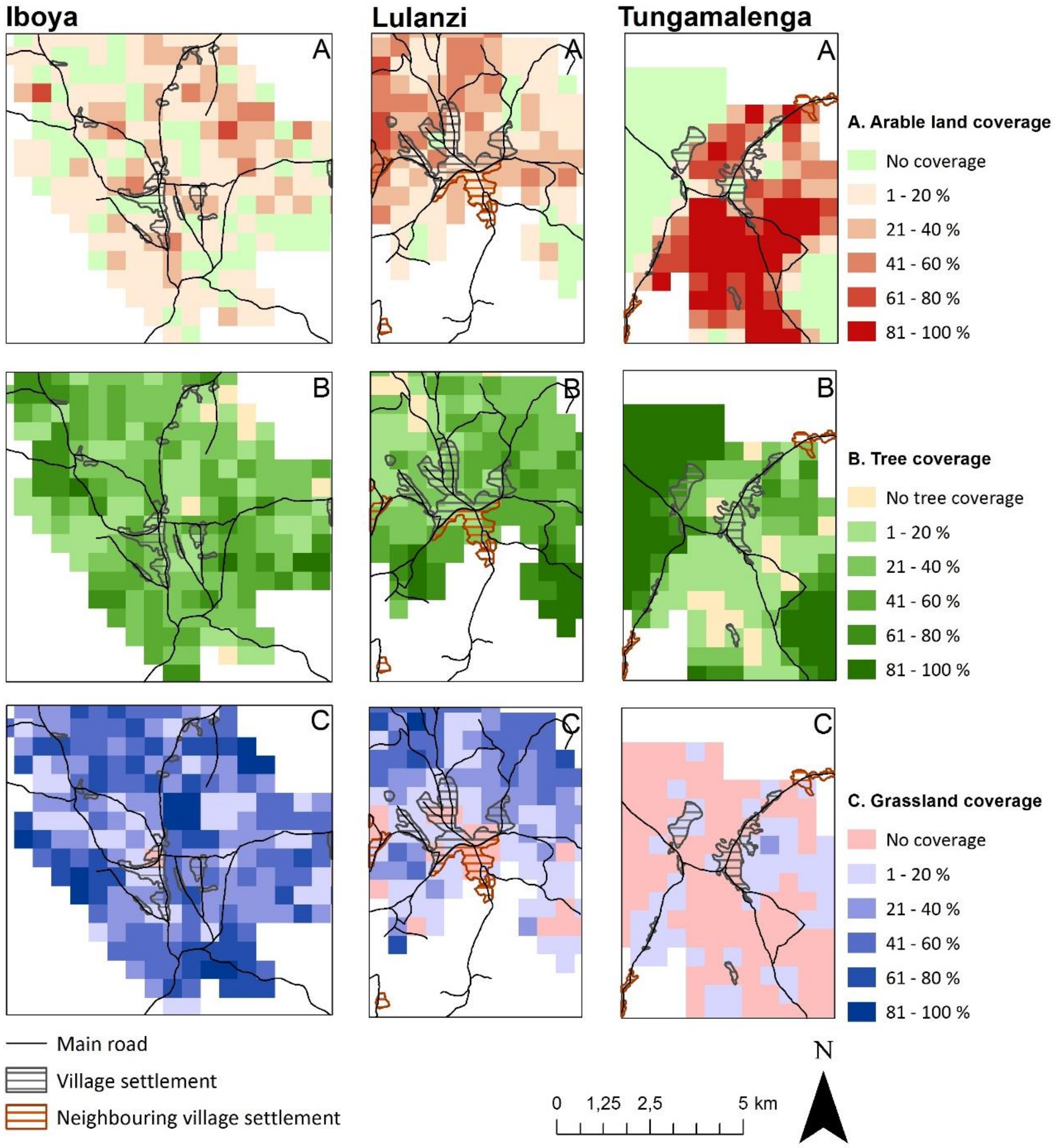


Figure 20. Examples of the mapped physical landscape properties in the study villages in the 500-meter cells. Arable land (A), tree (B) and grassland (C) coverage are the most common elements in the village landscapes. Tree coverage includes all tree coverage also when it is outside of the LULC classes natural forest, planted forest and semi-open woodland.

Similar trends can also be interpreted from the tree coverage map, where the semi-open woodland areas in Tungamalenga can be clearly noticed. Tree planting is practiced almost everywhere in the landscape in Iboya and Lulanzi creating smooth surfaces with relatively small variability. Only the larger village and municipal tree plantation can be clearly identified as areas of high tree coverage. As indicated by the proportional LULC results, grassland is only common in Iboya where it creates large uniform areas that are characteristic for the area. In the other villages that grassland areas are either the result of mixed use (Tungamalenga) or are used for grazing and are further away from the village center (Lulanzi) and cover small portions of the landscpe.

From the LULC classification (Figure 21) we see that s simplified classification can describe the structure of the village landscape in Tungamalenga as it is homogenous and is mostly dominated by clearly identifiable woodland, settlement and cultivation areas with a group of mixed areas where these different LULC meet. In Iboya and Lulanzi the classification also makes the interpretation of the more heterogeneous landscape more feasible as it can identify patches of forest, grassland and arable land dominated from the mosaic of mixed LULCs. The proportional coverage values of the LULC classification can be seen in Table 15 in chapter 5.3.2.

Overall the LULC coverage, central landscape property coverage and LULC classification coverage highlight the more homogenous structure of Tungamalenga compared to the other two villages. Similar interpretation can be done from the descriptive statistics on the physical landscape character (Table 10). Average LULC richness and LULC diversity are lower in Tungamalenga (2,5 and 0,54) than in Iboya (3,7 and 1,04) and Lulanzi (3,9 and 1,14). The difference is especially evident in the diversity values. The patch richness and average largest patch statistics also show similar trends. The differences between Iboya and Lulanzi are relatively small with structure of Lulanzi being a bit more heterogeneous. The proportional coverage of built environment (dense built and homestead) is quite similar in all the villages, when considering that the study area in Iboya is larger than in the other villages and that in Tungamalenga and Lulanzi the neighboring village centers are close-by which raises the amount of built environment in the area.

Table 10. Descriptive statistics of the physical landscape structure the study villages. LULC richness indicates the amount of different LULC categories in a cell on average (possible values between 1 – 10) and the LULC diversity presents the average Shannon’s H’ diversity index in the cell.

	Iboya	Lulanzi	Tungamalenga
Average LULC richness	3,7	3,9	2,5
Average LULC diversity	1,04	1,14	0,54
Average largest patch (% of cell size)	50,5	43,4	79,7
Patch richness (%)			
1 patch	0	0,7	33,3
2 to 3 patches	10,6	7,9	27,0
4 to 5 patches	32,3	18,6	20,1
6 or more patches	57,1	72,9	19,5
Built environment (%)			
Unbuilt environment	69,6	51,4	53,5
Homesteads	24,0	40,7	36,5
Dense built environment	6,5	7,9	10,1

The LULC richness and diversity results present a similar overview of the landscape structure in the three villages (Figure 21). High richness values are mostly present at the borders of the main settlement areas and in the homestead areas in all villages. Some exceptions can be found in areas where streams or rivers run in glens and form mixed LULC coverage consisting of cultivation, wetland, grassland, planted forest and scrubland. In Iboya and Tungamalenga areas of high and low richness are easy to identify but in Lulanzi there is less variability in richness values across the landscape.

The diversity results show more capacity for capturing the subtle changes in landscape structure compared to the richness results, although overall very similar general trends are identified. Diversity results bring more focus to areas where land use practices have created a mixed LULC mosaic with an even division of coverage within a cell. An example of this is the western border of the study area in Tungamalenga where tree-cutting has been practiced and now there is a mixture of cultivation, woodland, scrubland and grassland. An interesting exception to the rest of the areas is the north-west area of Iboya where richness is low compared to diversity indicating that the landscape is fragmented but mostly consisting of a mosaic of arable land, grassland and planted forest. Compared to the richness results the diversity shows even higher contrast between the high and low areas in Tungamalenga. But for Iboya there is less contrast, with the lowest values being associated only with the grassland areas. For Lulanzi the overall picture presented by the two indices is very similar.

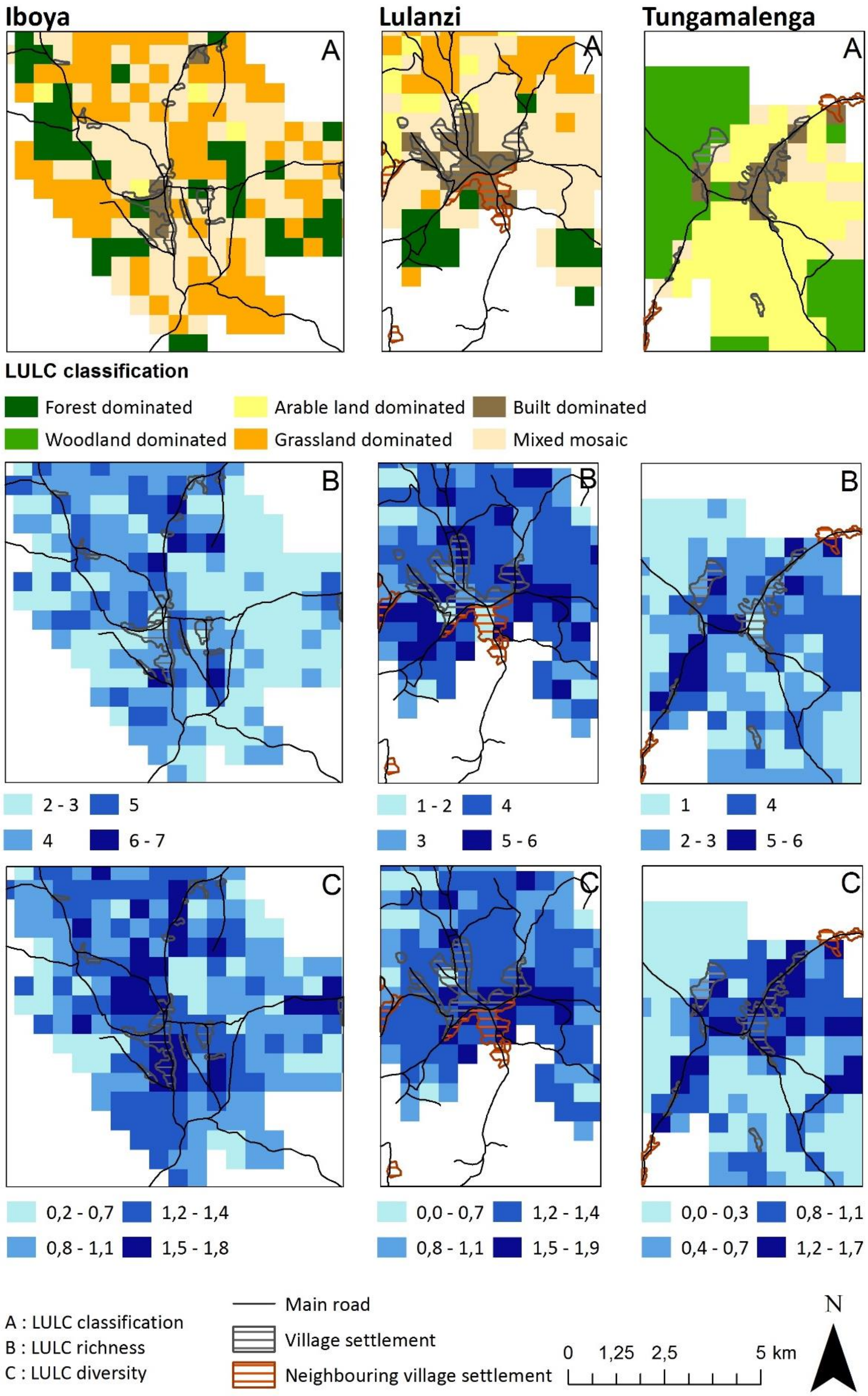


Figure 21. Description of the physical landscape structure in the study villages in the 500-meter cells. The LULC classification (A) present a simplified overview of the LULC coverage in the villages. Richness (B) the amount of different LULC in each cell (possible values 1 – 10) and diversity (C) is the diversity of LULC in the cell as a Shannon's H' diversity index value. Richness and diversity are visualized using Jenks natural breaks.

The Spearman's correlation coefficient analysis indicates that there are negative spatial associations between the physical landscape structure diversity and richness and the distance to village centers (Table 11). Correlation coefficients close to +/- 0,3 were also considered to be indicators of weak associations. On average the associations with diversity are higher. The highest associations are found in Lulanzi where both associations can be considered at least weak. In Tungamalenga there is a weak association between the distance and LULC diversity. In Iboya the association are on average lower than in the other villages.

Table 11. Spearman's correlation coefficients of the associations between village LULC structure richness and diversity and the distance to village center. The coefficients were calculated using information in the 500-meter cells. Correlation coefficients between -/+0,3 - -/+0,5 indicate a weak correlation and values above +/- 0,5 indicate a strong correlation.

		Village distance		
		Iboya	**Lulanzi**	**Tungamalenga**
LULC diversity	Correlation Coefficient	-,249**	-,517**	-,348**
	Sig. (2-tailed)	0.000	0.000	0.000
LULC richness	Correlation Coefficient	-0.125	-,298**	-,266**
	Sig. (2-tailed)	0.066	0.000	0.001

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

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

5.2 Distribution of landscape values in the villages

This chapter presents maps and spatial statistics of distribution (including intensity, richness and diversity) of landscape values, that are based on the aggregation of the landscape value points. In all the following results the presence of the neighboring villages and the historical development of the villages can be clearly seen (Figure 22). In Lulanzi the points are concentrated on the northern side of the road dividing the study area. This supposedly because the road also divides the settlement area into two villages with different administrations. In Tungamalenga the concentration of points in the north-west and south-east directions is dictated by the neighboring villages in the north-east and south-west. Iboya is located further away from any neighboring village and therefore no clearly visible patterns are noticeable. The homestead area in the north is also a high value intensity outside of main settlement area. In all three villages the respondents are mostly from the main settlement area with a few exceptions being from the homestead areas in the north of Iboya.

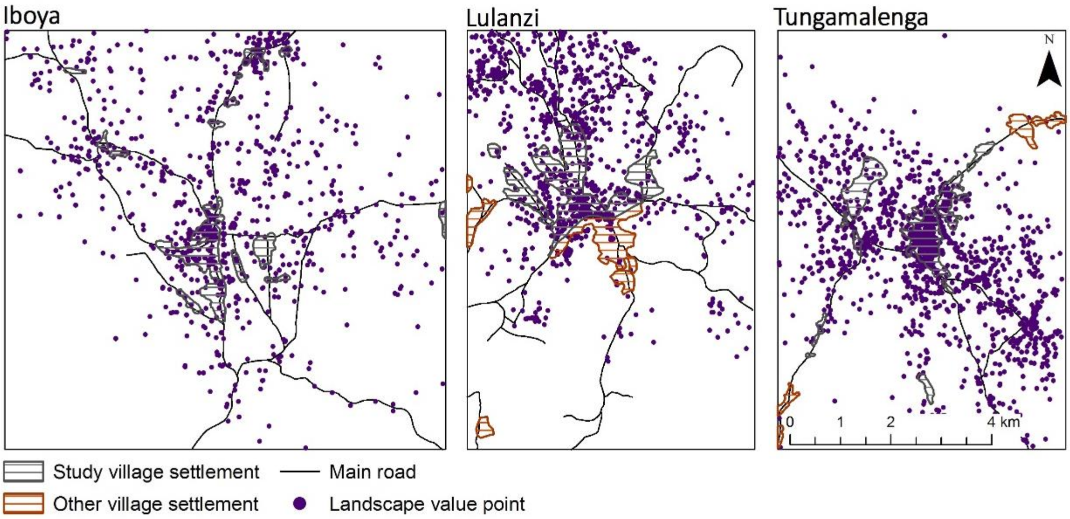


Figure 22. Mapped landscape value points in the three study villages. In Iboya 79 participants mapped 1509 points, in Lulanzi 95 participants mapped 2043 points and in Tungamalenga 139 participants mapped 2565 points.

