Assessing and Mapping Provisioning and Cultural Services: The Case Study of Lake Bosomtwe, Ghana

Ana Karina Aguilar Estrada
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Assessing and Mapping Provisioning and Cultural Services: The Case Study of Lake Bosomtwe, Ghana

by

Ana Karina Aguilar Estrada

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Thesis Assessment Board

Chairman: Dr. A.G. Toxopeus (University of Twente, ITC)
External Examiner: Dr. Ir. L.G.J. Boerboom (University of Twente, ITC)
First Supervisor : Ir. L.M. van Leeuwen (University of Twente, ITC)
Second Supervisor : Dr. A. Voinov (University of Twente, ITC)

ITC UNIVERSITY OF TWENTE.
FACULTY OF GEO-INFORMATION SCIENCE AND EARTH OBSERVATION

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Abstract

Different ecosystem functions have the capacity of providing a diversity of services. Lake ecosystems provide habitat for a variety of species, regulation functions such as water supply, production function, such as food and ornamental resources and Information functions, such as recreation and (eco) tourism, aesthetic, spiritual, cultural, scientific information.

Two ecosystem services were identified by stakeholders , i.e. provisioning services and cultural services. The first services were relevant to stakeholders from the local level, i.e. local communities from villages surrounding the lake, which livelihood depend heavily on the fish supply. On the other hand, cultural services were recognized by stakeholders from local to international levels. A significant relationship between the values perceived and stakeholders was found which permitted the assessment of ecosystem services per stakeholder groups.

This case study has demostrated how stakeholders perception of services and their interaction with the ecosystem can be combined to assess and map the ecosystem services. Stakeholders related the most important values to services they have experienced and most interaction with.

Criteria based on litterature review and observations in the field were used to build a series of indicators for each of the services assessed. Two criteria were identified to visualize the spatial variation of services values across the study area:

- The first criterion was the ability of the ecosystem to provide the services required. To infer the status of this criterion, the social value indicator was used. This indicator proved to be highly correlated with the two services.
- The second criterion was the possibility of interaction of human societies with the services provided. To infer the status of this criterion two indicators were used, the fishermen density (only for provisioning service) and the accessibility indicator (used to assess both services). The fishermen density proved low correlation for assessing provisioning services. The accessibility indicator proved to be very relevant for assessing provisioning services but not relevant for assessing cultural services.

The approach used for hotspot mapping was fuzzy logic which permitted the combination of the different indicators. The relevance of this method for assessing ecosystem services is that it reflects the spatial heterogeneity of the landscape services and allows gradual

transition as the ecosystem characteristics do not have sharp limits, neither do the services.
Keywords: Social Hotspots, ecosystem services, provisioning services, cultural services, social values, accessibility

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1. Introduction

1.1. Background and Significance

Ecosystem structure and processes can be interpreted in terms of functions which have the capacity to provide a series of goods and services to satisfy human needs (de Groot et al., 2002). For example, the filtering, retention and storage of water (processes in aquatic ecosystems) can be translated into a water supply function, which provides the service of water delivery for consumption. Similarly, attractive ecosystem features can be translated into the function of aesthetic satisfaction, which contributes to a service of providing enjoyment of natural areas. Thus, ecosystem services represent the benefits that populations obtain from the structure and processes of ecosystems (Costanza et al., 1997; de Groot, et al., 2002).

The Millennium Ecosystem Assessment (2003) has divided the ecosystem services into three categories that directly affect humans, i.e. provisioning services, cultural services, and regulating services. Additionally, a fourth category that maintains the former three is defined as supporting services (see figure 1). Within each category a series of goods and services, for simplicity called services, are grouped e.g. food, water, climate regulation, sense of place, and so on.

Different ecosystem functions have the capacity of providing a diversity of services. For instance lake ecosystems have several functions, such as those mentioned by Constanza et al. (1997) and de Groot et al. (2002):

- Habitat function for a variety of species
- Regulation functions such as water supply
- Production function, such as food and ornamental resources
- Information functions, such as recreation and (eco) tourism, aesthetic, spiritual, cultural, scientific and educational information.

Most human communities living around lakes deeply depend on their biodiversity and natural processes for provision of water, food and way of life (LakeNet, 2004). Additionally, aesthetic and recreational aspects can make the lake ecosystems a tourist attraction.

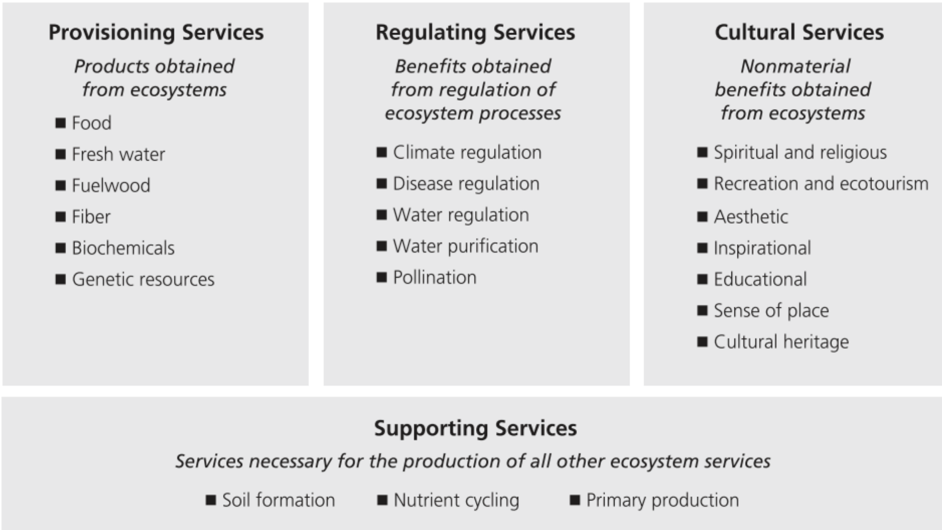


Figure 1. Services provided by Ecosystems, (most important lake ecosystem services are shown highlighted) source: Millennium Ecosystem Assessment (2003)

As population grows the demand for ecosystem services increases. Consequently, human actions such as the overexploitation of the services are reducing the capabilities of the ecosystems to meet those demands (Millennium Ecosystem Assessment, 2003). Such actions may temporarily support local livelihood although they might become unsustainable and endanger future generations' well-being. Moreover, the intensification of actions to increase the supply of a particular service may also impact other services, some not entirely recognized by local communities surrounding them (see figure 2). Negative impacts (e.g. harmful behaviour such as overfishing) may continue unless proper institutional change is achieved (Daily et al., 2009).

In this context, environmental policies formulation with the direct participation of stakeholders can enhance the contribution of ecosystems to human well-being and reduce the negative impacts (Farber et al., 2002). For this purpose, it is important to identify the stakeholders that benefit from ecosystem services. Hein et al. (2006) has defined stakeholders as "any group or individual who can affect or is affected by ecosystem services". Therefore the ecosystem services determine and are determined by relevant stakeholders.

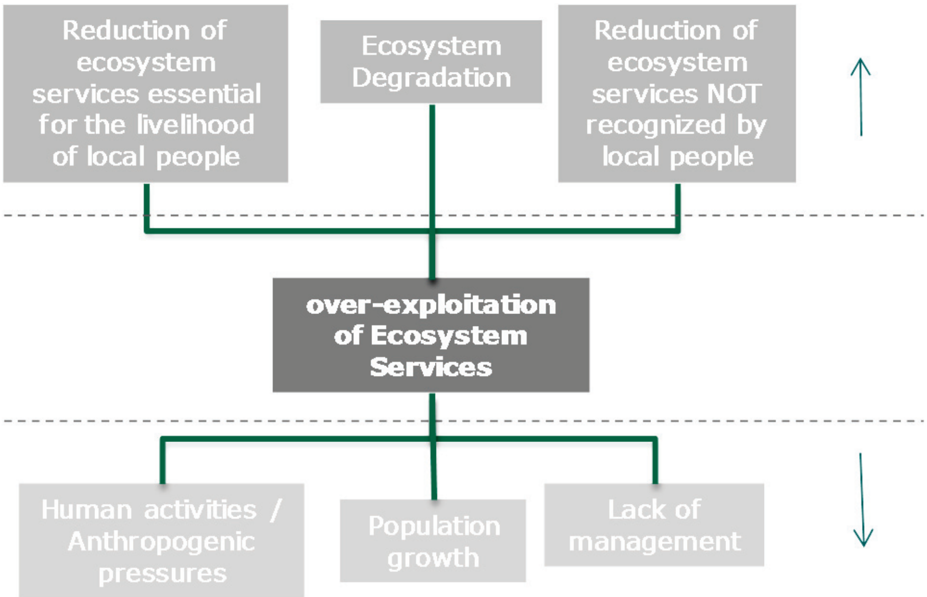


Figure 2. Overall Problem analysis

To support decision-making, researchers are contributing to increase the knowledge on ecological and social systems and understanding the factors that cause changes in ecosystems and their services. For instance, to assess the services provided by an ecosystem, it is important to understand people's behaviour and perception of the service provided. Usually people perceive the condition of an ecosystem in relation to its ability of providing the services required (Millennium Ecosystem Assessment, 2003). Moreover, some services condition e.g. provisioning or cultural services depend heavily on the direct and indirect human use (Hein, et al., 2006). Thus, different methods and measures have been developed to assess ecosystem service conditions.

Approaches for ecosystem services valuation

Ecosystem valuation represents the process of allocation of values for ecosystem goods and services (Farber, et al., 2002). In other words, ecosystem services provide the basis for ecosystem valuation (Hein, et al., 2006). In this context, Constanza (2003) defines valuation as the contribution of goods and services to meet user-defined goals, objectives or conditions. These goals may range from economic goals, e.g. efficiency, to social goals, e.g. social fairness or ecological sustainability.

Different disciplines analyze valuation concept in different ways (i.e. approaches) depending on their value systems. Value system refers to "the norms and precepts that guide human judgement" (Farber, et al., 2002). In this sense, it is important to differentiate two concepts of value, instrumental or use-value as the utilitarian concept and existence or non-use value as the non-utilitarian concept which includes ecological, socio-cultural and intrinsic values (Farber, et al., 2002; Millennium Ecosystem Assessment, 2003).

Under the utilitarian approach, the links between services and human societies are studied, valuing the specific usefulness people derive from services (Farber, et al., 2002; Hein, et al., 2006). In other words, it considers the specific utility and benefit human communities get from ecosystem services (directly or indirectly) as well as the human activities that in turn affect the ecosystems and the supply of services (Millennium Ecosystem Assessment, 2003). This approach usually measures the value only in economic terms, to be included in spatial planning for environmental management and conservation.

The non-utilitarian concept of value establishes that ecosystems have values irrespectively of human satisfaction (Costanza, 2003; Farber, et al., 2002; Millennium Ecosystem Assessment, 2003). Different cultural, ethical and religious communities have value systems that support the maintenance of ecosystems' rights to a healthy and sustaining condition. In this sense, ecosystem services are valued because they contribute to the preservation of the integrity of the ecosystem itself (Farber, et al., 2002).

Increasingly researchers (de Groot, et al., 2002; Farber, et al., 2002; Hein, et al., 2006; Millennium Ecosystem Assessment, 2003; Turner et al., 2003) are discussing and studying integral approaches that include utilitarian and non-utilitarian values of ecosystem services (see example of framework figure 3). Problems found so far are related to the difficulties on aggregating values leading to double counting during the valuation process (Hein, et al., 2006; Millennium Ecosystem Assessment, 2003; Turner, et al., 2003). In this sense, economical methods and measures are the most developed and commonly used for the valuation within scientific literature (Hein, et al., 2006).

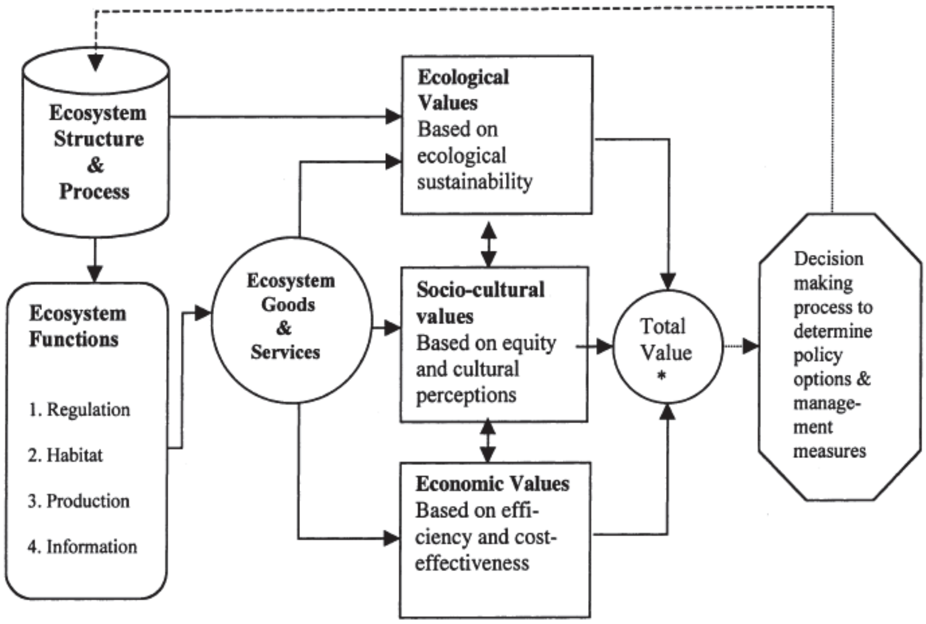
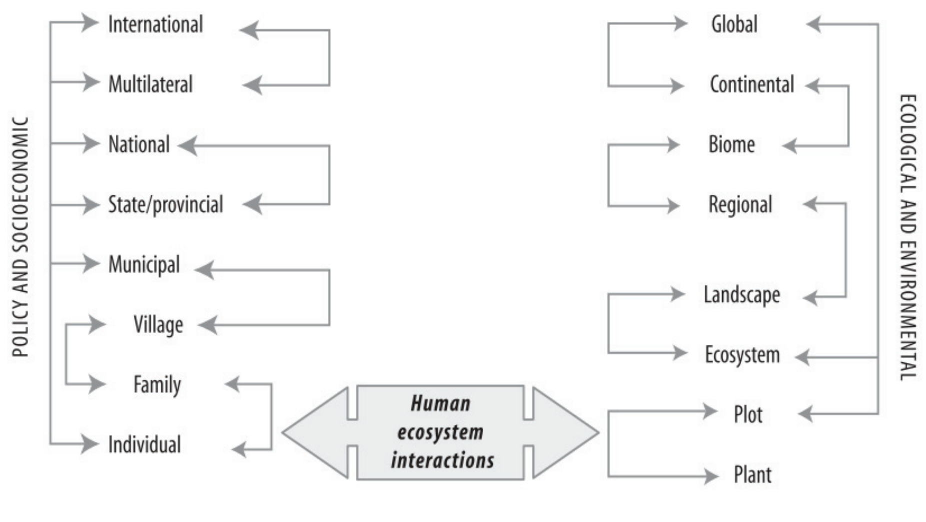


Figure 3. Framework for integrated assessment and valuation of ecosystem functions, goods and services (de Groot, et al., 2002)

However, recent research has included other types of measures based on the work done by Rolston and Coufal (1991), i.e. *Social Values* (Alessa et al., 2008; G. Brown, 2005; G. Brown et al., 2002; Gregory Brown et al., 2004; Bryan et al., 2011; Bryan et al., 2010; Duguma et al., 2011; Sherrouse et al., 2011). They refer to the values that people attach to the services provided by an ecosystem according to their relative importance. The aim of this social valuation is to measure the diversity of benefits humans get from the ecosystem and the reasons behind them. The inclusion of social values in spatial planning plays an important role in determining the importance of ecosystem to human societies (Bryan, et al., 2010; de Groot, et al., 2002).

Accordingly a theory proposed by Norton and Hannon (1997), environmental values place-based theory, suggests that social values (so-called environmental values) are largely influenced by the "sense of place", which refers to a type of attachment or emotional connection that people develop with a place (Williams et al., 1998). Subsequently, this theory was tested by Brown et al. (2002), in a case study in Alaska. The findings suggest that social values are not uniformly distributed across the ecosystem and that there are spatial relationships between the social values and the place of residence.

Ecosystem services are provided at different spatial and temporal scales, varying from short term, site level to long term, global level (Hein, et al., 2006). Moreover, Leemans (Millennium Ecosystem Assessment, 2003) recognizes there are interactions between these scales, so-called ecological scales, and institutional levels, where decision-making takes place (see figure 4). Therefore to support decision-making, it is important during valuation process to determine the scale at which the ecosystem service is delivered which in turn will determine the stakeholders that affect and are affected by the service (Hein, et al., 2006). Moreover, Hein et al. (2006) sustain that identifying stakeholders and scales can provide insights on management conflicts, e.g. between services relevant for different stakeholder levels.



Source: Courtesy of Rik Leemans.

Figure 4. Ecological scales and Institutional levels interactions, source: Rick Leemans, (Millennium Ecosystem Assessment, 2003)

Mapping ecosystem services and values

Valuation of ecosystem services requires the definition of the boundaries of the ecosystem itself (Costanza, et al., 1997; Hein, et al., 2006). The ecosystem under study may include other (sub-) ecosystems (Hein, et al., 2006).

Increasingly, scientific research is studying methods for mapping ecosystem services and finding spatial indicators to assess the ecosystem. Generally, scientific literature is focused on mapping ecosystem services using monetary terms with methods such as *Value Transfer* (Baral et al., 2009; Troy et al., 2006).

Other measures for mapping such as spatially explicit social values are gaining interest. There are different approaches for social valuation mapping of ecosystem services, e.g. multi-criteria analysis, gap analysis for conservation planning and "hotspots" identification (G. Brown, 2005). In this sense, social hotspots are defined as areas of spatial coincidence of multiple indicators.

Multi-criteria analysis (MCA) is a decision-support tool for assessing complex problems with quantitative and / or qualitative aspects that need to be addressed and combined during the decision-making process (Mendoza et al., 1999). Additionally, MCA includes three major conceptual tools, namely Principles, Criteria and Indicators, see example table 1, based on the present research: Based on fundamental principles of ecosystem sustainability, criteria for valuation of its services can be identified and information added through the indicators that can reflect the status of the criteria.

