MAKERERE UNIVERSITY

COLLEGE OF ENGINEERING, DESIGN, ART AND TECHNOLOGY

MASTER OF SCIENCE IN GEO-INFORMATION SCIENCE AND TECHNOLOGY

MASTERS FINAL YEAR PROJECT

TOPIC: EXPLORING THE USE OF PPGIS FOR MAPPING THE DISTRIBUTION of *Vitellaria paradoxa* (SHEA TREE)

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BY

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DECLARATION

I hereby declare that this submission is my original own work towards the award of Master of Science in Geographic information Science and Technology and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree.

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GLOSSARY

EU-INCO……………. European Union International Cooperation Program

IAPAD………………. Integrated Approach to Participatory Development

IUCN…………………International Union for Conservation of Nature

NEMA………………..National Environment Management Authority

NGO……………….....Non-Government Organization

NUSPA………………. Northern Uganda Shea Processors Association

PLA…………………. Participatory Learning and Action

PPGIS………………...Public Participatory Geographic Information System

PRA…………………. Participatory Rural Appraisal

USAID………………United States Agency for International Development

CHAPTER ONE: INRODUCTION

1.1 Background

Vitalleria paradoxa, commonly known as shea tree or “mo yao” in Northern Uganda/ Ekungur in Teso is a tree of the family Sapotaceae and the only species in genus vitalleria. The tree is indigenous to Africa where it grows naturally in the dry savannah belt stretching from Senegal to Ethiopia across 17 other countries namely, Benin, Burkina Faso, Cameroon, Central African Republic, Chad, Ghana, Guinea Bissau, Ivory Coast, Mali, Niger, Nigeria, Sierra Leone, Togo, South Sudan, Sudan, Guinea, and the Democratic republic of Congo. The shea butter tree is found in wet and dry savannahs where annual rainfall amounts to between 400 mm and 1500 mm and grows between the latitudes 9°and 14°N in West Africa, 7° and 12° N in central Africa and 2° and 8° in East Africa (Sanou & Lamien , 2011). For countries close to the Sahara Desert such as Niger, Mali and Burkina Faso, this zone corresponds to wetter parts of the country which is geographically in the south and for the wetter countries such as Uganda, this zone corresponds to the drier parts of the country.

In Uganda, the tree is endemic to West Nile, Northern, and North Eastern Uganda where it grows predominantly in the wild making it highly susceptible to harvesting for charcoal. The tree typically begins fruiting after 15 years and may continue bearing fruit for 300 years (Jøker, 2000). The shea tree is of high social economic value to the indigenous communities where it grows. The shea butter extracted from its kernels is used for cooking, for skin care, and for ceremonies such as birth. The butter has important therapeutic properties, particularly for the skin. It provides protection from ultra-violet (UV) radiation and has moisturizing, regenerative and anti-wrinkle properties. It is also used in personal care products, such as pomades, soaps and pharmaceuticals.

In spite of its high economic value, the tree is highly threatened and has been listed as vulnerable by the International Union for Conservation of Nature (IUCN) (Wildlife Conservation Society, 2016) . The tree produces high quality firewood and charcoal which has made it a target for charcoal traders.

According to Buyinza and Okullo (2015), other threats to the tree include bush burning, prolonged droughts, rapid human population growth and overstocking. The regeneration of shea seedlings is also threatened by prolonged dry spells, trampling by the large herds of cattle and termites.

In February 2018, the Government of Uganda, through the Ministry of Water and Environment suspended any cutting, transportation and sale of shea nut tree logs and their products. However, the ban has not been effective because the tree grows largely in the wild and on farmlands where law enforcement is difficult to achieve. There is also a general lack of knowledge on the precise location of the shea trees in the shea parklands. Most conservation efforts towards saving the Shea tree have been mainly targeted Acholi and Lango Sub regions with very little consideration given to the Teso sub region. For instance in 1995, The Shea Project for Local Conservation and Development with funding from the United states Agency for international Development was started. Under the project, more than 2000 members of rural women's groups formed the Northern Uganda Shea Processors Association to help process and market several tones of pharmaceutical grade shea butter to cosmetic industries in the Unites States, Europe, and Japan (Masters, Yidana, & Lovett, 2004).

The Shea Project for Local Conservation and Development, commonly known as the Shea Project, funded by USAID, the McKnight Foundation, and the (EU INCO) program also targeted the Northern Uganda districts of Lira, Gulu, Kitgum, Pader, Katakwi and Kotido.

Most of these conservation projects have targeted women and women led groups and yet land resources which include trees in the Ugandan culture are controlled by men. Leaving out men, who are rather mainly involved in felling the Shea tree for charcoal, means there is still a gap that still puts the tree a risk. Participatory approaches such a Public Participatory Mapping which involve both genders would be a more holistic approach to save the tree.

1.2 Problem Statement

Vitalleria paradoxa is listed as vulnerable by the International Union for Conservation of Nature (IUCN) (Wildlife Conservation Society [WCS], 2016). In February 2018, the Government of Uganda, through the Ministry of Water and Environment suspended any cutting, transportation and sale of Shea nut tree logs and their products. ("govt bans shea nut trees", 2018). However, the ban has not been effective mainly because the tree grows predominantly on private farmlands other than in protected zones which makes it difficult for government to monitor felling of the tree.

According to Dr. Tom Okurut, the former NEMA Executive Director, one of the strategies adopted to conserve the shea tree is to add value to shea tree products and make local people realise that biodiversity conservation supports livelihoods. (UNDP, 2018)

However, there is limited knowledge on spatial location of the shea processing communities that need to be targeted. While it is common knowledge that the tree grows in Northern Uganda and West Nile, it is not known which communities have the highest stocking density.

This project therefore sought to employ a PPGIS mapping method to generate spatial data that can be used by government, conservationists, and other stake holders in the conservation of the shea nut tree.