The average nearest neighbor (NN) analysis results indicate that most values are spatially clustered in all three villages (Table 12). Overall the patterns of spatial clustering in the three villages are similar. The slightly lower clustering values in Iboya can be explained by the larger study area. On average the cultural values are more clustered than the provisioning values. The most clustered values in all villages are social (I=28,19; L=-36,76 and T=-35,17) followed by religious (I=14,62; L=-15,81 and T=-19,64) and water (I=12,52; L=-15,66 and T=-25,16). These are values that are strongly connected to certain landscape elements in or near the settlement areas such as social halls, graveyards, churches, streams and wells. From all the values the lowest values can be identified in the values with lowest amount of mapped points. From the values with more than a 30 points handicrafts and traditional medicine shows the least tendency to cluster (I=0,75; L=-1,06 and T=-6,46).

Compared to the other cultural values with higher amount of points aesthetic values show relatively low NN values (I=-5,47; L=-8,87 and T=-12,61) although they are strongly likely associated with certain small scale landscape elements (such as rapids, lakes or beautiful buildings) (Table 12 and Figure 23). For example, in Iboya special natural elements such as the river and a large stone in the south of the village, in Lulanzi the natural forest and the Kilambo lake high and in Tungamalenga the river and socially important locations were intensively mapped. The relatively high NN values for cultivation (I=7,58; L=-6,29 and T=-12,31) are also relatively surprising as it could be expected that each village would have their own arable land patch (Table 12 and Figure 23). In, practice cultivation is most intensively practiced in small scale in the village centers and in wider scales in specific cultivation areas and these two areas can be spatially separated from each other. In Tungamalenga the cultivation is concentrated on the wet plain and the surrounding flat areas, which is also highlighted by the NN results. In Iboya and Lulanzi the cultivation areas outside the village center are more evenly spread into the landscape.

Overall Tungamalenga shows stronger spatial clustering of central provisioning values (especially firewood and charcoal) that are collected from the forested area compared to the other villages (Figure 23). In Tungamalenga the most easily accessible borders of the woodland areas are the most intensely mapped for firewood collection. In Iboya the practice is most scattered in the landscape with small tree plantations near the settlement and larger plantations farther being mapped with higher intensity. In Lulanzi the village plantations are identified as the main sources of firewood. The other provisioning values that are mostly collected in forested areas (wild food, wooden poles for building material and some of the handicrafts and traditional medicine species) show similar spatial patterns.

Table 12. Observed mean distance in meters, nearest neighbor (NN) ratio and Z score results of the average nearest neighbor analysis results. NN ratio values lower than 1 indicates clustering of the value points.

	Iboya			**Lulanzi**			**Tungamalenga**		
	Observed mean dist.	NN ratio	Z score	Observed mean dist.	NN ratio	Z score	Observed mean dist.	NN ratio	Z score
Provsioning values									
Cultivation	203	0,69	-7,58	135	0,80	-6,29	117	0,63	-12,31
Livestock	221	0,49	-8,15	120	0,53	-11,02	164	0,56	-9,36
Beekeeping	659	0,92	-0,76	436	0,80	-1,97	457	0,76	-2,49
Tree planting	356	0,99	-0,21	178	0,76	-5,43	277	0,46	-5,57
Wild food	282	0,86	-3,12	165	0,71	-6,69	184	0,76	-6,10
Wild animals	735	1,05	0,51	525	0,73	-1,99	NA	NA	NA
Water	135	0,37	-12,52	73	0,31	-15,66	45	0,26	-26,16
Firewood & charcoal	267	0,78	-4,63	144	0,70	-7,81	130	0,59	-11,54
Building material	203	0,63	-8,30	165	0,73	-6,30	117	0,65	-12,12
Handicrafts & traditional medicine	416	0,95	-0,75	284	0,94	-1,06	191	0,73	-6,46
Cultural values									
Social	38	0,18	-28,19	18	0,15	-36,76	25	0,17	-35,18
Religious	109	0,33	-14,62	48	0,17	-15,81	49	0,19	-19,64
Local culture	857	0,68	-1,83	198	0,32	-5,84	467	0,72	-2,69
Aesthetic	291	0,67	-5,47	149	0,55	-8,87	123	0,52	-12,61

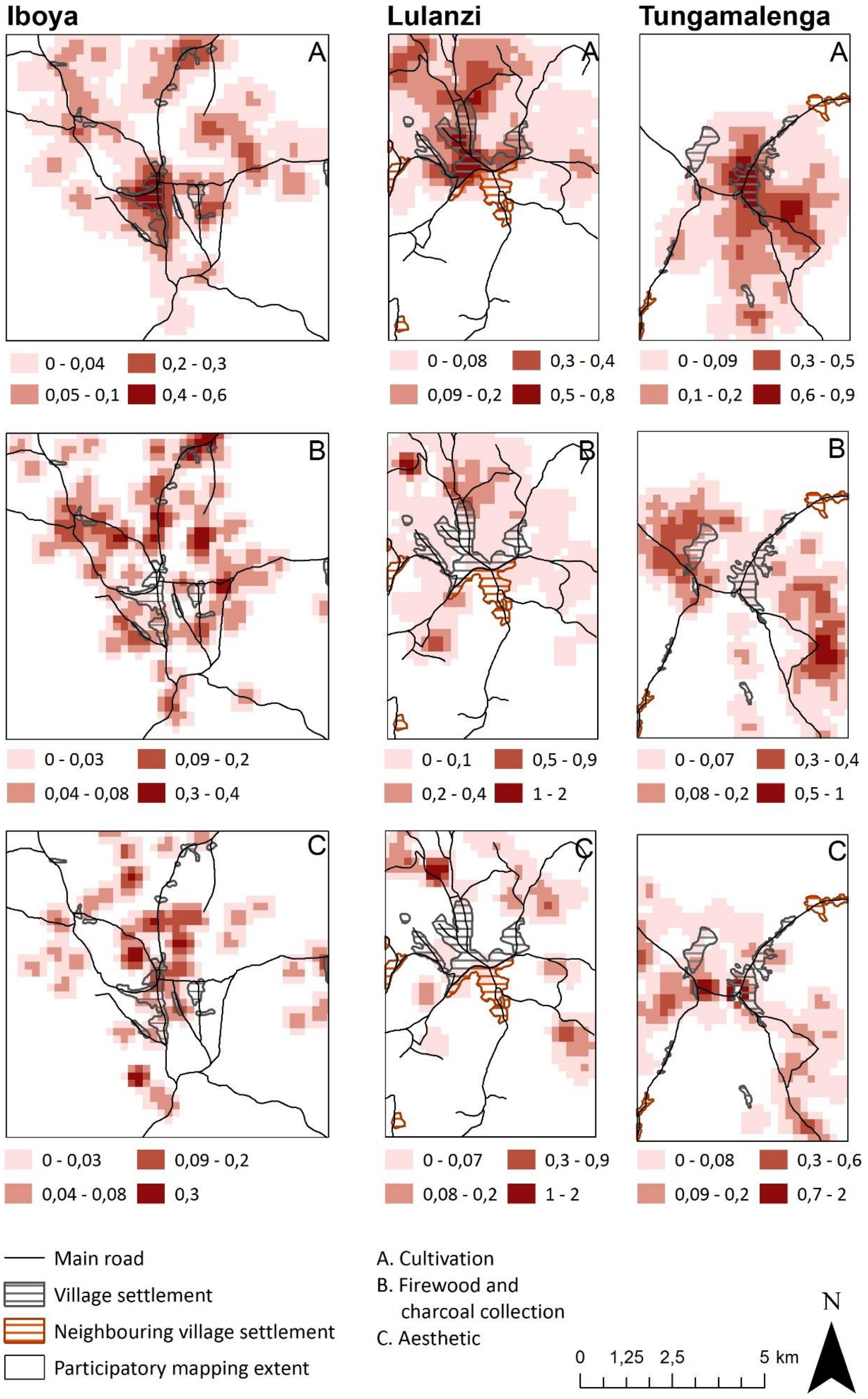


Figure 23. Kernel density surfaces of cultivation (A), firewood and charcoal collection and making (B) and aesthetic (C) landscape values visualized using Jenks natural breaks. Cell-size is 200 meters and the values indicate the amount of points per hectare.

For the landscape value count, richness and diversity in all the three village show similar trends and equally high and low values (Figure 24). Difference arise when identifying landscape elements and areas that are important for landscape value distribution in each village. The accessibility of areas through the main roads can be seen to affect value count, richness and diversity as highest values are often relatively near to roads and in directions of the main roads from the village settlement center. The highest value counts can be found from the main settlement areas of each village. Outside of the settlement areas higher values are at smaller settlement areas, some important forested areas and point like features that have been frequently mapped such as graveyards or important buildings and specific aesthetic locations.

Compared to count both value richness and diversity values are more spread out in the landscape. Main and secondary settlement areas are still the most clearly identifiable as areas of high richness and diversity, but other elements such as important forested areas and mixed use areas with cultivation, small plantations and grazing receive high values. For example in Tungamalenga the borders of the woodland areas in north-east and south-west and the mixed use area in the north and by the western border of the study area in Lulanzi are highlighted by both richness and diversity maps. When comparing richness and diversity we can notice that diversity better identifies small scale differences in value distribution and creates a more fragmented view of the spatial distribution of values in the villages. For example in forested and mixed use areas certain parts are presented as more diverse areas of service utilization compared to richness values.

Also the provisioning and cultural value kernel density results show similar trends in the villages (Figure 25). A general trend is that the cultural values receive higher intensity values because they are more concentrated into certain areas. The specific intensity values between the villages are relatively similar when taking into consideration the amount of participants in the mapping campaign in each village. The provisioning values are utilized quite widely around the village landscape with concentrations in settlement and other important areas such as forests where the points cluster easily. For example, cultivation areas are not highlighted because people have their own fields and therefore do not share locations for service utilization.

The cultural values are more focused around the settlement areas, where most of the important locations such as marketplaces and social spaces are. Outside of the settlement areas higher values can be observed in individual locations where there are either aesthetic elements or elements that are important to the local culture of the village. Examples of these are the Kilamba Lake in Lulanzi that was often experienced to be aesthetic and the now removed tower built by German colonialist south of the village center in Iboya.

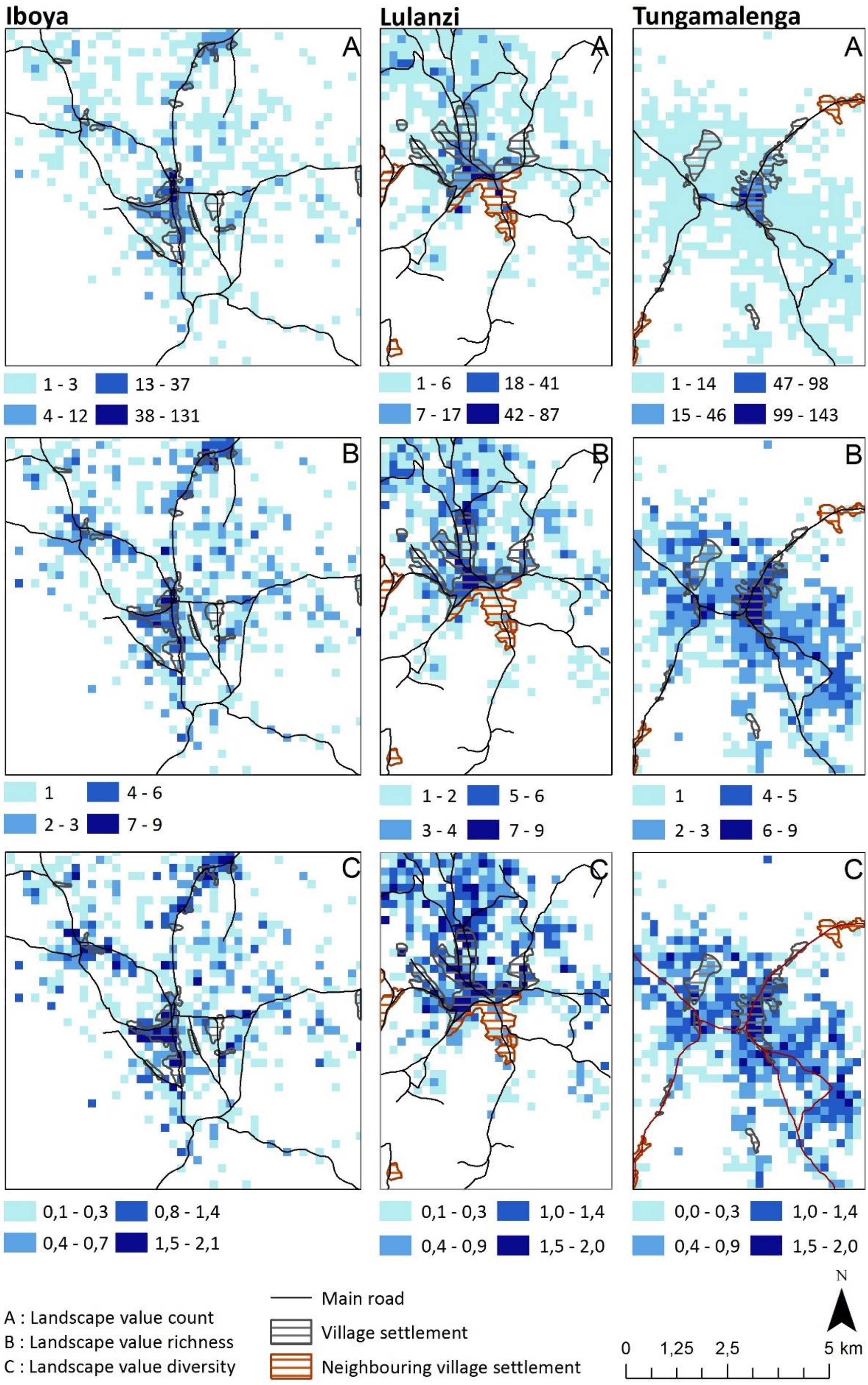


Figure 24. Landscape value count (A), richness (B) and diversity (C) in 200 x 200 meters cell grid visualized using Jenks natural breaks in the three study villages. Count is the number of points in each cell, richness the amount of different values in each cell (possible values 1 – 14) and diversity is diversity of LULC in the cell as a Shannon’s H’ diversity index value.