PRINCIPLE	***CRITERIA***
For Ecosystem sustainable management to take place (Mendoza, et al., 1999): P1. Ecosystem integrity / condition is maintained P2. Human well-being components are assured (security, basic material for good life, good social relations)	To assure human well-being it is important to measure: C1. The ability of the ecosystem to provide the services required C2. The possibility of interaction of human societies with the services provided.

Table 1. Conceptual tools for MCA assessment to be applied on this research

Among the different MCA spatial tools, fuzzy logic had been applied in a diversity of studies within the environmental field, e.g. air pollution assessment (Fisher, 2003), environmental impact assessment (Peche et al., 2009), and most recently for ecosystem service flows modelling and the hydroelectric sector (Locatelli et al., 2011).

Fuzzy sets are defined as a class of objects which in the real physical world do not have precisely defined criteria of membership (Zadeh, 1965). This notion can perfectly fit in the ecosystem services assessment considering that services are often unevenly distributed along the ecosystem, i.e. spatial heterogeneity (Hein, et al., 2006; Locatelli, et al., 2011), and that there are different criteria (quantitative and / or qualitative) that should be combined for the assessment. The spatial distribution of services supply may improve the analysis of potential conflicts in ecosystem management, e.g. difference in services' priorities for different stakeholders (Hein, et al., 2006; Troy & Wilson, 2006).

Priority management areas for ecosystem services have been studied recently through the social values perspective and are called *Social Hotspots* (Alessa, et al., 2008; G. Brown, 2005; Bryan, et al., 2010; Reed et al., 2003). Social hotspots are defined as areas of spatial coincidence of high valued areas for multiple spatial indicators (Bryan, et al., 2010). Different combinations of criteria for the identification of hotspots' mapping have been assessed by these studies, e.g. social values and ecological values, or social values with multiple spatial indices from ecological science.

So far the studies aforementioned have used similar methods for mapping ecosystem services focusing on the location of the values but not necessarily reflecting biophysical aspects of the ecosystem. Thus, limitations had been found related to the method accuracy and reliance on respondent geographic knowledge and familiarity (Alessa, et al., 2008; G. Brown, 2005). Recommendations suggest that further research should be oriented on improving and developing new methods that better reflect the ecosystem attributes and improve the accuracy of valued areas. Thus it is relevant to improve the method reflecting ecosystem features in relation to the scale at which the services are provided and targeting other relevant criteria that do not only reflect the stakeholder's perception of values (social values) but also the spatial relationship (interaction) between people and the ecosystem service under valuation (e.g. accessibility to service).

1.2. Research problem

Ecosystem services demand is increasing due to different factors such as population growth, harvest and resource consumption, land-use change (Millennium Ecosystem Assessment, 2003). For instance fisheries worldwide are declining due to overfishing. Moreover, MA (2003) recognizes that human pressures to increase the provision of services, have led into the change of other equally important services, some not entirely recognized by local communities, such as regulation and cultural services. Simultaneously, local livelihood depends heavily on the provision of these services.

Ecosystem research is contributing towards increasing the knowledge on the services provided by the ecosystem, scales of provision, approaches for valuation, services distribution and beneficiaries, just to mention a few. Progressively more studies are exploring mapping approaches for the valuation process as a support tool for ecosystem management, allowing (as stated earlier) the analysis of the spatial distribution and heterogeneity of the services across the landscape.

In this context, economical approach has received a lot of attention by different researchers and decision makers giving important guidelines for resource allocation (Hanley et al., 2009; Zhang et al., 2005). One of these studies (Chiabai et al., 2011) provides interesting outcomes about the key ecosystem services of biomes worldwide. Among its findings, cultural services (e.g. ecotourism opportunities) are considered as one of the most valued services after carbon stock and provisioning services.

On the other hand, more recent studies have argued that economical valuation has several deficiencies in the social and ecological contexts, affecting the sustainability and management of ecosystem services (Duguma & Hager, 2011; Kijazi et al., 2010; Sherrouse, et al., 2011). Increasingly researchers are interested in the assessment and mapping of social values. The reason behind it is that this assessment considers the stakeholders´ valuation perspective. Moreover the inclusion of social values in spatial planning can guarantee the engagement of stakeholders in the process (Bryan, et al., 2010).

Therefore it is relevant to contribute to ecosystem research by studying mapping approaches to assess the ecosystem services using spatial indicators such as social values which incorporate the beneficiaries' perspectives. The assessment of the social values that stakeholders put into the services can provide relevant information for the management of the services. Additionally, the incorporation of pertinent criteria describing the spatial relationships stakeholders-ecosystem is expected to provide insights in ecosystem services valuation and hotspot identification for management.

1.3. Research objective

1.3.1. General objective

Assess and map the main ecosystem services social hotspots according to the values assigned by stakeholders (i.e. valued service) and the spatial relationship people-ecosystem (i.e. access to service).

1.3.2. Specific objectives

1. Assess and map the spatial variation of the ecosystem services values.

2. Identify whether significant relationship between stakeholder group and values perceived exist.

3. Assess and map social hotspots to indentify high priority areas for management.

1.4. Research questions

Q1. What are the most important services provided by the ecosystem and what are the values stakeholders identify related to each service?

Q2. Is there any significant relationship between the stakeholder group and the values perceived?

Q3. Which criteria could be used to visualize the spatial variation of values of the services across the study area?

Q4. What is the approach to be used to combine the criteria to identify social hotspots?

2. Concepts and Definitions

2.1 Provisioning and Cultural Ecosystem Services

First, two terms need to be clearly defined for the purpose of this study:
Ecosystem, defined by Likens (1992) as, "the individuals, species and populations in a spatially defined area, the interactions among them, and those between the organisms and the abiotic environment". Following this definition Doing (1997) sees landscapes as ecosystems, defining them as "a complex of geographically, functionally and historically interrelated ecosystems".
Ecosystem boundaries, "the spatial delimitation of an ecosystem, typically based on discontinuities in the distribution of organisms, the biophysical environment (soil types, drainage basins, depth in a water body), and spatial interactions (home ranges, migration patterns, fluxes of matter)" (Millennium Ecosystem Assessment, 2003).
Ecosystem features are site-specific characteristics of a natural resource system (e.g., soil, ground cover, and hydrology) that establish its capacity to support various ecosystem functions. (King et al., 2000).

Provisioning services are "the products obtained from ecosystems, including, genetic resources, food, and fresh water" (Millennium Ecosystem Assessment, 2003). In the lake ecosystem the most important product provided is the fish as a basic material for good life followed by the water. To value these services it is essential to recognize that the local stakeholders are often the most important because they are the ones that harvest the resources (Hein, et al., 2006).

Cultural services are "the nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experience"(Millennium Ecosystem Assessment, 2003). Moreover the benefits people obtain from the cultural services mainly depend on the experiences during visits to the area, as well as indirect experiences and more abstract considerations (e.g. pictures of the area and natural heritage respectively). Therefore the assessment of these services require the analysis of the people benefiting from this service and the interaction with the ecosystem involved (Hein, et al., 2006). It has been stated that ecotourism opportunities may provide incentives to local people for the maintenance of cultural services (Millennium Ecosystem

Assessment, 2003). Nevertheless in this type of services beneficiates different levels of stakeholders which range from individual to international level (Hein, et al., 2006).

2.2 Valuation of Ecosystem services

MA (2003) defines valuation as "the process of expressing a value for a particular good or service in a certain context (e.g., of decision-making) usually in terms of something that can be counted, often money, but also through methods and measures from other disciplines (sociology, ecology, and so on)".

Valuation of ecosystem services is considered as an essential approach to assist the assessment of different alternatives for ecosystem management. Among the reasons to carry out the valuation of ecosystem services, the following are the most frequents (Millennium Ecosystem Assessment, 2003):

- To assess the overall contribution of ecosystems to human well-being
- To understand the use of ecosystems by stakeholders
- To assess the positive and negative impacts of different alternatives for ecosystem management

Conventional methods such as *Observed Behaviour Methods*, *Hypothetical Behaviour Methods* and *Benefit Transfer Methods* include the economical valuation (Millennium Ecosystem Assessment, 2003). *Observed behaviour Methods* make estimates of the value of ecosystem services according to the observed behaviour of producers and consumers. This behaviour is examined in actual or surrogate markets, i.e. on the actual ecosystem service or on a substitute market which is assumed to have a relation with the ecosystem service value. *Hypothetical Behaviour Methods* infer the value from people answers to questions related to hypothetical markets or situations. Within this category, measures such as willingness to pay (WTA) or willingness to accept (WTA) are used to estimate the value. Finally, *Benefit Transfer Methods* uses the estimates of a value from one context to obtain the estimates in another context with similar characteristics. This method was used by Troy and Wilson (2006) to develop a decision framework for spatially explicit value transfer.

More recent methods have added another measure for the valuation of services, i.e. social values. It refers to the values that stakeholders attach to the ecosystem services according to their perception and categorize them according to their relative importance (see the typology of values in table 3). The social valuation bases its notion on the fact that humans value ecosystems for different benefits not necessarily restricted to economical ones (G. Brown, 2005; Rolston & Coufal, 1991). Additionally Brown (2005) continues mentioning that multiple values may range from instrumental values (e.g., places that provide sustenance, use values) to symbolic values (e.g. places that represent ideas, non-use values).

No.	***VALUE***	***DESCRIPTION***
1	Economic	Areas valued because they provide economic opportunities such as fisheries, tourism, or processing
2	Subsistence	Areas valued because they provide necessary food and materials to sustain people’s lives
3	Aesthetic	Areas valued for the scenery—mountains, glaciers, forests, beaches, tidelands, bays and islands
4	Biodiversity	Areas valued because they provide places for a variety of plants, animals and wildlife
5	Cultural	Areas valued because people can continue to pass down wisdom, traditions, and a way of life
6	Future	Areas valued because they allow future generations to know and experience the areas as they are now
7	Historic	Areas valued because they are places and things of natural and human history
8	Learning	Areas valued because we can learn about the environment
9	Recreation	Areas valued because they provide places for outdoor, recreation activities and experiences
10	Spiritual	Areas valued because they are sacred, religious, spiritually important
11	Therapeutic	Areas valued because they make people feel better, physically and/or mentally

Table 2. Typology of values used for the services social valuation based on previous studies (Alessa, et al., 2008; G. Brown, 2005; Bryan, et al., 2010) and adapted for this research

Different studies have proposed frameworks for the valuation and mapping of ecosystem services, some using economic methods (Fisher et al., 2011; Troy & Wilson, 2006) and some using social methods (Alessa, et al., 2008; G. Brown, 2005; Bryan, et al., 2011; Fagerholm et al., 2012; Sherrouse, et al., 2011). Some of these studies, have their basis on the framework proposed by Hein et al. (2006) which considers the following basic steps of the analysis:

a. Specification of the boundaries of the ecosystem to be valued;
b. Assessment of the ecosystem services supplied by the system;
c. Valuation of the ecosystem services;
d. Aggregation or comparison of the values of the services.

2.2.1 Mapping Social values

In recent years the social valuation has become notably attractive for conservationists and researchers. Different approaches are trying to identify methods for quantifying and mapping social values. For instance, one study considers the spatial distribution of social values and enables the combination with economic and environmental data. (Bryan, et al., 2011). Another approach, software-oriented, has developed a GIS application to quantify, spatially explicit social value metrics in the analysis (Sherrouse, et al., 2011).

A recent and novel approach (Bryan, et al., 2011) proposes the use of spatial indicators from ecological science to map the social values and identify management priorities. The spatial indicators of abundance, diversity and risk (see table 4) were adapted to assess the services provided by natural and agricultural landscapes.

This study argues that most of scientific literature on social valuation of ecosystem services has been based on identifying areas where the values are abundant. Thus the areas highly valued are the ones where most of the values are concentrated. Nevertheless other indicators, such as diversity indicator, i.e. concentration of diverse values, or risk indicator, i.e. concentration of conflicting values from multiple stakeholders may assist and support ecosystem management. In this case, social hotspots are defined as areas of spatial coincidence between management priorities for multiple indicators (Bryan, et al., 2010). For example, a specific area where diverse social values are ranked by people as the most important (e.g. aesthetic, economic, recreation and biodiversity values), will be spatially represented as an area with “abundant” and “diverse” positive values; hence this area can be defined as a social hotspots for management priority.

SPATIAL INDICATOR	*DESCRIPTION*	*CALCULATION*
ABUNDANCE INDICATOR LAYER	Highly valued areas by participants	Overall magnitude of values calculated by summing spatially explicit intensity scores (total number of positive values)
DIVERSITY INDICATOR LAYER	Different values in the same area	Shannon Index, areas of high diversity of values across the 2 services
RISK INDICATOR LAYER	Parts where there is abundant social values and abundant threats	Spatial coincidence of values and threats

Table 3. Typology of spatial indicators used for social valuation (Bryan, et al., 2010)

2.3 Conceptual diagram of Ecosystem Services assessed

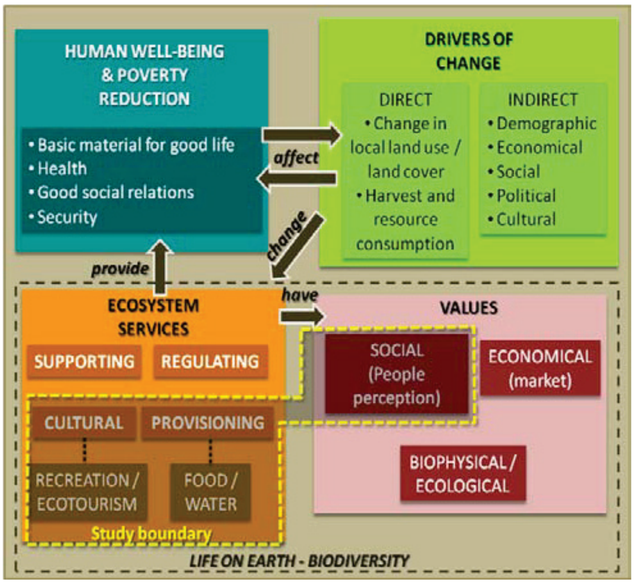


Figure 5. Conceptual Framework adapted for this study, from Millennium Ecosystem Assessment Conceptual Framework

The diagram (figure 5) represents the context in which ecosystem services interact. Different factors (e.g. demographic, economic) change the ecosystem hence the services provided, which affect human well-being. Cultural and provisioning are two of these services that will be assessed through their social values.

3. Materials and Methods

3.1 Study Area

Lake Bosomtwe is situated in the south-eastern part of Kumasi, capital city of the Ashanti Region (see figure 5). Lake Bosomtwe in Ghana is the only natural lake in the country and it was formed by a meteorite impact over a million years ago.

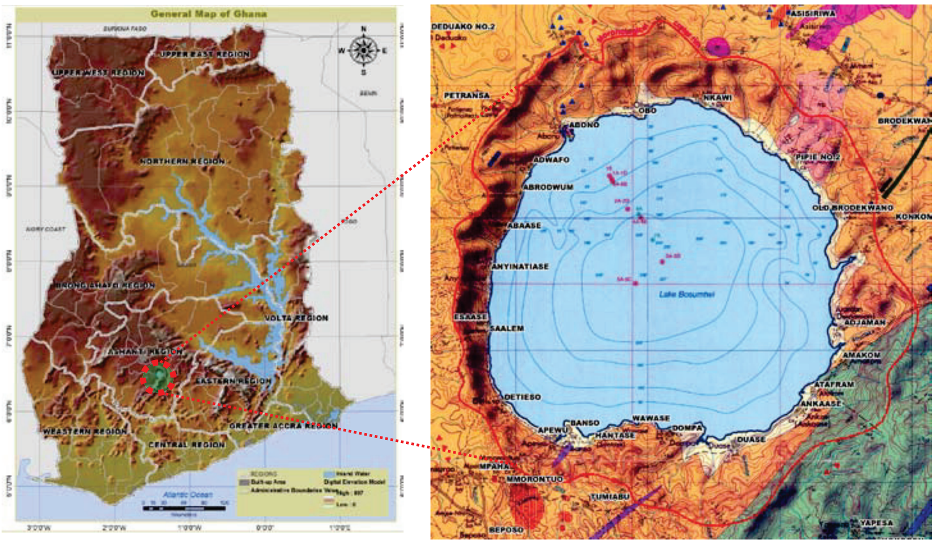


Figure 6. Location of study area, Lake Bosomtwe, Ghana

The average diameter of the crater is 10.5 kilometres. Additionally the hills reach altitudes of over 600 meters. The lake itself has an average diameter of 8.5 kilometres and 76 meters depth approximately. The main source of water entering Lake Bosomtwe is rainwater flowing inwards from the crater rim. There is also some water from streams. There are no rivers flowing out of the lake.

It is a hydrologically closed basin, meaning that the water stays inside the basin, and there are no in and outflows. All the inputs of the lake come from precipitation with an estimated 80% from direct precipitation to the lake surface (Otu, 2010). The lake ecosystem encompasses a semi-deciduous forest and lately an increasing cropland. For many years, Bosomtwe has been the principal source of income (particularly fishing) for local communities surrounding the lake. Simultaneously the area is well known as a touristic attraction for its natural beauty and surrounding rainforest. Additionally, due to its ancient history it has also been an important site for scientific research.

The population around the lake is approximately 30,000 inhabitants. There are 22 communities surrounding the lake. For many years the only source of income has been the fishing. Nevertheless with the growing population farming has become more and more important. In fact, the lower parts of the hills have been converted into farmland, exposing the ground to erosion and degradation of the soils. Nowadays local people are facing substantial problems caused by overfishing and inadequate farming methods. There are 11 known species of fish in the lake, including one endemic cichlid (Tilapia discolours). Nevertheless these days, people are only catching 5 different types of fish.

Figure 7. Type of fishes found on the study area, Lake Bosomtwe, Ghana

The lake has become a popular touristic destination having both natural and cultural resources as principal attractions. As part of the Bosomtwe development goals, the District is enhancing tourism potential, improving infrastructure to attract tourist operators. Simultaneously NGOs are supporting local communities for the development of ecotourism related projects.

3.2 Materials

The data used in this research comprises vector and raster data from primary and secondary sources (see table 4). Spatial data were collected during the fieldwork phase.

