Locals´ understanding of eutrophication, and perspective of land use of inner crater lakes slopes in western Uganda

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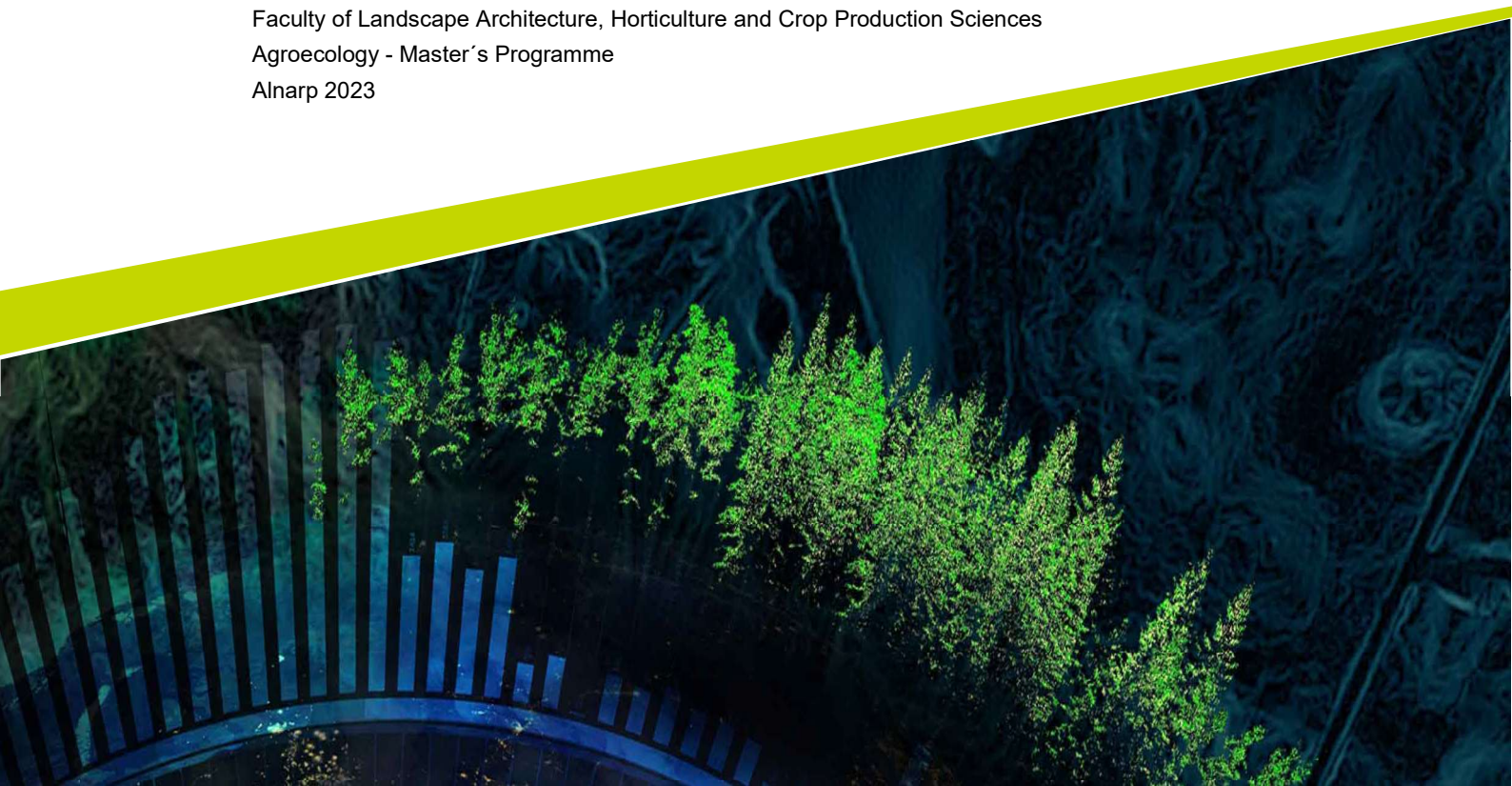

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Preface

During the two years master's programme in Agroecology at the Swedish University of Agriculture Sciences (SLU) my knowledge of the topic has developed into a deep understanding of its essence. This knowledge will follow me through life, and like a pair of glasses I can put them on when it is required.

"Agroecology is the integrative study of entire farm and food systems, embracing environmental, economic and social dimensions. Agroecological principles are applied in food systems to stimulate responsible action and target transitions towards more sustainable production, processing and consumption of food, including efficient use of resources and safe recirculation of nutrients." according to the teachers at SLU.

I have been using the principles of agroecology throughout the process of my master thesis. With *System thinking and the whole system approach* I have understood the value of the activities on the crater lakes´ slopes in western Uganda and how these also are a part of my own everyday life when I have my morning coffee. The farmers produce food not only for domestic use and local markets, their products also reach the regional and global markets with the export of coffee.

Interdisciplinary research and education are necessary for reaching a sustainable agriculture production, where social, economic and environmental aspects need to be considered. Farmers in Uganda experience that poverty is preventing the transition of the agriculture system, therefore we need to understand the complex relationships and processes and find solutions in the interdisciplinary sciences.

With *Participative and Action-oriented strategies* material and information for this research have been collected. For me as a researcher this approach gives me a common understanding with the participants, I see the uniqueness of the place and the factors that are influencing peoples' decisions. In this research reflections together with the participants have been an important activity and reflection can lead to action towards the desired transition towards sustainability.

This thesis has given me the chance to practice the knowledge and skills I have learned throughout the Agroecology master's programme. With agroecology we must understand the prerequisites of nature and and cooperate with its ecosystem which provides us services in return. I wish that small scale farming no longer must relate to poverty, I wish a change will come and that farmers in Uganda and all over the world can be given a chance to produce food in wealth. I believe if we give farmers good conditions to do their jobs, we will in return get food on our table and a world where biodiversity can flourish.

Abstract

Land degradation is a global issue and is causing enormous problems for humans and the environment as sediment from soil erosion is polluting the water; from ground water to river, lakes and oceans. In Uganda, this is a problem mainly caused by population pressure, deforestation, poor farming techniques and soil erosion. In the district of Kabarole and Bunyangabu 52 crater lakes are found. This study aimed to investigate local peoples´ experiences of living near crater lakes in Uganda, its benefits and challenges, understanding of current issues of land degradation and how it affects the lakes. Local people living near the lakes were selected trough purposive sampling for this study. The categories were lodge managers, fishermen, farmers, and village elders. In addition, agriculture students from the Mountains of the moon University and the District officer were interviewed as well. Two group discussions were held with participants residing close to two lakes; Nyabikere and Nyameteza. The results showed that the crater lakes are vital for local people since they provide fresh water and fish protein. The lakes also attract tourists to the area which can be beneficial for the local economy and development as well as for conservation activities. The important challenges for local people are problems with declining crop yields, soil erosion and changed weather conditions, especially rainfall in the "wrong" season and often with high intensity and amount. Local people relate the quality of the lake´s water to its suitability for domestic use purposes. There seems to be a weak understanding about eutrophication and their own contribution to it, even though the effects of eutrophication are known among the participants. Farmers had issues with soil erosion; crops and soil were washed away by runoff water. Erosion preventing techniques such as digging trenches was common practiced. Keeping the land fallow and planting trees were recommended by the participants to prevent soil erosion and improve soil fertility, but the ability to practice these techniques varied among the local people, and small land holding was a limiting factor to adopt such practices. The extension and advisory services regarding soil conservation seems inadequate within the country, and efforts to attract people to participate in meetings are necessary. Effective Risk Communication could be a way to address the issues with eutrophication and soil erosion in the crater lakes region in Uganda, and this should include stakeholders such as farmers, extension and advisory services, NGOs and the government. More research about soil conservation techniques and the transformation process among small scale farmers and their individual prerequisites are necessary for prevention of eutrophication and improvements of small scale farmers´ livelihood.

Keywords: crater lakes, effective risk communication, eutrophication, land degradation, participatory rural appraisal, soil erosion

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1. Introduction

Land degradation is a global issue and is causing enormous problems for humans and the environment. Siva Kumar & Ndiang´ui (2007) define land degradation as, - the loss of the land´s biological productivity, caused by human-induced factors and climate change. Example of factors can be deforestation, agriculture and change in land use. These activities can cause that sediment from soil erosion is polluting the water; from ground water to rivers, lakes and oceans (Karamage et al. 2017). Nutrients like nitrogen and phosphorous are lost from the soil which result in poor soil quality and in eutrophication of water bodies (Bamutaze et al. 2019a). There are natural triggers for soil erosion such as heavy rainfalls and earthquakes and together with human activity, the problems of soil erosion are accelerating.

In Uganda, during the last century, land degradation has been a big issue.This is caused by population pressure, deforestation, poor farming techniques and soil erosion (Hilhorst 2000). On the east African plateau and by the foothills of Rwenzori Mountains in southwest Uganda, the landscape consists of hills, valleys and several volcanic craters. Many craters are waterfilled and forms crater lakes. This unique landscape provides good prerequisite for the high biodiversity in the region. The area has a humid climate and high precipitation which together with the fertile volcanic soil gives good conditions for crop production (Hilhorst 2000). The region is important both nationally and globally since the area produce food for domestic consumption and cash crops for export. The crater lakes are a vital resource for the surrounding rural communities since they provide ecosystem provisioning such as drinking water and food fish (Nankabirwa et al. 2019). The health of the crater lakes and its environment are much dependent on its surrounding land use. Today agriculture is the main activity around the crater lakes, but during the last few decades a new type of industry has start to grow. Around the crater lakes a mix of luxury safari lodges, cottages and low budget campsites are mushrooming up (Adiyia et al. 2014). Even these developments will likely have an influence on the lakes´ environment and their surrounding area.

Measures needs to be taken to preserve this ecosystem. Several sustainable development goals (SDGs) of the United Nations Agenda 2030 such as; reverse land degradation and halt biodiversity loss, achieve food security and improved nutrition, promote sustainable agriculture, and end poverty in all its forms are strongly correlated with the issues around the crater lakes in Uganda.

The problems with eutrophication within the country have been investigated by researchers due to the severe problems in Lake Victoria, the largest lake in Africa. Lately scientists have put their interest even to the crater lakes, and in the district of Kabarole and Bunyangabu 52 crater lakes are found, but the surveys are few and often they focus on few lakes. More research needs to be done in this field as there is also a lack of systematic monitoring program (Nankabirwa et al. 2019) and these lakes are very important for the livelihood for many people living around them. The issue with land degradation in the area is well known by scientists and efforts with soil conservation programs were already introduced in the 1920s by the Ugandan government (Bamutaze et al. 2019). Even though, the issues with soil erosion are still a huge problem in the area. More knowledge is needed, such as about soil erosion techniques and why the programs are failing.