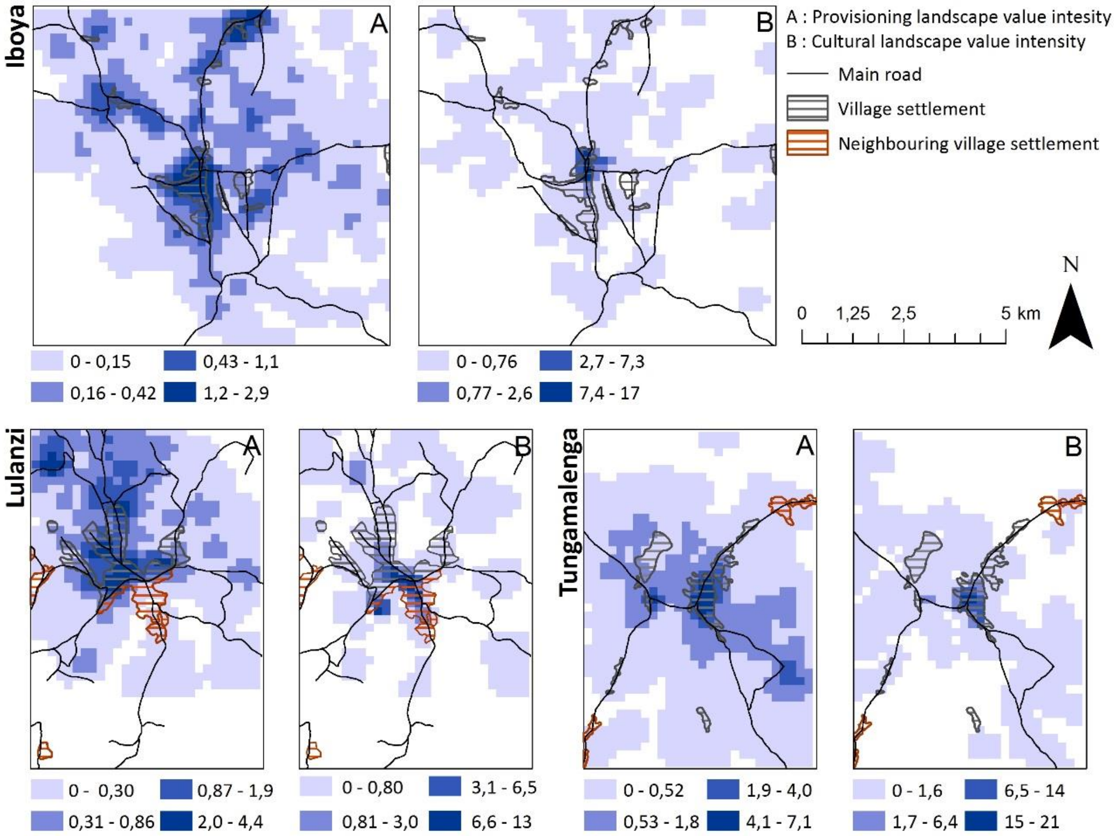


Figure 25. Kernel density surfaces of the provisioning and cultural values visualized using Jenks natural breaks in the study village landscapes. Cell-size is 200 meters and the values indicate the amount of points per hectare.

5.3 Value-landscape associations

Results from the Spearman's rank correlation coefficients indicate multiple significant correlations ($p<0,001$) and strong to indifferent positive and negative associations between the landscape value distribution and the physical landscape structure and distance to village center (Table 13). Weak association were found at Iboya between value count and LULC diversity (0,313) and village distance (-0,337), between value richness and LULC diversity (0,286) and between value kernel density and LULC diversity (0,306) and village distance (-0,501). In Lulanzi the only weak association was found between value count (-0,282) and value kernel density and village distance (-0,455). In Tungamalenga on the other hand association were found between value richness (0,309) and diversity (0,296) and LULC diversity. Especially strong associations were found between village distance and all four of the value indices (from -0,548 to -0,650). Overall in Lulanzi and Tungamalenga the associations were on average stronger than in Iboya. From the two value intensity measures, kernel density received a bit higher association with the physical landscape variables on average.

In Iboya and Tungamalenga the increase in number of patches results in higher scores in richness and diversity, but in Lulanzi the diversity values are similar across the categories (Table 14). In all cases the standard deviation values are high and the results should be interpreted with this in mind. Dense settlement has clearly the highest count and kernel density of the built classification categories in all villages, but from the perspective of richness and diversity homesteads receive approximately similar values. Unbuilt environment has clearly lower values in all the four value indices.

In the LULC classification the highest count (mean 98,1 and SD 130,8), density (mean 3,8 and SD mean 4,7), richness (mean 7,7 and 3,5 SD) and diversity (mean 1,47 and SD 0,6) scores are in the built dominated class. Highest values for all value indices are in Tungamalenga (count (mean 98,1 and SD 130,8), density (mean 3,8 and SD mean 4,7), richness (mean 7,7 and 3,5 SD) and diversity (mean 1,47 and SD 0,6)). Otherwise the count and density scores are relatively evenly spread among the different classes apart from 21,9 for arable land in Lulanzi. Mixed mosaic receives similar average values in both richness and diversity in all the three villages. Arable land gets very different values in the three study villages (I=2,6; L=6,1 and T=4,1) in Tungamalenga. Forest and woodland categories receive similar diversity and richness values in Iboya and Tungamalenga, but lower values in Lulanzi, which is most likely caused by the large natural forest area and the Kilolo municipal forest, where all wood collection activities are forbidden.

Table 13. Spearman’s correlation coefficients of the associations between village LULC structure and the distance to village center and the landscape value distribution. The coefficients were calculated using information in the 500-meter cells. Correlation coefficients between -/+0,3 - -/+0,5 indicate a weak correlation and values above +/- 0,5 indicate a strong correlation. Correlation coefficients close to +/- 0,3 were also interpreted as indicators of weak associations. Pairwise comparison of value richness/diversity/count and LULC richness and diversity. Weak (blue) and strong (red) correlations are highlighted.

			Value count	Value richness	Value diversity	Value kernel density
Iboya	**LULC diversity**	Correlation Coefficient	**,313****	**,286****	,238**	**,306****
		Sig. (2-tailed)	0,000	0,000	0,003	0,000
	LULC richness	Correlation Coefficient	,252**	,195*	,170*	,235**
		Sig. (2-tailed)	0,002	0,015	0,034	0,000
	Village distance	Correlation Coefficient	**-,337****	-,227**	-0.146	**-,501****
		Sig. (2-tailed)	0,000	0,003	0,059	0,000
Lulanzi	**LULC diversity**	Correlation Coefficient	0,110	0,180	,192*	,218**
		Sig. (2-tailed)	0,251	0,060	0,045	0,010
	LULC richness	Correlation Coefficient	-0,039	0,031	0,125	0,042
		Sig. (2-tailed)	0,684	0,746	0,193	0,625
	Village distance	Correlation Coefficient	**-,282****	-,223*	-0,149	-,455**
		Sig. (2-tailed)	0,002	0,017	0,113	0,000
Tungamalenga	**LULC diversity**	Correlation Coefficient	,261**	**,309****	**,296****	,211**
		Sig. (2-tailed)	0,003	0,000	0,001	0,008
	LULC richness	Correlation Coefficient	0,165	,206*	,211*	0,127
		Sig. (2-tailed)	0,065	0,021	0,018	0,110
	Village distance	Correlation Coefficient	**-,554****	**-,608****	**-,548****	**-,650****
		Sig. (2-tailed)	0,000	0,000	0,000	0,000

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

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

Table 14. Mean and standard deviation values of value richness, diversity, count and the kernel density for selected landscape structure variables. Calculated for the 500-meter grid.

			Value count		Kernel density		Value richness		Value diversity	
I	**Patch richness**	Cell count	Mean	SD	Mean	SD	Mean	SD	Mean	SD
	1 patch		NA	NA	NA	NA	NA	NA	NA	NA
	2 to 3 patches	17	3,4	2,5	0,1	0,1	2,9	2,1	0,76	0,6
	4 to 5 patches	46	9,7	29,7	0,3	1	3,1	2,4	0,80	0,7
	6 or more patches	105	9,3	20,9	0,4	0,7	4,0	2,5	1,08	1,1
	LULC classification									
	Forest dominated	31	7,4	9,7	0,3	0,3	4,1	2,8	1,06	0,7
	Woodland dominated	0	NA	NA	NA	NA	NA	NA	NA	NA
	Arable land dominated	4	6,5	7,8	0,3	0,4	2,8	2,2	0,59	0,5
	Grassland dominated	64	4,0	4,2	0,2	0,4	2,6	1,8	0,7	0,6
	Built dominated	4	77,0	81,9	2,8	2,7	9	2,6	1,79	0,4
	Mixed mosaic	65	10,3	25,5	0,4	0,8	4,2	5,5	1,17	0,6
	Built classification									
	Dense settlement	10	59,1	76,3	2,1	2,3	6,3	3,6	1,18	0,8
	Homestead	13	13,3	11,3	0,5	3,5	6,6	2,4	1,75	0,6
	Unbuilt	145	5,0	5,8	0,2	0,3	3,2	2,1	0,89	0,7
L	**Patch richness**									
	1 patch	1	NA	NA	NA	NA	NA	NA	NA	NA
	2 to 3 patches	11	64,4	75,8	2,1	2,4	5,9	3,3	1,22	1,5
	4 to 5 patches	20	16,8	17,1	0,7	0,9	4,8	2,4	1,20	1,4
	6 or more patches	82	11,8	14,3	0,5	0,6	4,5	2,7	1,15	1,3
	LULC classification									
	Forest dominated	15	7,4	12,9	0,3	0,5	2,2	1,32	0,46	0,5
	Woodland dominated	0	NA	NA	NA	NA	NA	NA	NA	NA
	Arable land dominated	9	21,9	20,2	0,8	0,7	6,1	3,3	1,43	0,7
	Grassland dominated	20	11	9,5	0,4	0,4	4,3	2,1	1,16	0,5
	Built dominated	13	68,2	65,2	2,6	2	7,5	2,6	1,54	0,6
	Mixed mosaic	57	10,7	13,1	0,5	0,5	4,5	2,5	1,21	0,6
	Built classification									
	Dense settlement	11	75,9	67,7	2,9	2	6,7	3	1,26	0,6
	Homestead	14	19,6	19	0,8	0,6	6,2	2,3	1,58	0,4
	Unbuilt	89	10,28	12,5	0,4	0,5	4,2	2,6	1,08	0,7
T	**Patch richness**									
	1 patch	41	7,9	7,1	0,3	0,3	3,3	1,9	0,91	0,6
	2 to 3 patches	35	30,3	82,7	1,2	3,1	4,2	3,0	0,98	1,2
	4 to 5 patches	29	20,9	32,0	0,9	1,2	5,1	3,0	1,24	1,4
	6 or more patches	24	23,3	41,3	0,9	1,4	4,9	2,7	1,21	1,5
	LULC classification									
	Forest dominated	0	NA	NA	NA	NA	NA	NA	NA	NA
	Woodland dominated	52	10,5	13,4	0,4	0,5	3,6	2,1	0,98	0,6
	Arable land dominated	57	11,1	10	0,5	0,5	4,1	2,3	1,04	0,6
	Grassland dominated	0	NA	NA	NA	NA	NA	NA	NA	NA
	Built dominated	9	136,7	142,6	5	5,3	9,4	9,8	1,63	0,7
	Mixed mosaic	11	13,2	16,8	0,5	0,5	4,1	2,3	1,11	0,6
	Built classification									
	Dense settlement	13	98,1	130,8	3,8	4,7	7,7	3,5	1,47	0,6
	Homestead	13	14,9	21,5	0,6	0,7	4,9	3,1	1,22	0,5
	Unbuilt	103	10,5	11,1	0,4	0,4	3,8	2,2	0,99	0,6

The result of the chi-square test for LULC classification in Iboya (X^2 =155,6 , df = 24 , p < 0,001), Lulanzi (X^2 = 431,6 , df = 24, p < 0,001) and Tungamalenga (X^2 = 748,5 , df = 18, p < 0,001) and for the built classification test in Iboya (X^2=149,0, df = 12, p < 0,001), Lulanzi (X^2 = 388,6 , df = 12, p<0,001) and Tungamalenga (X^2 = 354,2 , df = 12, p<0,001) show that there are significant associations between the variables as expected.

For the residuals analysis, the results show similar trends in all villages. The results are presented as figures and the the cross-tabulations can be found from the appendices (Appendix 2 and Appendix 3). The proportional coverage of the LULC categories for the three villages are different (Table 15). In Iboya the three largest classes are grassland, mixed and forest. In Lulanzi mixed is clearly the largest followed by an even distribution between the other categories, excluding woodland. Woodland is only present in Tungamalenga where the landscape is dominated by the woodland and arable land categories. For comparison purposes, it is sensible to think of forest dominated and woodland dominated as synonyms because they seem to fulfill the same function when it comes to service valuation.

For the LULC categories the amount of over- or under-represented values in the three villages are relatively different (Iboya 8 over/5 under, Lulanzi 9/9 and Tungamalenga 9/12) with on average highest negative and positive values in Tungamalenga and the lowest in Iboya (Figure 26). There are some similarities such as built dominated areas having low values of wild food (I=-2,7; L=-4,5 and T=-6,7) and firewood (I=-2,9; L=-6,1 and T=-6,3) and high values for water (I=2,5; L=9,4 and T=11,8). But there are also some dissimilarities such as mixed mosaic having a more mixed representation of values in Tungamalenga compared to the other villages.

For each of the village individual characteristics of value representation can be identified. In Iboya the strongest associations were at the forest and built dominated categories, where the values had a mix of under- and over-representation. This is logical as for example for the built dominated cultivation, water and aesthetic were over-represented while all of the provisioning services collected from the environment were under-represented. Similar trend for built dominated also applies to other villages. In Iboya the large cell-size has most likely caused some novelties in the results as water is over-represented in arable land (5,4) and aesthetic in grassland (4,3). These values are most likely in reality associated with specific landscape elements such as streams or lakes which have small spatial coverage.

In Lulanzi the aesthetic values are strongly over-represented with forest (5,6) and grassland (8,2) areas and water is clearly associated with only build dominated category. In Tungamalenga the division of values is more clear with woodland and to some level mixed mosaic receiving high values for wild food, firewood, handicrafts and aesthetic and then arable land for cultivation and built for water. Tungamalenga is the only village where cultivation is distinctively over-represented in the arable land category (10,0 and 67% of points) although the proportional coverage of the arable land dominated areas in the other villages is much lower (I=1,8%; L=10% and T=42,1%). In Iboya and Lulanzi cultivation is mostly present in the built and mixed mosaic categories (I= 62,7% and L=67,9%).

Table 15. Coverage of the LULC classification and built classification data sets in the study villages. The woodland dominated area in Lulanzi did not have any value points in it.

