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COLLEGE OF AGRICULTURE, ANIMAL SCIENCES AND VETERINARY MEDICINE

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MSc in AGROFORESTRY AND SOI MANAGEMENT

Effect of multi-stakeholder assessment in agroforestry practices to enhancing watershed management for sustainable farmer's livelihoods in highland of north-western of Rwanda.

Case study: Mugogo watershed.

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Declaration

I, **TUMUSENGE Eric**, hereby declare that, to the best of my knowledge, the work presented in this dissertation entitled: **''Effect of multi-stakeholder in agroforestry practices for watershed management and farmer's livelihoods in highland of Rwanda''** is my original work not submitted elsewhere for any academic qualification at any university or institution of high learning. Cited ideas in this work have been indicated in the bibliography.

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This dissertation has been submitted with my approval as the university of Rwanda- busogo campus supervisor.

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Dr RUKANGANTAMBARA Hamud

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The deepest gratitude, to my friends, classmates and relatives, I will not forget the precious moments, I have shared with you. Thank you for the pleasant cooperation and solidarity. May God bless you.

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Abstract

Multistakeholder partnership model in agroforestry is a useful approach in watershed management to promote sustainable use of various resources and to improve the economic well-being of the local people. Properly designed and managed agroforestry systems can provide various benefits and has potential to meet environmental and socioeconomic requirements. The research were focused on effect of multi-stakeholder assessment in agroforestry practices to enhancing watershed management for sustainable farmer's livelihoods in highland of north-western of Rwanda. Different multistakeholders such as Rwanda mountain tea environment officer, sector agronomists, farmers (71) and Reducing Vulnerability to Climate Change through Community Based Adaptation (RV3CBA project) were visited. Quantitative and qualitative were used through Interview, questionnaire, group discussion and key informant methods were used for different stakeholders involved in agroforestry practices for watershed management and then the collected data were subjected to descriptive analysis using STATA (version 16) tools. The result indicates that 19.72 % of local community participate in Mugogo watershed management, 36.6% 42.25 % of respondents had implemented agroforestry, 69.01 % of respondent had attended primary education, 16.90 were illiterate and 11.27 % had secondary education, 32.39 % and 67.61% of respondent were female and male respectively, 87.32% mentioned that there were no radical and 12.68 progressive terraces along Mugogo watershed, 91.55 % of respondent agreed that in the catchment of Mugogo there were no trees on ditches whereas 8.45 % agreed the presence of trees on ditches and water ways, the soil of Mugogo watershed are sandy loam and sand clay loam.

Watershed management are strengthened with different stakeholder who are sharing different activities in agroforestry practices such as distribution of seed tree, nursery preparation, tree planting, weeding, pruning, thinning and harvesting. Putting together the effort by different stakeholders is major solution for management of Mugogo watershed while improving living condition of local community.

Chapter I. Introduction

1.1 Background of study

Multistakeholder partnership model is a useful approach in watershed management to promote sustainable use of various resources and to improve the economic well-being of the local people. Properly designed and managed agroforestry systems can provide various benefits and has potential to meet environmental and socioeconomic requirements (**Sarvade .2015)**.

Community participation could integrate the indigenous knowledge and practice yet the different new approaches adopted don't recognize the traditional knowledge in soil and water management in watershed management while recent research finding revealed that local knowledge is important in watershed management option and should combine with modern technology **(Azene &Gathiru .2006)**. The community participation in decision making is still limited in climate change adaptation and food security. Collaboration in watershed management involving community based organization, extension institution, and non government organization is necessary at different scale in order to share different expertise and experience (**Uzamukunda, 2015**).

Researches in watershed management are important even thought in highland region of Rwanda there is a minimum weight to connect research and watershed management this is indicated by watershed projects which ignore the participation of local famers using top to bottom strategy and generate low adoption on the implemented practices. In addition the problem of technology up scaling does not fit to the current issues faced by farmers which call upon to the development of appropriate technology. This thesis aim to assess the effect of Multi-stakeholder in agroforestry Practices for watershed management and farmers livelihood in volcanic highland of Rwanda. Multi-stakeholder Agroforestry model= $\mu + \beta_1 Ei + \beta_2 Bc + + \beta_3 Wc + \beta_4 Hpi + \beta_5 Ru$

Where Ei: Economic incentive (costs and expected yield)