The software used comprise ArcGIS® as the main software for all the processes concerning ecosystem services mapping, SPSS® used for descriptive and inferential statistics and IDRISI® for the image classification and accuracy assessment.

DATA COLLECTED
1) Data from Survey and Observations on the field a. Questionnaires/map exercise b. Point observations c. Interviews with local authorities
2) Spatial data provided by the Faculty of Renewable Natural Resources, Kwame Nkrumah University Of Science and Technology (KNUST), vector data 1/50 000: a. Roads b. Rivers c. Settlements (point and polygon data) d. Contours e. District limits f. Additional data from Information Centre at Abono, i.e. Touristic map 1/50 000 (produced by the NGO Friends of Lake Bosomtwe in cooperation with KNUST, 2006) and Lake Bosomtwe information booklet (Ofosu, P.E. 2006)
3) Digital Elevation Model (DEM) 30 meter spatial resolution
4) ASTER L1B (15 m resolution) acquired on July 2007
5) Geological Map 1/50,000 (Geological Survey of Austria 2005)
6) Topographic map sheets 1/50,000
7) Additional information such as images from Google Earth

Table 4. Data collected

3.3 Methods

To be able to assess and map ecosystem services, this study based its assessment on the 4 basic steps from the framework develop by Hein et al. (2006) and adapted for the research objectives:

A. Definition of the boundaries of ecosystem to be valued
B. Identification of the most important ecosystem services supplied by the system according to stakeholders (i.e. beneficiaries of the services)
C. Identification of criteria for the valuation of the ecosystem services
D. Combination of criteria to define the social hotspots.

The general flowchart of this study is shown in figure 8.

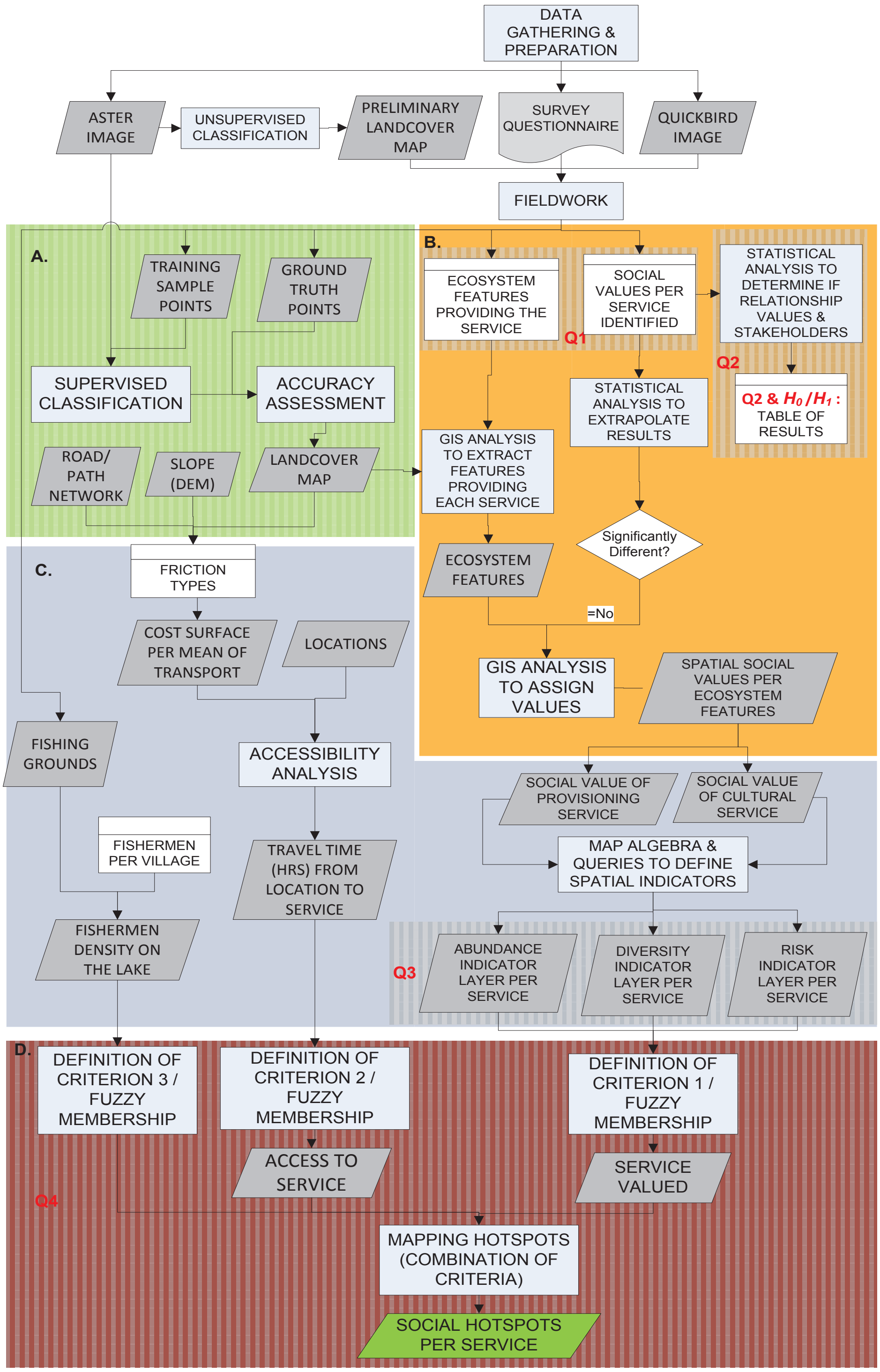


Figure 8. General Flowchart of the Overall Method

3.3.1 Fieldwork and Data Collection

The fieldwork activities were completed during the period of September- October 2011. They were mainly focused on collecting the following types of information:

- Identification of stakeholders and valuation of the most important ecosystem services according to stakeholders.
- Point data collection in the field from the location of services and related ecosystem features.
- Point data collection for the image classification to create a land cover map of the study area.

3.3.1.1 Identification of stakeholders and valuation of services

For the purpose of this research, the ecosystem was assessed at local level the two main groups of services that were identified as the most important for stakeholders are provision and cultural services.

To spatially locate the perceived values, the information was collected using questionnaires (see appendices 2, 3 and 4) coupled with a mapping exercise. This approach is based on the work done by Brown (2005) where stakeholders locate and weight the values and threats perceived from the ecosystem services. In this context perceived values refer to the values that stakeholders define as the most important. The threats refer to conflicting values perceived by different groups of stakeholders.

The target population in this study was defined as the stakeholders that directly benefit from any of the provisioning and cultural services provided by the lake Bosomtwe. Stakeholders benefiting from provisioning services are from the local level (i.e. people from villages surrounding the lake); while stakeholders benefiting from cultural services range from local to international level. Therefore two main groups of stakeholders were defined according to the service valued:

G1. Local communities for provisioning services valuation.
G2. NGO, researchers, tourists and tourist operators for cultural services valuation.

The sampling method for the participants' selection (interviews) was based on stratified sampling, according to the stakeholder groups mentioned above. The number of participants interviewed from G1:

- Local communities (60 including fishermen, farmers, and fishmongers);

The number of participants interviewed from G2:

- Tourists (18 including nationals and internationals)
- Tourist operators (the three existing ones from the local communities)
- Researchers (4 that had been working on the lake from KNUST university)
- NGO ('Friends from the Earth' that has been working for many years with the communities surrounding the lake).

Tourists, tourist operators and researchers were randomly selected (at the site and the university respectively). Then, from the two NGOs identified, working directly at the lake, one of them was could be interviewed.

Additionally, local authorities were interviewed (most of them from the Forestry Commission). These interviews were used to understand their point of view on the services provided but were not used on the valuation of services.

Sub-strata were used to sample local people from different villages. It was based on the village levels of development e.g. in terms of tourism and village accessibility by roads. The rationale behind it is that the social valuation is based on people perception, which might vary according to the village situation.

The villages selected were the following:

- One village in the touristic site, i.e. Abono which according to a study (Amuquandoh et al., 2007) is the most developed in tourism related activities and accessible by different means of transport (type of road: secondary road).
- One community on the east side of lake shore, opposite side of the touristic site, i.e. Pipie No.2, accessible by 4x4 cars / boat but mainly foot (type of road: track)
- One community on the south side of the lake shore, i.e. Banso, only accessible by boat or foot.

The typology of values used was based on previous studies (Alessa, et al., 2008; Bryan, et al., 2010; Rolston & Coufal, 1991) and adapted for this study (see table 2).

3.3.1.2 Ecosystem features identification

As stated earlier, the ecosystem valuation requires the identification of the ecosystem boundaries and its characteristics since the values are unevenly distributed across the landscape (Hein, et al., 2006;

Locatelli, et al., 2011). Thus, ecosystem features recognized by the stakeholders during the social valuation exercise were visited to collect their characteristics. For instance, data from the fishing grounds limits from 8 villages was collected. The rest of the fishing grounds per village were digitized using ancillary data to identify the boat slips per village. Additionally cultural services information e.g. preferred sites for natural or (eco) tourism opportunities was as well collected.

3.3.1.3 Fieldwork data collection for image classification

The scale of the ecosystem valued is local and the limits of the study area are defined by the crater rim (figure 6). The land cover provided information about the distribution of the services, which is directly related to the land cover.

Initially an unsupervised classification was performed on the ASTER image to identify four spectral groups in the data (i.e. clusters) to obtain a preliminary land-cover map for fieldwork. Additionally, sample points were selected through the stratified random sampling technique over the pre-defined clusters. Nevertheless due to the complex accessibility to some locations and the weather conditions only sixty points were visited. These points were subsequently divided into training sample points for the classification and ground truth points for the accuracy assessment. Four main land-cover classes were considered essential for the assessment: water, forest, built-up areas and cropland areas.

3.3.2 Spatial Analysis

This phase consists on a series of procedures to process and analyze the data collected in the field to indentify the social hotspots per service see the overall method in figures 9 and 10. These were the steps followed:

A. Definition of the boundaries of ecosystem to be valued
B. Identification of the most important ecosystem services supplied by the system according to stakeholders (i.e. beneficiaries of the services)
C. Identification of criteria and indicators for the valuation of the ecosystem services
D. Combination of criteria to define the social hotspots.

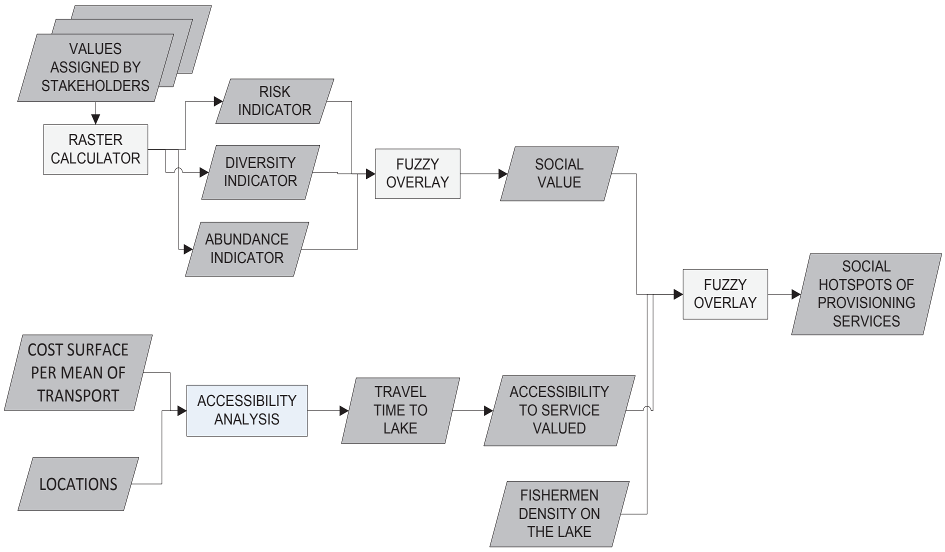


Figure 9. Flowchart to identify Social Hotspots for Provisioning Services

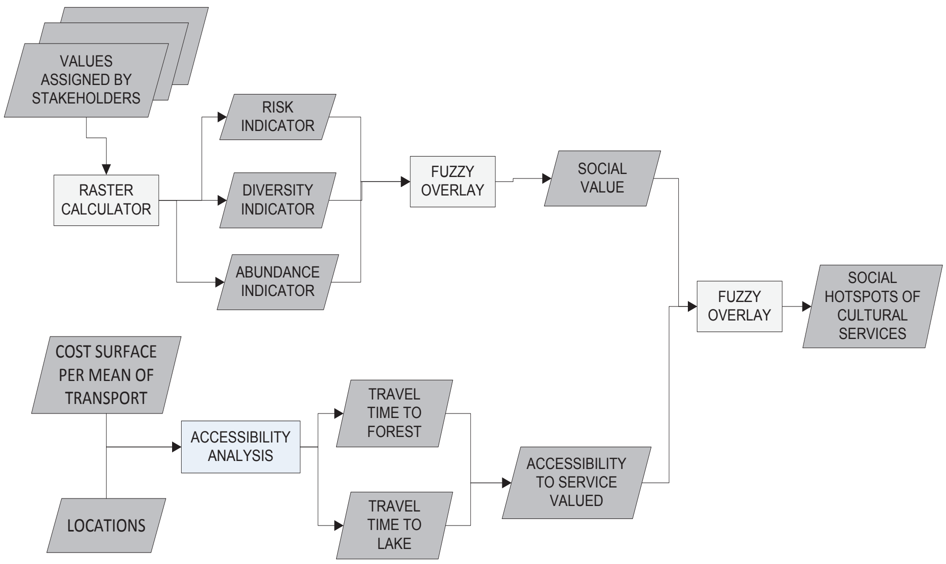


Figure 10. Flowchart to identify Social Hotspots for Cultural Services

3.3.2.1 Definition ecosystem boundaries

Land-cover mapping

To be able to identify the ecosystem features that contribute to the supply of ecosystem services, it was necessary to know the physical coverage of land. Land-cover map allowed the estimation values of services broken down by land-cover class. The procedure to create a land-cover map was based on remotely sensed image data, so-called image classification. It relies on the spectral distinctness of classes based on a per-pixel approach (Plummer, 2000). The method used was supervised classification testing two algorithms, i.e. minimum distance and maximum likelihood. The image used for this procedure was an ASTER Level 1B VNIR image data, i.e. visible and near infrared bands with 15 m spatial resolution (Land Processes Distributed Active Archive Center USGS, 2009). The land-cover classes of interest were four: water, forest, built-up areas and cropland areas.

The process considers four main steps:

- Definition of training areas, using the training sample points collected on the field plus ancillary data, i.e. Google Earth images.
- Creation of signatures for each class
- Classification, where each pixel is compared with class signatures and land-cover classes are assigned. Two classification algorithms were tested, in order to use the best according to the accuracy evaluation. The first one was "Minimum Distance to Means" is based on class means. This algorithm computes the mean distances for each unknown pixel and class membership is given according to the spectrally closest class. On the other had "Maximum Likelihood", similar at some point with the abovementioned algorithm, uses a probability function to compute the probability of a class to be correct for a pixel.
- Finally the evaluation of the classification accuracy uses independent sample points also collected previously on the field and reserved for this process.

3.3.2.2 Assessment of ecosystem services

After having the boundaries of the ecosystem, the land-cover map of the area, and additional data taken on the field, the next step considers the allocation of values per ecosystem feature identified. This procedure is based on the analysis of the spatial relationships between the services provided, the stakeholder benefiting from them, the social values allocated to the services and the ecosystem biophysical characteristics to which values were allocated (see the summary in table 5).

The ecosystem features were extracted from the information collected in the field during interviews with experts and local authorities, questionnaires with stakeholders' involved and additional communication with local people.

SERVICE	***STAKEHOLDER GROUP***	***VALUE***	***ECOSYSTEM FEATURE***
Provisioning	• Local communities	• Economic • Subsistence • Biodiversity	• Lake
		• Cultural	• Lake and lake shore
		• Future	• Lake
		• Historic	• Crater Rim (limit of the study area)
		• Learning	• Lake
Cultural	• NGO • Tourists • Tourist Operators • Researchers	• Aesthetic	• Lake and Forest
		• Biodiversity	• Forest
		• Cultural	• Lake and Lakeshore
		• Future • Recreation	• Lake and Forest
		• Historic • Learning	• Lake
		• Spiritual • Therapeutic	• Lake

Table 5. Allocation of values per ecosystem feature

Statistical analysis

Before being able to proceed with the analysis it was necessary to assess if the data collected from the villages selected was adequate and could be generalized for the entire area.

The statistical test used was *CHI Square* test because it was necessary to classify sample observations, i.e. participants' questionnaires, by more than one characteristic, i.e. values allocated and also because the information was mainly categorical, making this test suitable.

Thus two hypotheses had to be tested:

a. Ho (1): There is no significant relationship between stakeholder groups and values assigned by them. This hypothesis needed to be tested to prove if the data collected on the field, i.e. the relationship participants-values was found by chance, or if there was relationship.
b. Ho (2): There is no significant difference between the characteristics of the participants from different villages. This

hypothesis needed to be tested to decide if the data collected in three villages could be used for the other villages. In the case the Ho would be proved right the analysis could only be done using the three villages as three case studies.

3.3.2.3 Identification of criteria and indicators for the valuation of the ecosystem services

Definition of criteria for valuation

The criteria were defined using the conceptual tools from Multi-criteria analysis MCA (Mendoza, et al., 1999), i.e. principle, criteria and indicators, which made possible to build a consistent framework (see table 6). The advantage of MCA is that it has the capability to accommodate multiple criteria in the analysis. The process basis came from the information collected on the field and literature reviewed on similar topics. The principles were selected from study done by Mendoza et al. (1999), based on general principles from ecosystem sustainable management, i.e. ecosystem integrity and human well-being components assured.

The first criterion selected is the ability of the ecosystem to provide the services required. It was mainly based on primary data collected in the questionnaires and also literature reviewed (G. Brown, 2005; Costanza, 2003; Millennium Ecosystem Assessment, 2003). According to these studies, people’s perception on the value of a service is in relation to the capacity of an ecosystem to fulfil their needs. This criterion was measured using the indicator of social values, which reflects people valuation perspective.