	Coverage (%)		
	Iboya	**Lulanzi**	**Tungmalenga**
LULC classification			
Forest dominated	18,0	11,4	0,0
Woodland dominated	0,0	0,7	42,1
Arable land dominated	1,8	10,0	42,1
Grassland dominated	41,0	17,9	0,0
Built dominated	1,8	10,0	6,3
Mixed mosaic	37,3	50,0	9,4
Built classification			
Dense built	4,6	7,9	8,8
Homestead	6,5	12,1	10,1
No built	88,9	80,0	81,1

In the built classification category, the amount of over- or under-represented values are very similar (Iboya 6 over/6 under, Lulanzi 6/7 and Tungamalenga 6/6) (Figure 27). The proportional coverage of the built classification categories is similar in all villages with the less than 10 % coverage in dense settlement and above 80% coverage by the non-built areas (Table 15). In all villages highest values are for water in the densely built category (I= 5,5 & 47,2 %, L= 10,4 & 60,3 % and T= 8,3 & 57,1 % of points). Wild food and firewood show a clear under-representation in dense settlement and a negative trend in homesteads and then the opposite trend in unbuilt. In most of the values the trends are very similar between the villages but there are some exceptions. For example, aesthetic has a positive association with dense settlement Tungamalenga (3,6) and a negative one in both Iboya (-1,6) and Lulanzi (-4,0).

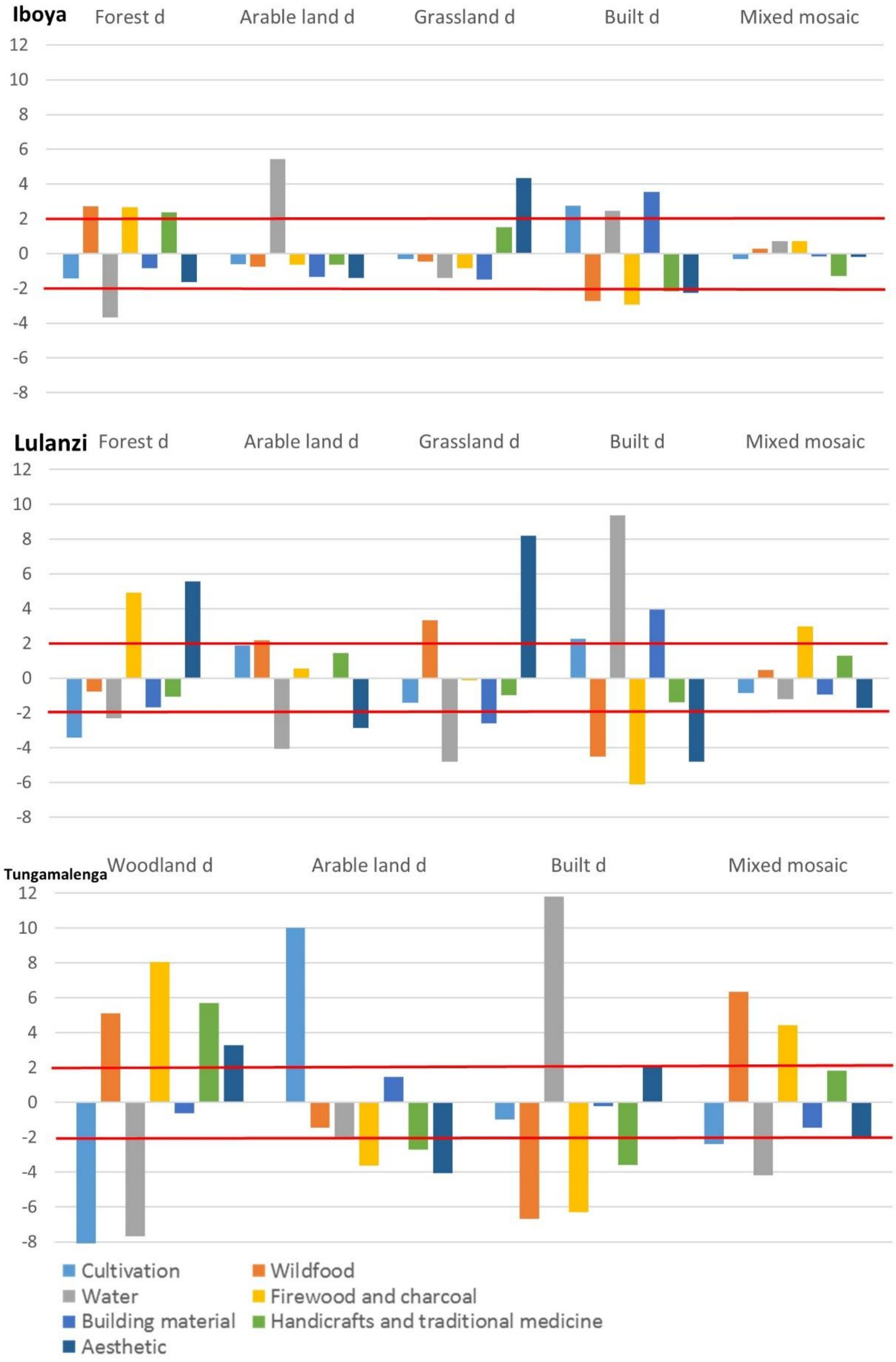


Figure 26. Associations between selected landscape services and the LULC classification as residuals (Y-axis). Standardized residual values of lower than -2,0 or higher than 2,0 indicate an over or under representation of the landscape service in the LULC category. The residual threshold are indicated with red lines.

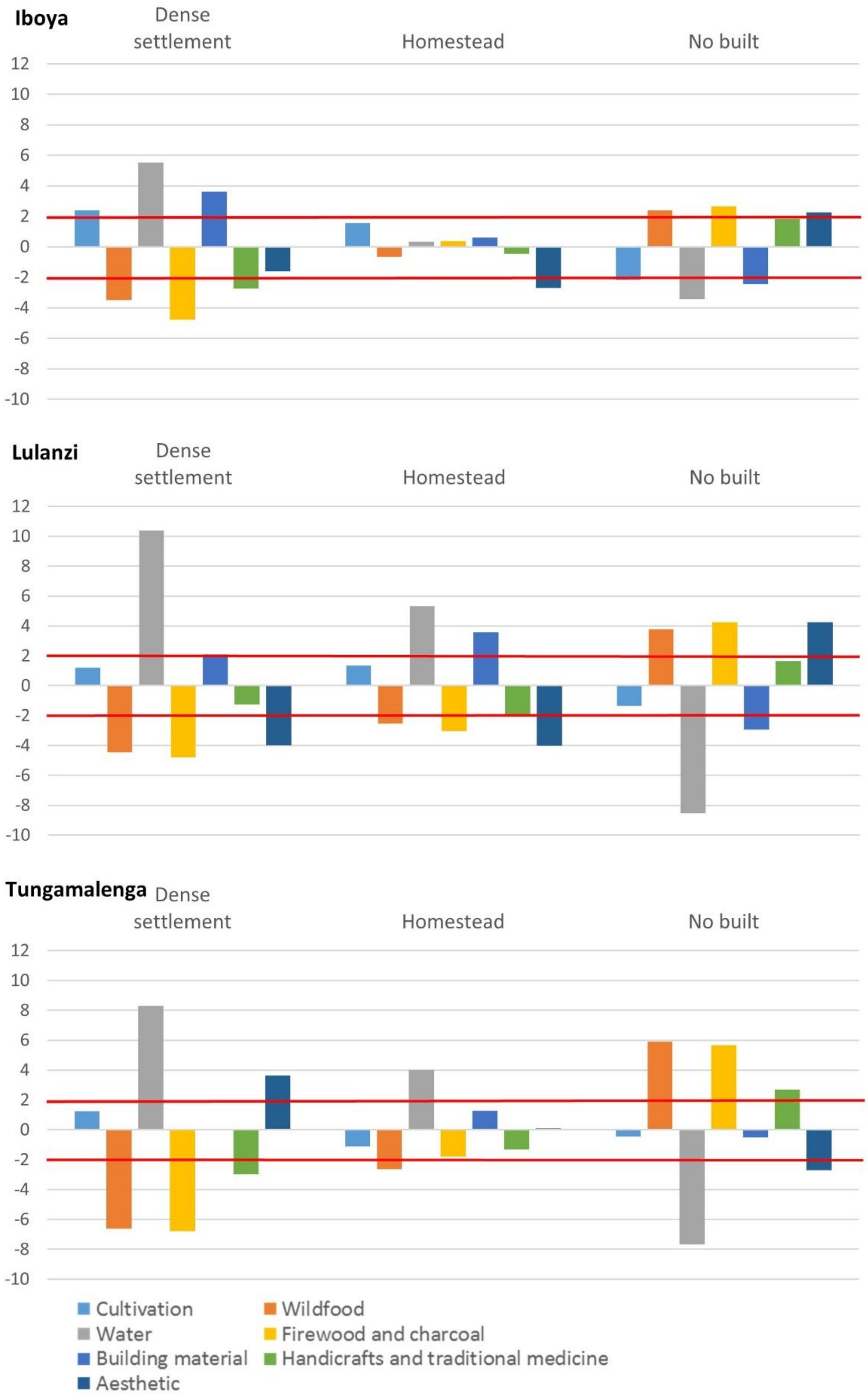


Figure 27. Associations between selected landscape services and the settlement classification as residuals (Y-axis). Standardized residual values of lower than -2,0 or higher than 2,0 indicate an over or under representation of the landscape service in the settlement category. The residual threshold are indicated with red lines.

The correspondence analysis results show the same phenomena that can be identified from cross tabulations and the residual analysis (Figure 28, Figure 29 and Figure 30). For example the associations between central settlement areas and water is easily identified. The correspondence analysis presents more clearly the possible spatial associations between value classes, between physical landscape characteristics and between these two. This enables especially the identification of situations where multiple values associate with certain landscape characteristics. For example, harvesting areas where wild food, firewood and charcoal, handicrafts and traditional medicine and to varying levels also building material (wooden poles) can be identified from all villages.

There are some similarities and differences in the LULC classification plots. In Iboya aesthetic is located close to grassland and the rest of the values (cultivation, building material, wild food, firewood and handicrafts) are located with forest dominated and mixed mosaic. In the built classification water, building material and cultivation are close to dense settlement and homestead. The rest of the values are located around the unbuilt category. In Lulanzi similar trends can be noticed as cultivation, wild food, firewood, building material and handicrafts are located together with mixed mosaic and arable land dominated categories. Water is also located together with dense settlement and building material and cultivation with homesteads. The rest of the values are gathered around the non-built category. In Tungamalenga a clearer structure can be seen with wild food, firewood and handcrafts being closest to woodland dominated and mixed mosaic categories. As mentioned earlier cultivation is closely associated with arable land. The aesthetic and building material are located between multiple different covers. The division is not as clear in the built classifications where handicrafts, wild food and firewood placing very close to the unbuilt category. The rest are relatively scattered, forming a group of associations.

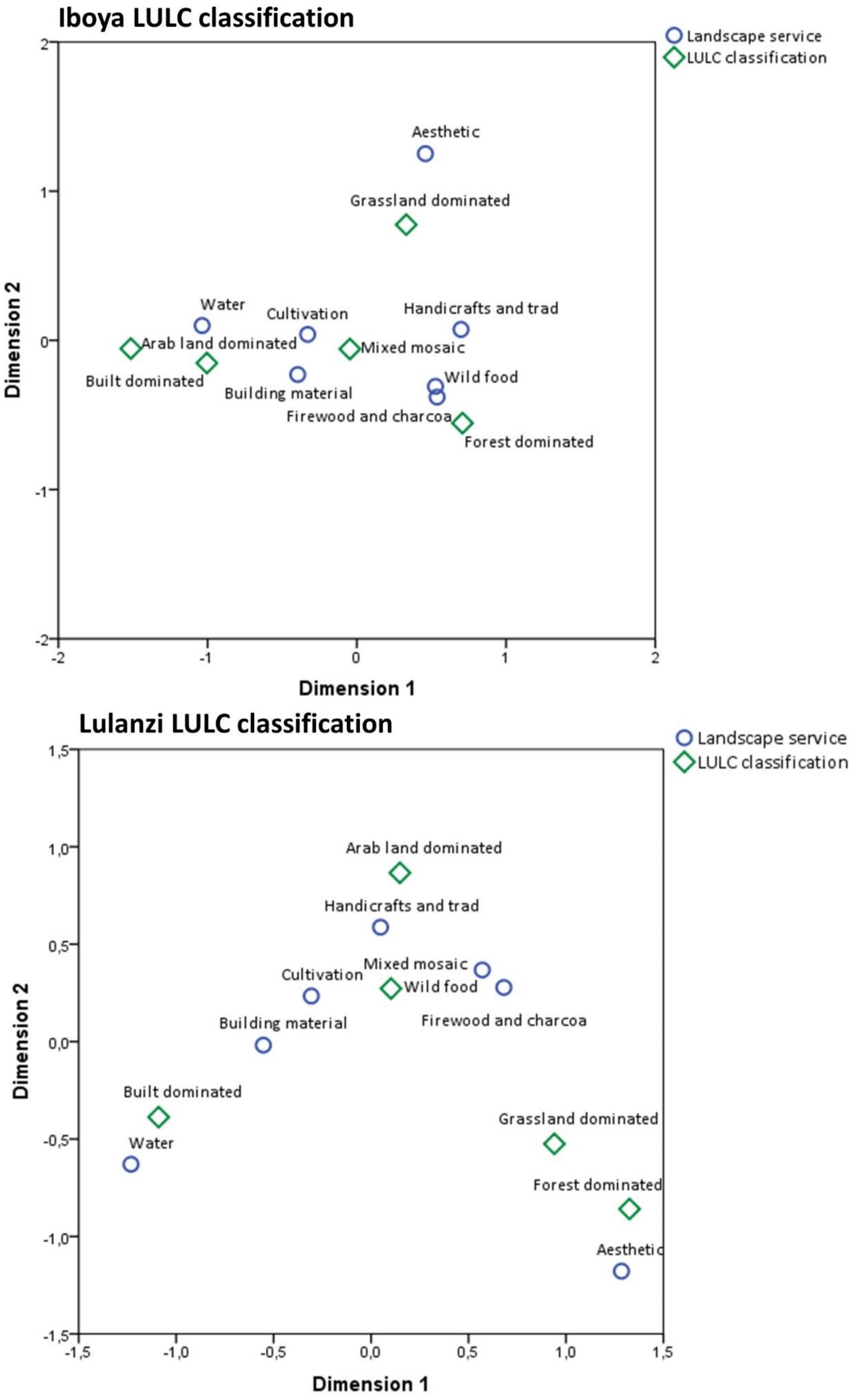


Figure 28. A normalized plot of the correspondence analysis results between the landscape values and the LULC classification in Iboya and Lulanzi.