Bc: Biophysical condition (slope, plot size, Wc: Wealth class

Hp: Householder preference and Ru: Risk and uncertainty

1.2. Problem statement

Recently multi-stakeholder participation has been implemented in watershed management in tropical regional as sustainable way to address the problem of soil degradation such soil erosion, flooding, drought, soil acidification, soil fertility decline and the impact of climate change as sustainable solution for these complex challenges. Unfortunately the success has not been achieved due to the concentration on technical matter without local community engagement and low that why there is a need of multi-stakeholders for watershed management **(Javier et al, 2013).**

Volcanic highland of Rwanda experience the effect of climate change as it is most high populated region 600habitat/square kilometer and 80 % rely directly or indirectly on agriculture (NISR,2015) .It has a fragile ecosystem, mountainous, high rain fall ,intensive cultivation and high population growth leading to land fragmentation and over cultivation **(Musanze DDP,2013).**

In addition improper farming practices, poor water and soil conservation practices, steep slope and deforestation increase the loss of watershed function in volcanic highland including displacement of 430 families living in the lowland of Mugogo **(Nkurunziza ,2018)**.This alarming has pushed the government of Rwanda to implement Reducing Vulnerability to Climate Change Through Community Based Adaptation (RV3CBA project)" in Nyabihu and Musanze districts to increasing adaptive capacity of natural systems and rural communities to climate change impacts in the affected areas and was executed by the Rwanda Water and Forestry Authority (RWFA).Land terraces channel, agroforestry practices , dams were constructed under project. However flooding, soil erosion still observed in the area.

Therefore a new approaches is required to overcome the barriers of low adoption of agroforestry in watershed management at different scale which integrated different stakeholders. This working tends to assess the contribution of Multi-stakeholder in Agroforestry model to the adoption of agroforestry technology for effective Mugogo watershed management.

1.3. Objectives of study

1.3.1. General objectives

The overall objective of study is to investigate effect of multi-stakeholder assessment in agroforestry practices to enhancing watershed management for sustainable farmer's livelihoods in highland of north-western of Rwanda.

1.3.2. The specific objectives

- To assess the contribution of institutional and local community stakeholder in Agroforestry model to the watershed management in the study area.
- To evaluate the social, economic and biophysical factors influencing the adoption of Agroforestry in watershed management in the study area.
- To inventory the adopted agroforestry practices in watershed management in the study area.
- To determine the contribution of multistakeholders agroforestry model to farmers livelihood in study area.
- To assess the soil texture in study area.

1.4. Research question

- What are the social, economic and biophysical factors influencing the adoption of Agroforestry in watershed management in the study area?
- What are the contributions of institutional and local community stakeholder in Agroforestry model to the watershed management in the study area?
- What are the adopted agroforestry practices in watershed management in the study area?
- How agroforestry model contribute to the farmers livelihood in the study area?
- What is the soil texture found in study area?

1.5. Significance of study

- ✓ Through Multistakeholder Agroforestry Model a consensus driven decision making will be made in watershed management in the study area.
- ✓ Level of adoption of agroforestry practice will increase based on community participation
- ✓ Indigenous knowledge will be taken into account by using Multistakeholder Agroforestry Model
- ✓ There is formation of cooperative that play role in removing sediment in channel and in caves for sustainable management of Mugogo lowland.
- ✓ Different researches results highlight the factors of adoption without promoting the understanding the contribution of multistakeholder.
- ✓ The use of charcoal stove and other source of energy will be increased for local community for proper forestry and agroforestry trees conservation.

1.6 Conceptual framework

The following diagram illustrates the major factor that determines the adoption of agroforstry practices for watershed management in the study areas**.**