1.2 Aims and Objectives

Main Objective

Generate indigenous knowledge/data on the spatial distribution of Vitellaria paradoxa through the use of Public Participatory Mapping in Airabet Subcounty, Kapelabyong District.

Specific Objectives

- Determine the most appropriate mapping method and scale to be used in the mapping exercise
- Identify and map out individual shea trees using indigenous knowledge of the public
- Evaluate the potential and effectiveness of using PPGIS for mapping individual shea trees

CHAPTER TWO: LITERATURE REVIEW

2.1 Vitellaria Paradoxa (Shea Tree)

Vitellaria Paradoxa, commonly known as the Shea butter tree, "Ekungur" in Ateso, "Mo yao" in Luo, is a nutritional, cultural, and economic resource amongst societies where it is prevalent.

2.1.1 BOTANICAL DESCRIPTION

Vitellaria paradoxa is a small to medium-sized tree that ranges between 7-15 meters in height; it is much branched, dense, spreading, round to hemispherical crown. In mature trees the bole is short, usually 3-4 m but exceptionally 8 m, with a diameter ranging from 0.3 to 1 m, but most frequently 0.6 m. Bark conspicuously thick, corky, horizontally and longitudinally deeply fissured. The hardy bark protects older trees against bush fires. broken twigs or petioles secrete a white sticky latex. Leaves grow in dense clusters, spirally arranged at the end of stout twigs. They are covered by thick bark showing numerous leaf scars. Petioles 5-15 cm long, leaves oblong. Juvenile leaves rust-red and pubescent, later coriaceous, glabrous and dark green, shining, 12-25 cm long and 4-7 cm wide, leaf margin wavy and bent. The flowers develop in the axils of scale leaves, at the extremities of dormant twigs, from buds formed 2 years previously. Inflorescence a dense fascicle 5-7.5 cm in diameter, at the end of a flowering twig, each usually containing 30-40 flowers, though 80-100 have been recorded. Individual flowers white or creamy-white, about 1.5 cm in diameter and subtended by scarious, brown, ovate or lanceolate bracteoles, which are abscised before flower opening. Fruit 5-8 cm long and 3-4 cm wide, elliptic, a yellow-green or yellow berry with thick butter-like, mucous pericarp; generally containing only 1 oval or round red-brown seed (the shea nut), surrounded by a fragile shining shell with a large, round, rough hilum on a broad base. The genus Vitellaria is considered by botanical authorities as monospecific, two subspecies are recognized ssp. paradoxa restricted to Western Africa and ssp. nilotica of Eastern Africa.

2.1.2 BIOLOGY AND ECOLOGY

The shea tree is a light-demanding species of open sites and parkland savannah; forming extensive pure stands in some areas but often also associated with other trees. The tree avoids swampy areas, those liable to flooding for any length of time, moist heavy loam soils or watercourses. The extensive root system is essential for survival in the 5-7-month dry seasons of savannah climates. The tree can withstand quite severe fires owing to its thick fissured bark.

The tree has been documented to grow in Benin, Burkina Faso, Cameroon, Chad, Cote d'Ivoire, Ghana, Guinea, Mali, Niger, Nigeria, Senegal, Sudan, Togo, Uganda between Altitude: 100-1200 m, mean annual temperature: 24-32 ^{o}C, mean annual rainfall: 600-1 400 mm. Its growth is favored by dry and sandy clay soils with a good humus cover but also tolerates stony sites and lateritic subsoil although reacting with lower yields.

The Shea tree bears hermaphroditic flowers that are usually cross-pollinated, but can be self-pollinated. Insects, especially bees, are important for pollination. Flowering lasts 30-75 days and the fruit takes 4-6 months to develop, reaching maturity early in the rainy season. The sugary pulp of the fruit makes it attractive to a wide range of animals. A large variety of birds, ungulates and primates, including humans, eat them, dispersing the seed in the process.

2.1.3 SHEA TREE PRODUCTS

Food: Shea butter extracted from the nuts is one of the most affordable and widely used vegetable fats in the Sahel. Today, shea nuts are important internationally and are sold to European and Japanese food industries. The refined fat is sold as baking fat, margarine and other fatty spreads under various trade names and finds increasing use in various foodstuffs. Shea butter has a fatty composition similar to that of cocoa butter, so is often used as a substitute for cocoa, and in pastry because it makes a highly pliable dough. Traditionally prepared unpurified, shea butter is sold in ‘loaves’ in markets and, if properly prepared and wrapped in leaves, is resistant to oxidative rancidity and will keep for years if not exposed to air and heat. Nuts that have been cleaned and lightly sun dried without previous maceration yield a tasteless, odourless fat. Traditionally prepared shea butter, after refining, is also tasteless and odourless. The edible fruit pulp constitutes 50-80% of the whole fruit. It is allowed to become slightly overripe before being eaten raw; it can also be eaten lightly cooked. Children eat the nuts raw, while the flowers are made into fritters by some ethnic groups. Caterpillars of Cirina butyrospermii A. Vuilet, which feed exclusively on the leaves of the shea-butter tree, are dried and sold in markets in Nigeria and Senegal. They are rich in protein and sometimes eaten in a sauce.

Fodder: Shea-nut cake is increasingly used for livestock and poultry feed. Leaves and young sprouts serve as forage. Sheep and pigs eat the sugary pulp of ripe fruit that have fallen to the ground. Apiculture: The tree is much sought after for placing hives in traditional apiculture. Vitellaria furnishes the bees with a great quantity of nectar and pollen.

Fuel: Excellent-quality firewood that burns with a fierce heat. The charcoal is not good quality, however; it burns rapidly and is friable and, although it provides enough heat for domestic use, is not suitable for iron-working. The sticky black residue from fat extraction can also be used as a substitute for kerosene when lighting firewood. Due to its value as a fruit tree, V-paradoxa is seldom cut for fuel.