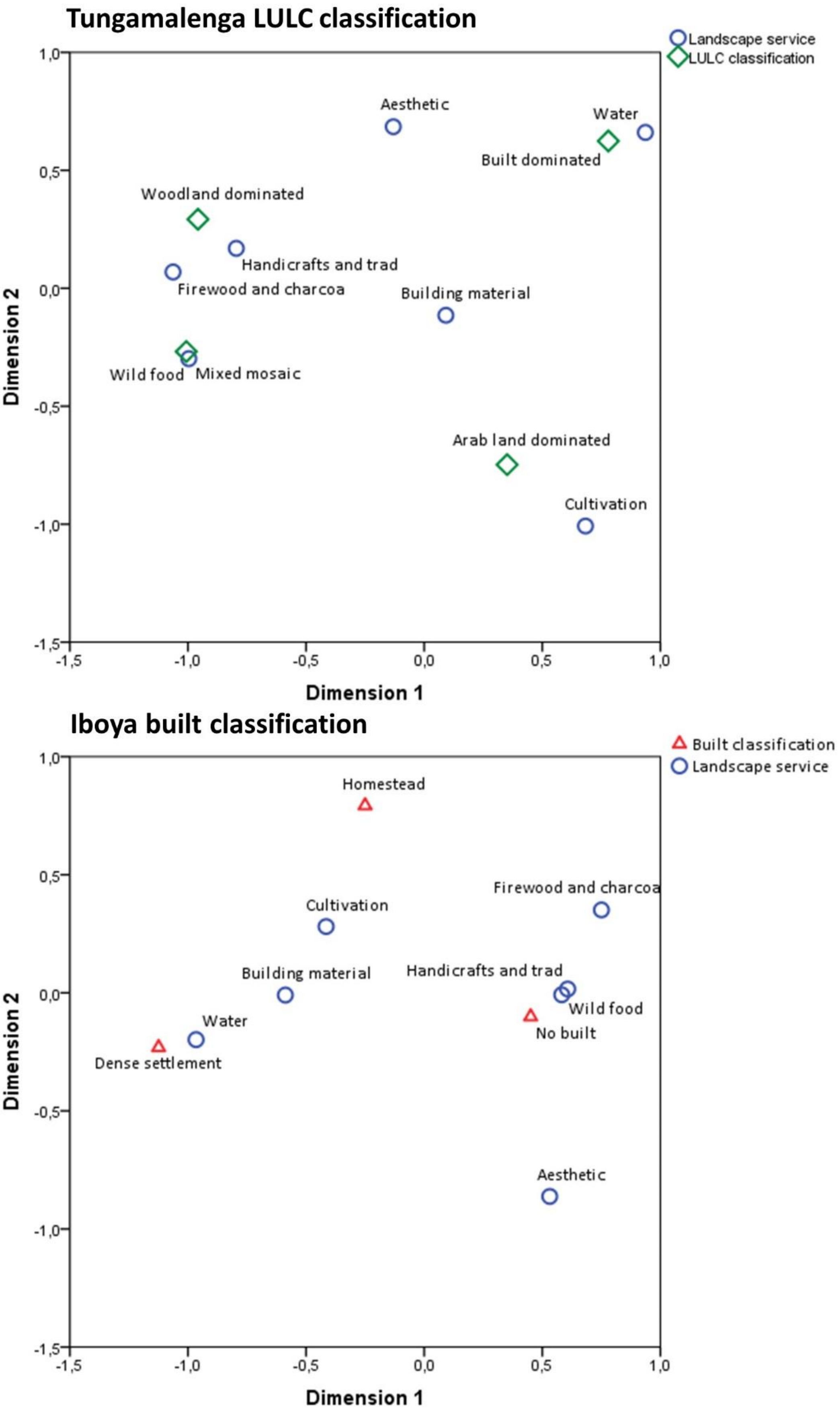


Figure 29. A normalized plot of the correspondence analysis results between the landscape values and the LULC classification in Tungamalenga and the built classification in Iboya.

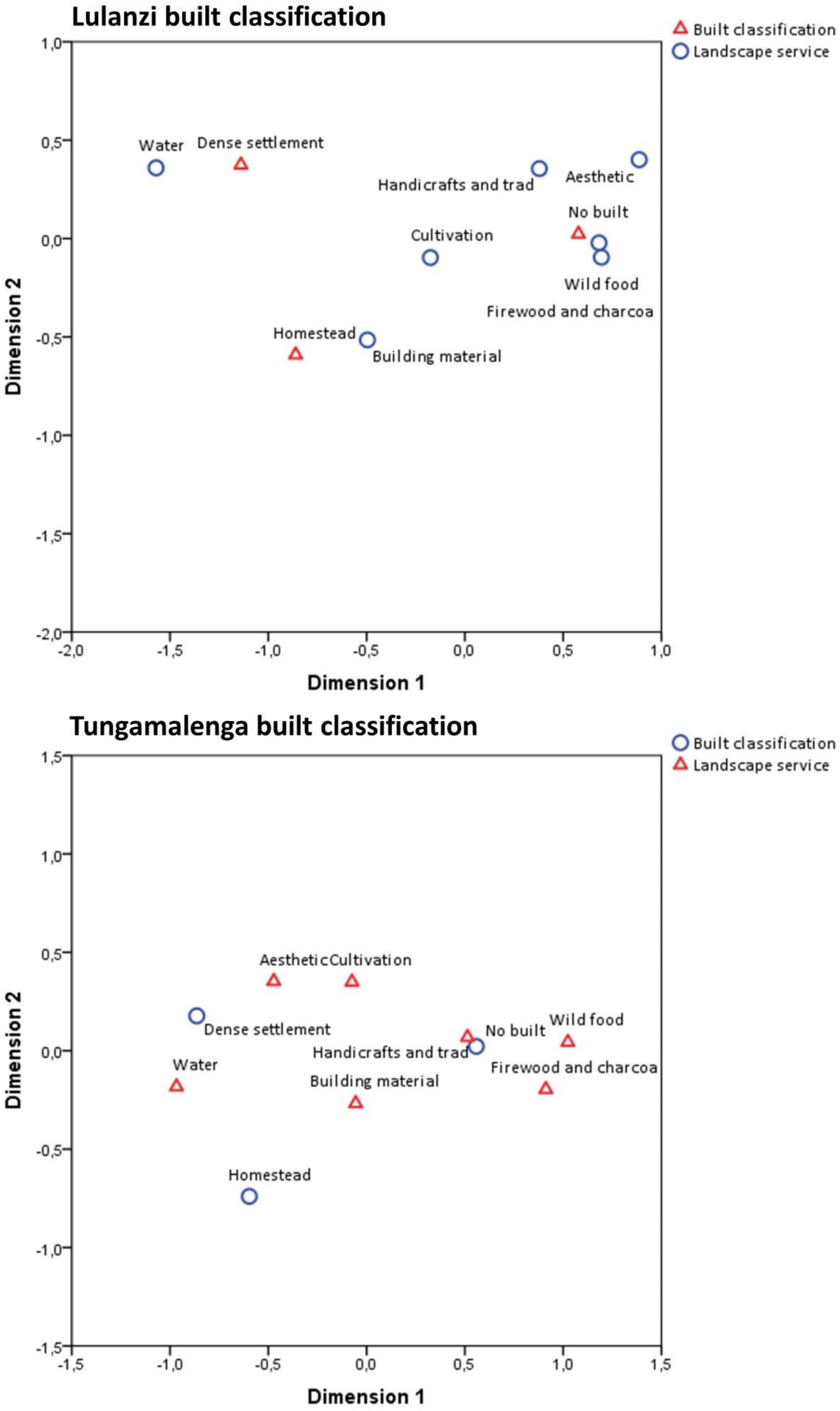


Figure 30. A normalized plot of the correspondence analysis results between the landscape values and the built classification in Lulanzi and Tungamalenga.

6. Discussion

6.1 Value-landscape associations in the multifunctional village landscapes

The Iboya, Lulanzi and Tungamalenga villages are situated in different socio-ecological contexts within in the Southern Highlands, which has created different landscape structures and landscape service valuation practices at the local scale. At the same time the general value-landscape associations are relatively similar in all the villages as the associations with multiple landscape elements are very practical. For example water is collected near the village settlement area and multiple natural resources at specific forest areas. The cultural values are mostly experienced in the village settlement areas with important locations for social interaction and social events such as weddings and funerals. The general trends of value indices of distribution and the value-landscape association related to them in the three villages are also relatively similar. For example, the area where services are valued does not seem to be circular but instead is defined by the neighboring villages and accessibility through the road networks.

At the same time the specific patterns of landscape values are defined by the socio-ecological context of the villages, which also defines the value-landscape associations. The biophysical and socio-economic contexts result in different livelihood practices in the villages as for example rice growing in the wet plains and tourism related to the Ruaha National Park is practiced in Tungamalenga while Iboya and Lulanzi have many forestry related activities. Even though Iboya and Lulanzi are located at relatively similar biophysical contexts, the availability of space, distance to neighboring villages and cities, different elements of the landscape and land use and tenure practices have created different valuation and utilization practices that have been realized as different landscape structures. The results support the view that the socio-ecological processes at the regional and national scale affect the local land use and valuation practices that are realized as livelihood activities and land use choices (Lambin and Meyfroidt 2010).

The found value-landscape associations seem to be embedded in the local socio-ecological context and are in practice guided by the land use practices of the area. For example, a forest patch can have different species of wild food available but collecting them is forbidden because of land ownership. This was the case for the municipal forest in Lulanzi while in Tungamalenga the accessibility to semi-open woodland areas is central to defining the areas within the woodlands for natural resource extraction. The participatory mapping approach proved to be useful, as cultural landscape values in most cases cannot be directly observed from the physical landscape and can therefore only be mapped either through direct inquire or a proxy measure of the human behavior based on inquire done elsewhere (Brown et al. 2015). Based on the results it can be argued that the same principles apply for some of the subsistence-based livelihood practices and the related values in the developing countries village context, as has been noted also by Ramirez-Gomes et al. (2015).

Through the application of value indices (Bryan et al. 2010) important areas of value clustering and spatial co-existence of values were identified. The village settlement area can be identified as the social and cultural hotspot of the villages as almost all the social and religious values are aggregated here. Simultaneously the multifunctionality of settlement areas was highlighted, as for example small scale cultivation is often practiced around homes and clay for making bricks collected where it was most accessible. The results then support the findings made by Fagerholm et al. (2012) in a similar context; the village settlement areas and their close surroundings are important hotspots for multiple different values in the village landscapes, which means that they are under high land use pressure which could cause conflicts. Outside the settlement areas another group of multifunctional locations are in tree covered areas where multiple provisioning values (wild food, firewood and charcoal, handicrafts and medicine and to some extent building material) were identified.

The landscape structure indices described the important elements of the village landscapes. The highly fragmented landscapes in Iboya and Lulanzi present a mosaic of landscape patches that have different importance for the service provision in the area. In Tungamalenga the more homogeneous structure enabled the easier identification of central landscape structures that mostly defined the value distribution. In all three cases the landscapes are heavily modified by human activities (e.g. changing LULC) for it to better serve their needs and well-being (Fu et al. 2013). The negative correlation between LULC heterogeneity and distance to village center indicates that the effects of the human activities on landscape structure are emphasized in the areas surrounding the village settlement cores. Because of the relatively small extent of the study area the wider influence of human activities on landscape structure was difficult to evaluate.

Mitchell et al. (2015) argues that fragmentation of natural land cover can affect both service supply and service flow (the delivery of services to people). The results indicate that growth in landscape structure richness and diversity results in higher value richness and diversity in Iboya and Tungamalenga. In Lulanzi associations were not as strong. Fagerholm et al. (2016) state that in multifunctional and heterogeneous landscapes areas of multiple values co-existence are less related to individual land systems and more with the landscape as a whole where all parts have a key role. The results of this study show that in a heterogeneous landscape with multiple smaller patches it is more likely that there will be higher value richness and diversity. At the same time, important landscape elements such as settlement centers and important forest patches could be identified as multifunctional areas in themselves.

The results support the view of Wu (2013b) that landscape is the most suitable scale for understanding the interactions between humans and nature. The local focus enabled the identification of patterns of provisioning and cultural landscape values that were scattered in different specific locations within the landscapes. As Fagerholm et al. (2012) note there is a lot of sensitivity to the way that the values are realized in the landscape and to capture this sensitivity, place-based methods focusing on the local scale should be applied. In practice, the value points identify elements in landscape with different extents. Defining their spatial extent accurately is impossible. Because of this, this thesis relied on the spatial aggregation of value points to analyze the wider patterns of value distribution and utilization in the village landscapes (Fagerholm et al. 2012). Different values presented different patterns of value clustering and distribution. Values that associated with small scale landscape elements (e.g. buildings) such as cultural and religious values were highly concentrated whereas most of provisioning values were more scattered in the landscape. The results were approached from a social-ecological perspective which puts the people's dependence on nature at the center of analysis (Fischer et al. 2015).

A major limitation to place-specific case studies of the associations is that they are mostly geographically limited to the study area and the population in question (Brown et al. 2015). The multiple study village setting enabled the estimation of the validity of this statement which also is a starting point for evaluating the usability of the results for value-transfer. The suitability of the found associations should be evaluated from the perspective of the three possible sources of generalization error presented by Eigenbrod et al. (2010b): uniformity, sample and generalization errors. The usefulness of value-associations are then approached by their fitness to a set of conditions presented by Brown et al. (2016) to reduce the possible errors related to value-transfer. First, there should be similarity in the LULC classes and their areal proportions between the primary data production area and the spatial value-transfer area. The different socio-ecological contexts have led to very different LULC distributions in the village which indicates that the defined associations should be used only in similar village areas, probably within the same region as the study village. Overall the associations defined at Tungamalenga are likely to work better, especially when transferring to landscapes with similar structures as greater homogeneity will reduce the potential generalization errors of spatial value-transfer (Brown et al. 2016). Only the identified indicators for value distribution indices are likely to produce sufficient results in Iboya and Lulanzi if used for value transfer. The two other conditions are related to the population of the area and their sampling: the social and cultural values and norms should be similar between the populations in the two areas and the participatory mapping should ensure large enough and unbiased sample of people. In this study both of these conditions are relatively well fulfilled.

Ultimately the spatial value transfer methods are dependent on both the availability, quality and suitability of the primary data and the indicator data and the truthfulness of the causal associations between them (Brown et al. 2016; Burkhard et al. 2012b; Troy & Wilson 2006). Defining sensible indicator data sets for spatial value-transfer in the data poor village context can be difficult. For example, it is likely that firewood collection is practiced in wooded areas but at the same time not all wooded areas are equally suitable. Land use practices, land ownership and accessibility will all affect how the firewood collection practices are realized. These results support the argument made by Sherrouse et al. (2011) that future studies need to identify additional data sets in different scales that provide descriptions and measures of the biophysical and social characteristics of the study area. Adding further data on top of the land use and land cover information can improve the accuracy and value of the value-transfer method (Brown et al. 2015). For example, as noted in their study by Lamy et al. (2016), models of service provision that include information on landscape configuration will more likely create better estimates. In this study the physical landscape characteristics variables were only able to capture the composition of the landscape structure. Although the found associations highlight some similarities, the similarities seem to be overruled by the local nuances of the socio-ecological context. This supports the findings by Brown et al. (2016) who state that because of the high likelihood of generalization error the approach is likely to be more suitable for identifying broader scale trends, for example possible risks to human well-being.