PRINCIPLE	**CRITERIA**	**INDICATOR**
For Ecosystem sustainable management to take place (Mendoza, et al., 1999): P1. Ecosystem integrity / condition is maintained P2. Human well-being components are assured (security, basic material for good life, good social relations)	To assure human well-being it is important to measure: C1. The ability of the ecosystem to provide the services required C2. The possibility of interaction of human societies with the services provided.	To measure the ecosystem ability to provide the service required: I1. Social values assigned by stakeholders: • Abundance Indicator • Diversity Indicator • Risk Indicator Indicators extracted from (Bryan, et al., 2010) I2. Population density: • Fishermen density per fishing ground To measure the interaction of people with services provided: I3. Accessibility to services: • Cost travel time from source locations to service valued areas

Table 6. Conceptual tools for MCA assessment to be applied on this research

Social values were assessed according to three spatial indicators, i.e. abundance, diversity and risk indicators according to the equations in table 7. Thus, the indicators were computed using queries of spatial analyst tools. The final social values were defined by their overlay, where spatial coincidence between the three spatial indicators was found.

SPATIAL INDICATORS	DESCRIPTION	CALCULATION
ABUNDANCE INDICATOR	Highly valued areas by participants	Σ ALL VALUES (TOTAL ABUNDANCE) Σ ALL VALUES PER SERVICE
DIVERSITY INDICATOR	Different values in the same area	$P = \frac{\Sigma \text{ ALL VALUES PER SERVICE}}{\Sigma \text{ ALL VALUES}}$ Div= - Σ(P * LnP)
RISK INDICATOR	Parts where there is abundant social positive and negative values	Linear transformation (for transforming the values between 0 and 1) a) $\frac{Abundance - Abundance\ min}{Abundance\ \max - Abundance\ min}$ b) $\frac{Negative\ values - Negative\ values\ min}{Negative\ values\ \max - Negative\ values\ min}$ c) a*b

Table 7. Spatial indicators
(Bryan, et al., 2010)

The second criterion selected was the possibility of interaction of human societies with the services provided. The selection of this criterion was mainly based on literature reviewed and observations in the field from the relationship of people with their environment. Deichmann (Bigman et al., 2000) defined accessibility as "the ability for interaction or contact with sites of economic or social opportunity". One study (Thomas et al., 2009) has found a positive relationship between accessibility (i.e. travel cost) and the perceived usefulness of the resources, meaning that more accessible sites are more useful for people, especially locals.

In the actual research context, the first criterion is supporting the idea of spatial heterogeneity of values in the landscape, defining levels of usefulness of services to contribute to social hotspots mapping. There are different measures for the calculation of accessibility, e.g. simple distance measures (G. Brown, et al., 2002; Verburg et al., 2004) and travel cost measures used by studies to be compared with other accessibility measures (Verburg, et al., 2004) or to relate them with other indicators, e.g. poverty indicators (Ahlström et al., 2011; Thomas, et al., 2009). Verburg et al. (2004) proved in his study that travel time cost measures have stronger relationship with the land-cover than simple accessibility measures.

In this study, the accessibility measure used was the travel time cost. This term is defined by Verburg et al. (2004) as "the time it takes to reach a destination (village, road or market) from a location (field)". In this case, travel cost for provisioning services, was defined as the time it takes local people to access the area valued from their villages. For cultural services, different considerations were taken due to the multiple stakeholders involved, e.g. tourists and local communities, each group having different source locations, e.g. hotels, information centre of the lake and the villages respectively.

Besides source location and destinations, other data included in the analysis are slope, means of transport, road network and streams. The types of frictions, used in the calculation are presented on table 8. Due to the similarities between the travel speed during wet and dry seasons, the dry season travel speed was used in this study.

	TRANSPORT TYPE (according to literature)						***Observations***
Type of Friction	**FOOT (travel speed km/h)**		**BIKE (travel speed km/h)**	**CAR 4X4 (travel speed km/h)**		**MOTORBOAT (travel speed km/h)**	**PADUA[1] (travel speed km/h)**
	DRY SEASON	WET SEASON	DRY SEASON	DRY SEASON	WET SEASON	ALL SEASONS	ALL SEASONS
Secondary road	6	6	11	35	35	-	-
Track	3	3	10.5	7.1	5.3	-	-
Footpath	2	2	-	-	-	-	-
Slope 0-5%	1.00	1.00	-	-	-	-	-
Slope 5%-10%	0.96	0.96	-	-	-	-	-
Slope 10%-20%	0.82	0.82	-	-	-	-	-
Slope 20%-30%	0.65	0.65	-	-	-	-	-
Slope 30%-45%	0.50	0.50	-	-	-	-	-
Slope 45%-65%	0.41	0.41	-	-	-	-	-
Slope >65%	0.29	0.29	-	-	-	-	-
Lake	-	-	-	-	-	7	2.15
Streams	0.3	0.3	-	0.3	0.3	-	-

Table 8. Frictions according to means of transport / road network quality (Ahlström, et al., 2011; Toxopeus et al., 1992; Verburg, et al., 2004)

According to questionnaires and observations in the field, the means of transport for local communities is Padua (men) and foot (men and women).

[1] The Padua is the traditional boat that fishermen use as their mean of transport. Motorboats are only used for touristic purposes.

Stakeholders, with different interests such as visiting the area (e.g. for recreation / cultural activities) the main means of transport are foot and motorboat. Car within the area is rarely used due to the poor conditions of the roads and tracks, even though most of the external visitors arrived by car (taxi, bus or owned car). Thus, the types of transport assessed in this study were foot, motorboat and Padua.

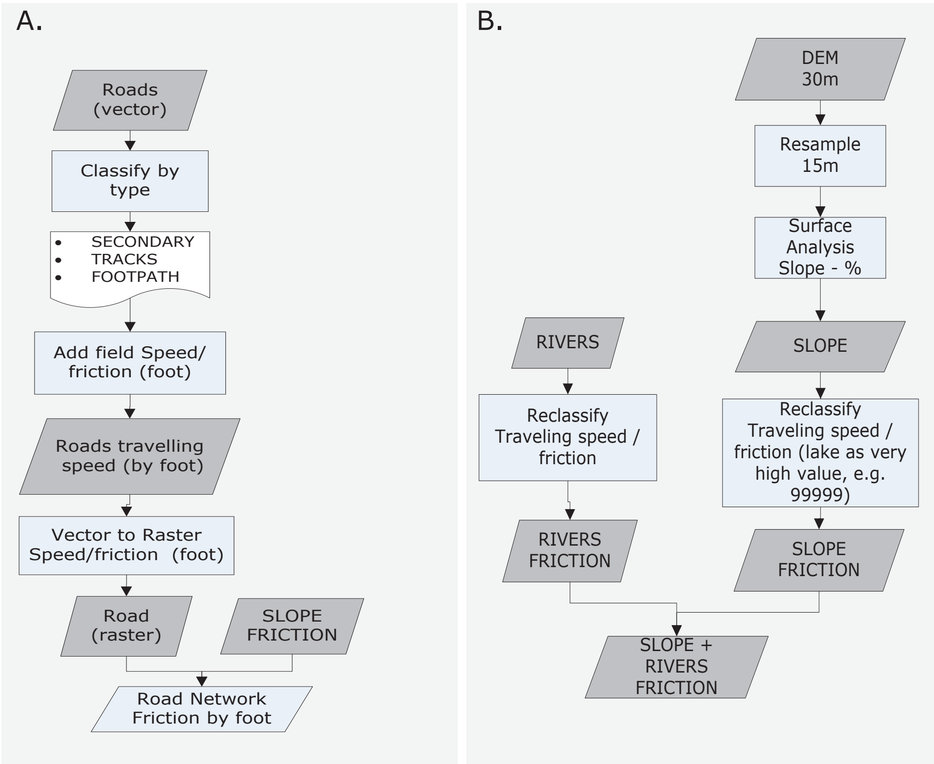


Figure 11. Flowchart of the allocation of frictions for A. Roads and B. Slope and streams

Travel cost method consists in a series of steps to combine the frictions per means of transport, according to the surface characteristics (e.g. slope, type of surface), from one source location to a destination. The initial step starts by converting all the vector data into raster, using the same cell size (in this case 15 m according to image resolution). Additionally the value assign to the raster was based on their friction type according to table 8.

Some data required more processing, e.g. the roads (see figure 11). Before converting them from vector to raster, the roads were classified by types (secondary roads, tracks and footpaths).

This typology was updated using ancillary data, in this case the touristic map of the area.

Other data, such as the DEM (see figure 11), required a surface analysis to convert it to slope (as a percentage) and then it was reclassified to assign the frictions according to table 8. The accessibility analysis carried out for the provisioning service is presented in figure 12; similar process was followed to assess the cultural services.

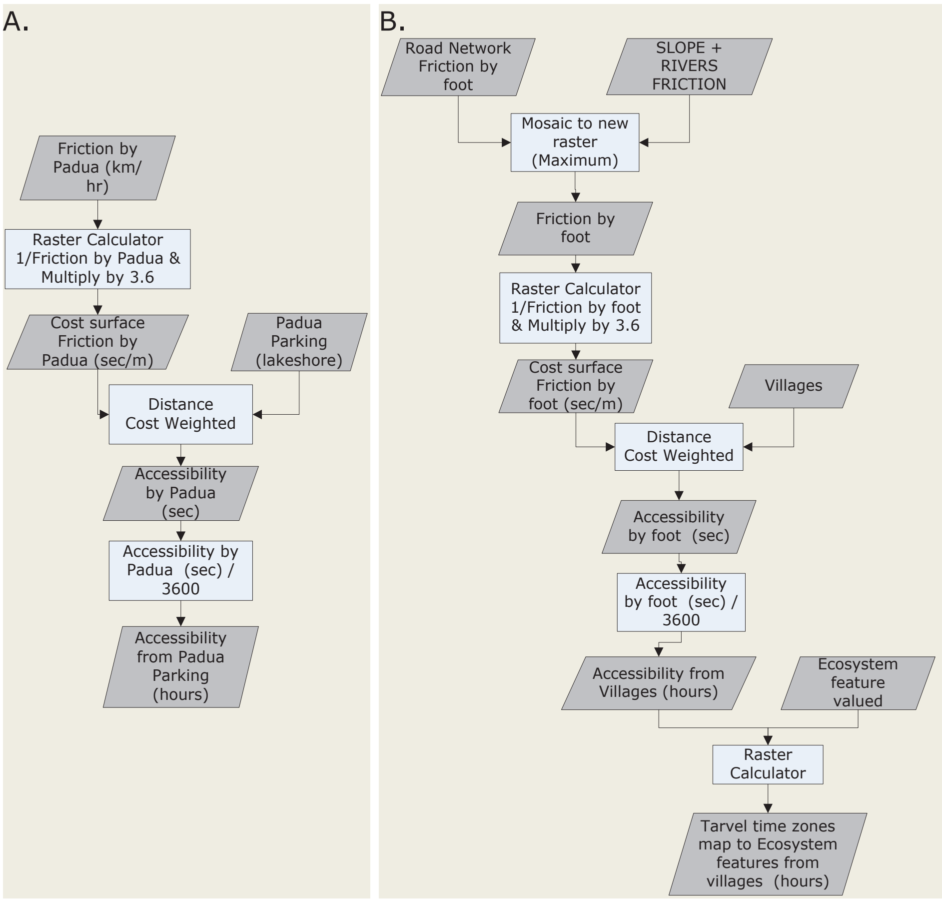


Figure 12. Summary flowchart of the accessibility analysis for Provisioning services (two means of transport, A. Padua and B. Foot)

One additional criterion was needed for the provisioning services, i.e. fishermen density. The definition of this criterion was mainly based on the observations on the field. Fishermen of Lake Bosomtwe prefer to fish at low depths.

In fact, according to locals, higher concentrations fish are found in depths above 15.24 meters. According to communications with researchers during interviews, the scientific reason behind it was that fish feed and breed in low depths, thus the concentration of fish is closer to the lakeshore. This fact creates high density of fishermen around these areas. Therefore limits for fishing are established per each of the villages from the lake shore to approximately 50 feet. Thus each village surrounding the lake has a fishing ground in front of it.

Actually, from literature reviewed (Bigman & Fofack, 2000; Verburg, et al., 2004) it was found that there is an accessibility measure related to population density called population potential. This measure adds the utility of a destination to the weighted distance from the destination (Verburg, et al., 2004). Accordingly the accessibility decreases with distance but increases with population size. Due to the equidistance from villages to fishing ground the results were very similar to the calculations of the travel cost. Therefore, only the density of fishermen per fishing ground was used as the third criterion for provisioning services.

3.3.2.4 Combination of criteria and comparison of the services valued

The combination of criteria was performed using fuzzy logic method. There are two basic steps in the method:

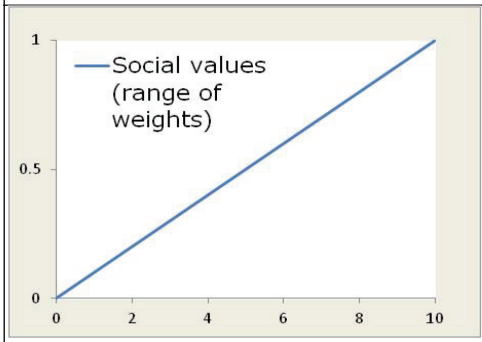
1. The selection of criteria which includes the criteria (table 9), indicators and constraints to build the fuzzy membership functions.
2. The combination of criteria required for defining the hotspots.

SERVICE	***CRITERIA***	***INDICATORS***
Provisioning service	The ability of the ecosystem to provide the services required	1. Social values per service 2. Fishermen density
	The possibility of interaction of human societies with the services provided.	3. Accessibility to service
Cultural Service	The ability of the ecosystem to provide the services required	1. Social values per service
	The possibility of interaction of human societies with the services provided.	2. Accessibility to service

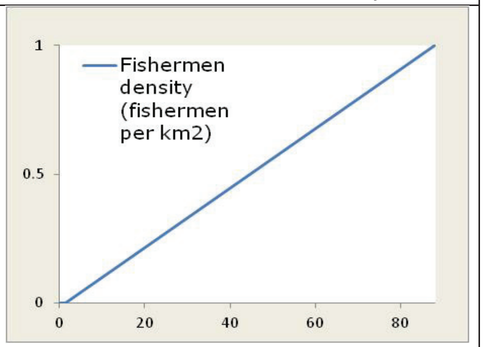
Table 9. Criteria for hotspot mapping per service

The membership functions of each indicator are shown in figure 13 and 14. These fuzzy memberships are linear functions, with a gradual transition from 0 to 1, where 0 represents no membership and 1 represents full membership. The selection of the linear membership function was based on the patterns of the data analyzed and literature review (Locatelli, et al., 2011), where fuzzy logic was used to define areas for forest conservation according to expert opinion.

13-a. Social value



13-b. Fishermen density



13-c. Local communities accessibility

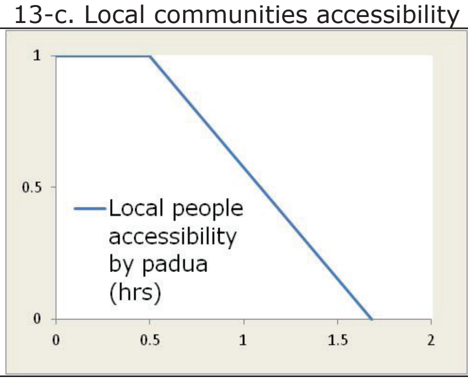


Figure 13. Fuzzy membership functions for provisioning service indicators

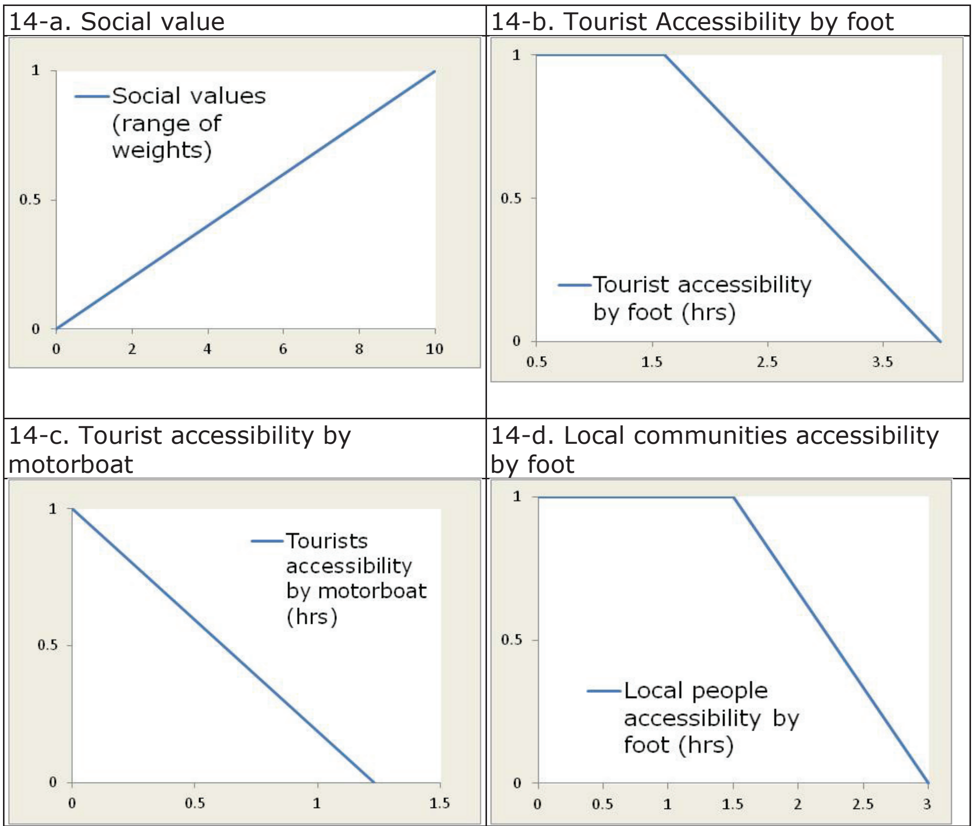


Figure 14. Fuzzy membership functions for cultural service indicators

The rationale behind the fuzzy memberships is based on the relationships of people and the ecosystem services, according to the analysis of the data collected from interviews, questionnaires and observations. For instance 13-c represents the accessibility patterns of local people to the valued area.