Timber: Wood brownish-red, darkens readily on exposure; strong, hard, heavy, durable, resilient, and weathers and wears well. Despite its hardness, it saws and planes well, takes an excellent polish, and glues, nails and screws well, but preboring is advisable to prevent splitting. Wood is used in engineering structures, house posts and support poles, also in ship building, for shingles, stakes and fencing, sleepers, medium and heavy-duty flooring, joinery, seats, household utensils, durable platters and bowls, pestles and mortars and tool handles. It is termite resistant.

Latex or rubber: The latex is heated and mixed with palm oil to make a glue. Latex obtained from the bark of the trees could be used as a chewing-gum base, but it does not have a very pleasant taste. Washing improves the taste but detracts from the chewing quality of the gum. The sap has been used traditionally to prepare punctured drums.

Tannin or dyestuff: Ashes from burnt wood are commonly used as the dye.

Lipids: The shea-butter tree is an important oil-producing plant, especially as it occurs where other such plants are rare. It is also useful in soap making, but it is unique in having a high fraction of oil (8%) that does not convert into soap; this fraction has numerous medicinal qualities. The sticky black residue that remains after the clarification of butter is used for filling cracks in hut walls.

Wax: The high melting point of the fat renders it especially suitable for candle manufacture.

Poison: Waste water from traditional shea-butter extraction is believed to keep white ants away. Traditionally, shea butter, at a rate of 5 ml oil/kg of seed, has been shown to protect Vigna subterranea against Callosobruchus maculatus. A root-bark extract (100 ppm) is effective against Bulinus globosus; when mixed with tobacco, the roots are used as a poison by the Jukun of northern Nigeria. Infusions of the bark have selective antimicrobial properties, being effective against Sarcina lutea and Staphyllococus aureus.

Medicine: Shea butter protects against sunburn, so is a useful ingredient in sun-protection or post-sun-exposure products. It also encourages wound healing and soothes skin irritation. Shea butter is stable and permits the fast release of medicaments; it can therefore be used as a base for suppositories and ointments. Shea butter is traditionally used in medicines, particularly for the preparation of skin ointments, and is used to treat inflammation, rashes in children, dermatitis, sunburn, chapping, irritation, ulcers and as a rub for rheumatism. Leaf decoctions are used for stomach-ache, headache and as an eye lotion. Roots and root bark are ground to a paste and taken orally to cure jaundice, or are boiled and pounded to treat chronic sores and girth sores in horses. They are also used for the treatment of diarrhoea and stomach-ache.

A bark concoction is used in a bath to facilitate childbirth in Cote d'Ivoire; it is drunk to encourage lactation after delivery, although in northern Nigeria such a concoction is said to be lethal. A bark infusion is used as an eyewash as a footbath to help extract jiggers, and to neutralize the venom of the spitting cobra. Infusions have been taken for the treatment of leprosy in Guinea-Bissau and for gastric problems as well as for diarrhoea and dysentery. Macerated with the bark of Ceiba pentandra and salt, infusions have been used to treat cattle with worms in Senegal and Guinea. Tapinanthus globifera, one of the most common parasitic plants on Vitellaria, also has many medicinal uses.

Other products: Shea butter is used as a base for many commercial preparations. Increasingly, cosmetics, especially those that prevent skin drying and good-quality lipsticks, use shea butter. As a result, cosmetic industries in the Sahel and elsewhere market this ingredient in many soap, shampoo and skin-cream preparations. Today, Vitellaria is the 2nd most important oil crop in Africa, after oil palm, but it takes on primary importance in areas in West Africa where annual precipitation is less than 1000 mm and therefore unsuitable for oil palm. The residual meal of the seed cake is applied to the exterior walls of mud huts, doors, windows and traditional beehives, in a similar way to shea butter, to provide a waterproof layer.

2.1.4 SERVICES

Erosion control: It regenerates well, and is traditionally favoured and protected by farmers. As a result, it has played a significant role in soil and water conservation and environmental protection in semi-arid West Africa.

Soil improver: The husks of the seeds make a good mulch and fertilizer.

2.2 Participatory Mapping

Public participatory GIS (PPGIS) is a "field within geographic information science that focuses on ways the public uses various forms of geospatial technologies to participate in public processes, such as mapping and decision making." (Tulloch, 2008)

Participatory mapping also known as community-based mapping is a general term used to define a set of approaches and techniques that combines the tools of modern cartography with participatory methods to represent the spatial knowledge of local communities. It is based on the premise that local inhabitants possess expert knowledge of their local environments which can be expressed in a geographical framework which is easily understandable and universally recognized.

The participatory approach to mapping dates back to the late 1980s when social workers and development agencies adopted Participatory Rural Appraisal (PRA) methods such as sketch mapping, photo-mapping and transect walks in their methods of work (Rambaldi, Chambers, McCall & Fox, 2006). This method hinges on evoking local knowledge and building on local dynamics to facilitate communication between insiders (local communities) and outsiders, such as researchers and government officials. Different participatory mapping strategies including participatory photo-mapping and sketch mapping as well as participatory GIS (PGIS) have traditionally been involved in the collection of data. These mapping strategies have specifically been used for land use planning and management and environment and natural resource management.

In the Nguti Subdivision of Cameroon, public participatory mapping was used to map the existing occupation and traditional tenure of forest lands and identify where conflicts of use or rights already exist or could arise. (Temgoua & Eyan, 2018). The study revealed that the participatory mapping process was a better basis for decision making on the management of natural resources as compared to the use of the Cameroon forestry atlas and satellite images.

Another study on the public use (leisure and visitation) in the Ebro Delta Natural Park in Spain using PPGIS showed that the method was an effective procedure for measuring public use in protected areas and may be a valuable tool for park managers and planners. (Buendía, Albert, & Giné, 2019). This study used an online survey that was designed using Google Maps API, HTML, and JAVASCRIPT. The survey had 209 correspondents providing 2617 georeferenced opinions.