The research approach showed that in addition to providing primary information on the landscape scale, the mapping of landscape values and landscape structure done in this thesis provided a suitable starting point for estimating value-landscape associations in a socio-ecological context where these types of approaches have been rarely applied. The understanding on the service utilization practices aids in the selection of landscape character data for the analyses and can enhance the capability of the researcher to estimate the validity of the found associations. Limited information on the functioning of the complex SES in the village landscapes was available for this. This creates a problematic setting for the study as for example argued by Meacham et al. (2016) the spatial distribution of values seem to be codetermined by multiple social and ecological factors. They continue by stating that to understand how these different factors affect values, it is necessary to study the supply of values over time. Because of this, the goal was not to try to explain the social and ecological factors that cause the spatial distribution landscape values, but instead to try to study the spatial value-landscape associations. This argument is based on the idea that the landscape values are spatial realizations of the complex social and ecological processes (based on the ideas of Ostrom 2009) on-going in the study village landscapes and only therefore capture a snapshot of the continuous changes. This thesis brings new inside in to the field of landscape values from two perspectives.

First the study creates new information from the developing countries socio-ecological context as most studies have been done in the developed world context (Brown et al. 2013). And second as the focus on the local landscape scale brings new insight to values and experiences of stakeholders for local land use management and decision-making in the African context as there are only few studies that have mapped values at the local scale in Africa (Wangai et al. 2016).

6.2 Strengths and weakness of the methods

The results indicate that participatory mapping data produced by non-expert participants enables the estimation of spatial distribution of values. An enduring challenge for the use of these methods is that they are without commonly defined set of best practices, which means that no data quality standards exist (Brown & Fagerholm 2015). The analysis of the point data indicates that the mapping technique used in this thesis is suitable for creating an accurate and thematically comprehensive data set for spatial distribution and association analyses. The comparison of the results to other studies, because of the uniqueness of the mapping approach, should in any case viewed critically.

Although the used typology was planned together with local experts following experiences from Fagerholm & Käyhkö (2009) and Fagerholm et al. (2012), it is unclear how it has affected the results and it is difficult to say whether it could capture all the important benefits that people receive from the landscapes. As noted by Fagerholm et al. (2012) it would be beneficial to study new typologies rising for the conceptualization of the landscape values that are different from the non-western societies. An interesting approach for the future studies is the one applied by Ramirez-Gomez et al. (2013 & 2015) where they included the stakeholders in defining the value typology. Another challenge related to the value typology was highlighted by the within category heterogeneity. For example, building material was collected from forest (wooden poles) and near the settlement areas (clay). The associations with LULC categories differs significantly between these two locations, which can be problematic for the quantification of associations as values are less likely to be over- or under-represented in a LULC category when calculating standardized residuals.

As multiple studies, have shown (e.g. Bryan et al. 2010; Fagerholm et al. 2012) the value indices (count, kernel density, richness and diversity) can describe important components of value distribution. In this thesis, a mixed definition approach was presented to estimate the cell-size and distance threshold for the kernel density analyses which resulted in relatively successful results. The presented approaches were still met by some methodological challenges. As mentioned earlier it is impossible to define the actual extent of a value point which can cause possible errors when spatially overlaying the points with a grid. The analysis is unable to estimate the areal extent of a point and forces each point to spatially associate with one cell. The effects of this on the richness, diversity and residual analysis are difficult to evaluate.

Because of the spatially unprecise nature of participatory mapping methods, spatially specific analysis of the mapping data might not be reasonable and, as Fagerholm et al (2012) state, the interest lies in identifying the broader spatial patterns of values and their indicators. From this perspective, the use of polygons instead of points could have achieved similar accuracy and the collection of them would probably be less laborious. For example, Ramirez-Gomes et al. (2015) used focus groups and PGIS methods to map polygon areas of service use in an indigenous area in Colombia.

Although participatory mapping methods have been identified as one of the most viable methods for defining spatial distribution of landscape values in a developing world context (Ramirez-Gomez et al. 2015) the usefulness of the produced information is hindered by the lack of suitable data on physical landscape character. At the local scale, the values can be spatially associated with small scale features such as village forest patches or streams near the village. Most national and global data sets that were tested for the analysis were not precise enough to be used at the local scale. This is a major challenge, as noted by de Groot et al. (2010): methods of landscape value mapping are by definition data-driven and require extensive spatial data sets that cover the full area of interest. The selection of methods to study the associations were strongly dictated by the available data on the physical landscape character. Other methods such as the SolVES tool presented by Sherrouse et al. (2011 and 2014) were deemed unsuitable because of the restrictions set by the physical landscape character data. To overcome the issue of landscape structure data availability this study presented a method of using Open Foris Collect Earth to collect information on the physical landscape character in a context where heterogeneous structure of the landscape makes the creation of LULC data challenging. The results show that the using Collect Earth for wall-to-wall type surveys can create suitable information, but is laborious and time consuming which resulted in to compromises related to cell-size selection.

The 500-meter cell-sizes proved to be relatively suitable for identifying multifunctional areas and associating value intensity, diversity and richness with landscape structure. At the same time the cell-size could result in insensible associations between individual values and the physical landscape characteristics as the cell-size was not able to capture the small-scale features of the landscape that are very crucial for the values. The structure of the landscape defined the suitability of the cell size: in Iboya and Lulanzi the cell-size was not able to capture all the important elements in heterogeneous landscape, whereas in Tungamalenga the achieved results were more accurate. The proxies based on such coarse datasets are less likely to define accurate associations and as an indicator data are likely to give poor estimates of the actual value distribution (Eigenbrod et al. 2010a).

The use of standardized residuals enabled the identification of significant associations between value categories and physical landscape character categories. The residuals assume that the deviations of the realized value counts from the expected counts indicate the relative importance of different character categories for the selected value (Brown et al. 2015). In practice the method approach assumes that all areas within a landscape character category are equally suitable for the selected value. For example, in Tungamalenga provisioning services collected from woodland are collected from the border between arable land and woodland because of easier accessibility, which indicates that there is within category differences in the service provision. The weakness of the method is that it does not take into account the proportions of different landscape character categories in the study area (Brown et al. 2015).

The results of this study show that the use of these methods are dependent on the quality and spatial accuracy of character data. This is indicated through two examples: First, only data with clearly identifiable homogeneous categories could be used because otherwise the found associations might be based on false assumptions. Because of this continuous data sets such as tree coverage could not be used because they could not be classified in a sensible manner. Second, as the NN analysis shows, the values tend to cluster in the landscape, which means that for a certain value the associations defined with the residual analysis can be defined mostly by a small number of cells. For example, in Lulanzi an important patch of community forest is in the middle of a grassland area and the cells are classified as grassland dominated. In this case a strong association between for example firewood collection and grassland areas can be found, although this association in reality does not exist.

The use of correspondence analysis is a useful way of graphically present the associations (Brown & Brabyn 2012a), as it was identified that when comparing multiple values with multiple physical landscape categories the size of the cross-tabulations grew large. The strength of the correspondence analysis was to highlighting the potential for multifunctionality in certain landscape elements by locating multiple values near them.

6.3 Implications for land use management

In the African rural context the direct dependency on natural resources and the indirect for regulating services is common (Egoh et al. 2012). This demand for resources is usually realized at the local scale where land use decision and livelihood activities are done. To guide and sustain the use of natural and cultural resources local decision-making requires accurate information on the multiple dimension of ecosystem services (supply, demand, natural conditions, societal values etc.) (Wangai et al. 2016).

All landscapes, whether they are natural or human influenced, provide ecosystem services in different qualities and amounts (Wu 2013b) and therefore identifying areas where important service utilization areas are located is crucial for management and decision-making. This thesis presented an approach for creating information on the distribution landscape values and their associations with landscape elements that are important for provision of multiple values in the village landscapes. The approach supports the point made by Brown & Fagerholm (2015) that participatory mapping has the capacity to produce spatially accurate knowledge on landscape values that could be integrated into land use management. Integrating the local understanding with scientific knowledge in a way that is accessible for decision-makers at all levels is important for securing livelihoods and well-being provided by the natural environment.

In addition to the production of spatial information for decision-making, the use of participatory mapping methods can create important discussion between different stakeholders in the study area and enhance the capacity of stakeholders to participate and argument on issues that affect their everyday practices (Fagerholm et al. 2013). In this research project the initial mapping campaign results were presented over to the villages in participatory workshops to endorse participation and community discussion through validation of the results and valuation of the services. Another round of workshops with the results from this thesis could increase the discussion on important landscape elements and the possible land use interests related to them.

The process of turning complex spatial information on value-landscape associations into comprehendible simple visualizations, i.e. maps, can help to engage communities in decision-making processes (Paydual et al. 2015). For example Ramirez-Gomes et al. (2013) note that maps can work as a starting point for initiatives related to land use, management of natural resources and nature conservation. The approach done in this thesis supports the view that maps should be considered as valid data sources among others for environmental decision making (Brown 2011) although relying solely on the maps should be avoided because of their descriptive nature. Also, including valuations to landscape value maps can be especially useful for land use management, because communities do not value services equally and are not able to manage all the services with equal importance because of limited resources (Paudyal et al. 2015). Integrating the valuation information collected at the participatory workshops with the thesis results could further increase the potential usefulness of the information for management purposes.

The use of value indices for intensity, richness and diversity identified important multifunctional areas where values co-exist in the village landscapes. Focusing actions to the identified key elements of high diversity in the village landscapes can enable the protection and development of multiple values (Bryan et al. 2010). Further information is needed to identify important value bundles where a set of values repeatedly exist together. Raudsepp-Hearne et al. (2010) state that to manage values, the focus should be put on the interactions between values and how these interactions are molded by the social and ecological factors in different areas of the landscape. According to them, future work should focus on finding what kind of bundling of the values there is and are there any social or ecological conditions that affect how the values are bundled.

Cultural values have been less commonly mapped in the African context (Wangai et al. 2016). The inclusion of cultural ecosystem to the assessment is crucial as they have rarely been studied in the African context and they can be important for enhancing economic, socio-cultural and spiritual welfare of many communities (Wangai et al. 2016). In a similar developing world context Sinare et al. (2016) for example focus only on the provisioning values as they can be directly translated to livelihood benefits that the participants are highly dependent on and they also acknowledge that e.g. cultural and regulating services have a major impact on the whole landscape system. The inclusion of cultural values in this study revealed important landscape-value associations that should be included in land use management.

The possible usefulness of the results for decision-making from the perspective of spatial value transfer should be approached with healthy skepticism. As Brown & Brabyn (2012a) note, using value-transfer methods to map landscape values in decision making might cause significant changes to the landscape and should always be approached with a case specific measurement of value distribution. From a broader perspective, the association could work as a basis for discussion when combined with other information sources. As Brown et al. (2016) note, the suitability of spatial value-transfer methods is dependent on the intended use of the maps. I agree with the Troy & Wilson (2006) when they state that although the use of transferred landscape values for decision making is tempting, they should only be used as one source of evidence among others to gain a good overview of the issues at hand. From the developing world perspective it can also be argued that when value-transfer is practiced, it should not be done with the price of participation which is a crucial part of the whole land use management process.

Although using proxy information of value distribution is likely to always be problematic, it should be seen as an alternative strategy whenever collection of primary information is not feasible. For example, Troy & Wilson (2006) argue that using proxy information for valuation is much better than not assigning any value to landscape services. Burkhard et al. (2009) point out that generalizations and simplifications of the human-environmental systems need to be tolerated to receive a holistic picture of these complex systems. When modeling systems, we must make decisions on how we reduce these complexities to create a method that can provide suitable information that can guide the decision-making on the natural resources and land use.

6.4 Future study interests

The study approach applied in this thesis is faced with multiple unanswered questions related to data suitability and mapping method among other things. In this chapter I will present the most intriguing future study questions that still need answers. Actual value-transfer methods were not used in this research, but by comparing the associations between the villages we can make assumption on the possible accuracy of the transfer. The results indicate that the general trends in value-landscape associations are relatively similar between the villages, but at the same time are so embedded into the social-ecological landscapes of the study villages that value-transfer methods would not have likely produced accurate results. The obvious next step would be to test the value-transfer methods and try to define a more suitable set of indicator data to better describe the value-landscape associations for developing countries subsistence-based village landscapes.

Likely because of the heterogeneous structure of the village landscapes multifunctionality and the co-existence of values seems to be common. Future research could approach the value-landscape associations by using bundles of values that are likely to form in landscapes (Raudsepp-Hearne et al. 2010) instead of value indices or individual values. Although, Brown et al. (2015) studied the use of bundles for value-transfer and noted that the method is sensitive to study context and could hinder its suitability as mapping approach. Still I would argue that testing this approach in developing countries village context could be beneficial.

When working in heterogeneous multifunctional village landscapes it can be difficult to define landscape characteristics that alone would have meaningful associations with landscape values at the landscape scale. Rather than searching for more accurate data, another useful approach would be to create meaningful characterization of physical landscapes that capture the service valuation and use practices of communities. These approaches are based on understanding the landscape as a whole and integrates the discussion between stakeholders as a part of association definition process.

For example Fagerholm et al. (2013) created a synthetic landscape characterization which combined cultural and provisioning landscape value maps with a characterization map of physical landscape structure and important settlement areas that also considered temporal changes in the landscape characteristics. Another approach is used by Sinare et al. (2016) who present the concept of social-ecological patch, which can be defined as a landscape unit that matches the description of local people when they describe their landscapes and in practice these units are characterized by a combination of LULC and topography. These social-ecological patches then have different profiles of service provision for the people who helped to identify and utilize them. According to Sinare et al. these characterizations need to be developed at the local scale and in the future further effort in translating them to suitable scales for landscape management needs to be assessed.

The knowledge on value-landscape associations should also be used to define indicators that enable the study of temporal changes in service provision. It is likely that different results will be achieved when temporal changes are considered in studies of spatial co-existence of values (Tomscha & Gergel 2016). The study of annual changes in Southern highlands context would be especially interesting as most of the people living in Iringa and Njombe districts are dependent on the annual fluctuations of precipitation for agriculture (URT 2012). The temporal perspective could reveal important information on the service utilization practices that could benefit the management related to natural resources. This need is identified also at the global scale as the sustainable use and development of land-based ecosystems is highlighted in the United Nations 2030 Agenda for Sustainable development (UN 2016). The goal is to ensure that the benefits gained from the ecosystem will also be available for the future generations. Participatory mapping of landscape values could fullfill the information needs to make knowledge based decisions on the service capacity and demand.

Unfortunately, the information produced in mapping campaigns is in the end rarely used for land use management (Brown & Fagerholm 2015). New ways of integrating landscape value information into decision making at the local and regional scales need to be developed. Ramirez-Gomes et al. (2015) state that to truly empower the local people the actors responsible for land use management need to aid the communities to link the collected data in to concrete management activities. Presenting the results of this study to local and regional actors in land management could work as a starting for discussion on service management in the villages.

Further studies should focus on the different practices of land use management and identify ways of integrating the produced information as supportive material in the decision-making process (Brown & Fagerholm 2015). In regions with limited data availability participatory mapping and value-landscape associations analyses can create baseline information of service utilization practices that can work as a starting point for understanding the processes and possible effects of different actions that need to be considered in decision making.

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References

Alessa, L, Kliskey, A & Brown, G 2008. Social-ecological hotspots mapping: A spatial approach for identifying coupled social-ecological space. *Landscape and urban planning* 85, 27–39.