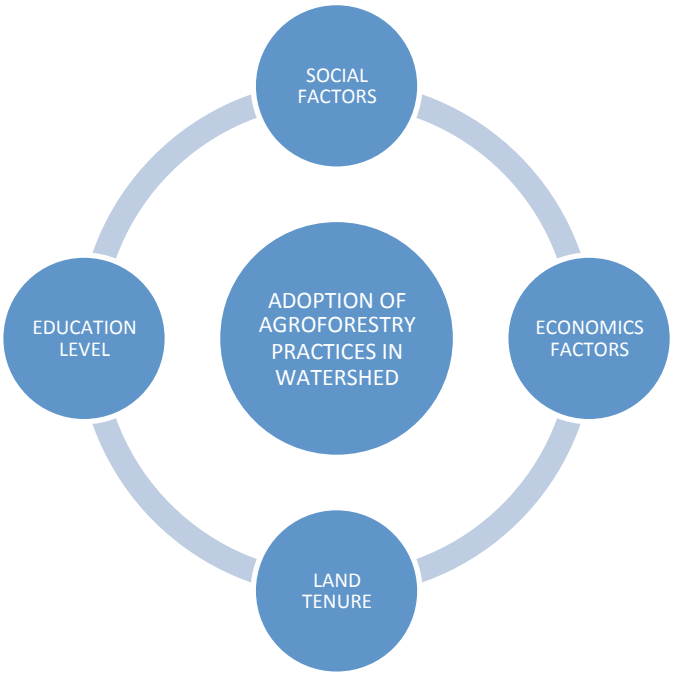


Figure 1: ***Illustration of the conceptual framework of agroforestry adoption in watershed management.***

Chapter 2: Literature review

2.1. Multi-stakeholders participation in agroforestry practices

The participation of different stakeholders (local community, environmental officers, sector agronomists and Rwanda mountain tea) are more powerful for watershed management due to collection of multi functional done for environmental conservation. They had diverse activities such as preparation of tree seeds, tree planting, wedding, thinning and pruning and extension services on policies of watershed management.

2.2. Role of agroforestry for improving livelihood of local community

2.2.1. Agroforestry

Agroforestry is the practices of growing crops are with trees and or animals in conservative way in special arrangement and temporal arrangement **(Gold & Garrett, 2009).**It provides goods and services which play important to improve livelihood of people and environment conservation such as watershed management, flood and erosion control, stakes, food, herbal medicine, increase of agriculture production and maintaining environmental quality and Biodiversity **(Gradwohl *et al.,* 1990).**

2.2.2. Role of agroforestry in improving livelihood of farmer's

The most important for participation in agroforestry practices used for increasing the well being of population due to climate change improvement by reducing the concentration of carbon dioxide in the atmosphere which helps the farmer adopts to change. Generally agroforestry play important on Minimized the risks of natural disasters, Increase of agriculture production, Increase soil biomass cover, Enhance soil quality improvement, Increased income generation activities, fuel wood for farm, Improved biodiversity (Habitat of flora and fauna),Climate change adaptation and mitigation, environmental health, nitrogen fixation trees that are intercropped between rows of crops to help the plant to recover the limited nutrients used by food crop with aims of increase farm productivity **(Nabunya,. 2017).**

There is an unstated belief among many of the implementing organizations that erosion occurs because farmers do not know how to manage soil and water properly. As a result, the organizations invest a great deal of effort to advise, train and 'educate' farmers about erosion-control methods **(Ellis-Jones and Mason, 1999)**.

Some organizations even pay farmers with food or access to credit to adopt soil and water conservation practices. Environmental conservation campaigns are organized, with posters, bulletins and radio announcements praising the virtues of conservation, reforestation, contour ploughing, etc. Demonstration plots are set, and many hours are spent with farmers to develop land management plans for farms and small watersheds **(Garrity et al., 1998)**.

Organizations managing watersheds should select practices that are low-cost, productivity, value-adding to the farm income, risk-reducing in the short term and which require little labor or management investments**,** in order to ensure their enhancing wide spread adoption among neighboring farmers. The economic viability of the farming households and the ecological health of the watershed depend on the farmers' access to cash via cash crops and other income-generating activities **(Perez & Tschinkel, 2003).**

2.3. Factors Influencing Adoption of Agro forestry Technologies

There are great numbers of factors that influencing the adoption of agroforestry. Economic value of trees is a key factor in farmers' adoption **(Scherrs, 1995)** and the type of tree species available to the farmers for planting. Farmers in most cases tend to accept multipurpose and fast growing tree species that yield benefits early rather than those that have long maturity periods **(Sharma, 1995)**.

Another factor that determines farmers' adoption is the availability of labor. Labor shortage has tended to discriminate against categories of farmers **(Aboud, 1997),** when tree production requires a high input of labor **(Kerkhof, 1990)**, farmers tend to resist. They prefer small gradual changes in farming methods that are not labor intensive.