2.2.1 PARTICIPATORY MAPPING METHODS

2.2.1.1 Sketch Mapping

Sketch mapping or "resource mapping" helps people in picturing resources and features on a given base and in graphically manifesting the significance they attach to them. It is a method for collating and plotting information on the occurrence, distribution, access and use of resources within the economic and cultural domain of a specific community (Integrated Approaches to Participatory Development (IAPAD), 2010). Sketch mapping is a slightly more elaborate method. A map is drawn from observation or memory. It does not rely on exact measurements, such as having a consistent scale, or georeferencing. It usually involves drawing symbols on large pieces of paper to represent features in the landscape. The sketch mapping method is detailed and requires more time to compile than the photo-mapping method, since maps are drawn from the participants' memory, whereas photo-maps are drawn from georeferenced remotely sensed images.

The International Fund for Agricultural Development (IFAD), describes sketch mapping as a "hands-on mapping that includes basic mapping methods in which community members draw maps from memory on the ground (ground mapping) and paper (sketch mapping)." These maps represent key community-identified features on the land from a bird's eye view. They do not rely on exact measurements, a consistent scale or georeferencing, yet they do show the relative size and position of features. These maps have been commonly used in Rapid Rural Appraisal

(RRA), Participatory Rural Appraisal (PRA) and Participatory Learning and Action (PLA) initiatives.

2.2.1.2 Photo-Mapping

Photo-mapping exercise is usually carried out on the printouts of georeferenced or ortho-rectified remotely sensed images (Rambaldi *et al.*, 2006). Ortho-photo maps are one of the sources of accurate remotely sensed data that may be used for large scale community mapping. The International Fund for Agricultural Development stated that "local knowledge is identified through conversation and then drawn directly onto a photocopied map or remotely sensed image or onto clear plastic sheets placed on top of the map. The position of features is determined by looking at their position relative to natural landmarks, such as rivers, mountains, lakes." This method is commonly used where accurate and affordable scale maps are available. This method also works well with aerial and satellite images, which can be particularly helpful when working with people who cannot read a topographic map and with non-literate communities, including those from marginal livelihood systems, such as indigenous peoples, forest dwellers and pastoralists. Additional information can be collected in the field using GPSs and later be transferred to the map (International Fund for Agricultural Development, 2009).

Photo-mapping techniques are a good format for communicating community information to decision-makers because they use formal cartographic protocols, such as coordinate systems and projections. Information can be incorporated into other mapping tools, including GIS and GPS data can be easily transposed onto these scale maps. When accuracy is required where scale maps are not available, scale maps can be made using survey equipment including compasses and GPS tools. Like sketch mapping, the International Fund for Agricultural Development maintains that the photo-mapping approach "is relatively cheap and fast and still provides an accurate spatial representation of local knowledge, particularly if the information drawn on the map is 'ground-truthed' using a GPS. The resulting map can be used to determine quantitative information such as distance and direction."

Generally speaking, sketch mapping and photo mapping are mostly used in rural areas where technology is a limiting factor. These methods promote the inclusion and empowerment of marginalized or under-represented populations in the development and use of spatial information. They have been mainly used in regional, environmental, and conservation studies (Greg & Marketta, 2014).

Table 1. Regional and environmental PPGIS studies (1998-2013)

Year	Implementation Mode	Location	Planning Purpose
2013	Internet (Google Maps)	Tongass National Forest (Alaska)	National forest planning
2013	Internet (Google Maps)	New South Wales, Australia	Outdoor recreation planning (mountain bike and horse riding)
2013	Internet (Google Maps)	Adelaide, Australia	Urban Park planning
2012	Paper	South Suriname, South America	Conservation planning
2012	Internet (Google Maps)	Sierra, Sequoia, and Inyo National Forests (California)	National forest planning
2012	Internet (Google Maps)	Chugach National Forest (Alaska)	National forest planning
2011	Internet (Google Maps)	Otago Region (New Zealand)	Regional conservation
2011	Internet (Google Maps)	Southland Region (New Zealand)	Regional conservation
2011	Internet (Google Maps & Google Earth)	South West Victoria (Australia)	Regional conservation and national park management
2010	Internet (Google Maps)	Kangaroo Island (South Australia)	Tourism and conservation
2010	Internet (Google Maps)	Grand County (Colorado, U.S.)	Ecosystem service mapping
2009	Internet (Flash)	Alpine Region (Victoria, Australia)	National Park planning
2007	Internet (Flash)	Mt. Hood National Forest (Oregon, U.S.)	National forest planning
2007	Internet (Flash)	Deschutes/Ochoco National Forest (Oregon, U.S.)	National forest planning
2006	Internet (Flash)	Coconino National Forest (Arizona, U.S.)	National forest planning
2006	Paper	Murray River, Victoria (Australia)	River conservation
2005	Paper	Otways Region, Victoria (Australia)	Tourism and conservation
2004	Paper	Kangaroo Island (Australia)	Tourism and development planning
2003	Paper	Anchorage Parks and Open Space (Alaska)	Urban Park and open space planning
2002	Paper	Kenai Peninsula (Alaska)	Coastal area management
2001	Paper	Alaska Highways (Alaska)	Scenic byway nomination
2000	Paper	Prince William Sound (Alaska)	Marine conservation
1998	Paper	Chugach National Forest (Alaska)	National forest planning

2.2.1.3 Internet Based Mapping

This approach employs the use on an online base map to enable local communities put their data on the map. While the method is effective for large surveys in a relatively short period of time, it may not be appropriate for developing countries like Uganda where access to internet is still limited and the literacy levels of the local communities is relatively low.