For the purpose of the study, it is fundamental to identify highly valued areas but also underestimated areas by specific groups of stakeholders. In the case of local communities, the highly valued areas are within the lake (near the lakeshore) whereas the forested areas are underestimated. This is because in terms of livelihood, cultural services do not represent relevant economic and subsistence benefits for them. Moreover, due to population growth, the most accessible areas had been transformed by the locals into farmlands, causing negative impacts on the forest and the whole ecosystem.

Consequently it was important to define what is “accessible” and “not accessible” for local people, looking into the accessibility patterns in cropland areas. This information helped to identify forested areas with equal access than cropland areas to contribute to build the social hotspots for cultural services. For fishermen density graph 1c, the information used was based on the density pattern on the lake. Same reasoning has been used for provisioning services social hotspots. In this case, fishing grounds overlap with recreational areas, thus these areas where identified by the risk indicator during the process of build these hotspots.

Tourist accessibility patterns, i.e. 14-b and 14-c, were assessed in terms of the time spent in the study area, and benefiting from the cultural services, based on the data collected on the field.

The overall criteria combination process is explained on the flowchart from figure 15. There are different combination for fuzzy variables, Fuzzy AND, Fuzzy OR, Fuzzy SUM and Fuzzy PRODUCT (Longley et al., 2005). Fuzzy AND produces a combination where the criterion with the lowest membership decides the total value of the combination. Fuzzy OR, opposed to the previous one, produces a combination where the highest criterion decides the total value of the combination. Fuzzy SUM produces a combination where the result has higher importance than the each criterion alone. In contrast, Fuzzy PRODUCT produces a combination where each criterion is more important than their combination. In this study Fuzzy Sum was the combination used because both criteria were consider equally relevant and complementary for the hotspots mapping. The formula used (1) by fuzzy overlay is presented below:

(1)

$$\text{Fuzzy Sum} \quad 1-\prod_{i=1}^{n}(1-\mu_i) \qquad 1- ((1- (\mu_1))^* (1- (\mu_2) \; ^*\ldots(1- (\mu_n))$$

The expected outputs from the combination of criteria are the social hotspot per type of services.

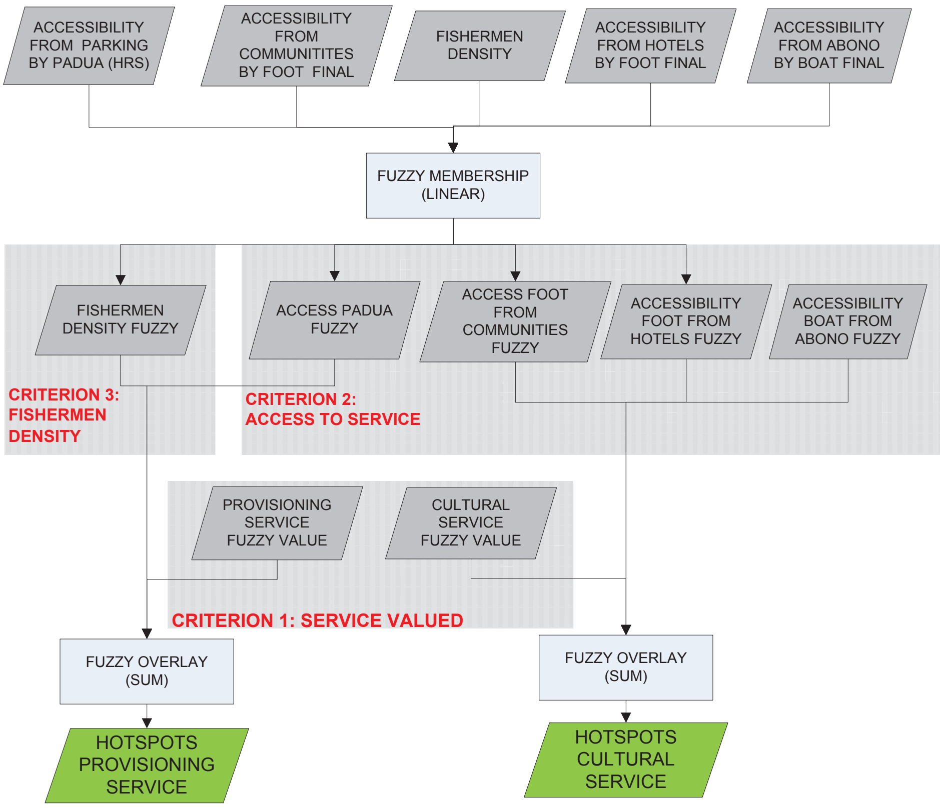


Figure 15. Flowchart of criteria combination for social hotspot mapping

4. Results

4.1 *Definition ecosystem boundaries*

4.1.1 Land cover map

The land cover map is presented in figure 16. The boundary of the study area is defined by the surrounding crater rim, which represents the uppermost portion of the crater and the limit of the lake Bosomtwe basin. There are four land cover classes identified: water, forest, cropland and built-up areas. More than half of the study area, approximately 55% is covered by water, followed by forest 25% and cropland 19%, while built-up only represents 0.31% of the study area (see table 10). The land cover map represents the first step for the valuation of ecosystem services.

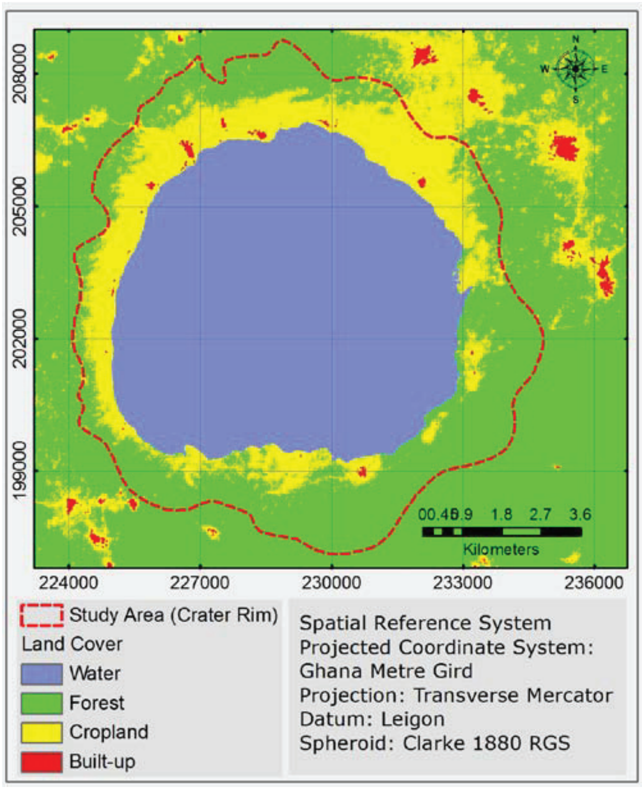


Figure 16. Land Cover map

CLASS NAME	*Study Area boundary (Crater Rim)*	
	AREA SQUARE KILOMETERS (KM2)	PERCENTAGE
water	55.75	54.72%
forest	26.25	25.76%
Cropland	19.58	19.21%
Built-up	0.31	0.31%
Total Area	101.89	100.00%

Table 10. Area per land Cover class

Table 11 shows the error matrix used to evaluate the accuracy of the image classification. The producer's accuracy represents the probability of a point in the field being correctly map; and the user's accuracy represents the probability of a random point on the map being correctly mapped. In this case, the class "forest" has the highest producer accuracy, while the class "water" has the highest user's accuracy. The overall accuracy of the classification is 85.71% and the overall kappa is 0.81.

	evaluation classes						
	class name	Forest	Cropland	Built-up	Water	**Total**	User accuracy
Map Classes	Forest	11	0	0	2	13	84.62%
	Cropland	1	17	4	0	22	77.27%
	Built-up	0	2	11	1	14	78.57%
	Water	0	0	0	21	21	100.00%
	Total	12	19	15	24	70	
	producer accuracy	91.67%	89.47%	73.33%	87.50%		
	Overall accuracy	85.71%					
	Overall Kappa	0.81					

Table 11. Error matrix for accuracy Assessment of the image classification

4.2 Assessment of the most important ecosystem services and their values

This section addresses the research question Q1, regarding the most important services provided by the ecosystem and the values identified by stakeholders.

4.2.1 Ecosystem Services

Five groups of stakeholders participated on the assessment of ecosystem services, i.e. local communities, NGO, researchers, tourists and tourist operators (see table 12).

Stakeholder group	participants	Gender	
		Male	Female
Local Communities	60	30	30
NGO	2	1	1
Researchers	3	4	-
Tourist	18	9	9
Tourist operators	3	3	-

Table 12. Participants per stakeholder group

Each group defined the most important services provided by the lake according to their perception. The response per group is presented in figure 17. The bar chart shows that the most important services provided are the provisioning and the cultural services. Additionally, researchers have also recognized the importance of regulating and supporting services at regional scale.

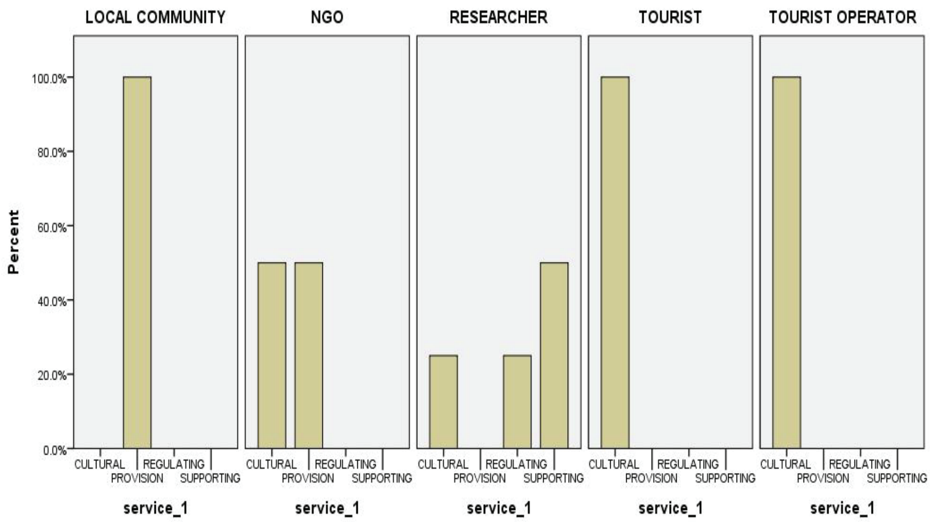


Figure 17. Most important services according to each stakeholder group

Based on this result, all the stakeholders were divided into two main groups for the valuation of provisioning and cultural services:

G3. Local communities for provisioning services valuation.

G4. NGO, researchers, tourists and tourist operators for cultural services valuation.

Some of the characteristics of these two main groups of stakeholders (G1 and G2) are presented in the following figures 18 and 19.
According to locals, their main occupation used to be exclusively fishermen and fishmongers. Nowadays due to the decrease in income from fishery, most of them have also become farmers.

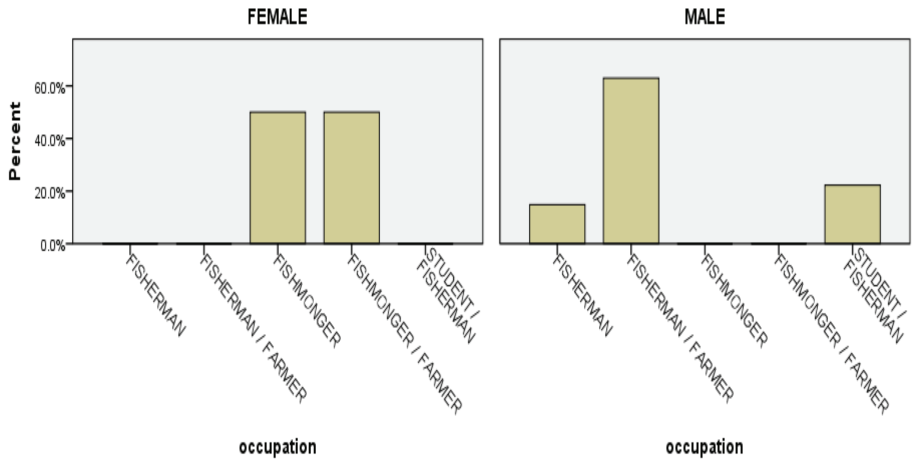


Figure 18. Occupation and gender of local community participants (G1)

The cultural service has been valued by a range of stakeholders, mostly from Ghana (19 participants), but also internationals (8 participants).

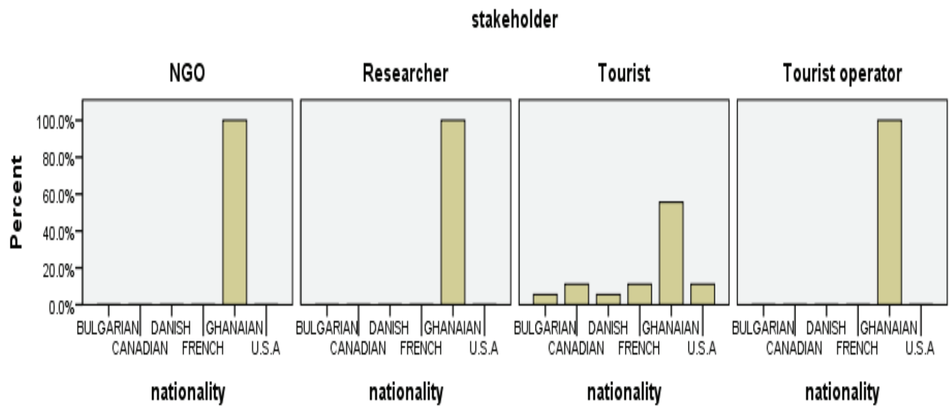


Figure 19. Gender and nationality of participants (G2)

4.2.2 Ecosystem Services Values

From the typology of values (table 2) stakeholders allocated and weighted up to five values for the two services assessed.

4.2.2.1 Provisioning Services Values

The values allocated by local communities to the provisioning services are presented in figure 20. The bar chart shows the values as the percentage from the total values allocated to the service. In total, local communities recognized seven types of values.

As expected, the highest values perceived are economic and subsistence. Nevertheless, local communities also recognized other values such as biodiversity, cultural, future, historic and learning as part of the valuation of provisioning services. For instance they valued biodiversity because for some, fish diversity is translated into a higher income. Furthermore, the fishing activity represents to them part of their culture and should be transmitted from generation to generation, therefore cultural, historic, future and learning values of the provisioning service are also important for them.

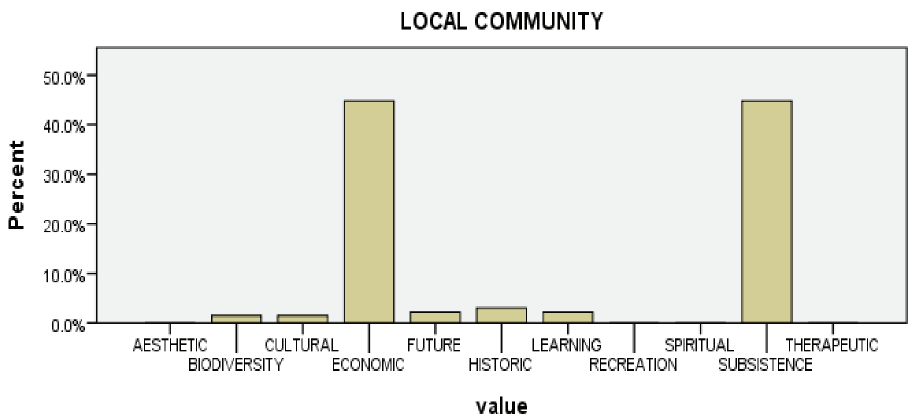


Figure 20. Provisioning service values

4.2.2.2 Cultural Services Values

Figure 21 represents the range of values that stakeholders allocated to the cultural services. In total, the four stakeholders groups (within G2) recognized nine types of values. Aesthetic, biodiversity and recreation values were included by all the stakeholders. The interesting fact is that the biodiversity value allocated by these stakeholders makes reference to the diversity of plants and trees found in the area during their visits, whereas the biodiversity value of provisioning services refers to fish.

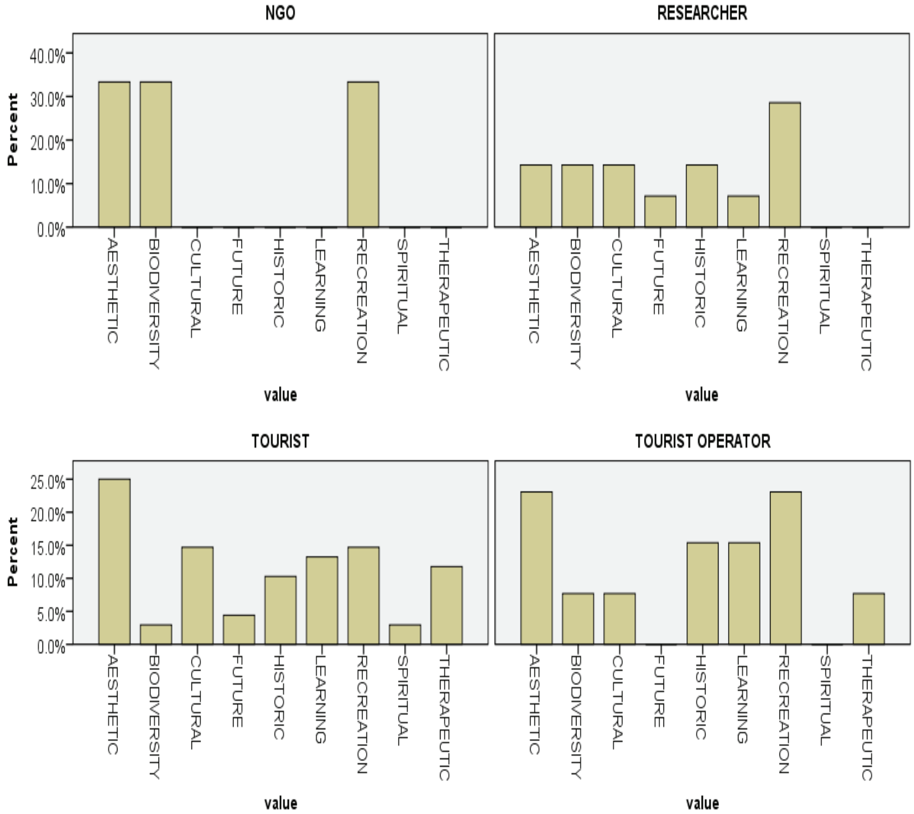


Figure 21. Cultural service values

4.2.2.3 Statistical analysis

This section addresses the research question Q2, regarding the relationship between stakeholder groups and the values perceived. For this purpose, a statistical analysis was done to assess this relationship.

a. Ho (1): The null hypothesis is that there is no significant relationship between stakeholder groups and the values assigned by them.
b. H1 (1): There is a significant relationship between stakeholder groups and values assigned by them.