The experiences of and perception of local people on the situation about this issue is not researched before and this study will contribute to the local peoples´ understanding of land degradation and eutrophication of crater lakes. This information could be vital for both advisory services, public awareness and for water quality programs to give advice and follow up the development of the lake's ecosystem.

1.1.1 Aim

The main aim of this present study was to investigate local peoples´ experiences of living near crater lakes in Uganda, and the understanding of current issues of land degradation and how it affects the lakes´ condition.

1.1.2 The specific objectives were to:

1. Identify the opportunities and challenges which the communities living around the lakes are facing.
2. Assess local people's awareness about the lake's condition and their own contribution to eutrophication.
3. Evaluate measures to reduce land degradation, eutrophication of crater lakes and improve livelihood of local people.

2. Material and methodology

2.1.1 Study area

The current study took place in western Uganda in the district of Kabarole 0.5896682 N, 30.25487887 E and Bunyangabu 0.4870918 N, 30.2051096 E which can be seen in Figure 1, marked surrounded in red coulor dots. The district lies very close to the border of Democratic Republic of Congo. With recommendations from Kabarole Research and Resource Centre and the District officer different lakes were observed, and the type of land use was studied through visual observation of the lakes and their surrounding area. After the observation six crater lakes were selected for this study, Saaka, Nkuruba, Nyabikere, Marusi, Lake Kasenda and Nyameteza, (Figure 2), based on eutrophication level and surrounding land use.

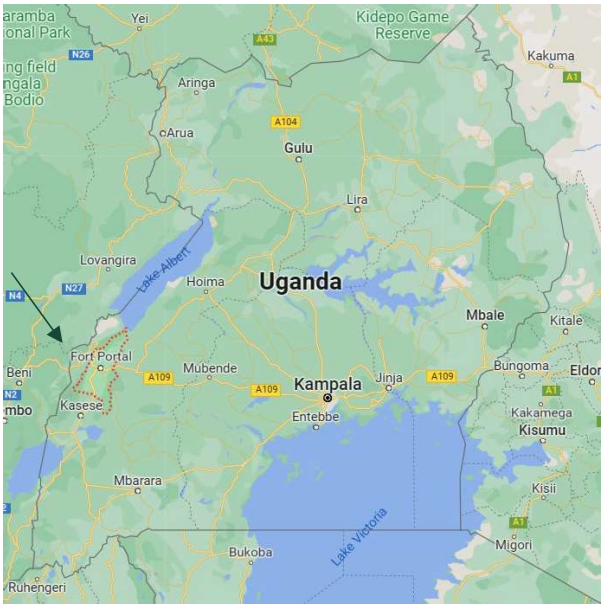


Figure 1. The map shows Kabarole and Bunyangabu District in Western Uganda. Source: Google Maps (2023)

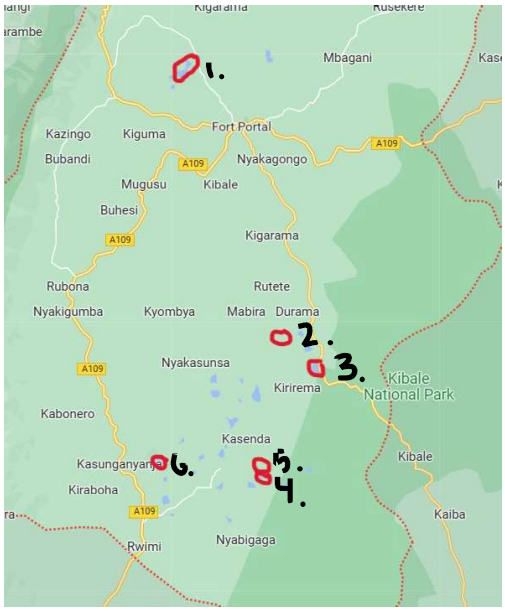


Figure 2. The map shows lake Saaka(1), Nkuruba(2), Nyabikere(3), Marusi(4), Kasenda(5) and Nyameteza(6). Source: Google Maps (2023)

2.1.2 Climate condition of the studied area

The many crater lakes are found at an altitude of 925m to 1520 m above sea level. The size of the lakes varies from a couple of hundred square meters up to one square kilometre, and as well the depth varies from 0.25 m to 180m (Chapman et

al. 1998). The characteristics of the crater lakes are deep lakes surrounded with a steep crater slope. Usually the slopes are densely populated since they have fertile volcanic soils (andosols) which is suitable for a diverse of crops (Ngecu et al. 2004). The area has high seismic activity and earthquakes regularly occurs. The region is humid with two dry seasons January-February and June-July (Muhamud 2015). The monthly rainfall within these two dry seasons is less than 50 mm. The wet season is March to May and August to December and has an average monthly rainfall of 203 mm (Muhamud 2015). Rainfall and topographic factors, soil properties and cover management conditions influence the variation of soil loss rates (Karamage et al. 2017). Because of big variation in rainfall distribution and slope gradient there is a high fluctuation in soil erosion risk from one place to another (Karamage et al. 2017).

2.1.3 Data collection

This research is a qualitative study where local peoples experiences of eutrophication are studied. Up to my knowledge this specific field is unexplored and therefore the method of participant observations is useful to understand the topic in a deeper sence. In this research influences of participant observations has been used like, everyday conversation as an interview technique, informally observing during leisure activities and using both tacit and ecplicit information in analysies and writing (DeWalt & DeWalt 2011). Furthermore, the method opens up for continual reassessment of the first planned research and interview questions. This makes it possible for further development of new questions since new insights are obtained as a result of increasing familiarity with the context. (DeWalt & DeWalt 2011) Participant observation include “living in the context for an extended period of time”. In the case for this research all meetings and discussions with stakeholders, such as locals, authorities, organisations, drivers and interprenter has been used to understand the context. Two and a half month was required for field work and collection of material. Fort Portal town was the base and from there daytrips was made to the field, where 1-5 interviews were made in a day.

For the interviews local people living near the lakes were selected trough purposive sampling (Campbell et al. 2020) to represent all key stakeholders that were necessary for this study. The categories were lodge owners and managers, fisher folks, farmers and village elders. On each lake, five semi-structured interviews were conducted and translated by an interpreter from Kabarole Research and Resource Centre. This included three to four farmers, one fisherfolk, one to two elder persons (50 years old and above) and one to two hotel managers. The elder person was among the category of farmers or fisherfolks (Table 1).

Table 1: Categories and number of interviews at each lake.

	Lake Kasenda	Marusi	Nkuruba	Nyameteza	Nyabikere	Saaka
Farmers	2(father and son)*	4	3	4	3	3
Fisherfolks			1	1	1	(fishing was forbidden)
Elder persons	1	2	1	1	1	1
Lodge managers	2(father and son)*		1	2	1	1
Students						7

*One interview was held with the land owner and his son surrounding Lake Kasenda and they are both lodge owners and farmers.

The farmers were represented by twelwe women and five men, the lodge managers were represented by six male and one female. The fisher folks were only represented by men since it is in their culture that men are fishing, and women are in charge of the fish-selling business. The elder persons where represented by four women and three men and the students where represented by one women and six men. In addition, one semi-structured interview with the District officer of Kabarole was done. The interview took place at his office in Fort Portal town, and was the first interview, with possibilities to follow up with questions through email. The interview gave an understanding of the situation of the crater lakes and its local people, and he highlighted lodge owners as an important stakeholder.

Lake Kasenda was an exception, where only one landowner was interviewed. This was because much research had already been done near Lake Kasenda and locals expressed that they didn't want to give anymore interviews. To get a fair understanding of the land use, one interview seemed enough, in which both the landowner and his son attended. Lake Kasenda was an important lake for this study since it had forested land on the crater slopes and was having high nutrient load in the water. The land is 150 acres (60 ha) and includes both forest conservation, agriculture and a lodge. The lodge has been operating for twenty years and have fifteen rooms.

Stakeholders around lake Saaka were diverse compared to other lakes since the lake is near the tourism city Fort Portal. Large establishment like a prison and a university (Mountain of the moon university) are located close to the lake. Agriculture students from the University were involved in a group discussion with adapted semi structured questions, with a total of seven participants.

Semi-structured interviews were suitable for this research since it provides the context and content of the interview (Edwards & Holland 2013). These interviews allow more space for interviewees to answer on their own terms. There is a flexibility in how and when questions are put and gives a chance for a discussion

to emerge within the interview (Edwards & Holland 2013). Important keywords and topics were used in an interview guide and the questions have been modified during the process (Edwards & Holland 2013). As can be seen on Table 2, the stakeholders were diverse and as such keywords/themes for questions were adapted based on the knowledge and experiences that were expected to be shared by them. Lodge owners and farmers were the most common types of landowners around the lakes and were therefore important stakeholders. They provide information about the land use and and activities on the crater slopes. The elderly people had a good knowledge about the study area and provided a historical perspective of the land use while the fisher folks contributed with a deep knowledge of the lakes biophysical condition.

Table 2: The categories of people and guiding topics for interviews.

Farmers	**Fishermen**	**Lodge manager**	**Students**	**District officer**
Personal background	Personal background	Personal background	Personal background	Personal background
Farm size and production	Experiences of being a fisherman	Operating time	Understanding of eutrophication	Situation of eutrophication among crater lakes
People living on the farm	Fishing regulations	Business and activity	Land degradation	Local people's use of the lakes
Farming techniques	Advisory	Land use now and before	Improvements and farming techniques	Regulation and programs for protecting the lakes
Use of chemicals	Benefits of staying in the community	Use of the lake	Benefits and challenges with pesticides	Implementation and local people's attitudes
Soil erosion	Challenges of staying in the community	Environmental changes in the area	Alternative techniques	Benefits of the lake for local people
Challenges of being a farmer in the area	Benefits with the lake	Environmental changes of the lake	Benefits from the crater lake	Challenges for local people
Advisory	Environmental changes	Regulations and directives	The universities effect on the lake	Improvements of the lakes condition
Benefits from the crater lake	Water quality	Water quality	Improvements of environmental issues in the area and in the lake	Improvements of local people's livelihood
Condition of the lake	Improvements for the lake´s condition	Interaction with local community	Challenges of being a farmer	
Awareness of contribution of the lakes condition	Improvements of local people´s livelihood	Improvements of the environment	Improvements of local people's livelihood	
Improvements of the environment		Improvements of local people's livelihood		
Improvements of livelihood				

Two group discussions were held with two of the lake's participants, lake Nyabikere and lake Nyameteza, see figure 3. Two meetings were held separately from each other, one for each lake. The invited people were the same that were interviewed around the lakes (farmers, fisher folks and lodge manager). At lake Nyabikere one women and four men attended and at lake Nyameteza five women and one man attended. The purpose was to initiate a group discussion to evaluate measures to reduce land degradation, eutrophication of crater lakes and improve livelihood of local people. The method of Participatory Rural Appraisal (PRA) was used for the group discussion which aims to enable local people to express, enhance, share and analyse their knowledge of life and conditions, to plan and act (Chambers 1994). PRA contains a reversal of learning, to learn from local people directly on the site and face to face. This to get insight to their local, physical, technical and social knowledge (Chambers 1994).