Table 2. Urban base PPGIS studies (2008-2013)

Year	**Implementation mode**	**Location**	**Research theme**	**Participants (approximate)**
2013	Internet (Google Maps)	Pacific Beach, San Diego, USA	Community development together with NGO	120
2012	Internet (Tailored address maps with layers)	Kainuu, Finland	Socio-ecological tools for ecotourism planning	260
2012	Internet (Tailored address maps)	Tampere, Finland	Everyday mobility of urban tribes	3300
2012	Internet (Tailored address maps)	Kuninkaankolmio, Helsinki metropolitan area	Everyday mobility of urban tribes	1100
2011	Internet (Tailored address maps)	Kirkkojärvi, Espoo, Finland	Perceived safety of a neighborhood	330
2011	Internet (Finland: Tailored address maps, Japan, Australia: Google maps)	Kauhajoki, Finland Tokyo, Japan Bendigo, Australia	Environmental child friendliness of various contexts	1200
2010	Internet (Tailored address maps)	Vaasa, Finland	Continuous softGIS service for participatory urban planning	1200
2010	Internet (Two map options: Tailored address maps and aerial photos)	Helsinki, Finland	Urban environment promoting active lifestyle of children	1100
2010	Internet (Tailored address maps)	Soukka, Espoo, Finland	Mapping local services	900
2010	Internet (Tailored address maps)	Billnäs, Finland	Participatory urban planning: Mapping local character	110
2009	Internet (Two map options: Tailored address maps and aerial photos)	Helsinki and Espoo	Urban densification & social sustainability	3100
2009	Internet (Tailored address maps and aerial photos)	Tammisalo, Helsinki, Finland	User feedback regarding an urban park	200
2008	Internet (Tailored address maps and aerial photos)	Muotiala, Tampere, Finland	Perceived safety of a CPTED neighborhood	180

2.3 Best Practices in PPGIS

Each profession and culture caries different moral parameters and codes of ethics. PPGIS is a multidisciplinary approach that brings together actors from different backgrounds and it is therefore important to identify and adopt best practices that suit a given community and mapping exercise. (RAMBALDI, CHAMBERS, MCCALL, & FOX, 2006). The following guiding principles should be taken into consideration for a successful PPGIS exercise;

Be open and honest

This applies right from the beginning, and throughout the process. Practitioners must explain clearly and in the local language(s) the strengths and limits of their ability to influence outcomes, and while the potential benefits of PGIS are explained, no claims must be made for results that are not within the power of the facilitators or their organization to achieve.

Purpose

Be certain and clear about the purpose – why do people get involved in this particular exercise? Before embarking on the process, discuss openly the objectives of the PGIS exercise and what the different parties may expect from it.

Obtain informed consent

As in any research with people, participation must be voluntary. In order for participation to be voluntary, the participant needs to know what kind of map is going to be made (showing them an example would be ideal), the type of information that will be on the map, and the possible implications of the maps being made public. People must agree to participate and be able to withdraw at any time without prejudice. Obtaining informed consent should be set in advance. Do your best to recognize that you are working with socially differentiated communities and that your presence will not be politically neutral PGIS is always a political process and will, therefore, most likely have unintended consequences for the communities you work with regarding the complex issues of who is empowered and who might actually be disempowered. Be aware that the internal workings of socially differentiated communities are very context dependent and unpredictable.

Avoid raising false expectations

Any process of analysis facilitated by an outsider is liable to raise expectations of some benefit, even when the outsider explains that he/she has no provisions for follow-up and few concrete changes may follow from his/her visit.

Be flexible

Despite the necessity for a long-range vision, the approach should remain flexible, adaptive, and recursive, without sticking rigidly to pre-determined tools and techniques, or blindly to the initial objectives of the mapping exercise (participation is two-way learning between several sets of 'experts', scientific or NGO outsiders, and community insiders).

Use Appropriate Technologies

Consider using spatial information technologies that can be mastered by local people (or local technology intermediaries) after being provided sufficient training

The use of GIS is not a must: it is an option. As technology complexity increases, community access to the technology decreases. Ask yourself: is a GIS really necessary? Would GIS add anything that cannot better be achieved through other participatory mapping methods?

Be considerate in taking people's time

The time of poor people is, contrary to some professional belief, often very precious, especially at difficult times of the year (often during the planting or weeding seasons). Rural people are often polite, hospitable and deferential to outsiders, who do not realize the sacrifices they are making. A day of weeding lost at a critical time can have high hidden costs in a smaller harvest.

Do not sacrifice local perception of space in the name of precision

Spatial precision is relative and only has value when very detailed data on boundaries or areas is needed. Too often the emphasis is on precise measurements rather than on seeking and checking what are the spatial phenomena the people are really talking about, e.g., better to expend effort in understanding different types of overlapping customary land tenure, than on measuring arbitrary boundaries down to meters or centimeters.

Ensure genuine custodianship

Ensure that the original physical output of a participatory mapping exercise stays with those who generated it and specifically with a trusted entity nominated by the informants.

Taking outputs away – even if for a short time – is an act of disempowerment. Making copies of community-generated outputs involves more time spent in the village, additional efforts, more inputs and financial resources. Meeting this condition of good practice increases the cost and the time, but ensures that those who generated the spatial information are not deprived of their intellectual property (IP) and effort.

Acknowledge the informants

If not prejudicial to the security of the informants, and with their prior consent, include the names of the contributors to the generated maps and/or data sets.

CHAPTER THREE: METHODOLOGY

3.1 Description of Study Area

Kapelebyong district was curved out of Amuria in North Eastern Uganda in July 2017. The district is bordered by Amuria to the south, Otuke and Alebtong to the West, Napak to the East, Abim to the North East and Katakwi to the South East. The district also neighbors the Bokora Wildlife reserve to the North East. The study Area, Airabet subcounty has a predominantly flat terrain that covers an area of 130sq km.