Antorp, M 2000. Background concepts for integrated landscape analysis. *Agriculture, ecosystems and environment* 77, 17–38.

ArcGIS online Help 10.3: How Average Nearest Neighbour works <http://pro.arcgis.com/en/pro-app/tool-reference/spatial-statistics/h-how-average-nearest-neighbor-distance-spatial-st.htm> 5.6.2017.

ArcGIS Online Help 10.3: How incremental spatial autocorrelation works. <http://desktop.arcgis.com/en/arcmap/10.3/tools/spatial-statistics-toolbox/how-incremental-spatial-autocorrelation-works.htm> 12.08.2016.

Bastian, O, Grunewald, K, Syrbe, R-U, Walz, U & Wende, W 2014. Landscape services: the concept and its practival relevance. *Landscape ecology* 29, 1463–1479.

Bennet, E, Peterson, G & Gordon, L 2009. Understanding relationships among multiple ecosystem services. *Ecology Letters* 12, 1398–1404.

Berkes, F & Folke, c 1998. Linking social and ecological systems for resilience and sustainability. in Berkes, F, & Folke, C (ed.): *Linking social and ecological systems: management practices and social mechanisms for building resilience*, 1–27. Cambridge University Press, New York

Berkes, F, Colding, J & Folke, C 2003. Introduction. in Berkes, F, Colding, J & Folke, C (ed.): *Navigating social-ecological systems. Building resilience for complexity and change*, 1–34. Cambridge University Press, Cambridge

Beverly, J, Uto, K, Wilkes, J & Bothwell P 2008. Assessing spatial attributes of forest landscape values: and internet-based participatory mapping approach. *Canadian journal of forest research* 38, 289–303.

Brown, G 2005. Mapping spatial attributes in survey research for natural resource management: Methods and application. *Society and Natural Resources* 18, 17–39.

Brown, G & Reed, P 2011. Social Landscape Metrics: Measures for understanding place values from Public Participation Geographic Information Systems (PPGIS). *Landscape Research*, 1–18.

Brown, G & Brabyn, L 2012a. An analysis of the relationship between multiple values and physical landscapes at a regional scale using public participation GIS and landscape character classification. *Landscape and Urban Planning* 107, 317–331.

Brown, G & Brabyn, L 2012b. The extrapolation of social landscape values to a national level in New Zealand using landscape character classification. *Applied Geography*,35, 84–94.

Brown, G & Pullar, D 2012. An evaluation of the use of points versus polygons in public participation geographic information systems using quasi-experimental design and Monte Carlo simulation. International Journal of Geographical Information Science 26(2), 231–246.

Brown, G, Montag, JM & Lyon, K 2012. Public participation GIS: A method for identifying ecosystem services. *Society & Natural Resources* 0, 1–19.

Brown, G & Kyttä, M 2014. Key issues and research priorities for public participation GIS (PPGIS): A synthesis based on empirical research. *Applied Geography* 46, 122–136.

Brown, G & Fagerholm, N 2015.Empirical PPGIS/PGIS mapping of ecosystem services: a review and evaluation. *Ecosystem services* 13, 119–133.

Brown, G, Montag, J & Lyon, K 2012. Public participation GIS: a method for identifying ecosystem services. *Society & natural resources* 25(7), 633–651.

Brown, G, Kelly, M & Whitall, D 2013. Which 'public'? Sampling effects in public participation GIS (PPGIS) and volunteered geographic information (VGI) systems for public lands management. Journal of *Environmental planning and management*, 1–25.

Brown, G, Weber, D & de Bie, K 2014. Assessing the value of public lands using public participation GIS (PPGIS) and social landscape metrics. *Applied Geography* 53, 77–89.

Brown, G, Hausner, V & Lægreid, E 2015. Physical landscape associations with mapped ecosystem values with implications for spatial value transfer: An empirical study from Norway. *Ecosystem services* 15, 19–34.

Brown, G, Pullar, D & Hausner, V 2016. An empirical evaluation of spatial value transfer methods for identifying cultural ecosystem services. *Ecological indicators* 69, 1–11.

Bryan, B, Raymond, C, Crossman, N & Macdonald, D 2010. Targeting the management of ecosystem services based on social values: Where, what, and how? *Landscape and urban planning* 97, 111 – 122.

Burkhard, B, Kroll, F, Müller, F & Windhorst, W 2009. Landscapes' capacities to provide ecosystem services – a concept for land-cover based assessments. *Landscape Online* 15, 1–22.

Burkhard, B, de Groot, R, Costanza, R, Jørgensen, S & Potschin, M 2012a. Solutions for sustaining natural capital and ecosystem services. *Ecological indicators* 21, 1–6.

Burkhard, B, Kroll, F, Nedkov, S & Müller, F 2012b. Mapping ecosystem service supply, demand and budgets. *Ecological indicators* 21, 17–29.

Bürgi M & Russell, EWB 2001. Integrative methods to study landscape changes. *Land Use Policy* 18, 9–16.

Campell, J. (2008). *Introduction to Remote Sensing*. Fourth Edition. The Guildford Press. New York.

Carpenter, R, DeFries, R, Dietz, T, Mooney, H, Polasky, S, Reid, W & Scholes, R 2006. Millennium Ecosystem Assessment: Research Needs. *Science* 314, 257–258.

Carpenter, S, Mooney, H, Agard, J, Capistrano, D, DeFried, R, Díaz, S, Dietz, T, Duraiappah, A, Oteng-Yeboah, A, Pereira, H, Perrings, C, Reid, W, Sarukhan, J, Scholes, R & Whyte, A 2009. Science for managing ecosystem services: Beyond the Millenium Ecosystem Assessment. *PNAS* 106 (5), 1305–1312.

Costanza, R 2008. Ecosystem services: multiple classification systems are needed. *Biological conservation* 141, 350 – 352.

Crow, T 2006. Farmlands for farming and nature. in Wiens, J & Moss, M (ed.): *Issues and perspectives in landscape ecology*, 201–207. Cambridge University Press, Cambridge

de Groot, R, Wilson, M & Boumans, R 2002. A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecological Economics* 41, 393–408.

de Groot, R 2006. Function-analysis and valuation as a tool to asses land use conflicts in planning for sustainable, multi-functional landscapes. *Landscape and Urban Planning* 75, 175–186.

de Groot, R, Alkemade, R, Braat, L, Hein, L & Willemen, L 2010. Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. *Ecological Complexity* 7, 260–272.

Egoh, B, O'Farrell, P, Charef, A, Gurney, L, Koellner, T, Abi, H, Egoh, M & Willemen, L 2012. An African account of ecosystem service provision: Use, threats and policy options for sustainable livelihoods. *Ecosystem services* 2, 71–81.

Eigenbrod, F, Armsworth, P, Anderson, B, Heinemeyer, A, Gillings, S, Roy, D, Thomas, C & Gaston, J 2010a. The impact of proxy-based methods on mapping the distribution of ecosystem services. *Journal of Applied Ecology* 47, 337–385.

Eigenbrod, F, Armsworth, P, Anderson, B, Heinemeyer, A, Gillings, S, Roy, D, Thomas, C & Gaston, K 2010b. Error propagation associated with benefits transfer-based mapping of ecosystem services. *Biological conservation* 143, 2487–2493.

Fagerholm, N & Käyhkö, N 2009. Participatory mapping and geographical patterns of the social landscape values of rural communities in Zanzibar, Tanzania. *Fennia* 187(1), 43–60.

Fagerholm, N, Käyhkö, N, Ndumbaro, F & Khamis, M 2012. Community stakeholders' knowledge in landscape assessments – Mapping indicators for landscape services. *Ecological Indicators* 18, 421–433.

Fagerholm, N, Käyhkö, N & Van Eetvelde, V 2013. Landscape characterization integrating expert and local spatial knowledge of land and forest resources. *Environmental management* 52, 660–682.

Fagerholm, N, Oteros-Rozas, E, Raymond, C, Torralba, M, Moreno, G & Plieninger, T 2016. Assessing linkages between ecosystem services, land-use and well-being in an agroforestry landscape using public participation GIS. *Applied Geography* 74, 30–46.

Fahrig, L 2006. When is landscape perspective important? in Wiens, J & Moss, M (ed.): *Issues and perspectives in landscape ecology*. 3–10. Cambridge University Press, Cambridge

Fahrig, L, Baudry, J, Brotons, L, Burel, F, Crist, T, Fuller, R, Sirami, C, Siriwardena, G & Martin, J-L 2011. Fuctional landscape heterogeneity and animal biodiversity in agricultural landscapes. *Ecology letters* 14, 101–112.

Fang, X, Zhao, W, Fu, B & Ding, J 2015. Landscape service capability, landscape service flow and landscape service demand: A new framework for landscape services and its use for landscape sustainability assessment. *Progress in Physical Geography* 39, 817–836.

Farina, A 2006. *Principles and methods in landscape ecology. Towards a science of landscape*. Dordrecht, The Netherlands: Springer.

Fischer, J , Gardner, T, Bennet, E, Balvanera, P, Biggs, R, Carpenter, S, Daw, T, Folke, C, Hill, R, Hughes, T, Luthe, T, Maass, M, Meacham, M, Norström, A, Peterson, G, Quieroz, C, Steppelt, R, Spierenburg, M & Tenhunen, J 2015. Advancing sustainability through mainstreaming a social-ecological system perspective. *Current opinion in environmental sustainability* 14, 144–149.

Fisher, B, Turner, R, K & Morling, P 2009. Defining and classifying ecosystem services for decision making. *Ecological Economics* 68, 643–653.

Fu, B, Wang, S, Su, C & Forsius, M 2013. Linking ecosystem processes and ecosystem services. *Current opinion in environmental sustainability* 5, 4–10.

Gulickx, M, Verbug, P, Stoorvogel, J, Kok, K & Veldkamp, A 2013. Mapping landscape services: A case study in a multifunctional rural landscape in The Netherlands. *Ecological Indicators* 24, 273–283.

Haines-Young, R 2006. Landscape pattern: context and process. in Wiens, J & Moss, M (ed.): *Issues and perspectives in landscape ecology*. 103–111. Cambridge University Press, Cambridge

Haines-Young, R, & Potschin, M 2010. The links between biodiversity, ecosystem services and human well-being. In: Raffaelli, D & C. Frid (eds.): *Ecosystem ecology: A new synthesis.* 1 – 31. Ecological Reviews series, CUP, Cambridge.

Hausner, V, Brow, G, Laegreid, E 2015. Effects of land tenure and protected areas on ecosystem services and land use preferences in Norway. *Land use policy* 49, 446 – 461 .

Jones, L, Norton, L, Austin, Z, Browne, A, Donovan, D, Emmett, B, Grabowski, Z, Howard, D, Jones, J, Kenter, J, Manley, W, Morris, C, Robinson, D, Short, C, Siriwardena, G, Stevens, C, Storkey, J, Waters, R & Willis, G 2016. Stocks and flows of natural and human-derived capital in ecosystem services. *Land use policy* 52, 151–162.

Kangalawe, R, & Lyimo, J 2010. Population dynamics, rural livelihoods and environmental degradation: some experiences from Tanzania. *Environment, Development and Sustainability* 12, 985–997.

Lambin, E & Meyfroidt, P 2010. Land use transitions : Socio-ecological feedback versus socio-economic change. *Land use policy* 27, 108–118.

Lamy, T, Liss K, Gonzalez, A, & Bennet, E 2016. Landscape structure affects the provision of multiple ecosystem services. *Environmental research letter* 11(12), 1–9.

Lillesand, T, Kiefer, R, & Chipman, J 2008. *Remote Sensing and Image Interpretation*. Sixth edition. John Wiley & Sons, Inc.

Li, H & Wu, J 2004. Use and misuse of landscape indices. *Landscape ecology* 19, 389–399.

Liu, J, Dietz, T, Carpenter, S, Folke, C, Alberti, M, Redman, C, Schneider, S, Ostrom, E, Pell, A, Lubchenco, J, Taylor, W, Ouyang, Z, Deadman, P, Kratz, T & Provencher, W 2007. Coupled human and natural systems. *Ambio* 36(8), 639–649.

Mango, G, & Kalenzi, D 2011. *Report on the study to develop a strategy for establishing cost effective land use plans in Iringa and Njombe regions*. United republic of Tanzania. National Land Use Planning Commission.

Martinez-Harms, M & Balvanera, P 2012. Methods for mapping ecosystem service supply: a review. *International journal of biodiversity science, ecosystem services & management* 8(1 – 2), 17 – 25.

McGarical, K & Cushman, S 2006. The gradient concept of landscape structure. in Wiens, J & Moss, M (ed.): *Issues and perspectives in landscape ecology*, 201–207. Cambridge University Press, Cambridge

McGarigal, K, Tagil, S & Cushman, S 2009. Surface metrics: an alternative to patch metrics for the quantification of landscape structure. *Landscape ecology* 24, 433 – 450.

Meacham, M, Quieroz, C, Norström, A & Peterson, G 2016. Social-ecological drivers of multiple ecosystem services: what variables explain patterns of ecosystem services across the Norrström drainage basin? *Ecology and Society* 21(1): 14.

Millennium Ecosystem Assessment, 2005. *Ecosystems and Human Well-being: Synthesis*. Island Press, Washington, DC.

Ministry of Natural Resources & Tourism (MNRT) 2015. *NAFORMA - National Forest Resources Monitoring and Assessment of Tanzania Mainland*.

Mitchell, M, Suarez-Castro, A, Martinez-Harms, M, Maron, M, McApline, C, Gaston, K, Johansen, K & Rhodes, J 2015. Reframing landscape fragmentation's effects on ecosystem services. *Trends in ecology & evolution* 30(4), 190 – 198.

Monitoring African Food and Agricultural Policies (MAFAP) 2013. *Review of food and agricultural policies in the United Republic of Tanzania*. MAFAP Country Report Series, FAO, Rome, Italy.

Nassauer, J & Opdam, P 2008. Design in science: extending the landscape ecology paradigm. *Landscape ecology* 23, 633–644.

National bureau of Statistics 2013. *2012 population and housing census. Population distribution by administrative areas.*

Opdam, P, Nassauer, J, Wang, Z, Albert, C, Bentrup, G, Castella, J-C, McAlpine, C, Jianguo, L, Sheppard, S & Swaffield, S 2013. Science for action at the local landscape scale. *Landscape Ecology* 28, 1439– 1445.

Ostrom, E, 2009. A general framework for analyzing sustainability of social-ecological systems. *Science* 325, 419–422

Palomo, I, Martín-López, B, Zorrilla-Miras, P, García Del Amo, D & Montes, C 2014. Deliberative mapping of ecosystem services within and around Doñaba national park (SW Spain) in relation to land use change. *Reg Environ Change* 14, 237–251.

Paudyal, K, Baral, H, Burkhard, B, Bhandari, S & Keenan, R 2015. Participatory assessment and mapping of ecosystem services in a data-poor region: Case study of community-managed forest in central Nepal. *Ecosystem services* 13, 81–92.

Plummer, M 2009. Assessing benefit transfer for the valuation of ecosystem services. *Front Ecol Environ* 7(1), 38–45.