With a focus on learning, probing question was asked to the participants in a semi structured way and translated by an interpreter. Every participant shared their opinion for each topic and since most of the participants shared the same challenges agreements were easily made. Disagreements existed and were respected and handled well among the participants by understanding each other's perspectives.

Plan and act is a part of the aims of PRA, but because of time limitations of the research project this was not prioritised, instead the there was a focus on learning and reflexion and this for all participants including the researcher. This itself can lead to *plan and act* in an indirect way. Otsuki (2015) mention that individuals continually reflect on the changing social circumstances and shape their action based on the reflection instead of the predetermined structures. This also correlate with Effective Risk Communication and its three levels, where level one is to identify or becoming aware of a risk and the last level leads to action for the individual (Nassanga 2019). (More information about Effective Risk Communication is found in chapter 4c, Identifications of measures).

Figure 3. The figure expresses the group discussion at Lake Nyabikere. (Photographer Lars Svennersten 2023, used with the copyright holder's permission.)

3. Findings and discussion

3.1 Opportunities and challenges which the communities living around the lakes are facing

This chapter will discuss the first of the three objectives. Based on the participants answers different subheadings are made and will explain opportunities and challanges for the communities living around the lakes from the perspective of land use.

3.1.1 Crater lakes, social and environmental diversity

Understanding the stakeholders and the activities that are taking place around the crater lakes today provides a useful backround information to better understand the opportunities and challenges faced by the people living around the crater lakes shores.

There were, as mentioned before 52 crater lakes in Kabarole and Bunyangabu district. From the visual observation of the crater lakes, it could be seen that the lakes´ surrounding and the environment differed among them. It was found from the interview with the district officer, that two main activities were taking place on the land near the crater lakes, and these were agriculture and lodges for tourists.

The land around the lakes attracts foreign investors, and this was seen around several crater lakes. This was also described by the district officer, who said that the “whites” like to come here and buy land near the lakes. Most of the lakes surface area are less than a square kilometre, the small size of the lakes creates opportunities for one person to buy land surrounding a whole lake. One example is lake Kyaninga (not included in this survey) where a man from Great Britain has bought the land surrounding the entire lake. The lake was seen to be one of the most beautiful lakes because of its clear blue water, the man was also letting the natural forest grow back again on the crater slopes. He constructed a high-class lodge on the land including a helicopter pad where luxury tourists can fly in.

Foreign investors were common and could also be seen by the lakes Nyabikere, Nyameteza and Marusi in this survey. The upper class in Uganda/the financial rich

people also invest in land near the lakes, for example by lake Nyabikere a member of the parliament was constructing a new lodge, according to the locals.

The area of the crater lakes is famous for the incredible nature and the biodiversity is high (Naughton-Treves et al. 2011). It was mentioned by the participants that five of the studied lakes had monkeys in the surrounding area. Kibale national forest in the region, has a high density and diversity of primates, including chimpanzees. The lodge manager at lake Nkuruba mentioned as such:

- "*Just ten years back in time chimpanzees could be seen by the lake. Now there is not any forest connecting the lake with Kibale Forest and the natural route for the wild animals are lost"*.

This can be due to an ongoing deforestation process since 1900^{s} because of population growth, and agriculture expansion, which is a threat to the biodiversity (Naughton-Treves et al. 2011). Despite these deforestation activities, many of the crater slopes have remained forested longer than the surrounding landscape, the steepness of the slopes has made it difficult to clear trees (Pomeroy & Seavy 2003). For many water birds the dramatic change around the lakes has threaten their habitats and some are even facing the risk of being extinct (Pomeroy & Seavy 2003).

Among the six studied lakes there were two that were surrounded by natural forest, lake Nkuruba and Lake Kasenda. The land that surrounded lake Nkuruba was owned by catholic priests and the place was called Lake Nkuruba Nature Reserve and Community Campsite and it was run as a community project according to the lodge manager. Lake Kasenda as well, was surrounded by natural forest. The landowner had inherited the land from his father who was an Indian. According to the current owner, the land was before a sugar cane plantation. The plantation was burned during the Idi Amin regime and the father was killed, as Indians during that time were banned in the country. The current landowner took new initiatives after his father's death and started conservation work, and the land near the lake has become a natural forest. The main idea with the forest conservation was to attract tourists, and in the past 20 years there has been a lodge operating on the land.

Lake Nkuruba and Lake Kasenda were both surrounded by natural forest made through conservation work. The initiatives for conservation were from the landowner's interest. Among the 52 crater lakes five are within the borders of Kibale forest reserve and therefore protected by the government (Pomeroy & Seavy 2003). The main activity around the crater lakes in Kabarole and Bunyangabu district were small scale farming, and this was also the case for the lakes in the current investigation. In Table 3 the activities around each lake are described.

Table 3: Description of the main activities on the crater lakes slopes.

Lake	Main Activities
Kasenda	Forest, lodge
Marusi	Agriculture
Nkuruba	Forest reserve, lodge
Nyabikere	Agriculture, lodges, Forest reserve
Nyameteza	Agriculture, lodge
Saaka	Agriculture, university, prison, upcoming lodge

To futher explain the activities on the crater slopes a description of the farmers in this survey will take place.

Seventeen farmers were visited during the interviews, most of them stayed in simple houses, constructions made of clay. Some houses had better standard and were made of bricks, many still under construction. The size of the families staying at the farms varied from three up to twelve people and every household had children. The people working at the farms were the adults, with assistance from the elder children. Nine farmers expressed that they often or sometimes hired people to help in the farm. The most common crop that was produced among the farmers was banana, it is called `matoke´ and it is mostly used for cooking. Other common crops were beans, cassava, ground nuts, sorghum, maize, potatoes, millet and tomatoes. Many farmers were also rearing animals; chicken and goats were the most common followed by cattle and few of them had pigs. Table 4 shows the household and production for each farm and the lakes they are staying nearby. Twelve of the farmers had some parts of their production for sale and tree farmers had the production only for domestic use.

Table 4. Information about age, gender, education, size of farm, people living on the farm, years staying at the farm, and animal raring for each farmer and lake.

Lake		Age	Gender	Education level	Size of farm/lodge	People living on the farm	Years of staying at the farm	Crop production	Animal raring
Marusi	Farmer 1	53	Female	No school	1.5 acres	5 people	50	cassava, beans, potato, banana	goats, pigs
Marusi	Farmer 2	24	Male	Primary 7	1.5 acres	1 adult and 2 children	7	banana, groundnuts, maize, sweet potato	No
Marusi	Farmer 3	61	Female	Primary 5	14 acres	3 adults and 3 children	30	maize, beans, banana	5 goats, 10 chicken
Marusi	Farmer 4 (manager)	36	Female	Primary 7	12 acres	4 adults 1 child	6	beans for eating coffee for sale	2 pigs, goats, chicken
Nyabikere	Farmer 1	48	Female	Primary 2	1 acre	5 adults and 3 children	34	potato, beans, cassava, groundnuts	goats, chicken
Nyabikere	Farmer 2	24	Male	Primary 6	0,5 acre	2 adults and 2 children	24	potato, maize, sweet potato, banana	No
Nyabikere	Farmer 3	80	Female	No School	8 acres	1 adult and 2 children	61	potato, groundnuts, beans, avocado	Goats
Nyametza	Farmer 1	30	Female		1 acre	2 adults and 3 teenagers	10	beans, maize	chicken, goats
Nyametza	Farmer 2	46	Female	No school		4 adults and 3 children		potato, beans, sorghum, millet, maize	cows, goats
Nyametza	Farmer 3	32	Female	Primary 6	3 acres	6 adults and 4 children	long time	sorghum, beans, groundnuts, banana, maize	
Nyametza	Farmer 4	30	Female		1 acre	4 adults and 6 children	30	beans, maize, sorghum	6 goats
Nkuruba	Farmer 1	65	Female	Senior 2	5 acres	2 adults and 3 children	35	banana, potato, cassava, beans, groundnuts	4 cows
Nkuruba	Farmer 2	46	Female	Primary 2	3,5	5 adults and 7 children	5	tomato, potato, beans, onion	goats and chicken
Nkuruba	Farmer 3	47	Male	Primary 6	2 acres and rent 3acres	3 adults and 2 children	25	groundnuts, casava, banana, sweet potato	cows, goats and pigs
Saaka	Farmer 1	26	Male	Construction engineer	0.5 acres	4 adults and 3 children	16	Minor production for home use, mainly banana	4 cheep and 7 cows
Saaka	Farmer 2	35	Male	Senior 3	2.5 acres	7 workers	4	banana, potato	No
Saaka	Farmer 3	30	Female	Senior 4	1 acre	1 adult 2 children	10	cassava, jams, beans, banana, potato	4 cattle

3.1.2 Soil erosion

Beside lake Saaka near the catholic monks' centre, bare rocks could be seen on the ground. An old man that was passing by explained that there used to be more vegetation, but now too much rainfall was a problem. He looked at the ground and said that these rocks were not here before, the water has taken the soil away and now nothing can grow here anymore.

The short talk with the old man explains well the situation for farmers in Kabarole and Bunyangabu District. The result from the interviews shows that this is one of the biggest challenges the local people are facing.

The locals from the six studied lakes expressed that the topsoil is washed away from the ground by heavy rainfalls. The farmers described difficulties with planting crops when only stones remain on the ground. Issaka & Ashraf (2017) report that agriculture activities can speed up the process, and that hilly areas and slopes are more sensitive to erosion. The eroded soil ends up in waterbodies, it pollutes the water and causes issues with higher nutrition levels which lead to eutrophication (Issaka & Ashraf 2017).

Agriculture is today the most common activity on the crater slopes. According to the participants in the study, the challenges are many and extreme in relation to their agriculture activities. They reported that changed weather condition with heavy rainfall and rainfall in the wrong season cause problems with both soil erosion and crops that get rotten. Soil erosion leads to loss of nutrients resulting in lower crop yields. One farmer expressed that *"before we got good yields, we could even construct a house, now we dig and then we can't even afford to buy the seeds"*, and according to Hillhorst (2000) the issue is so serious that in Kabarole district the nutrition in the soil might be lost within one century if not any measures are implemented.