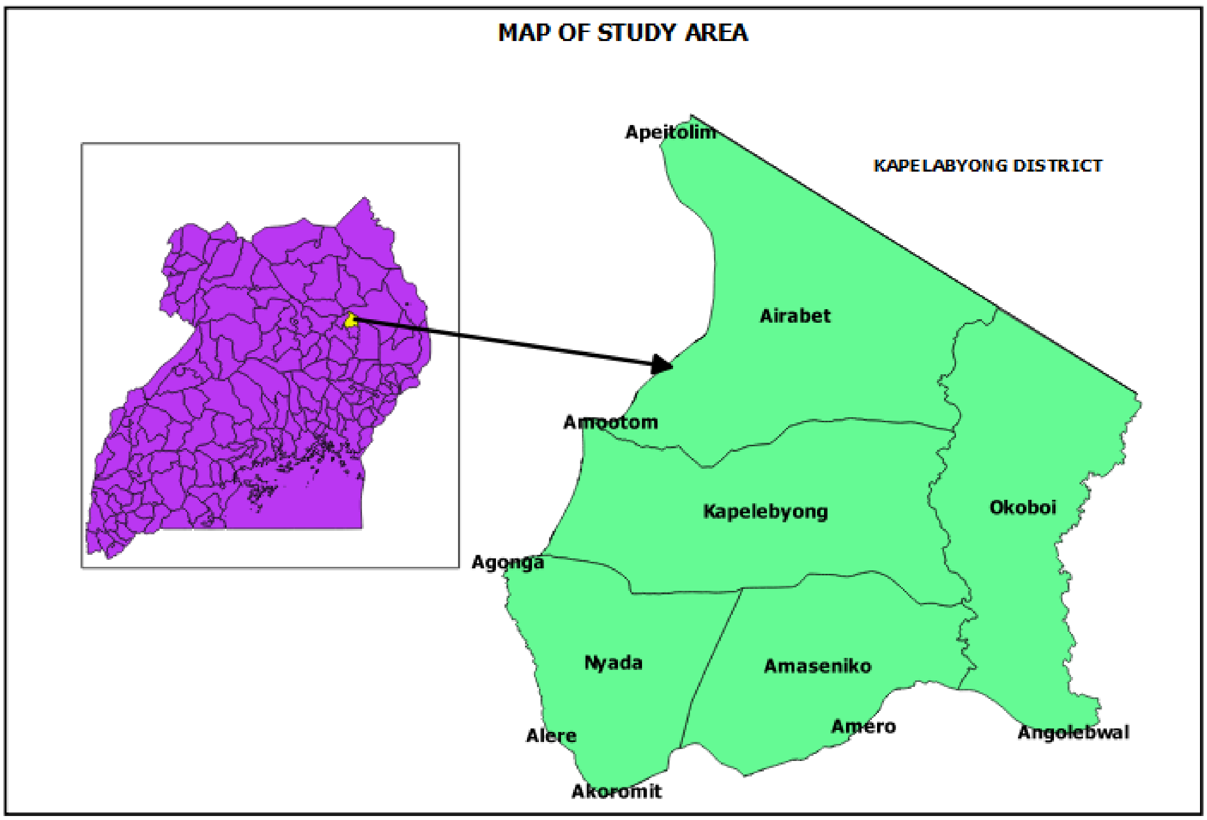

Figure 1. Map of Airabet Parish

3.2 Determining and appropriate scale and mapping method

The method employed in participatory mapping largely depends on the socio-economic status of the community. Community based research projects in developing countries often differ in goals, methods, and access to technology than those in developed countries (Warner 2015). In developing countries, basic technology access is usually the biggest challenge.

Projects in developing countries generally utilize GPS and paper maps to record their indigenous knowledge which usually focuses on qualitative data like locations of health facilities, boundaries, and other features of importance.

In developed countries, technology is more widely available, affordable and accessible. It is easier to reach out to communities through the internet, mobile applications and social media platforms. PPGIS Projects in developed countries thus typically use internet-based applications for participatory mapping.

A study of the demographics of the study area is necessary in determining an appropriate means of mapping to be used by the local community.

3.2.1 Demographics of Kapelebyong

- Population-87,580
- Literacy-13,795 (39.8%) Persons aged 18 years and above are illiterate
- USE OF ICT-10,476 (19.3%) of persons aged 10 years and above owned at least a mobile phone
- 2,466 (4.5%) persons aged 10 years and above use the internet
- SOURCE OF LIVELIHOOD- 15,222 (95.6%) of the households are engaged in farming (growing crops or livestock farming)
- HOUSING CHARACTERISTICS-19,544 (90%) of the households are owner occupied

Source: (UBOS, 2017)

Basing on the above demographics, cognitive paper mapping was chosen over internet/mobile based implementation of the project.

3.2.2 Determining an appropriate scale

The scale of paper maps used directly influences the accuracy of the results obtained from the mapping exercise. In order to create a map of an area for the characteristic of interest, the pixel size cannot be smaller than the minimum frequency of data points. (Warner, 2015). Basing on field observations, shea tree crowns typically ranged from 10 to 20 meters in diameter.

- Google hybrid base maps from QGIS webmapservice plugin were used
- The base map was zoomed to a resolution that allows for clear identification of individual trees, and other land features such as roads and buildings which would be used as benchmarks during the mapping exercise. The resolution of images used was 3.5m.
- The appropriate mapping scale was determined to be 1:500.

3.3 The participatory mapping exercise

- Mapping was done in four neighboring villages of Airabet, Aminit, Olilia, and Opungur. This was mainly done in trading centers where there was a reasonable count of people that would form a group. It was difficult to achieve a group of more than four willing people outside trading centers due to the sparse population of the study area.
- Framing key issues (as per the meeting guide). The meeting guide helps in orientation of the project’s participants to the goal of the mapping exercise
- Capture of local knowledge on paper maps. The participants of the project were requested to mark points on the paper where they perceived shea trees to be located. This was done after discussion and reaching consensus among the members.

Figure 2. Participants mapping out shea tree locations on paper maps in Aminit trading center

- Validation of the paper maps. Using internet enabled mobile mapping application (SW Mapper), 115 GPS points of sample shear trees were recorded in the study area for accuracy assessment.
- The paper maps were transformed into a digital format to enable storage, display, and analysis in a GIS. This involved scanning, georeferencing, and digitizing.