2.3.1. Biophysical Factors

The nature of soil, source of water and topography, climate and slope is the ones of Biophysical factor factors influencing the adoption of agroforestry technology. In most watersheds, soil degradation is influenced by topography coupled with anthropogenic activities. Agroforestry is a possible option to sustainably redress the degrading socio environmental situation this influences people‟s decision in adopting agroforestry technologies. In another vein, availability of water resources for farming influences farmer decision in adoption of agroforestry technologies. A study in Machakos county of Kenya found that farmers do not adopt agroforestry technologies due to the high water demand in production especially at the nursery**(Asempah, 2016)**.

2.3.2. Socio Factors

Results from empirical studies on agricultural technology adoption suggest that, socio-cultural factors such as gender, farmers‟ age, level of education, and family size influence adoption rate of new agricultural technologies among farmers **(Ayinde *et al*., 2010; Idrisa *et al*., 2012)**. For example, **Ayinde *et al*. (2010)** in their study found that gender, education level of farmer, farming experience, access to extension agents and access to credit have significant and positive influence on adoption.

Gender is one of the important variables in adoption study. The dominance of male in agricultural activities has been recorded in many studies on account of the fact that men are more empowered in access to resources for agricultural activities than their female counterparts who are generally discriminated against in terms of access to resources and information **(Nkamleu and Adesina, 2000 and Jamala *et al*. 2013)**. Also, **Asfaw and Admassie (2004)** opined that men are more likely to get information about new technologies and engage in risky businesses than their female counterparts. A study by **Nhemachena and Hassan (2007)** finds contrary results, arguing that female-headed households are more likely to take up climate change adaptation options when they are exposed to information.

2.3.3. Economic Factors

Off-farm income and value of household assets are some of the major economic factors that influence adoption of agricultural technologies. The ability or inability to afford pesticides, fencing material, seeds and other inputs required for implementing new agroforestry technologies is dependent on household income. With low incomes, many households would not be able to acquire the inputs required for substantial crop production, let alone for managing agroforestry projects **(Chitakira and Torquebiau, 2010).** A similar observation was made by **McGinty *et al.* (2008)** on smallholder farmers of Southern Bahia in Brazil. A study carried out in Kenya and Zambia showed that there was an association between wealth and adoption of improved fallows in Zambia and Kenya **(Franzel, 1999).** Similarly, a study conducted by **Phiri*et al*. (2004)** found a positive association between farmers‟ wealth status and adoption of improved fallows.

They found higher adoption among wealthier farmers than their poor counterparts. Similar results were obtained by **Keil*et al*. (2005)** who found that adoption of agroforestry.

Socio-economic factors are aspects that relate to social and economic conditions in communities and less to the cultural and biophysical environment. These include: income, occupation, education level, farm size and family size. These factors variously influence the adoption of farm forestry technologies among farmers. In Western Kenya, income, occupation and education level were found to influence tree planting **(Ong'ayo, 1993).** Most studies show relationship between adoption and income as a direct one. For instance, in Nigeria, adopters were older, wealthier farmers who own more than average amounts of land **(FAO, 1989).**

2.4. Watershed management

A watershed also called catchment is natural phenomena in which water are drained into common livers or lacks. Agriculture and other human activities are the ones for influencing the quality and quantity of water down stream in livers and lacks. Upstream activities influence river flows and water quality downstream. It also called a drained basin or catchment; it goes to common outlet **(Wani et al. 2008).**

2.5. Challenges faced on watershed management

2.5.1. Constraints to Farmers Adoption of Agro forestry Technologies

The importance of trees and need to retain and remove them has always conflicted with the need for Agricultural land **(FAO, 2000)**. Tree planting generally coincides with Agricultural activities which are always given first priority. The need to provide food through agriculture is a first priority all over the world while the need to conserve forests is to ensure sustainability of the global ecosystem **(Sharma, 1992).**

Due to the fact that a large percentage of the world's land resources are arid and cannot support food production, there is competition for the productive land between agriculture and forests. This is why Agroforestry is the best option for optimizing land resource use **(Sharma, 1992).**

Krause et al., (2000) reported the following barriers for watershed conservation: Lack of up-to-date watershed data and useful decision-support tools, Weak environmental legislation, Excessive bureaucracy and politics, Lack of sustainable funding, Lack of monitoring and evaluation procedures, Resistance to change, Fragmentation of responsibilities among agencies, Lack of technical expertise and/or technical assistance.