In the interviews 75% of the farmers mentioned that soil erosion is a problem on their farm. Indeed, 13 % of the farmers expressed that they are using techniques which helps to prevent soil erosion, and 12 % didn't experience any problems at all, see figure 4. Karamage et al. (2017) express that intensification of agriculture without soil conservation activities can have detrimental effects on soil, like low soil fertility, erosion and landslides

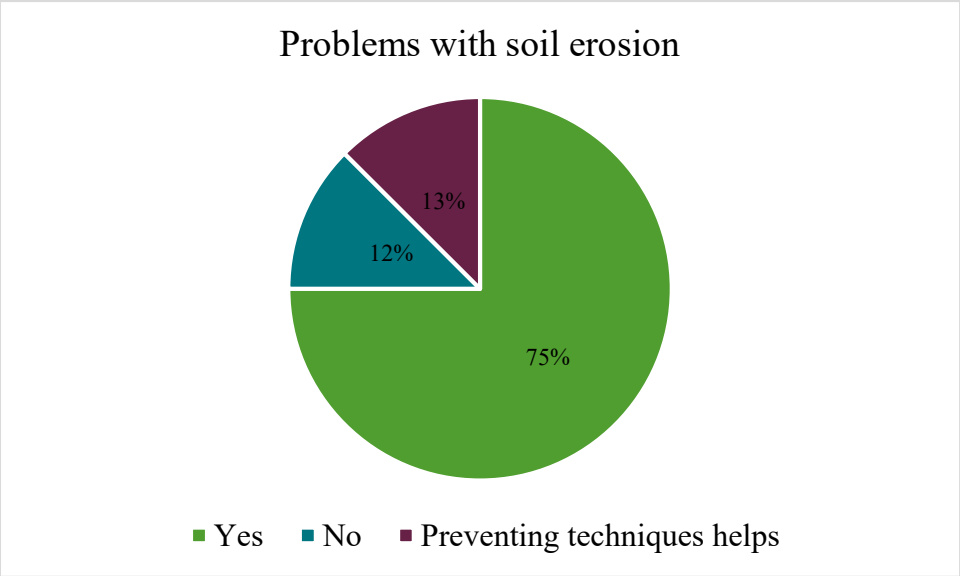


Figure 4. The circle diagram expresses if farmers experience problem with soil erosion. The answers are yes, no or if preventing techniques helps.

When asked if they use any techniques to prevent soil erosion, the answers from the farmers who experienced problems did all use preventing techniques, even though the issue remained. All farmers except one dug trenches to prevent soil erosion. The farmers dig trenches in the ground and leads the water away from the planted crops, this helps the plants from being washed away by rainfall. Other methods such as, mulching, plant in blocks, terracing and make borders with sticks were also mentioned by the farmers as ways to prevent soil erosion. The different techniques are shown in Figure 5. It was only by lake Marusi the technique of planting in blocks was mentioned. The blocks are built with soil, to rise up the area where the crops are planted, and the water is lead on the side of the blocks in trenches. Among the farmers that said that preventing techniques help, were all using the technique with planting in blocks.

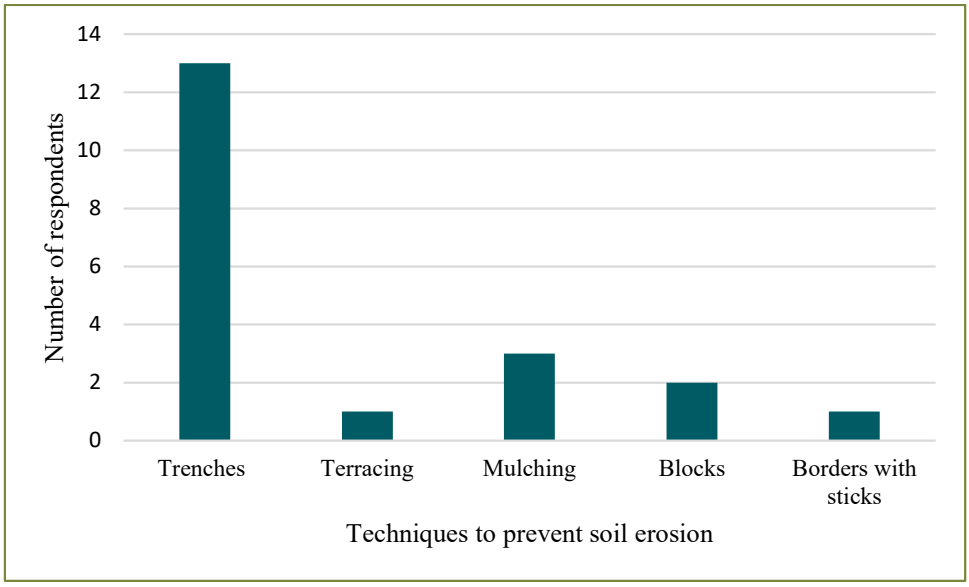


Figure 5. The bar plot shows the number of farmers using trenches, terracing, mulching, blocks and borders with sticks.

One of the important problems mentioned by the farmers was that the efficiency was quite low of the soil erosion preventing techniques. Karamage et al. (2017) also reported that there is a lack of effective soil conservation methods in Uganda. During the group discussion on preventing soil erosion at lake Nyabikere which was attended by five participants, one of them explained that the main purpose of the techniques was not to prevent soil erosion. The techniques were mainly used to protect the crop from being washed away by runoff water. The different techniques which were practiced by the farmers to reduce crops damages by heavy rainfall and runoffs water also helped reduce soil erosion though this were not the intended target. According to the farmers and the fisherman the situation in Nyameteza is critical, they express that the soil is disappearing and there are only stones underneath. The slope was the steepest one among the studied lakes, and landslides was common. Figure 6 show the cultivated land on the steep slope at lake Nyameteza. On figure 7 the land after a land slide can be seen by the same lake, the land is not cultivated but is probably deforested and used for grazing.

Figure 6. The picture shows the steep slope that are used for agriculture activities at lake Nyameteza. (Photographer Lars Svennersten 2023, used with the copyright holder's permission.)

Figure 7. The picture shows where a landslide has been on the crater slope of Nyameteza. (Photographer Lars Svennersten 2023, used with the copyright holder's permission.)

The fisherman explained that the landslides also cause problems to the neighbouring village, since the lake overflows and destroy their homes and gardens.

Another issue that was discussed was the increase in risk of fires. The group discussions participants said unanimously that, - when the land is bare, it absorbs heat and fires starts easily. The respondents from Lake Kasenda, described that problems with fires have a correlation with eucalyptus trees. This issue of eucalyptus trees associated with wild fires has also been reported by Scott (1993). Furthermore Scott (1993) describes that the soil beneath eucalyptus is highly repellent to water which means that water runoff can reach detrimental levels in eucalyptus plantation and that especially after fire. On the top of the hill at lake Nyameteza an eucalyptus plantation was seen, this plantation can in cause of fire

contribute to the issues with soil erosion caused by runoff water that the farmers experience.

From all the responses in different studied lake areas there was an awareness of the importance of trees to prevent soil erosion. The land near the lake shoreline is protected by regulations and it is illegal to cut down trees. Despite this knowledge among the participants, they still did not use the technique on their farmland in a wider sense. The government sometimes carry out initiatives of planting trees and giving out tree seedlings to farmers to reduce soil erosion.

3.1.3 Soil fertility and used techniques among farmers

The result from the interviews showed that it was a challenge for farmers to keep soil fertility, many farmers experienced that the crop yields had decreased over time. The farmers described the opportunities of different techniques they used to keep the soil fertile, but also the challenges they had with the effects of pesticides. This will be further described within this section.

Several well-known techniques to keep soil healthy were used by interviewed famers. All of them used either diverse crop rotation and/or intercropping in their farming system. When crop rotation and intercropping are practiced the farmer plant legumes either in a rotating system with other crops or in an integrated system together with other crops to increase the nitrogen in the soil. Mulching was also a common practise among the interviewed farmers, where organic remains are put on the ground, to prevent weed, keep soil moister and provide nutrition to the soil. Many farmers were aware that it was important to let the soil rest (fallow), and if they have the possibility they also use this technique. Manure as fertilizer was used by the farmers who had livestock (cattle and goats). Stockless farmers bought livestock manures from their neighbours, or used synthetic fertilizer.

Fertilizer contributes to the problems with eutrophication and synthetic fertilizer has increased the problems globally (Khan & Mohammad 2014). In developed countries, use of synthetic fertilizer increased considerably during the mid-twentieth century and has affected many waterbodies (Khan & Mohammad 2014). The use of synthetic fertilizer in Uganda is still low as the high costs and the availability prevent farmers from using it (Wairegi & van Asten 2010). Among the interviewed farmers, less than 50% of them used synthetic fertilizers (Figure 8). In addition, those who used fertilizers said that they use it sometimes. There is a lack of information whether the use of synthetic fertilizer around the crater lakes in this research effect the level of eutrophication or not.

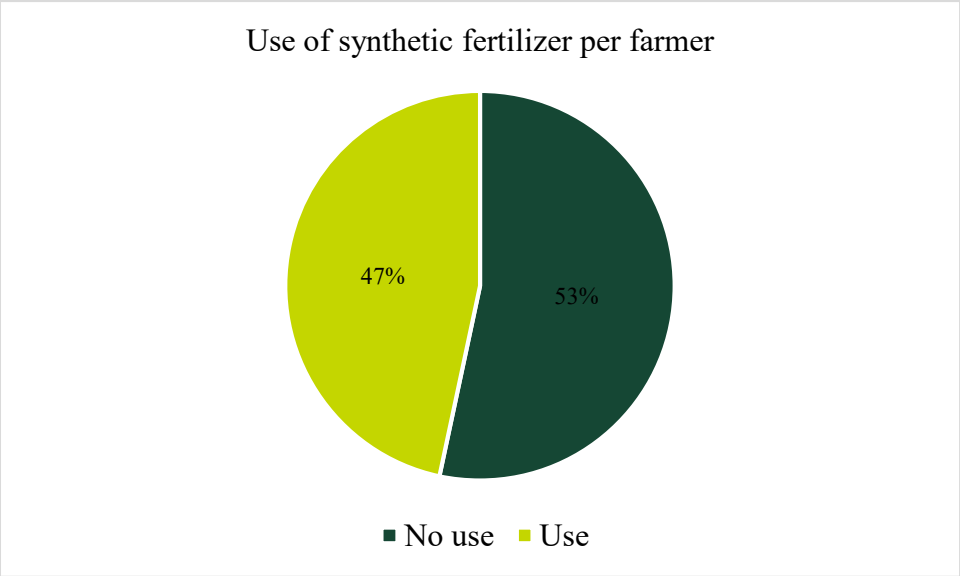
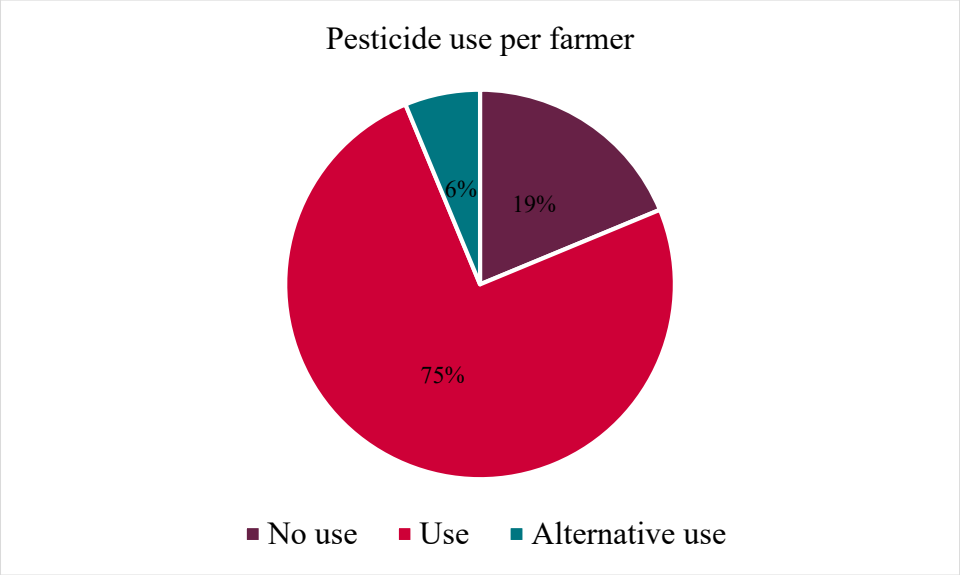


Figure 8. The figure depicts the number of farmers who use synthetic fertilizer.