FORMULA	RESULTS
$\chi^2 = \sum_{all\ cells} \frac{(f_o - f_e)^2}{fe}$	201.30
Degrees of freedom (d.f.) = (r-1)(c-1)	d.f.= (5-1)*(11-1) = 40
α	0.005
χu^2	66.77
$\chi^2 > \chi^2 u$	201.30 > 66.77

Table 13. Chi square test for relationship value - stakeholder

According to the calculation in table 13, the null hypothesis $\boldsymbol{H_0}$ is rejected, meaning that there is sufficient evidence that the stakeholder groups and the social values are related at α = 0.005. This means that the data collected in the field can be associated with the stakeholder groups and used to assess the ecosystem services per group.

The second hypothesis was used to assess the possibility of using the data collected from the three villages and generalize them for the other ones. Therefore a test was performed to assess if similarities existed between the values perceived by locals per village.

a. Ho (2): There is no significant difference between the values perceived by participants from different villages.
b. H1 (2): There is a significant difference between the values perceived by participants from different villages.

FORMULA	RESULTS
$\chi^2 = \sum_{all\ cells} \frac{(f_o - f_e)^2}{fe}$	25.501
Degrees of freedom (d.f.) = (r-1)(c-1)	d.f.= (3-1)*(7-1) = 12
α	0.005
χu^2	28.30
$\chi^2 > \chi^2 u$	25.501< 28.30

Table 14. Chi square test for significant differences between values – local communities

According to the calculation in table 14, the null hypothesis H_0 is not rejected, meaning that there is no sufficient evidence that the values perceived by locals are significantly different at $\alpha = 0.005$. This means that the data collected in the field can be used for the other villages.

4.2.2.4 Spatial location of values

After the two hypotheses were tested, it was possible to make the spatial representation of the service values in the entire study area.

a) Spatial location of provisioning service values

Stakeholders related the values perceived with the characteristic of the ecosystem, i.e. ecosystem feature, they had recognized as the provider of the service. Three features were identified, each of which was related to a specific value. These features are:

1. The whole study area, i.e. the crater limited its rim.
2. The lake
3. The lake shore, where the 22 communities are located.

Additionally, data collected from observations, experts' opinion and communication with locals, permitted to spatially locate the values and their weights per ecosystem feature (see figure 22). Among this information, the more relevant is related to water depth and certain values such as economic, biodiversity and subsistence. These three values are concentrated on the shallow parts of the lake because a higher concentration of fish is found in these areas. For this reason the weights of the three aforementioned values follow the depth contours patterns. The weights are represented from a scale from 0 to 10, being 0 no value and 10 the highest possible value.

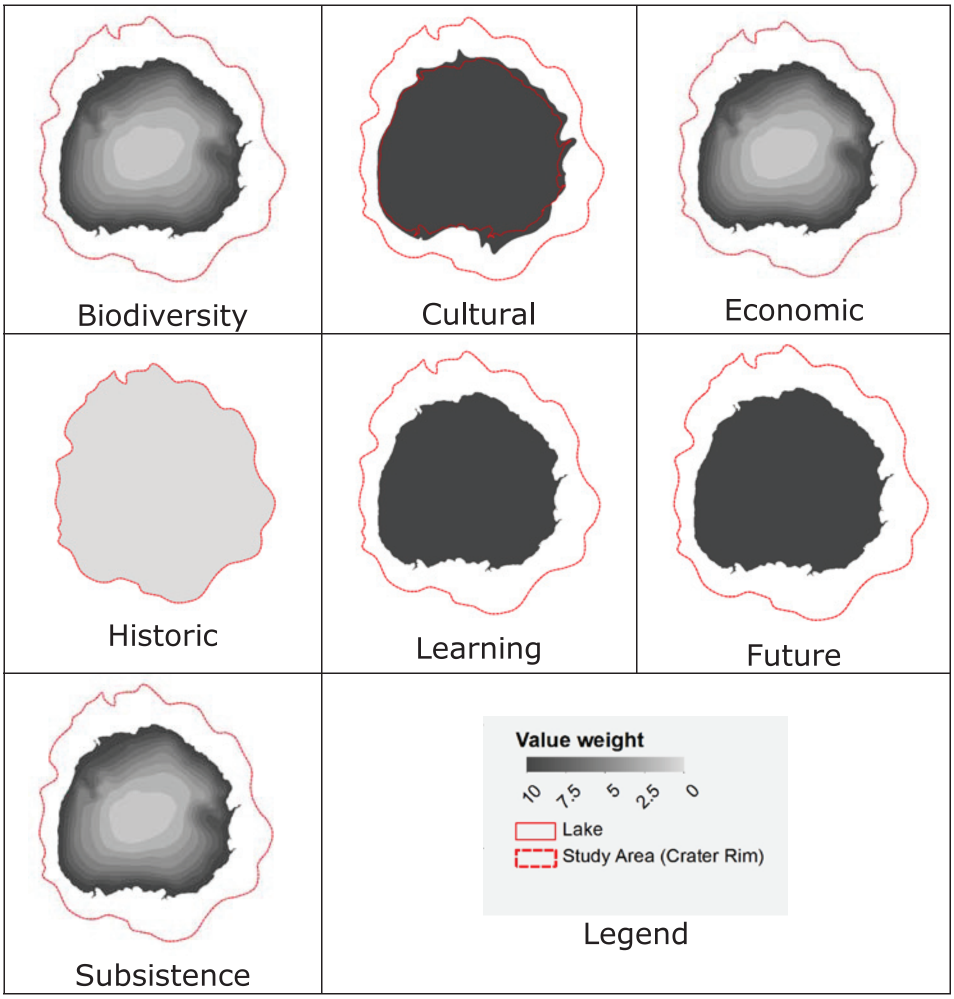


Figure 22. Spatial value weights for provisioning service, based on local people's perception

b) Spatial location of cultural service values

In this case, stakeholders had identified the following features are:

1. The whole study area, i.e. the crater limited its rim.
2. The lake
3. The lake shore, where the 22 communities are located
4. Forested areas surrounding the lake
5. Specific parts of the lake, e.g. shallow areas for recreation value, and deeper areas for learning and historic value relevant for research (see appendix 1, showing an undergoing research from the International Continental Scientific Drilling Program).

The spatial location of values is presented in figure 23.

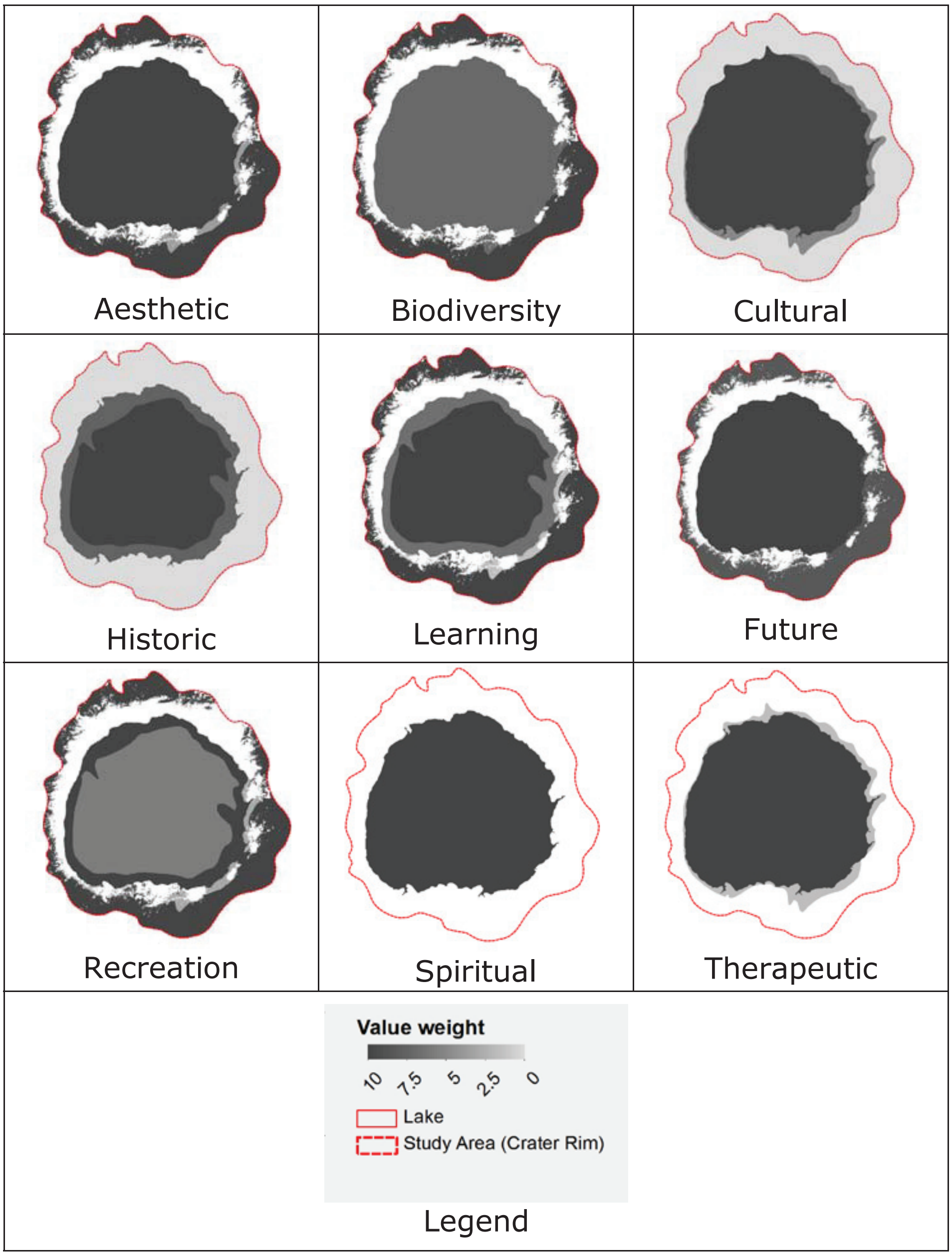


Figure 23. Spatial value weights for cultural service

4.3 Criteria for social hotspots mapping

4.3.1 Definition of criteria and indicators

This section addresses the research question Q3, regarding the criteria used to visualize the spatial variation services' values.

4.3.1.1 Provisioning service criteria and indicators

The criteria and indicators used for mapping the social hotspots of the provisioning service are presented on table 15.

SERVICE	***CRITERIA***	***INDICATORS***
Provisioning service	1. The ability of the ecosystem to provide the services required	1a. Social value per service (combination of abundance, diversity and risk indicators)
	2. The possibility of interaction of human societies with the services provided.	2a. Fishermen density per fishing ground 2b. Accessibility to service: Travel time to the service valued

Table 15. Criteria and indicators for provisioning service hotspot mapping

The first indicator is the social value of the provisioning service (1a, table 15). It is the result of combining the seven values perceived by local communities based on the three specific spatial indicators described here below (see figure 24):

1. Abundance (figure 24-a), which identifies where the highest concentration of values for provisioning service was found, in this case near the lake shore, on less deep waters. This abundance indicator follows the pattern of depth contours, reducing the concentration of values accordingly. This result is highly influenced by the economic, biodiversity and subsistence values.

2. Diversity (figure 24-b), represents the concentration of different values in the study area. The diversity indicator follows a pattern somehow opposed to the abundance one. This means that different values, which are not necessarily perceived as the most important ones, e.g. historic, learning, and future are also contributing to the spatial variation of the provisioning service.

3. Risk (figure 24-c), represents the areas where there is conflict with other services values; in this case the value of recreation from the cultural service represents a negative value for the provisioning services. The reason behind it is that recreation activities are seen by locals as negatively affecting their fishing activities.

The social value indicator (figure 24-d) was built by combining the three indicators of abundance, diversity and risk using fuzzy overlay. The spatial coincidence of the three indicators created a surface where the highest values are clearly defined, located near the lake shore and the lowest are in the centre of the lake and in the lake shore where the villages are settled.

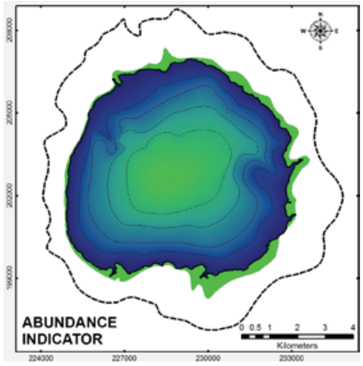


Figure 24-a. Abundance Indicator

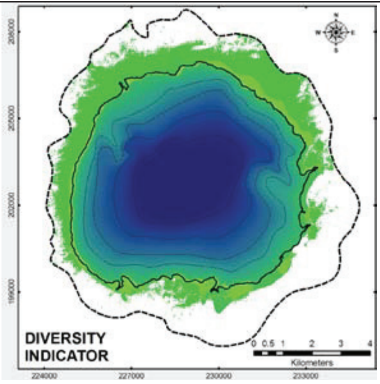


Figure 24-b. Diversity Indicator

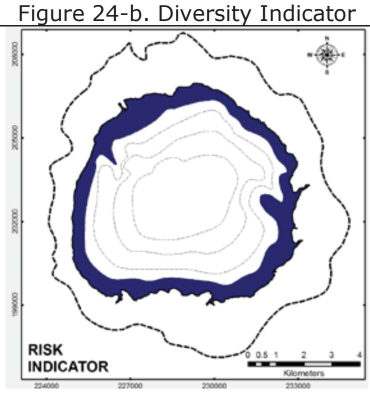


Figure 24-c. Risk Indicator

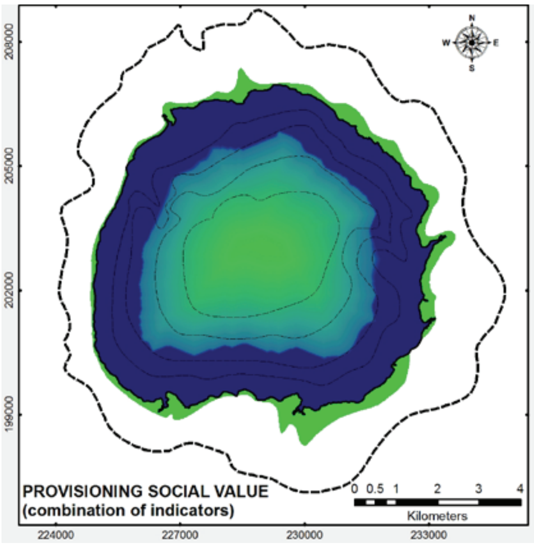
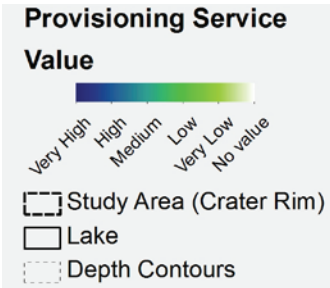


Figure 24-d. Provisioning Service Social Value (Combination of Indicators)



Legend

Figure 24. Spatial representation of the three indicators and the Provisioning Service Social Value

The next two indicators, fishermen density 2a and accessibility to service 2b (table 15) had been chosen because they explain how the local communities interact with the service they depend heavily on.

The fishermen density per fishing ground is the result of combining information about fishing areas, which have clear limits on the lake areas, and the fishermen per village (see figure 25). This indicator was constructed based on fishermen density per village. The data collected on the field showed that at least 20% of the population per village are fishermen. The fishermen density was calculated per fishing ground, allocating 50% of fishermen on the fishing grounds near the lakeshore and the rest following the depth contours. This indicator permits to visualize the variability in usefulness of the lake per village and differentiate overfishing levels in terms of use.

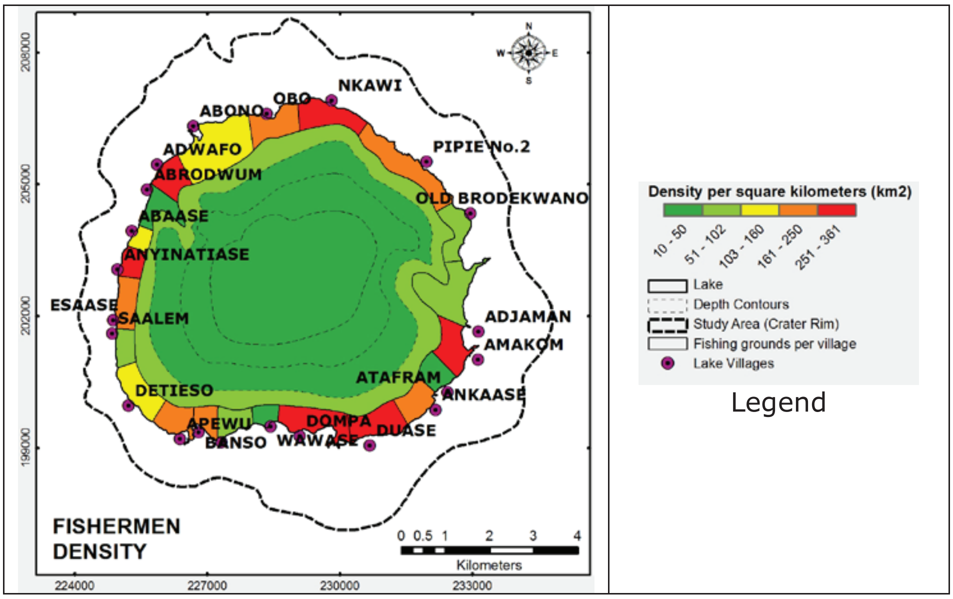


Figure 25. Fishermen density per fishing ground

The indicator 2b (see table 15) of the provisioning service is related to the accessibility to the lake by their local transport boat, called Padua used to fish on the lake (see figure 26). According to communication with locals during interviews, it takes from five minutes to thirty minutes to arrive to their fishing location, and they spend between one and two hours to have a good catch. The fishing times are twice per day during three hours each time. This information was use to create the map that shows the most accessible areas in terms of travel time.