CHAPTER FOUR: RESULTS AND DISCUSSION

This section will exploit, discuss and interpret the project findings, based on the research methodology established in chapter three which is also in accordance with the research objectives as stipulated in chapter one.

The research results have been analyzed empirically with the goal of answering research questions in order to facilitate convincing conclusions which will in turn support decision making.

- To answer objective one, -Determine the most appropriate mapping method and scale to be used in the mapping exercise.

The paper mapping method proved to be appropriate for all the community members involved in the mapping exercise at the chosen scale of 1:500. Participants did not have any difficulty in visualization and identification of individual shea trees on the map. At the chosen scale, participants could clearly identify and pin point (place markers) shea tree locations on the map. The size of paper maps used was A3.

However, the pool of active participants was severely limited by physical space around the paper map, yet the project was carried out during the COVID-19 outbreak where social distancing was paramount. Opinion on the location of the shea trees was also largely dominated by a few individuals who stood out in the group and suppressed the views of others.

There was also a problem of some participants finding bearings on the map. Those that could not establish the relative location of features to get a clear map orientation quickly lost interest in the mapping exercise thereby limiting the number of participants.

Printing larger paper maps on paper size A0 or A1 could help increase the number of participants permitted by the physical space around the map.

To answer objective two, -Identify and map out individual shea trees using indigenous knowledge of the public

A total of 369 points were mapped by 34 participants over an area of 6 km^2 in the four villages of Airabet, Aminit, Okungur, and Olilia.

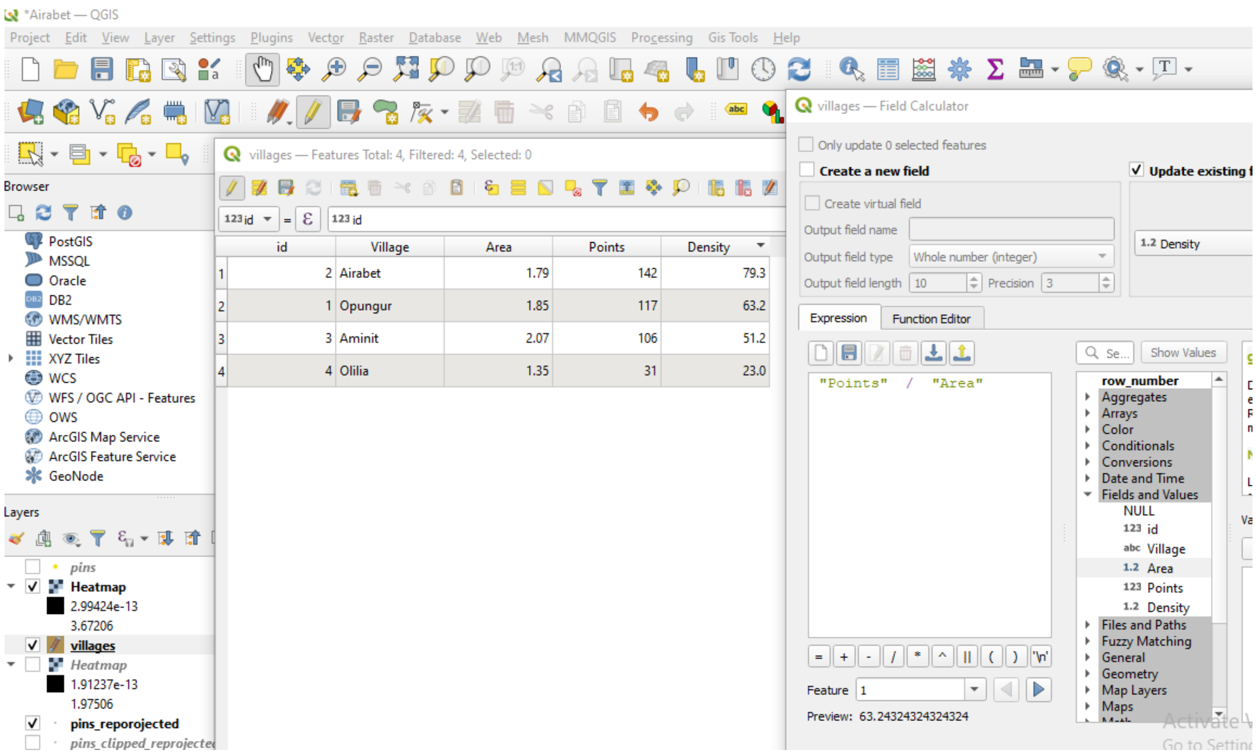

Figure 3. QGIS analysis of shea tree stocking density per village

The created maps provide sufficient information on the relative abundance and distribution of the shea trees across the study area. However, analysis of a heatmap of the mapped trees shows that mapping density was generally high along roads and around trading centers and settlements and compared to vast open spaces without any vivid landmarks. This could be attributed to the fact that it is easier to memorize spaces close to landmarks and features that support their everyday life such as buildings and roads.