The use of pesticides was much more common among the interviewed farmers (Figure 9). But the experience of the chemicals was not always reported positive on crop yields. In the group discussion at Nyameteza the participants expressed that the chemicals turn the soil from black to white and that the yields in the coming year get effected in a negative way.



FigureFigure 9: The figure expresses how many that are using pesticides or other alternative use among the interviewed farmers.

According to Sanjay & Divia (2016) chemical pesticides have a significant impact on soil health as it affects the non-target and beneficial micro-organisms whose activities are essential for maintaining soil fertility. The chemicals reduce

soil bacteria, fungi and almost all flora and fauna (Sanjay & Divia 2016). This could be the reason why some of the interviewed farmers experienced reduced soil fertility and reduced yields in subsequent year after application of pesticides.

It has been reported that the use of pesticides in Uganda is often unsafe because of poor information and limited instruction of usage (Staudacher et al. 2021). It can cause harm to humans with acute symptoms like headache and respiratory effects or chronic health effects like cancer and cognitive health impairment (Staudacher et al. 2021). It does also affect the environment as systematic use of insecticides may kill bees and other important pollinators (Sanjay & Divia 2016). Pesticides pollute air, soil and water resources and disrupt the ecosystem balance (Sanjay & Divia 2016). When cultivating on the crater slopes there are high risks that the chemicals leak to the lake and effect the water quality and its organisms.

During the interviews there was just one farmer saying that she avoided chemicals and instead she used old techniques to prevent pests. She explained that urine, ash and chili were better alternatives. It seems that there is an embarrassment of using these techniques since there was just one person who mentioned about it in the first round of interviews. In the group discussion at the lake Nyabikere the participants started to talk about the old techniques and in the end, all told that they used them actively. Among the participants, the group discussion might have felt like it was free from preconceptions since they dared to talk about something that could been embarrassed. According to Andersson (2015) there are culture norms and taboos of using urine in agriculture production in Uganda. The techniques were also discussed at the lake Nyameteze, and there all the participants knew about the techniques but none of them used it, instead these farmers used high dosage of chemicals. The techniques that are used can vary much from one place to another, and local conditions and traditions is a cause of what they decide to use.

3.1.4 Poverty and increasing human population

In the interview with the two participants from Lake Kasenda the challange of increased human population and land degradation was discussed. The two participants explained that the parcels of land are getting smaller and smaller, as children inherit land from their parents and the land is divided among them. Each child then constructs a house on the land and the land is then not enough for their livelihood. The population growth in Uganda is high and according to the UN data the population rate (annual percentage) was 3.186 while the average rate of Africa was 2.352 in 2021 (data.un.org). As mentioned before the crater slopes have been deforested for farming purposes later than surrounding land. At Lake Nyameteza the interviewed people remember that the slope towards the lake was covered with forest back in the 80s. Bamutaze et al. (2019) also reported that the encroachment

of steeper slopes and forest is caused by population growth, this put pressure on fragile land by over cultivation.

At lake Nyameteza, the participants expressed the best way to preserve land could be to let the land fallow, but there was a concern about how the poorest people can do restoration work on their land on the slope if they don't have anywhere else to farm. This issue is also mentioned by Niringiye Aggrey et al. (2010) where the author considers the relationship between poverty and land degradation. Small scale farmers in Africa are many times living on limited resources and are dependent on the food they grow. If they do not plant, they might not have anything to eat in the coming months, which makes it almost impossible to keep fallow lands. The population growth both put pressure on the land and keep families in poverty. In Africa poor families produces twice as many children as compared to wealthy families and the burden on women increases with care and domestic work which leads to reduced income possibilities for women (Beegle & Christiaensen 2019).

3.1.5 Rainfall and climate change

Rainfall was a problem for the farmers, if it was too much or came in the wrong season. During the interviews nine farmers mentioned rainfall as a challenge, because it washed away the crops and the crops got rotten. Five famers mentioned that they also experienced a change of the weather conditions. This was discussed at the group discussions at the two lakes Nyabikere and Nyameteza. The participants from the lakes expressed that the rainfall was a problem and that they could see a change with the weather, with longer rainy seasons. This is also mentioned by Kisakye et al. (2018) as an effect of climate change, in Uganda the consequence is that the dry season is dryer and the rainy season is longer. No one of the participants have mentioned any correlation of climate change and the changed weather. It seemed like the knowledge of climate changed was low among the participants. The topic climate change was highlighted at the group discussions, at lake Nyameteza the participants confirmed that they knew the concept, but with no further comments. By lake Nyabikere, they explained that the weather is God's plan and that the rainfall is caused by trees, wetlands and many lakes in the area. This explains the natural hydrological process in the region, where wetland and lakes surface is a key source to rainfall according to Zekarias et al. (2021). But still the change in weather couldn't be explained by the participants by lake Nyabikere.

3.1.6 Tourism - a challange or an opportunity?

Kabarole District is a popular place for tourists. Kibale Forest National Park in the district has the highest population of primate species in whole east Africa. Together with the scenic Rwenzori mountains and the many crater lakes, it makes the area appropriate for the tourism industry. The number of lodges around the

crater lakes are increasing at a fast rate, and the land near the lakes is highly valued. According to the District officer lodges and tourists can disturb the natural environment. This is also described by Dokulil (2014), constructions of roads, airports, hotel and resorts are necessary for the industry but it can have huge effect on the local environment. "Negative impacts from tourism occur when the level of visitor use is greater than the environment's ability to cope with this use within the acceptable limits of change" (Dokulil 2014:82). Lakes are attractive for tourists where they can offer beautiful nature and relaxation as well as swimming, boat rides and fishing. The risk of environmental damage is high if the industry isn't regulated. Hotels and lodges near lakes often puts a strain on water resources and compete with local communities for critical resources (Dokulil 2014).

In a conversation with the District officer he explained that it can be beneficial with lodges by the crater lakes since they are within the environmental regulations and laws. He expressed that it is easy to work with the lodge owners and many of them have an interest in conservation and planting trees. Among the lodges in this study, four of them had done some work for conservation. The lodge owners by lake Kasenda and Nkuruba had both done forest conservation surrounding the whole lake.

The District officer also explained that the lodges often help to develop the local communities. They buy food and products from the local market and provide job to local inhabitants. In this regard, the local people also expressed that it was good to have lodges in the area as they help to improve the roads and at lake Nyametze they have even supplied locals with tap water instead of fetching water directly from the lake which requires walking downhill. The lodges sometimes even help with school and hospital fees, this was told by the farmers and the fishermen by lake Nyameteza and also by the lodge manager at lake Nkuruba. The big landowners in lake Kasenda and Nkuruba, also rent their land out to neighbouring farmers. In Kasenda the lodge owner (who also is a farmer), has a big interest of sustainable agriculture, and he has a system where the farmers instead of paying rent for the land they come and work for him once a week. When they work at his farm they also learn new things. They bring new knowledge back home and use on their own farm. Both the lodges in Nkuruba and Kasenda are much integrated with the local community and development work.

According to the lodge managers, tourists likes to swim in the crater lakes, but this is not without any risks. Swimming in lakes is seen as ecosystem threats, whereby the water can be contaminated by coliform bacteria, faecal streptococci, yeast and fungi (Dokulil 2014). Urine contribute to eutrophication with nutrition like phosphorous and nitrogen (Dokulil 2014). By swimmers themselves this is not often seen to be an issue, but when the swimmers become many the problems are there. To go on a boat ride on a crater lake was also a popular activity, and according to Dokulil (2014) all boats that interact in aquatic ecosystem disturb the habitats.

However, the major effect is coming from motorized watercraft, and these were rarely seen on the crater lakes. But with fast increasing tourism this can come to change. Furthermore Dokulil (2014) describe that turbidity effects the water clarity and increase the nutrients and thereby the algal blooms. Fuel leakage and emissions do also affect the water quality (Dokulil 2014). The ecosystem of shorelines are sensitive and is under high pressure of human activity, tourism have a direct impact through facilities, trampling and littering (Dokulil 2014).

Indeed, there are risks with tourism but at the same time it can help to finance conservation work. With a regulated tourism industry this can help to protect the crater lakes. The tourism is an opportunity for the local societies, which is also mentioned by the respondents in this study. The concept of ecotourism is used both by Lake Kasenda and Nkuruba. Ecotourism´s two main ideas are that the travel destination is preserved as pristine and untouched and that the revenues should contribute to the conservation of nature and development of local communities (Tancau 2011). However, ecotourism can also be problematic as revenues do not necessarily reach those who bear the costs of conservation. When developing ecotourism projects basic questions should be asked like, who has a share in tourisms´ revenue, and who benefits from tourism (Tancau 2011).

3.1.7 Conservation

Forest conservation can be an opportunity to reduce the risk of soil erosion since the trees protect the soil from eroding. Furthermore, forest conservation contributes to higher biodiversity, which also can be a challenge for the farmers who are staying near by the protected land. When lodges have conservation activities on their land this increases the primates´ and birds' populations. In the perspective of biodiversity this is a good thing. By five of the lakes, it was mentioned by the respondents that there were monkeys in the area. Some of the farmers expressed that the monkeys became a problem for them, because of crop raiding, and this especially by lake Nyabikere. Primates are topping the list of wildlife species that damage crops around Africa (Hill 2017). Lake Nyabikere is a lake that has parts of Kibale Forest Reserve within its catchment area, which means that wildlife is moving in the region. To avoid elephants from crop raiding on farmers´ land the government has made deep and wide didges that the elephants can´t pass over. This helps the farmers from losing their crops and get their home destroyed by elephants.