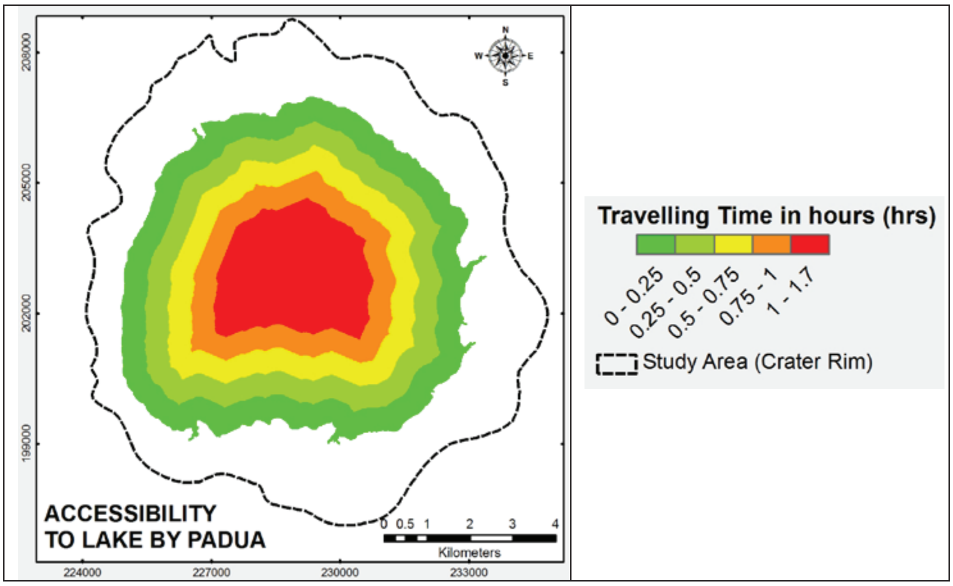


Figure 26. Accessibility by Padua

4.3.1.2 Cultural service criteria and indicators

The criteria and indicators used for mapping the social hotspots of the cultural service are presented on table 16.

SERVICE	***CRITERIA***	***INDICATORS***
Cultural service	1. The ability of the ecosystem to provide the services required	1a. Social value per service (combination of abundance, diversity and risk indicators)
	2. The possibility of interaction of human societies with the services provided.	2a. Accessibility to service: Travel time to the service valued

Table 16. Criteria for cultural service hotspot mapping

The first indicator is the social value for the cultural service (1a, table 16). It is the result of combining nine values perceived by four stakeholder groups (i.e. group G2) based on three specific spatial indicators (see figure 27):

1. Abundance (figure 27-a), which shows the distribution of the *sum of all values* over the area. It demonstrates that the highest concentration of values for the cultural service is uniformly distributed along the lake area. This result was

expected and directly related to the fact that all the stakeholders allocated most of their values to the lake as a whole.

2. Diversity (figure 27-b), represents the concentration of *different values* in the study area. The diversity indicator identifies areas evenly valued. For this reason, it recognizes areas not necessarily highly valued but uniformly valued. These areas are targeted to enhance and protect their values.

3. Risk (figure 27-c) for cultural service represents areas with conflict of interests between different stakeholder groups. In this sense, forested areas represent areas of abundant values and threats. The lack of values not perceived by local communities for these areas is affecting the values of biodiversity, aesthetic and future perceived by stakeholders for the cultural services.

Subsequently, the social value indicator for cultural services (figure 27-d) was built by combining the three indicators of abundance, diversity and risk using fuzzy overlay. The spatial coincidence of the three indicators emphasizes the equal importance of forest and lake as sources of enjoyment of scenery, development of research, and cultural exchange.

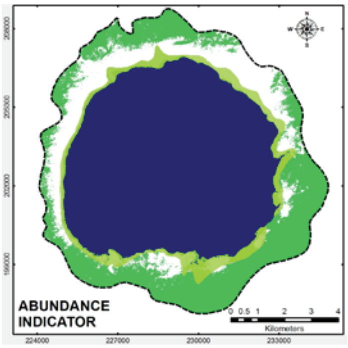


Figure 27-a. Abundance Indicator

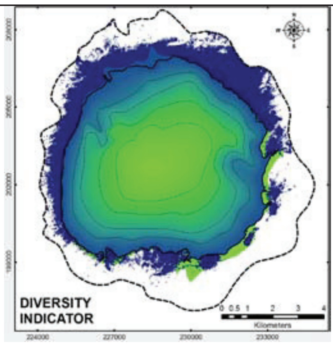


Figure 27-b. Diversity Indicator

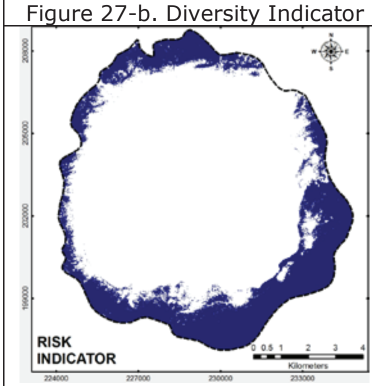


Figure 27-c. Risk Indicator

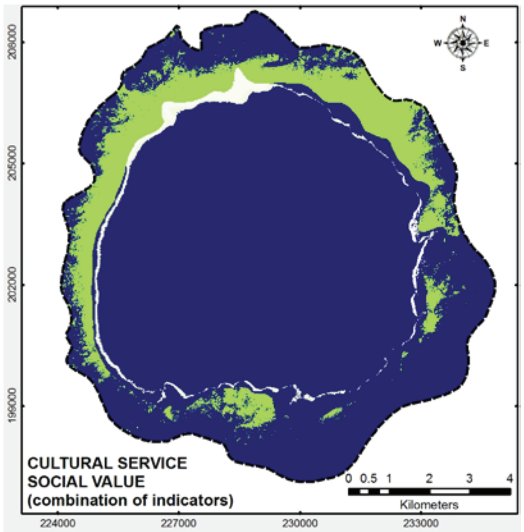
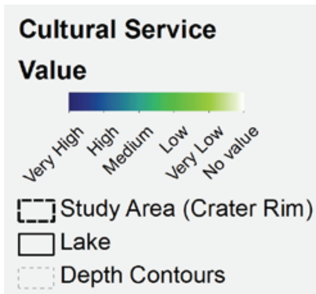


Figure 27-d. Cultural Service Social Value (Combination of Indicators)



Legend

Figure 27. Spatial representation of the three indicators and the Cultural Service Social Value

The next indicator 2a (see table 16) of the cultural service is related to the accessibility to the valued areas, i.e. forest and lake. According to communications with stakeholders, the level of interaction with the valued sites is directly related to the time spent in the area (e.g. enjoying and making use of the services provided by this ecosystem). Stakeholders, especially tourists, spend between few hours and a weekend in the area.

They do hiking activities from two to four hours per day. The level of usefulness has been linked to the level of accessibility to the valued area. Figures 28-a and 28-b (see figure 28) represent the accessibility by foot and motorboat to forested areas and lake respectively. In the case of the accessibility to lake by motorboat (28- the cost surface is homogenous, thus the result equals to the *Euclidean distance* measure calculation. From local tourist guides it was learned that it takes approximately eight to nine hours (two days hiking) to go around the lake. Therefore, the accessibility analysis using friction values from literature (table 8) agreed with the data collected on the field.

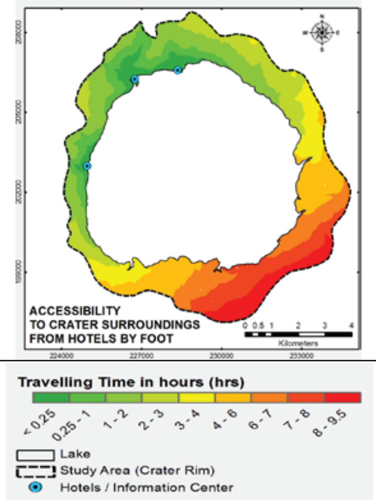


Figure 28-a. Accessibility by foot from hotels

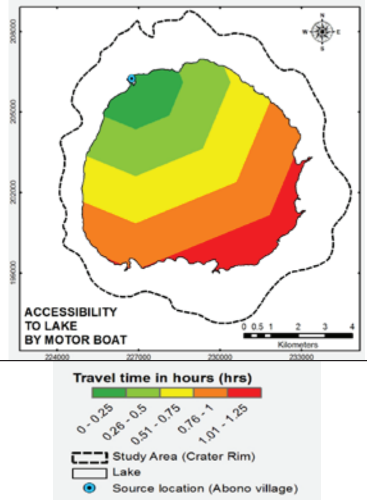


Figure 28-b. Accessibility by motorboat from Abono village (source location)

Figure 28. Accessibility to cultural services

The third accessibility measure used in the analysis is presented in figure 29 and 30. It represents the accessibility by foot from the villages to the forested areas (classified per travel time zones). The map (figure 29) represents only an extraction of the areas of interest from the accessibility analysis, i.e. forested areas per travel zones. These zones are divided in six classes, each 0.5 hours (see table 17). This measure was used to compare the forested areas that are equally accessible than the cropland areas, in terms of travel time (see figure 30). This measure gave additional information to the already defined risk indicator (figure 27-c). Based on the proven fact that accessibility is related to land-cover patterns (Verburg, et al., 2004), this indicator gave more information about the forested areas at risk. It gives an indication on the levels of risk within the forested areas. Thus forested areas accessible within the travel time zones one to three (from 0 to 1.5 hours) were considered as part of the accessibility indicator for cultural services hotspot mapping.

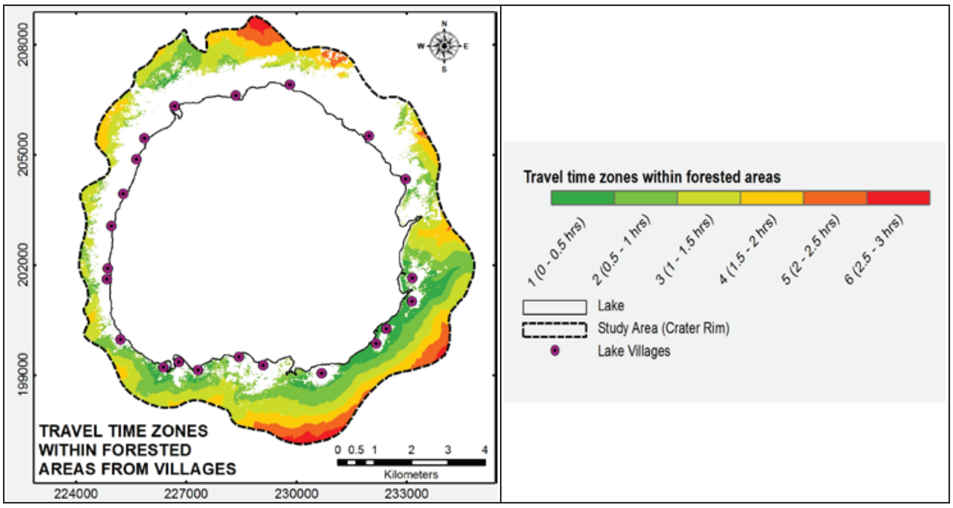


Figure 29. Travel time zones within forested areas from villages

TRAVEL TIME ZONES	*TIME RANGE (hours)*	*TRAVEL TIME ZONES*	*TIME RANGE (hours)*
1	0 - 0.5	4	1.5 - 2
2	0.5 - 1	5	2 - 2.5
3	1 - 1.5	6	2.5 - 3

Table 17. Travel time zones

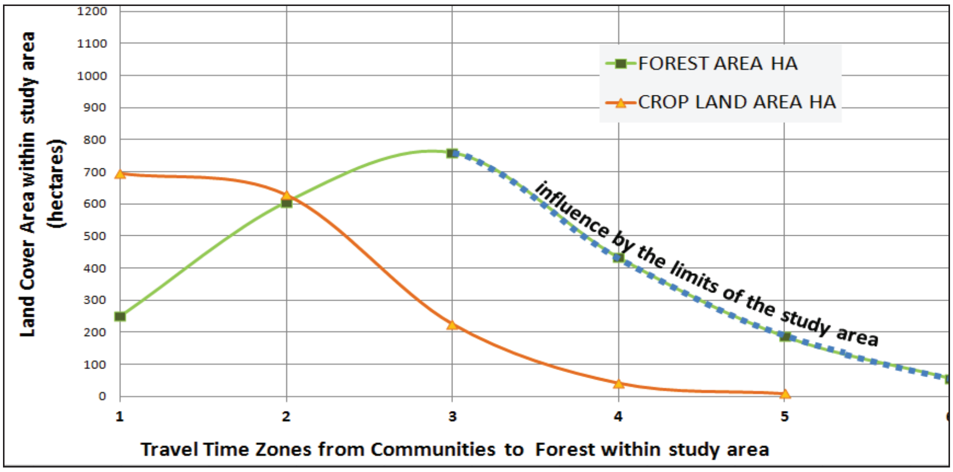


Figure 30. Area of forest and cropland per travel time zones

4.3.2 Combination of criteria

This section addresses the research question Q4, regarding the approach used to combine the criteria for hotspot mapping. The combination of criteria was performed using fuzzy overlay of the indicators per service.

4.3.2.1 Provisioning service criteria combination

The provisioning service social hotspot is presented in figure 31. It combines the three indicators: social value of provisioning service, fishermen density per fishing ground and accessibility to the service. Each indicator was transformed into a fuzzy membership function according to the constraints established in figure 13.

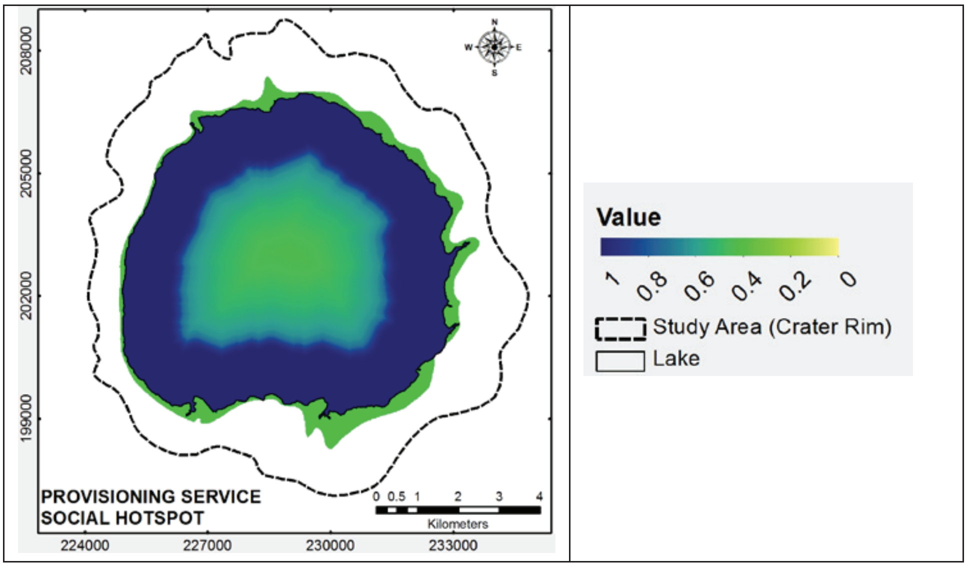


Figure 31. Provisioning Service Social Hotspot

The result shows that the provisioning service hotspot was influenced by the spatial variation of the indicators, i.e. the fishermen density, the levels of accessibility and the service social value. Nevertheless, not all the indicators influence the result in a similar manner. A sensitivity analysis was done to see the influence of each indicator in the final result using the Pearson's correlation coefficient (see table 18).

Correlations Provisioning Service					
		Provisioning service social hotspot	Accessibility by Padua	Fishermen Density	Social Value
Pearson's Correlation	Provisioning service social hotspot	1.000	0.922*	0.145*	0.958*
	Accessibility by Padua	0.922*	1.000	0.210*	0.991*
	Fishermen Density	0.145*	0.210*	1.000	0.190*
	Social Value	0.958*	0.991*	0.190*	1.000

Table 18. Pearson's correlation coefficient between indicators for provisioning service
* significant at 0.05 level

Results from the table show that there is a positive and very high correlation between the provisioning service hotspot and the social value. Secondly, the accessibility to the service by Padua has also a positive and still high correlation. However, the indicator of fishermen density has a very low (almost inexistent) correlation.

4.3.2.2 Cultural service criteria combination

The cultural service social hotspot is presented in figure 32. It combines the two indicators: social value of cultural service, and accessibility to the service. Each indicator was transformed into a fuzzy membership function according to the constraints established in figure 14.

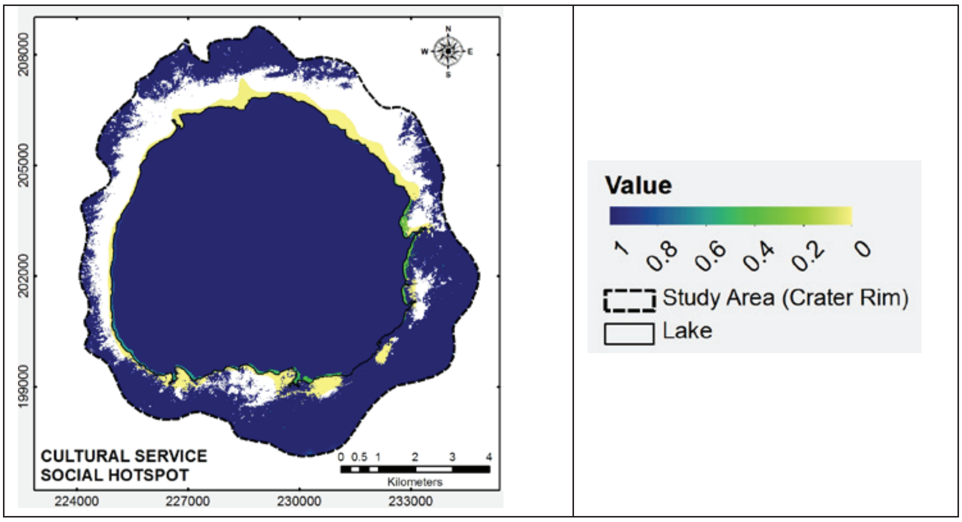


Figure 32. Cultural Service Social Hotspot

The result shows uniform high values for forested areas and lake. There is not a large spatial variability of the service. The areas less valued are areas near the lakeshore where the villages are settled. To see the influence of the indicators on the final result, the Pearson's correlation coefficient was run (see table 19). It was found that the cultural service hotspot is very much influenced by the social value (similarly to the provisioning service results). Nevertheless the indicator of accessibility has very little and negative influence on the final result.