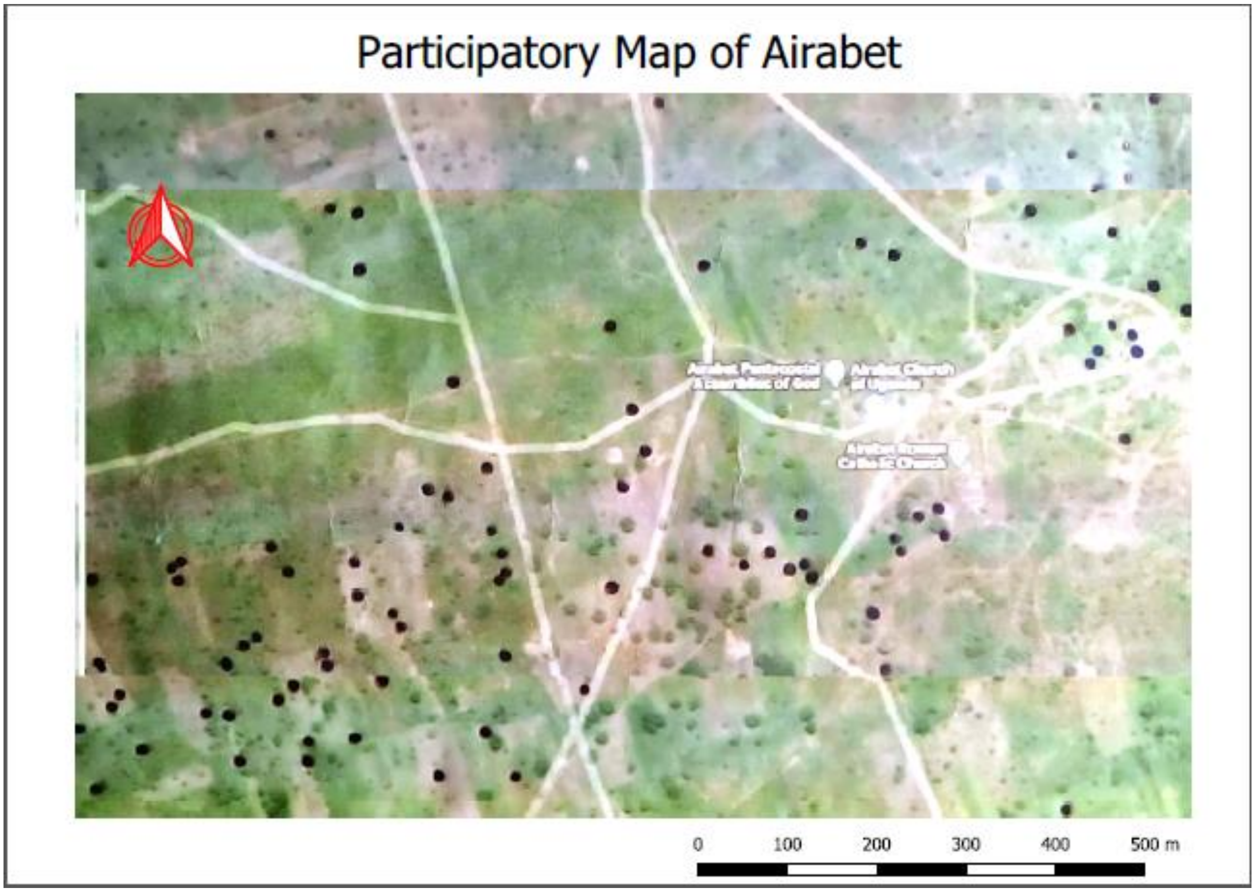

Figure 4. A participatory map showing location of shea trees marked in black ink

- To answer objective three, - Evaluate the potential and effectiveness of using PPGIS for mapping individual shea trees.

  At the time of the start of this study, there was no available literature that showed any prior attempts to map individual tree species in Uganda using Public Participatory GIS. There has been generally very limited research on the mapping and inventorying of shea trees in Uganda.

  The formal evaluation of public participation without a GIS component is historically scarce (Sewell & Phillips, 1979). Even with a resolve to engage in evaluation, there is no universal format in use for evaluating public participation that can be applied widely

(Chess, 2010; Halvorsen, 2001; Rowe & Frewer, 2004). The evaluation of the effectiveness of the method used in this project is based on comparison with results from a shea tree mapping project that was done in the neighboring district. Evaluation id further based on accuracy assessment that was done using ground truth data in QGIS 3.16.10 software.

Between 2014-2016, the Government of Uganda, with funding from the UNDP and GEF undertook the mapping of shea trees in the districts of Abim, Agago, Kitgum and Otuke in North Eastern Uganda. The project, which was implemented through NEMA, NFA and UWA used a traversing method where tree locations were captured using a hand-held GPS receiver. Results from this project indicate that the average shea tree stocking density was 34 trees per ha in the districts of Agago, Kitgum, and Otuke. However, average shea densities of 1 to 14 stems/ha were encountered across Morulem Sub-county in Abim district.

The Stocking density in Abim district is consistent with that established by this study (0.8 trees/ha). Given that the Abim shares a geographic boundary with the study area, conclusions can be inferred that PPGIS is an effective method for mapping shea threes. The effectiveness of PPGIS is also be hinged on low cost and quick data collection.

CHAPTER FIVE: CONCLUSION AND RECCOMENDATIONS

Information on the distribution and abundance of tree species is of primary importance in the planning and implementation of biodiversity conservation. In Uganda, shea tree conservation efforts, especially those by NGOs, such as the COVOL project, have mainly targeted areas where shea tree presence has been documented there by ignoring areas with less documentation.

PPGIS has the potential to generate the lacking information on shea tree presence in areas that have barely benefited from conservation efforts thereby arising awareness by mapping the unmapped.

This project has demonstrated that PPGIS can be used to generate spatial data that can be useful in range of conservation efforts and scientific research such as establishing the area of occupancy, extent of occurrence, and studying spatial patterns such as stocking density in relation to land use. The use of PPGIS is fast, effective and requires minimal investment in terms of technology and skilled human resource. However, the field of PPGIS is relatively new and still faces challenges such as lack of formal evaluation frameworks.

Accordingly, the following recommendations have been reached to enhance PPGIS projects aimed at mapping individual tress

- Need to increase public participation. During this project, participation rates were generally low. This could be based on the fact that the research was purely academic and did not have any direct benefit to the participants or host communities. It is therefore imperative to devise incentives to participants in order to get a wider audience and more inclusive/representative views of the public.
- Need to streamline who participates. Participation in this project was mainly dominated by males and even where females were present, their input was minimal. This could lead to biased views especially where the different gender have different interests in regard to the shea tree. For instance, women are mainly engaged in processing of shea butter and would therefore be interested in the conservation while men are mainly engaged in charcoal burning and show little concern for conservation.

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