Indeed, they had another issue, at lake Nybikere there were two hippopotamuses staying in the lake. The Hippopotamuses were moving between lake Nyabikere and two other lakes nearby. How they came to the lake at the first time is a bit unclear, but it seems like they didn't come there naturally, humans have been involved in the movement. Among the participants at the group discussion, including the lodge manager all experienced only problems with the hippopotamuses. They come at night and destroy and eat from their gardens. One old woman was really upset, she

said that there is not even any reason to plant because the hippo will destroy it anyway. When humans and wildlife have a direct competition over access to resources it often results in human-wildlife conflicts (Kolinski & Milich 2021), and this is what is what is happening by lake Nyabikere.

3.1.8 Sewage

All people staying around the lakes are producers of sewage, farmers as well as tourists. For local people, the most common is to have a pit latrine on their land. These are very deep and can be used for several years. When they are full, they just cover it with soil and dig a new one on a new spot. One of the locals expressed, *"It is very good to plant your bananas on an old pit latrine, they grow very well"*. However, the pit latrines can also contribute to eutrophication of crater lakes when it leaks down to the lake. For the lodges handling of sewage differed from one place to another. At one lodge they collected it from the place and then dug it down in the ground in the same area. Another lodge got it collected and transported to a treatment plant.

3.2 Local people´s awareness about the lake´s condition and their own contribution to eutrophication

In order to understand objective number two this chapter starts with a description of the situation of eutrophication among the crater lakes. The following sub-sections will describe the results from the participants and their experiances of the situation.

"The crater lakes, they are all suffering from eutrophication, you see it on the surface water, they are full of algae blooms" (Professor at Kabarole research and resource centre, October 2022)

This was a spontaneous reaction of a short introduction of this study by a professor working at Kabarole Research and Resource Centre. There is not a clear picture of the conditions of the crater lakes in western Uganda because there is a lack of monitoring programs for water quality, authors like Nankabirwa et al (2019) and Busobozi (2017) also confirmed this issue. Research done in the topic of eutrophication of the crater lakes in Uganda and related issues are rare.

The District Officer explained that the situation of the crater lakes is alarming. He says that the population pressure makes farmers encroach the crater slopes. The lakes are polluted by agriculture activities, and soil is entering the water which leads to eutrophication. Eutrophication of water bodies is caused by high nutrient levels in the water (Khan & Mohammad 2014). There are several things that can cause the high nutrients levels, both human activity and natural processes. Natural

eutrophication is a slow process and occur when natural disturbances cause imbalance between production and consumption within the lake (Callisto et al. 2014). Wildlife can contribute to eutrophication, for example hippopotamus (which exist in Nyabikere), they feed on land during night-time and then return in the water where they spread their dung and nutrients get released (Okello & Kurmayer 2011). Cultural eutrophication is caused by human activities, agriculture, fertilizer, change in land use and deforestation (Khan & Mohammad 2014). Even to introduce new fish into a lake can be a reason for eutrophication, whereby the structure of the food web changes (Salazar Torres et al. 2016). According to the fishermen at both lake Nybikere and Nyameteze new fish were often introduced. *"When the fish die, the government is introducing new species in lake"* (fishermen at lake Nyameteza)

The levels of eutrophication differed among the studied lakes (Table 5). The input levels of nutrients is termed oligotrophic, mesotrophic eutrophic and hypertrophic, which correspond to low, intermediate, high and greatly excessive nutrient inputs (Smith et al. 1999). At the mesotrophic level the water quality gets effected and the problems increase with the higher levels (Khan & Mohammad 2014). It doesn't exist a worldwide classification system instead the trophic levels tend to be region specific, this because of systematic differences that exist in waterbodies across different regions (Busobozi 2017).

Eutrophication of the crater lakes was very individual and could differ much from lake to lake. To understand why a lake is suffering from eutrophication it is necessary to understand the local conditions. The catchment of the lake is substantial since it has a significant effect of the lakes` water quality (Ryves et al. 2011). The size of the catchment and its environment is therefore important to consider when it comes to understand the trophic status of a lake (Ryves et al. 2011). Lake Nkuruba which was surrounded by a forest reserve the eutrophication levels had decreased over time. But the system is complex and at the two lakes Kasenda and Marusi which were located just next to each other the situation was not as expected. Lake Kasenda that was surrounded with natural forest was suffering from eutrophication and this has even increased over time. Lake Marusi on the other hand was surrounded by areas with agriculture activities and was not affected and was defined as oligotrophic. The map on figure 11 shows the catchment area of Lake Kasenda and it is rather big, 2 km^2, which can explain why it is suffering from eutrophication even though it is surrounded by forest. The map also shows the location of lake Marusi but unfortunately not the catchment. Lake Wandakara is seen on the map and compared to Lake Kasenda this catchment area is much smaller in size. Probably even the catchment area of lake Murusi is smaller than Lake Kasenda, but that information could unfortunately not be found whitin this research.

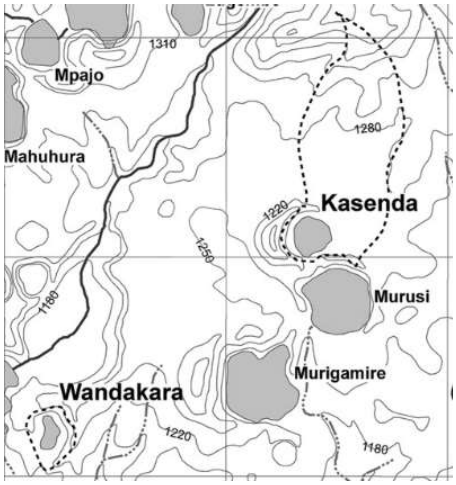


Figure 10. The figure depicts the catchment area of Lake Kasenda and lake Wandakara. (Ryves et al. 2011)

The land use within the catchment has changed much during the last decades, whereby forest land has been transformed in to agriculture land (Nankabirwa et al. 2019). According to Hunt, L.H. (2000) there is a rapid change in eutrophication levels of the crater lakes in Uganda, over a period from 2006 – 2019 seven out of nineteen lakes were increasing their trophic levels (Hunt et al. 2000).

The trophic levels differed between the studied lakes, and since there was not any implemented monitoring system of the lakes´ the references differed between the lakes. Table 5 gives an indication of the condition of each lake in this study.

Table 5. Eutrophication level for each lake.

Lake	**Trophic level**	**Change in trophic level**
Kasenda	2006 Oligo, 2015 Eutro, 2019 Meso.	Increase
Marusi	2007 Oligo, 2019 Oligo	No change
Nkuruba	2004 Eutro, 2007 Eutro, 2019 Oligo	Decrease
Nyabikere	2004 Eutro, 2017 Hyper	Increase
Nyameteza	2022 Eutro	
Saaka	2017 Hyper	

The terms oligotrophic, mesotrophic eutrophic and hypertrophic correspond to low, intermediate, high and greatly excessive nutrient inputs. Sources: Kasenda, Marusi and Nkruba 2006, 2007 and 2019 refer to Hunt et al. (2000). Nkruba and Nyabikere 2004 refer to Okello et al. (2009). Nybikere and Saka 2017 refer to Busobozi (2017). Nyamiteza refer to staff member of Kabarole Research and Resource Centre, whereby no other sources were found.

3.2.1 Awerness of the lakes´ condition

Among the six crater lakes the water quality varies much. For lake Marusi, Kasenda and Nkuruba the experience of the water was better than lake Saaka and Nyabikeere, and lake Nyameteza is somewhere in between. This was described by the local people. When the local people describe water quality the reference is if the water is good for domestic use or not. Lake Saaka was reported by the participants to have the worst quality water, the locals described that they cannot use it at all. Instead, they need to get water from another nearby lake. The local people expressed that there were chemicals in the water, and it was done by the government. The reason why the chemicals were put in the water was unclear among the interviewed. The question was asked to the district officer, who explained that there are not any chemicals that are spread in the water by the government. So, whether there were chemicals or not in lake Saaka remains unclear, and further investigation of the phenomenon that the locals express is necessary.

Eutrophication was not well known among the interviewees, but its effect was more familiar to them. From the group discussion at lake Nyabikere and Nyameteza the participants expressed that during rainy season the water turn brown and during dry season they see the algal blooms on the surface. There were also experiences of fish mortality and fish with bad health, whether it was an effect of eutrophication or not was not clear to the respondents, but it was an issue that the locals and especially the fisherfolks experienced.

3.2.2 Toxic water and parasites

Another important finding was that the local people experienced that the water was becoming toxic and loaded with parasites, this problem relates to the issue with eutrophication.

From all the studied lakes the respondents described that during dry season the phytoplankton could be seen at the lakes´ surface area. When nutrients accumulate in the water it stimulates phytoplankton growth. Phytoplankton appears in a variety of species (Nankabirwa et al. 2019). Cyanobacteria even called blue-green algae are common among the phytoplankton and in the crater lakes in Uganda it stands for 78 % of the phytoplankton next followed is green algae which represent 17 % of the total. (Nankabirwa et al. 2019). Cyanobacteria cause serious health problems both to humans and animals through drinking water (Khan & Mohammad 2014).

One farmer describe that he let his cattle drink the water from lake Saaka, but it is not without any problems, the cattle get often ill from drinking the water. He says, - *"it because there are germs in the water"*. In lake Saaka which is a shallow lake the appearance of microcystin is high (Okello & Kurmayer 2011). Microcystin are probably the most abundance toxins produced by cyanobacteria in freshwater

(Okello & Kurmayer 2011). The microcystin is found in several freshwater lakes around Uganda, but environment of shallow lakes provides favourable conditions for them to flourish (Okello et al. 2009). The appearance of microcystin among the crater lakes is not well documented. In lake Nkuruba indication of microcystin is found, but the deepness of the lake helps it from flourish (Okello et al. 2009). The situation of microcystin among the other crater lakes are not known, except for Nyabikere where no microcystin was found (Okello et al. 2009). Which bacteria that were making the cattle's ill is not known in this study, but it was also mentioned by the respondents that bilharzia (*Schistosomiasis*) exist in the water of lake Saaka. It is a water parasite that can cause disease to both humans and animals (Zhou et al. 2021).

Even the water in Nyabikere the locals refuse to use for domestic use. They mention that there is bilharzia (*Schistosomiasis*) in the water. Many waterbodies in Africa are effected with the parasite bilharzia (*Schistosomiasis*) and so even the crater lakes in Uganda (John et al. 2008). The local people were aware of the disease, and they had somehow good knowledge if they can be infected or not from the lake they stay nearby. There is possible treatment for the disease, and health centres hand out medication to the local people according to the participants. It is a serious diseases and it kills over 200 000 people annually and 240 million people are infected worldwide whereby the majority of the cases are in sub Saharan Africa (Tabo et al. 2022). Before it was thought that there was an altitude transmission threshold for bilharzia, i.e. - higher the altitude the lower risk of infection (John et al. 2008). But according to John et al (2008) the threshold needs to be changed since *Schistosomiasis* are found even at the higher altitudes in the crater lakes of western Uganda. The author argues that this can be an effect of climate change. Even Tabo et al. (2022) described that the weather affects the presence of bilharzia as, the high rainfalls events caused more runoff into freshwater, which increased the supply of organic matter and feed the intermediate host snail *(Biomphalaria and Bulinus)* which the bilharzia parasite is dependent on for reproduction. Even small variations with precipitation might have a significant impact on the host snail (Tabo et al. 2022). There are two species of the host snail Biomphalaria and Bulinus and in all the studied lakes either both species or one of them appear, (John et al. 2008, Tabo et al. 2022). According to the local people lake Saaka and lake Nyabikere were infected by bilharzia whereby other lakes like Nkuruba, Kasenda and Nyameteza were not disturbed. There might be a natural variation of the quantity of the parasite between the lakes and the risk of being infected varies among them.