Correlations Cultural Service

		Cultural service social hotspot	Social Value	Accessibility to valued area
Pearson's Correlation	Cultural service social hotspot	1.000	0.999*	-0.139*
	Social Value	0.999*	1.000	-0.140*
	Accessibility to valued area	-0.139*	-0.140*	1.000

Table 19. Pearson's correlation coefficient between indicators for cultural service
* significant at 0.05 level

5. Discussion

This case study has demonstrated how stakeholders' perception of services and their interaction with the ecosystem can be combined to assess the ecosystem services. Social values had been previously used for the assessment of services at regional scale (Alessa, et al., 2008; G. Brown, 2005; Bryan, et al., 2011). In this research social values were analyzed at a local scale where stakeholders suggested additional aspects to be considered in the valuation of services at this level, i.e. their interaction with the services. In this sense, additional indicators were explored to increase the knowledge on ecosystem services at local level and complement the social values.

The use of the accessibility indicator to assess the interaction stakeholder-ecosystem for service valuation was not studied until recently (Fagerholm, et al., 2012). This recent study has found that 12 from 19 values perceived by locals were located within 1 kilometre distance from the informant residence (the measure used was the Euclidian distance). In the present research, the accessibility was measured using travel time cost, which takes into account the time that it takes to reach the service valued from the location of the stakeholders e.g. residence or hotels.

This accessibility analysis proved to be very useful for the definition of social hotspot for provisioning services. It is strongly correlated to the social value indicator (r= 0.991 at 0.05 level of confidence) and to the final social hotspot (r=0.922 at 0.05 level of confidence). This means that the access to the service is determinant for assessing provisioning services. Therefore, the high accessibility to the lake can be linked to the high importance that local communities gave to the fish provisioning. This is shown by the social hotspot of provisioning services which identified spatial coincidence of high social value and high accessibility. Moreover, accessibility is a measure that can define levels of usefulness of the ecosystem services. This statement follows the findings of a study that proved a positive correlation between accessibility and the perceived usefulness of natural resources (Thomas, et al., 2009).

The accessibility indicator for assessing the cultural service proved not been relevant in the assessment. It had an almost inexistent and negative correlation (r=-0.139 at 0.05 level of confidence). The low correlation can be interpreted as the small influence that this indicator has on the cultural hotspot. While the negative sign of the correlation means that some of the valued areas (i.e. forested areas) are areas with low access but still highly valued by their beauty, future, learning and history. This result implies that some values perceived for the cultural services may not need direct contact, interaction or use to be valued, as they can be perceived from long distance or learned from books. In this case accessibility could be further studied to differentiate direct use and non-use values. Therefore other measures should be studied and considered to increase the knowledge about these services.

The second indicator is the social value which was highly correlated to the resulting hotspots on both services (i.e. r=0.9 at 0.05 level of confidence). This result indicates that the social hotspots depend heavily on the values perceived by the stakeholders. In this sense, the survey process is an important part of the assessment. The survey carried out on the field followed the process proposed by Brown (G. Brown, 2005)and proved by other studies (Alessa, et al., 2008; Bryan, et al., 2011). Besides the use of a predefined technique for survey, the inclusion of different stakeholder perspectives have also produced a more balanced assessment of the ecosystem under study, avoiding a bias analysis compared to using only one perspective. In this sense, the identification of different groups of stakeholders made possible the identification of different services. It also permitted to locate areas of conflict between different services as proposed by Hein et al. (2006).

The fishermen density indicator was used because it was considered, according to the observations on the field, that highly valued areas were related with the areas where most of the fishermen were concentrated. Nevertheless the use of this indicator prove no relevance, as the correlation coefficient indicates (r=0.145 at 0.05 significance level).

The social value is derived from the combination of three indicators, abundance, risk, and diversity. The abundance and risk indicator gave expected results. Nevertheless, the diversity indicator gave results not easily understood. According to Bryan et al. (2010), the diversity indicator indentifies areas where there are diversity and more even social values across different services. In the actual research the highest diversity value was found on the cropland areas, which were areas not valued by stakeholders, except when the values were assigned for the whole study area (including the croplands). The reason can be that croplands had lack of values but are evenly valued for both services. Thus this indicator may need further analysis.

Stakeholders related the most important values to services they depend on or have experienced and most interaction. Nonetheless some values perceived for cultural services didn't follow this logic as it was discussed above. The results show the spatial heterogeneity of the services' values along the landscape, as the interaction of humans and the ecosystem is dynamic and complex (Fagerholm, et al., 2012). In this context, local communities recognized values specifically for the provisioning services because their perception mostly depends on the use values that an ecosystem service can provide. This means that their valuation is closely related to the usefulness derived from the services (Millennium Ecosystem Assessment, 2003).

All the participants from local communities assigned economic as their most important value followed by subsistence. These two values were located on the lake which shows how this ecosystem is extensively used for provisioning of fish mainly for economical purposes. Nevertheless the lake wasn't valued uniformly for the provisioning service. The maps of values show the spatial variation of economic, subsistence and biodiversity values within the lake. This is because the fish concentration determines their valuation. This particular aspect of the valuation can only be observed at local scale with local stakeholders. Thus the importance of assessing the ecosystem at an appropriate scale and stakeholder level (Hein, et al., 2006).

Other services not representing economical benefit for local communities were barely considered and recognized. For instance, tourism opportunities in the area represent very little benefit for locals, thus they were not valued as an important service, even though the area is largely recognize for these benefits by other groups of stakeholders. Moreover, some values from cultural services, such as recreation were considered as threats in specific parts of the lake. In contrast, other stakeholders such as tourists visualized a link between provisioning and cultural services as they enjoy watching the traditional fishery.

The identification of service values that benefit stakeholders from different levels made possible to identify the conflicts between services, following the statement made by Hein et al. (2006) in their study. In this study, stakeholders found conflicts between services provided during the interviews. For instance, fishermen identified conflicts between the provisioning and cultural services especially on the lake, near the lakeshore. Another example was the forested areas where tourists, NGO and researchers found conflict because of the low value that these areas represent to local communities. These areas where identified as part of the valuation process (within the risk indicator).

The concept of spatial scale for the assessment of ecosystem services is also relevant. Ecosystem services should be analyzed at a scale where the impacts of the resource use can be clearly identified Hein et al. (2006) Additionally, MA (Millennium Ecosystem Assessment, 2003) recommends the assessment of services at a specific spatial and temporal scale to simplify the analysis, because of the heterogeneity of the services supply and their change over time. In this study the lake was assessed at local scale and present time, where anthropogenic pressures such as overfishing and the consequent harvesting of the forest, were assessed according to stakeholders perspective.

Nevertheless the services assessed change during the year therefore the valuation and interaction with stakeholders also experience changes. This issue was not considered in this study and it represents a weakness. For instance, even if the fishermen do their activity along the entire year, the highest season for fishing is during September to November. Similarly the tourism activities are present during the entire year but the highest season for tourism is during December and June-August. This type of information should also make vary the valuation of services.

The spatial variability in use of services was analyzed through the social values and accessibility to the service. In this research, highly valued and most accessible areas for provisioning services were also identified as risk areas (i.e. areas were overfishing and deforestation actions occur). This type information can support the definition of priority management areas for services enhancement and conservation.

6. Conclusions and Recommendations

6.1 Conclusions

1) Two ecosystem services had been identified by stakeholders , i.e. provisioning services and cultural services. The first services were relevant to stakeholders from the local level, i.e. local communities from villages surrounding the lake, which livelihood depend heavily on the fish supply. On the other hand, cultural services were recognized by stakeholders from local to international levels.

2) A significant relationship between the values perceived and stakeholders was found which permitted the assessment of ecosystem services per stakeholder groups.

3) Two criteria were identified to visualize the spatial variation of services values across the study area:
    a. The first criterion was the ability of the ecosystem to provide the services required. To infer the status of this criterion, the social value indicator was used. This indicator proved to be highly correlated with the two services.
    b. The second criterion was the possibility of interaction of human societies with the services provided. To infer the status of this criterion two indicators were used, the fishermen density (only for provisioning service) and the accessibility indicator (used to assess both services). The fishermen density proved low correlation for assessing provisioning services. The accessibility indicator proved to be very relevant for assessing provisioning services but not relevant for assessing cultural services.

4) The approach used for hotspot mapping was fuzzy logic which permitted the combination of the different indicators, establishing rules and constraints determined by each indicator. The relevance of this method for assessing ecosystem services is that it reflects the spatial heterogeneity of the landscape services and allows gradual transition as the ecosystem characteristics do not have sharp limits, neither do the services.

6.2 Recommendations

The identification of social hotspots using social values should be complemented with the assessment of services with economical and ecological values to target priority management areas.

The criteria and indicators require further study. It is necessary to include more relevant criteria to increase the knowledge on the services provided. The accessibility analysis could be further studied to assess the levels of usefulness of the ecosystem services for their valuation.

The services social values can be assess considering the temporal and spatial scale to visualize the changes and other implications.

Besides the analysis of services in the area, future studies should also assess the flows of services. This recommendation is especially for provisioning services for local communities where the access to markets may also influence the interaction of the humans with the ecosystem.

7. References

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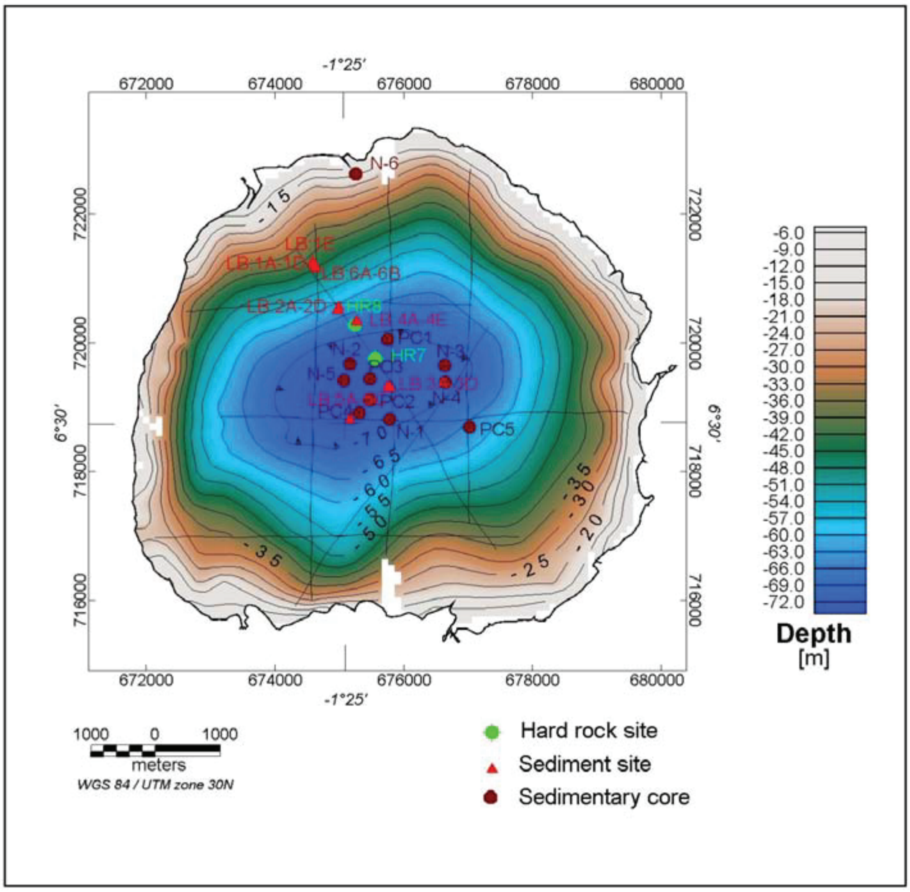
8.Appendices



Appendix 1. Undergoing research, drilling project from International Continental Scientific Drilling Program (ICDP)

QUESTIONNAIRE No.		STAKEHOLDER GROUP	

1. GENERAL INFORMATION					
DATE:			village		
coordinates	X (longitude)		Y (latitude)		
NAME			GENDER	F ( )	M ( )
AGE		OCCUPATION			
EDUCATION LEVEL	Illiterate ( )	Literate ( )	Primary ( )	Secondary ( )	Tertiary ( )
Family size		No. dependents			

2. MOST IMPORTANT SERIVICES (WITH AID OF MAP)

a) Which do you think is the most important service the lake Bosomtwe provides to you? Which activity do you carry out in the Lake?

PROVISIONING		TOURISM / ECOTOURISM		OTHER
WATER ( )	FOOD ( )	( )	( )	

b) Where do you carry out this activity (specific area on the lake)

Lake	( )	Lake shore	( )	Village(s)	( )	which	

c) How far do you walk to do your activity	Hours ( )	Kilometers ( )

d) Within the service identified, what are the most important values for you? Rank the 5 most important ones from 1 to 5, being 1 the most important to 5 the least important of the five chosen

1. Economic ( )	2. Subsistence ( )	3. Aesthetic ( )	4. Biodiversity ( )	5. Cultural ( )	
6. Future ( )	7. Historic ( )	8. Learning ( )	9. Recreation ( )	10. Spiritual ( )	11. Therapeutic ( )

e) Within the 5 values identified, give a rate from 1-10, being 10 the highest and 1 the lowest

1. Economic ( )	2. Subsistence ( )	3. Aesthetic ( )	4. Biodiversity ( )	5. Cultural ( )	
6. Future ( )	7. Historic ( )	8. Learning ( )	9. Recreation ( )	10. Spiritual ( )	11. Therapeutic ( )

f) What do you think about other activities on the lake besides the most important for you, such as (eco)tourism /fishing or other

POSITIVE ( )	NEGATIVE ( )	NO OPINION ( )	WHY	

Appendix 2. Questionnaire used with local communities

QUESTIONNAIRE No.		STAKEHOLDER GROUP	NGO

1. GENERAL INFORMATION

DATE:		Village /place			
coordinates	X (longitude)		Y (latitude)		
NAME		GENDER	F ( )	M ( )	
NGO NAME		YEARS WORKING IN AREA	____________ SINCE_______		
OBJECTIVES					

Where is your work concentrated (specific area on the lake / communities)

NO. WORKERS	( )	AVERAGE EDUCATION LEVEL	Primary ( )	Secondary ( )	Tertiary ( )
PERCENTAGE OF FOREIGNERS		PERCENTAGE OF LOCALS			

2. MOST IMPORTANT SERIVICES (WITH AID OF MAP)

a) Which do you think is the most important service(s) the lake Bosomtwe provides to you? Which services / activity (ies) are the most important around the Lake?

PROVISIONING		TOURISM / ECOTOURISM		OTHER
WATER ( )	FOOD ( )	( )	( )	

b) Where do you think this service / activity (ies) takes place (most important areas)

Lake	( )	Lake shore	( )	Village(s)	( )	which	

c) Within the service identified, what do you think are the most important values? Rank the 5 most important ones from 1 to 5, being 1 the most important to 5 the least important of the five chosen

1. Economic ( )	2. Subsistence ( )	3. Aesthetic ( )	4. Biodiversity ( )	5. Cultural ( )	
6. Future ( )	7. Historic ( )	8. Learning ( )	9. Recreation ( )	10. Spiritual ( )	11. Therapeutic ( )
OTHER(S)					

d) Within the 5 values identified, give a rate from 1-10, being 10 the highest and 1 the lowest

1. Economic ( )	2. Subsistence ( )	3. Aesthetic ( )	4. Biodiversity ( )	5. Cultural ( )	
6. Future ( )	7. Historic ( )	8. Learning ( )	9. Recreation ( )	10. Spiritual ( )	11. Therapeutic ( )
OTHER(S)					

e) What do you think about other activities on the lake besides the most important stated earlier, such as (eco)tourism /fishing or other

POSITIVE ( )	NEGATIVE ( )	NO OPINION ( )	WHY (SPECIFIC	

Appendix 3. Questionnaire used with NGO

QUESTIONNAIRE No.		STAKEHOLDER GROUP	TOURIST

1. GENERAL INFORMATION

DATE:		Village/Place			
coordinates	X (longitude)		Y (latitude)		
NAME			GENDER	F ( )	M ( )
NATIONALITY					
AGE		OCCUPATION		Duration of Stay at lake	Days ( )
				First time	Y( ) N ( )

2. HOW DID YOU FIND OUT ABOUT THIS PLACE (THE LAKE)

COME REGULARLY ( )	TOURIST OFFICE ( )	INTERNET ( )	OTHER

3. MOST IMPORTANT SERVICES (WITH AID OF MAP)

a) What type of tourism do you practise in the lake area?

TOURISM	NATURAL TOURISM	ECOTOURISM	OTHER
( )	( )	( )	

b) Where do you carry out this activity (most special places in the area)

Lake Lake shore Hotel &surround-dings	( ) ( ) ( )	forest	( )	Village(s) which	( )	Other where	( )

c) How far do you walk to do arrive to the special places	Hours ( )	Kilometers ( )

d) Within the service identified, what are the most important values for you? Rank the 5 most important ones from 1 to 5, being 1 the most important to 5 the least important of the five chosen

1. Economic ( )	2. Subsistence ( )	3. Aesthetic ( )	4. Biodiversity ( )	5. Cultural ( )	
6. Future ( )	7. Historic ( )	8. Learning ( )	9. Recreation ( )	10. Spiritual ( )	11. Therapeutic ( )

e) Within the 5 values identified, give a rate from 1-10, being 10 the highest and 1 the lowest

1. Economic ( )	2. Subsistence ( )	3. Aesthetic ( )	4. Biodiversity ( )	5. Cultural ( )	
6. Future ( )	7. Historic ( )	8. Learning ( )	9. Recreation ( )	10. Spiritual ( )	11. Therapeutic ( )

f) What do you think about other activities on the lake besides the most important for you, such as (eco)tourism /fishing/farming or other

POSITIVE ( )	NEGATIV E	NO OPINION	NO EFFECT	WHY	

Appendix 4. Questionnaire used with Tourists