Potschin, M, & Haines-Young, R 2006. Landscapes and sustainability. *Landscape and urban planning* 75, 155–161.

Potschin, M, Haines-Young, R 2013. Landscapes, sustainability and the place-based analysis of ecosystem services*. Landscape Ecology* 28, 1053–1065.

Ramirez-Gomez, S, Brown, G & Tjon Sie Fat, A 2013. Participatory mapping with indigenous communities for conservation: challenges and lessons from Suriname. *Electronic journal of information systems in developing countries* 58(2), 1–22

Ramirez-Gomez, S, Torres-Vitolas, C, Schreckenberg, K, Honzák, M, Cruz-Garcia, G, Willcock, S, Palacios, E, Pérez-Miñana, E, Verweij, P & Poppy, G 2015. Analysis of ecosystem services provision in the Colombian Amazon using participatory research and mapping techniques. *Ecosystem services* 13, 93–107.

Raudsepp-Hearne, C, Peterson, G & Bennet, E 2010. Ecosystem service bundles for analyzing tradeoffs in diverse landscapes. *PNAS* 107(11), 5242–5247.

Reyers, B, Biggs, R, Cumming, G, Elmiqvist, T, Hejnowicz, A & Polasky, S 2013. Getting the measure of ecosystem services: a social-ecologial approach. *Front Ecol Environ* 11 (5), 268–273.

Rutledge, D 2003. Landscape indices as measures of the effects of fragmentation: can pattern reflect process? *Doc science internal series* 98, 1 – 27.

Schaafsma, M, Morse-Jones, S, Posen, P, Swetnam, R, Balmford, A, Bateman, I, Burgess, N, Chamshama, S, Fisher, B, Freeman, T, Geofrey, V, Green, R, Hepelwa, A, Hernández-Sirvent, A, Hess, S, Kajembe, G, Kayharara, G, Kilonzo, M, Kulindwa, K, Lund, J, Madoffe, S, Mbwambo, L, Meilby, H, Ngaga, Y, Theilade, I, Shannon, C & Weaver, E 1949. *The Mathematical Theory of Communication*. University of Illinois.

Sherrouse, B, Clement, J & Semmens, D 2011. A GIS application for assessing, mapping, and quantifying the social values of ecosystem services. *Applied Geography* 31, 748–760.

Sherrouse, B, Semmens, D & Clement, J 2014. An application of Social Values for Ecosystem Services (SolVES) to three national forets in Colorado and Wyoming. *Ecological Indicators* 36, 68–79.

Sherrouse, B & Semmens, D 2014. Validating a method for transferring social values of ecosystem services between public lands in the Rocky Mountain region. *Ecosystem Services* 8, 166–177.

Silverman, B, 1986. *Density Estimation for Statistics and Data Analysis*. Chapman and Hall, New York.

Sinare, H, Gordon, L & Kautsky, E 2016. Assessment of ecosystem services and benefits in village landscapes – a case study from Burkina Faso*. Ecosystem services* 21, 141–152.

Syrbe, R-U & Walz, U 2012. Spatial indicators for the assessment of ecosystem services: Provisioning, benefiting and connecting areas and landscape metrics. *Ecological indicators* 21, 80 – 88.

Thermorshuizen, JW & Opdam, P 2009. Landscape services as a bridge between landscape ecology and sustainable development. *Landscape Ecology* 24, 1035–1052.

Tomscha, S & Gergel, S 2016. Ecosystem service trade-offs and synergies misunderstood without landscape history. *Ecology and Society* 21(1): 43.

Troy, A & Wilson, M, 2006. Mapping ecosystem services: Practical challenges and opportunities in linking GIS and value transfer. *Ecological economic* 60, 435–449.

Turner, M, O'Neill,R Gardner, R & Milne B 1989. Effects of changing spatial scale on the analysis of landscape pattern. *Landscape ecology* 3(3/4), 153–162.

Turner, M, Gardner, R & O'Neill, R 2001*. Landscape ecology in theory and practice. Pattern and Process.* United States of America: Springer.

Ungaro, F, Zasada, I & Piorr, A 2014. Mapping landscape services, spatial synergies and trade-offs. A case study using variogram models and geostatistical simulations in an agrarian landscape in North-East Germany. *Ecological indicators* 46, 367 – 378.

United Republic of Tanzania (URT) 2012. *National sample census of agriculture 2007/2008. Volume Vk: Regional report – Iringa Region.*

United Republic of Tanzania (URT) 2013. *Key findings, 2011/12 Household budget survey Tanzania Mainland.* National Bureau of Statistics, Ministry of Finance.

United Republic of Tanzania (URT) 2013. *Iringa Rural district council socio-economic profile, 2013.*

United Republic of Tanzania (URT) 2013. *Kilolo district council socio-economic profile, 2013.*

United Republic of Tanzania (URT) 2014. *2012 Population and Housing Census, Basic Demographic and Socio-Economic Profile, Key Findings.*

United Nations 2016. *The Sustainable Development Goals Report 2016*. New York.

Van Riper, C H Kyle, G 2014. Capturing multiple values of ecosystem services shaped by environmental worldviews: a spatial analysis. *Journal of environmental management* 145, 374–384.

Verhagen, W, Van Teeffelen, A, Compagnucci, A, Poggio, L, Gimona, A & Verburg, P 2016. Effects of landscape configuration on mapping ecosystem service capacity: a review of evidence and a case study in Scotland. *Landscape ecology* 31, 1457 – 1479.

Wangai, P, Burkhard, B & Müller, F 2016. A review of studies on ecosystem services in Africa. International journal of sustainable built environment 5, 225–245.

Willemen, L, Verburg, P, Hein, L, van Mensvoor, M 2008. Spatial characterization of landscape functions. *Landscape and urban planning* 88, 34–43.

Willemen, L, Veldkamp, A, Verburg, P, Hein, L & Leemans, R 2012. A multi-scale modelling approach for analyzing landscape service dynamics. *Journal of Environmental Management* 100, 86–95.

Wu, J 2013a. Key concepts and research topics in landscape ecology revisited: 30 years after the Allerton Park workshop. *Landscape Ecology* 28, 1–11.

Wu, J 2013b. Landscape sustainability science: ecosystem services and human well-being in changing landscapes. *Landscape ecology* 28, 999–1023.

Appendices

Appendix 1. Information interpreted from satellite image using Open Foris Collect Earth.

Landscape attribute	**Definition**	**How is it going to be mapped**
LULC classes	Insert the amount of points covered by each of the 10 LULC classes.	Count the amount of points covered by each LULC class in the cell. The point location and its' surrounding will be used to define the class.
LULC richness	Enter the amount of LULC classes in the cell with minimum cover of 1 guide point	Include all classes that cover at least 1 guide point in the grid cell
Largest patch	Largest patch within the cell	Calculate the amount of vertically or horizontally adjacent points of the same LULC
Patch richness	Categories of percentage of patches regardless of LULC class	Amount of patches within the cell that cover at least 1 guide point.
LULC patch structure	An interpretation of patch sizes and diversity will be categorized in to predefined classes	Visual classification with the aid of classification plan defined before starting
Tree and scrub coverage	Categories of percentage of tree coverage in the cell	Count the amount of guide points covered by trees or scrubs and the select the suitable category.
Grass coverage	Categories of percentage of grass coverage in the cell	Count the amount of guide points covered by grass and the select the suitable category
Built environment	Three categories of built environment within the cell: no build environment, homesteads and dense build environment	Select the suitable option from the three possibilities if there are any signs of built environment in the cell. The built environment does not need to be overlaid by a guide point.
Important elements of the landscape	Are there paths, roads, streams, rivers, solitary trees or wood fences or tree plantations? Is there any signs of cultivation? Are there Solitary trees or wood fences?	A simple yes or no question, which does not take in to consideration the amount or size of the element within the cell. The element does not need to be overlaid by a guide point.

Appendix 2. Results of cross tabulations with standardized residual between Landscape services and land use and land cover classification. The LULC classifications are F (forest dominated), W (woodland dominated) A (arable land dominated), G (grassland dominated), B (build dominated) and M (Mixed mosaic)

			x^2 =155,6 , df = 24 , p < 0,001						X^2 = 431,6 , df = 24, p < 0,001									
		Iboya						**Lulanzi**						**Tungamalenga**	X^2 = 748,5, df = 18, p < 0,001			
			LULC classification							LULC classification					LULC classification			
		F	A	G	B	M	Total	F	A	G	B	M	Total	W	A	B	M	Total
Cultivation	Count	25	3	32	39	62	161	1	51	35	89	95	271	6	201	81	12	300
	%	15,5%	1,9%	19,9%	24,2%	38,5%	100%	0,4%	18,8%	12,9%	32,8%	35,1%	100%	2,0%	67,0%	27,0%	4,0%	100%
	Residual	-1,4	-0,6	-0,3	2,8	-0,3		-3,4	1,9	-1,4	2,3	-0,8		-8,6	10,0	-1,0	-2,4	
Wild food	Count	41	2	25	8	54	130	5	30	39	9	57	140	88	49	5	38	180
	%	31,5%	1,5%	19,2%	6,2%	41,5%	100%	3,6%	21,4%	27,9%	6,4%	40,7%	100%	48,9%	27,2%	2,8%	21,1%	100%
	Residual	2,7	-0,8	-0,4	-2,7	0,3		-0,8	2,2	3,3	-4,5	0,5		5,1	-1,5	-6,7	6,3	
Water	Count	5	12	16	27	48	108	1	2	0	93	45	141	21	91	221	5	338
	%	4,6%	11,1%	14,8%	25,0%	44,4%	100%	0,7%	1,4%	0,0%	66,0%	31,9%	100%	6,2%	26,9%	65,4%	1,5%	100%
	Residual	-3,7	5,4	-1,4	2,5	0,7		-2,3	-4,1	-4,8	9,4	-1,2		-7,7	-2,1	11,8	-4,2	
Firewood and charcoal	Count	38	2	21	6	53	120	24	29	29	5	94	181	124	41	14	35	214
	%	31,7%	1,7%	17,5%	5,0%	44,2%	100%	13,3%	16,0%	16,0%	2,8%	51,9%	100%	57,9%	19,2%	6,5%	16,4%	100%
	Residual	2,7	-0,6	-0,8	-2,9	0,7		4,9	0,6	-0,1	-6,1	3,0		8,1	-3,6	-6,3	4,4	
Building material	Count	23	1	20	37	52	133	3	22	12	64	51	152	86	123	95	18	322
	%	17,3%	0,8%	15,0%	27,8%	39,1%	100%	2,0%	14,5%	7,9%	42,1%	33,6%	100%	26,7%	38,2%	29,5%	5,6%	100%
	Residual	-0,9	-1,3	-1,5	3,5	-0,2		-1,7	0,0	-2,6	3,9	-0,9		-0,6	1,5	-0,2	-1,5	
Handicrafts and traditional medicine	Count	24	1	21	4	22	72	2	17	10	15	39	83	80	31	21	18	150
	%	33,3%	1,4%	29,2%	5,6%	30,6%	100%	2,4%	20,5%	12,0%	18,1%	47,0%	100%	53,3%	20,7%	14,0%	12,0%	100%
	Residual	2,4	-0,6	1,5	-2,2	-1,3		-1,1	1,4	-1,0	-1,4	1,3		5,7	-2,7	-3,6	1,8	
Aesthetic	Count	9	0	33	4	29	75	18	4	51	2	29	104	78	31	73	7	189
	%	12,0%	0,0%	44,0%	5,3%	38,7%	100%	17,3%	3,8%	49,0%	1,9%	27,9%	100%	41,3%	16,4%	38,6%	3,7%	100%
	Residual	-1,6	-1,4	4,3	-2,3	-0,2		5,6	-2,8	8,2	-4,8	-1,7		3,3	-4,1	2,1	-2,0	
Total	Count	165	21	168	125	320	799	54	155	176	277	410	1072	483	567	510	133	1693
	%	20,7%	2,6%	21,0%	15,6%	40,1%	100%	5,0%	14,5%	16,4%	25,8%	38,2%	100%	28,5%	33,5%	30,1%	7,9%	100%

Appendix 3. Results of cross tabulations with standardized residual between Landscape services and built density classification.

		Iboya	X^2=149,0, df = 12, p < 0,001			**Lulanzi**	X^2 = 388,6 , df = 12, p<0,001			**Tungamalenga**	x^2 = 354,2 , df = 12, p<0,001		
		Built classifcation				Built classifcation				Built classifcation			
		Dense settlement	Homestead	No built	Total	Dense settlement	Homestead	No built	Total	Dense settlement	Homestead	No built	Total
Cultivation	Count	50	31	80	161	65	51	155	271	107	22	171	300
	% within services	31,1%	19,3%	49,7%	100%	24,0%	18,8%	57,2%	100%	35,7%	7,3%	57,0%	100%
	Residual	2,4	1,6	-2,2		1,2	1,4	-1,4		1,2	-1,1	-0,5	
Wild food	Count	10	16	104	130	5	10	125	140	7	6	167	180
	% within services	7,7%	12,3%	80,0%	100%	3,6%	7,1%	89,3%	100%	3,9%	3,3%	92,8%	100%
	Residual	-3,5	-0,7	2,4		-4,4	-2,5	3,8		-6,6	-2,6	5,9	
Water	Count	51	17	40	108	85	47	9	141	193	54	91	338
	% within services	47,2%	15,7%	37,0%	100%	60,3%	33,3%	6,4%	100%	57,1%	16,0%	26,9%	100%
	Residual	5,5	0,3	-3,4		10,4	5,3	-8,5		8,3	4,0	-7,7	
Firewood and charcoal	Count	2	19	99	120	8	12	161	181	12	12	190	214
	% within services	1,7%	15,8%	82,5%	100%	4,4%	6,6%	89,0%	100%	5,6%	5,6%	88,8%	100%
	Residual	-4,8	0,4	2,6		-4,8	-3,1	4,2		-6,8	-1,8	5,7	
Building material	Count	49	22	62	133	43	41	68	152	102	37	183	322
	% within services	36,8%	16,5%	46,6%	100%	28,3%	27,0%	44,7%	100%	31,7%	11,5%	56,8%	100%
	Residual	3,6	0,6	-2,4		2,1	3,6	-2,9		0,0	1,3	-0,5	
Handicrafts and traditional medicine	Count	5	9	58	72	12	6	65	83	27	9	114	150
	% within services	6,9%	12,5%	80,6%	100%	14,5%	7,2%	78,3%	100%	18,0%	6,0%	76,0%	100%
	Residual	-2,7	-0,4	1,8		-1,2	-1,9	1,7		-3,0	-1,3	2,7	
Aesthetic	Count	10	2	63	75	3	0	101	104	88	18	83	189
	% within services	13,3%	2,7%	84,0%	100%	2,9%	0,0%	97,1%	100%	46,6%	9,5%	43,9%	100%
	Residual	-1,6	-2,7	2,2		-4,0	-4,0	4,3		3,6	0,1	-2,7	
Total	Count	177	116	506	799	221	167	684	1072	536	158	999	1693
	% within services	22,2%	14,5%	63,3%	100%	20,6%	15,6%	63,8%	100%	31,7%	9,3%	59,0%	100%