3.2.3 Fish mortality

It was reported hat the condition of lake has deteriorated severely in the recent years which has led to algal blooms and mortality of fish.

At lake Nyabikere the locals expressed that during rainy season when the water turns brown the fish doesn't taste good. It is even during this time, ones a year the fish in the lake die, and they can see fish floating on the water. According to the district officer the fish mortality in the crater lakes are caused by low oxygen levels.

During algal blooms at lake Nyameteza the fisherman expressed that the intestines get black, he explained that the fish are not good for eating. Algal blooms and presence of cyanobacteria is a hazard to the fish in the lakes, it can cause fish mortality and according to Nankabirwa et al. (2019) this is a common problem among the crater lakes in Uganda. Indeed, the fishermen at lake Nyameteza didn't experience fish mortality correlated with the algal bloom. Instead, the fisherman explained that fish mortality is caused by heat coming from the underground, which is triggered by earthquakes.

In the case of Nyameteze it is worth to consider the information from the fishermen about underground activity. The area is known for high seismic activity, (Cheriberi & Yee 2022) and not far away in Semuliki National Park the hot springs are found, where boiling water is coming from the ground. In a review from 2021 a database is made with implications for volcanic hazards among volcanic lakes in Africa (Rouwet et al. 2021). The review confirm that the crater lakes in Uganda are getting heat and gas that enters from the lakes bottoms (Rouwet et al. 2021). The review lacks information about each specific lake in the area, but it is important to consider the experience from the locals and more research is needed to confirm the correlation. Seismic activity in form of earthquakes can also affect the lakes water level and in 1994 an earthquake caused that lake Nkuruba sank with 3 meters, according to the lodge manager at the lake. Research about seismic activity and its effect on crater lakes was difficult to find.

3.2.4 Awareness of contribution of eutrophication

Some lakes have small catchment areas and other lakes have catchment areas that reach far away from the lake. This study has focused on the people staying nearby the lakes, and their awareness of their own contribution of the lake´s condition and eutrophication. The participants were asked if they believe that they affect the lakes´ condition in any way, see Figure 10. Fourteen farmers responded the question, where eight out of them believed that they do not affect the lakes´ conditions. Half of the ones that answered No, believed that the preventing techniques are working. For the ones who answered Yes, they expressed that digging the lands too close the lake and cutting trees along the shoreline affect the conditions of the lakes. How the land is used within a lake´s catchment area is reported to substantially affect the lakes´ water quality (Ryves et al. 2011). The size of a catchment area can varies from one lake to another (Ryves et al. 2011).

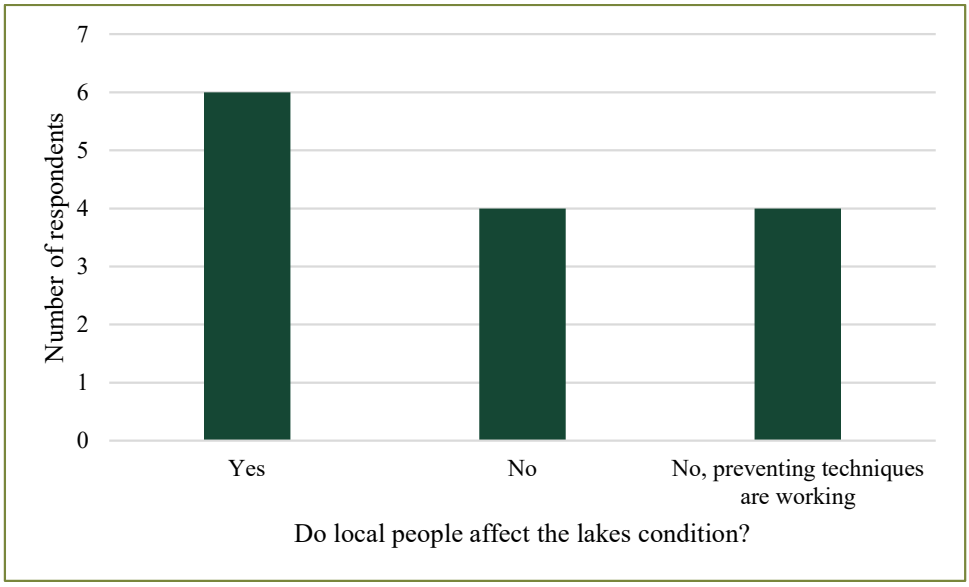


Figure 11. The table expresses if the interviewed believe that they effect the lakes condition.

This information is vital because if the understanding among the local people who are staying near the lakes are low about their own contribution of the lakes´ condition then it is probably even lower among the ones staying further away. Most likely many local people don't even know that they stay within a lake's catchment area as soon their location is not on the slope. There is a believe that as long as they don't touch the land along the shoreline that is controlled by the government the lake will be fine. To do restoration work just by the shoreline or the crater slope seems not effective if the catchment area is much bigger. Among the interviewed participants it was only the student from Mountain of the Moon University who could explain the the meaning of eutrophication, the couse and the affect on the lake.

3.3 Measures to reduce land degradation, eutrophication of crater lakes and improve livelihood of local people

This chapter aims to discuss the last objective of the study i.e. to understand measures to improve the land degradation and reduce eutrophication. The results from the questionnaire showed that the majority of the farmers had problems with soil erosion, it also showed that most farmers used the technique of building tranches to prevent the issue. Trenches didn't seem to be effective enough since the problem remained. According to Karamage et al. (2017), there is a lack of effective soil conservation methods. The efforts made for conservation have often failed and this because of structural weaknesses, in the conservation programs in Uganda, there is lack of responsibility, expertise in the subject area, education for policy

administration as well as lack of legislation and enforcement (Bamutaze et al. 2019b).

The question such as, “how to improve the crater slopes from land degradation, how to avoid crater lakes from eutrophication and how to improve the livelihood for local people” were discussed by participants inhabiting along shores of the two lakes, Nyabikere and Nyameteza. At lake Nyameteza there was a long discussion about possible ways to improve the steep slope from erosion. They were all of the opinion that the best thing to do would be to stop farming on the slope, but that was not realistic since they were dependent on the food they grow on the slope. In the end, they discussed that the possible solution is to let the land fallow and grow crops that is more suitable for the slope, for example fruit trees. To integrate trees in the farming system “agroforestry” can be beneficial for small scale farmers in many ways. Quandt (2020) report that agroforestry is good for preventing soil erosion since it is reducing water flow and speed, and the trees prevent the soil and nutrients from being washed away by water. Agroforestry do also help during the dry season since it provide shade and preventing drought (Quandt 2020), this can be beneficial for the farmers by lake Nyameteza since they experience problems with drought and fires.

A challenge pointed out by the participants with planting trees, was that they must wait several years before they can harvest, and many farmers are dependent on the “fast” growing crops for their food supply. The participants at lake Nyameteza discussed about the possibilities of making a transformation of the food production. To let the land fallow and planting trees on the slope can be done by farmers that have other land as well where they can grow their food crops. One farmer explained that to have a production with trees can be beneficial for the ones that have cattle and goats because they can be grazing on the land, like a silvopastoral system (Levin 2022). For the farmers that only have land on the slope, there were no possible suggestions on how the situation could be improved. Even by lake Nyabikere the farmers are facing the same issues with soil erosion and lower yields. Pros and cons for techniques preventing soil erosion were discussed. Participants at lake Nybikere expressed that planting trees are good since it works as a windbreaker, but then they have the issues with crop raiding by monkeys and birds. To improve the soil health and the issues with lower yields the recommendation to let the soil rest was the main suggestions even here. They explained about a technique where they leave the crop residue after harvesting, they dig it down and let it fallow for two months, which brings the fertility back to the soil. In a survey from the south of Uganda where farming on steep slopes also is common the author describes the practice of land fallow and its importance to counteract soil erosion and to keep a nutritious and healthy soil (Grisley & Mwesigwa 1994). In the article, which is written in the 90s the authors were warning for the increased population pressure which could force farmers to more

intense agriculture where the practise of land fallow could be reduced, and this is what is happening today 30 years later after the report was written. Farmers are facing the tough reality of making decisions where they either grow food on the land for the household's short time needs or let the land fallow for the future and better yields. For the farmers at lake Nyametza and Nybikere they have the knowledge about how the slope can be improved, but it is a great challenge to make changes in land use, and issue of poverty and the fear of not producing enough food is preventing them from doing a transformation of the production system.

Grisely and Mwesigwa (1994) discuss soil conservation techniques like terracing and agroforestry, but they mean that these techniques require big investments which is not possible for small scale farmers. The government do make efforts for land preservation. They provide farmers with tree seedlings that they can grow on the slope. Two farmers at lake Nyameteza expressed that they were distributed with 4000 coffee seedlings, unfortunately they didn't survive since the soil had been washed away by runoff water. This help should have been implemented in an earlier stage when the soil was still productive. Quandt (2020) mentioned regarding agroforestry,

it is important that any agroforestry policies or projects take into account the local environmental, social, and economic contexts when promoting certain agroforestry practices.

For the farmers on the slope these contexts are always necessary to take into account when development work is taking place.

From the result of this study a knowledge gap is identified, the transformation process of small scale farmers production system. This change require a holistic approach where the farmers` individual situations have to be acknowledged. The environmental, social and economic conditions differ among them and the possibilities of making changes and transformation. For farmers who are fighting with poverty advice in agriculture techniques might not be enough to make a change. When poverty is holding them back from doing the transformation a broader information system and guidance is required. George (2023) report that human capital is significant for poverty reduction, and this includes education, training and health care. When population pressure is a problem for keeping a healthy soil advice in family planning can be important.

It seemed to be an issue that farmers didn't show up at meetings for agriculture consultation. One participant expressed as such,

it is common that farmers do not appear on meetings for advertising, you must join their own local financial associations where they have an interest of showing up.

For consultants it is necessary that the farmers have an interested of their message, as Nassanga (2019) describes the importance of a message being relevant for the individual. In this study different life situations have been discovered among

the people staying on the crater slopes. Like the lonely father with two kids at lake Marusi who was fighting to manage the situation, he had just sold parts of his land to a "white" person, and he had no longer any animals for raring. After his wife left him, the situation became difficult, and he was now alone taking care of the one-and-a-half-acre farm and was struggling to get food on the table for the kids. Or the old lady, staying near lake Nyabikere at the top of the hill, she seemed to be happy and satisfied with her life as a farmer. She said that she does not need any improvements. She had much land, 8 acres and the family were staying around, and for an 80-year-old lady that might be enough for a good life. The young man at lake Nyabikere with only half acre of land, he had a strong believe in if you work hard, you can improve your life. He liked to try new things and listened carefully to advice on the farmer's radio, for example he learned about how to rare cattle in a very small area. Or the women who refused all modern technology and instead learned from her grandparents the old techniques of farming.

For an advisory service it is necessary to understand how their message can be relevant for each one of them. If the farmer see that the information is adequate this will motivate the person to continue to think about the message, seek additional information which can lead to the desired action (Nassanga 2019). As well Bamutaze et al. (2019) mention that if the farmers should adopt the conservation methods, they also need to be convinced that they will benefit from the work they need to do.

The indication from the interviews was that the knowledge about eutrophication and its risk are low among the participants. There is a need to educate the population in the crater lakes region about eutrophication and its risks before the issues are getting worse. Mass media is an effective way to reach out to lots of people, and Nassanga (2019) mention that radio is the media that reaches most rural people in Uganda. When environmental issues are communicated it is necessary that the information is useful for the receivers, but according to Nassanga (2019) mass media often report news with a with a frame of catastrophe and disaster, and this is even in Uganda. For example, Nassanga (2019) mention that small scale farmers rarely experience any solutions from mass media in issues of climate change, when farmers are the ones that are most affected. Nassanga (2019, p 601) describe the three steps off effective risk communication.

(i) The first stage is risk identification that involves identifying or becoming aware of the risk.
(ii) The second stage involves risk assessment, where the person assesses the probability and the likely severity of the consequences that the risk could cause.
(iii) The third stage is risk reduction or protection that requires identifying and choosing an action(s) that can eliminate or reduce the risk.

In the case of eutrophication in the crater lakes region in Uganda the risk communication must start from point one, which is to make people aware of the

problem. With the issues of soil erosion most of the farmers are at level two where they can do risk assessment of the problem. The big challenge is level three, and this is all for farmers, extension and advisory services, NGO`s and the government to identify and choose an action that eliminate or reduce the risk of soil erosion.

The lodge managers had a positive view on how their business could help to improve both the local community and conservation of land. Among the participants around lake Nyameteza, their experiences of the tourism industry were positive. The local people were benefitting from the lodge in the area, the infrastructure in the area was improved, farmers could sell their products and locals got employments. The tourism activity can be a part of the transforming process if it is handled in a correct way, where it can help farmers to an improved livelihood and where they can get the opportunity to make the desired transformation on the farm.

The main attraction for tourism in the area is the wildlife. The farmers at Nybikere, who lived close to the wildlife sanctuary didn't experience anything positive from the wildlife. They expressed,*" It is only making a loss"*, and this because of crop raiding wildlife. The wildlife was only beneficial for the lodge manager at lake Nyabikere since it attract tourists. However, one farmer reported benefits from tourism as, *there are craft shops around and if we need to buy a gift we can go there.* But this was the only positive thought about the tourism industry by lake Nyabikere from the farmers point of view.

There are four important identifications of measures that are necessary to be improved for the crater lakes and its surrounding inhabitants.

1. Education about eutrophication and its risks among the population in the crater lake region and a developed program for the three steps of effective risk communication is required.
2. Research and development and adequate knowledge are required about the transformation process to sustainable soil conservation techniques for small scale farmers.
3. Transdisciplinary work is necessary to fight poverty where agronomists, social workers and family planning centres work together.
4. Development of ecotourism programs where revenue from the tourism industry should support conservation and land preservation which will improve the livelihood among local people.

4. Conclusions

This study has put an eye on a topic that, up to my knowledge, not is documented in the literature. It brings the perspective of the rural people and their experiences of soil erosion and eutrophication. To prevent eutrophication and improve livelihood for rural people this information is vital, and development always comes from individuals that must make a change in their lives. The conclusions of this study are as follows.

1. The crater lakes are vital for local people since it provides fresh water and food fish. The lakes also attract tourists to the area which can be beneficial for the local economy and development as well as for conservation activities.

2. The challenges for local people are problems with decreased yields, soil erosion and changed weather conditions, especially rainfall in the “wrong” season and often with high intensity and amount.

3. There seems to be a weak understanding about eutrophication and the locals´ contribution of it, even though the effects of eutrophication are known among the participants.

4. Farmers had issues with soil erosion, where their crops and soil were washed away by runoff water. Preventing techniques were used, and tranches were the most common one. Unfortunately, the technique was not effective to prevent soil erosion.

5. Keeping the land fallow and planting trees were recommended by the participants to prevent soil erosion and improve soil fertility, but the ability to practice the techniques varied among the local people and for small land holding it is a limiting factor.

6. Transdisciplinary advice is required for soil conservation especially to farmers who lives in poverty.

7. The extension and advertising services regarding soil conservation seems too inadequate within the country, and efforts to attract people to participate in meetings are necessary.

8. Effective Risk Communication could be a way to address the issues with eutrophication and soil erosion in the crater lakes region in Uganda, and this should include stakeholders such as farmers, extension and advisory services, NGOs and the government.

9. More research about soil conservation techniques and the transformation process among small scale farmers and their individual prerequisites are necessary for prevention of eutrophication and improvements of small scale farmers livelihood.

5. Limitations and recommendations

Time is always a limitation for any kind of work. Two and a half months for field work was spent in Uganda, and there has been "time thief's" in this process. To get practical things in order delayed the start of the interviews for example the access to a research assistant/local guide. The access was also limiting through the whole process since he was busy working as a teacher as well. The weather conditions were also a limitation since it was difficult to enter the field because of the heavy rainfalls that caused very muddy roads.

There has been much struggling with the questionnaires, for this qualitative study it is important to understand how and why things are like they are. With little practise of making this kind of interviews it was difficult to find a way how to ask the questions so the participants could feel comfortable to talk about their experiences. Dealing with new information was also a challenge, since it opened up for more questions. To introduce more questions to the questionnaire for the next lake to visit could make the information from the interviews more valuable but at the same time the questionnaire had to be as similar as possible trough out the process to be able to make a fair comparison between the lakes. This struggle took time, and it was difficult to follow the red line trough the process.

If a second chance was given, more interviews would take place and that also with different stakeholders such as the sub county agriculture officer, the district officers for agriculture, environment, and tourism. This could have given a more diverse picture of the situation.

Recommendations for future research would be to focus on different topics as follows:

- Monitoring crater lakes status of eutrophication and condition
- Preventing techniques for soil erosion
- Soil health and fertility
- Transdisciplinary advice for small scale farmers

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Popular science summary

Land degradation is a global issue and is causing enormous problems for humans and the environment. Example of factors can be deforestation, agriculture and change in land use. These activities can cause that sediment from soil erosion is polluting the water; from ground water to rivers, lakes and oceans. Nutrients like nitrogen and phosphorous are lost from the soil which result in poor soil quality and in eutrophication of water bodies. In Uganda, during the last century, land degradation has been a big issue. This is caused by population pressure, deforestation, poor farming techniques and soil erosion. On the east African plateau and by the foothills of Rwenzori Mountains in southwest Uganda, the landscape consists of hills, valleys and several volcanic craters. Many craters are waterfilled and form crater lakes. This unique landscape provides good prerequisite for the high biodiversity in the area. The crater lakes are a vital resource for the surrounding rural communities since they make available ecosystem provisioning such as drinking water and food fish. In the district of Kabarole and Bunyangabu 52 crater lakes are found, and issues with eutrophication are becoming more common among the lakes. Unfortunately, there is also a lack of systematic monitoring program of the lakes. The main aim of this study was to investigate local peoples´ experiences of living near crater lakes´ in Uganda, and the understanding of current issues of land degradation and how it affects the lakes´ condition.

Lodge owners and farmers were the most common types of landowners around the lakes and were therefore important stakeholders. Semi-structured interviews were made with local people and two group discussions were held to evaluate measures to reduce land degradation, eutrophication of crater lakes and improve livelihood of local people. The method of Participatory Rural Appraisal (PRA) was used for discussion which aims to enable local people to express, enhance, share and analyse their knowledge of life and conditions, to plan and act.

Farmers reported that changed weather condition with heavy rainfall and rainfall in the wrong season cause problems with both soil erosion and crops that get rotten. Soil erosion leads to loss of nutrients resulting in lower crop yields. One farmer expressed that *“before we got good yields, we could even construct a house, now we dig and then we can’t even afford to buy the seeds”,* and the issue is so serious that in Kabarole district the nutrition in the soil might be lost within one century if not any measures are implemented. The District Officer explained that the situation

of the crater lakes is alarming. He says that the population pressure makes farmers encroach the crater slopes. The lakes are polluted by agriculture activities, and soil is entering the water which leads to eutrophication.

The farmers knew that the best way to preserve land and get the fertility back would be to let the land fallow, but there was a concern about how the poorest people can do restoration work on their land on the slope if they don't have anywhere else to farm. Poverty prevents many farmers from doing changes in their farming system, they are dependent on fast growing crops for their survival, but the land is getting degraded. Restauration often requires long time work of transformation. To manage this transdisciplinary work is necessary, to fight poverty agronomists, social workers and family planning centres must work together.

There seems to be a weak understanding about eutrophication among the locals´ and their own contribution of it, even though the effects of eutrophication are known among the participants. The extension and advertising services regarding soil conservation seems too inadequate within the country, and efforts to attract people to participate in meetings are necessary. The strategy of Effective risk communication can be used as a tool for agencies when working with farmers, which include the three steps of risk identification, risk assessment and risk reduction.

There are four important identifications of measures that follows:

1. Education about eutrophication and its risks among the population in the crater lake region and a developed program for the three steps of effective risk communication is required.
2. Research and development and adequate knowledge are required about the transformation process to sustainable soil conservation techniques for small scale farmers.
3. Transdisciplinary work is necessary to fight poverty where agronomists, social workers and family planning centres work together.
4. Development of ecotourism programs where revenue from the tourism industry should support conservation and land preservation which will improve the livelihood among local people.

This study has put an eye on a topic that, up to my knowledge, not is documented in the literature. It brings the perspective of the rural people and their experiences of soil erosion and eutrophication. To prevent eutrophication and improve livelihood for rural people this information is vital, and development always comes from individuals that must make a change in their lives.

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Since I started the agroecology master's program at the Swedish University of Agriculture Sciences my dream was to do field work for my Master Thesis in Uganda and Kabarole District. The area has a special place in my heart and will always have. The people, the landscape and the richness of biodiversity makes me feel to come back over and over again.

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