2.5.2. Various hazards and their impacts in the Mugogo watershed

As earlier mentioned Mugogo watershed is one of the Northern Province area prone to hazards such as flood, erosion and moderate landslide. The underlying causes of these hazards are natural (heavy rainfall, fragility of the soil, volcanism) and anthropogenic (over-cultivation, agriculture on steep areas without the adequate soil conservation measures etc.) In fact, the scarcity of land, poverty and a lack of alternative, off-farm livelihoods have inadvertently been responsible for unsustainable land use practices resulting in persistent and severe land degradation. Land is over-cultivated and no longer set aside for fallow periods, grazing land has been cultivated and the steep slopes that were previously forested or covered in natural vegetation are increasingly being cultivated and settled on(**Nkurunziza,. 2018)**.

This settlement and cultivation on steep slopes as well as deforestation have led to erosion and declining soil fertility, destabilized the hillsides and has contributed to watershed degradation increasing the risk of flooding and landslides that is enhanced by the fragility of the soil as well as higher porosity of the volcanic rocks and caves. The following are the hazards identified in Mugogo watershed: Flooding, Erosion, Siltation and sedimentation, Landslides, Deforestation (**Nkurunziza,. 2018).**

2.6. Land and Tree Tenure Rights

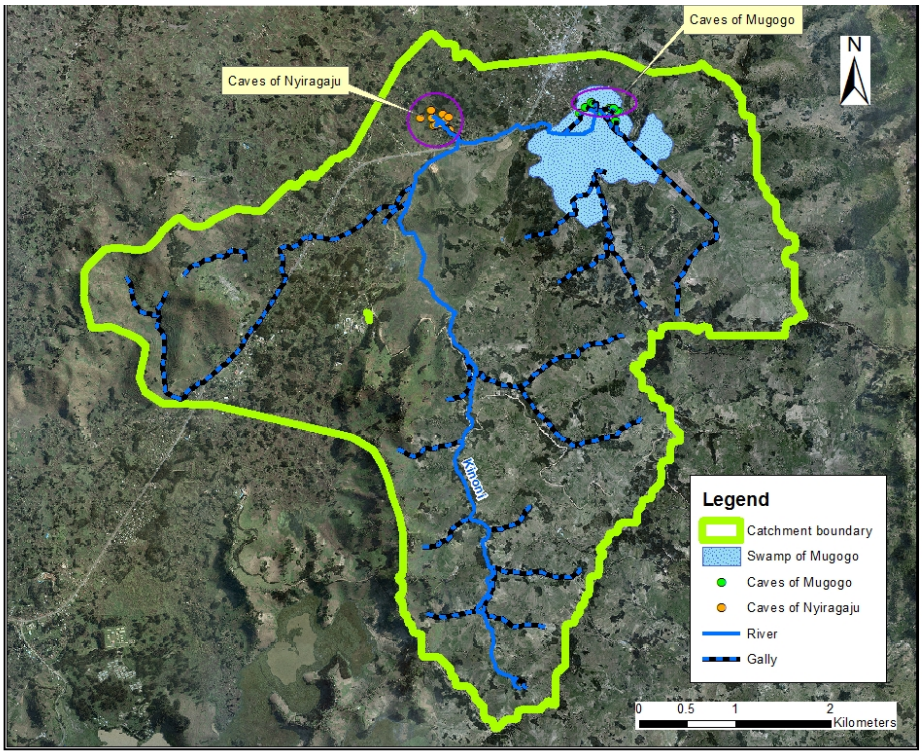
Land tenure refers to the possession or holding of the rights to the use of land. Agro forestry production systems that involve the local farmers are directly be related to the flexibility of the land tenure system **(Adayoju, 1984).** Secure tenure provides for proper incentives for farmers to make investments in the long term productivity of their land **(Panayotou, 1993).**

Busienei **(1991)** found out that the low participation in Agro forestry activities in Ainabkoi Division of Uasin Gichu district was due to lack of title deeds. Closely related to land tenure is the issue of tree tenure. Farmers who do not legally own land tend to feel they cannot possibly own the trees and hence see no need of planting them.

Chapter3. Materials and methods

3.1 Site description

Mugogo watershed is located in Busogo sector / Musanze District mainly its lowland while its upstream is located in Mukamira and Kintobo sector /Nyabihu district. The rainfall ranges in 1300-1500 mm per year with temperature of 15 ^{0}c and according to FAO soil classification it is dominated by Andosols. The slope range between (13-55) % while the dominant crops are Irish potato, wheat, climbing bean, maize and pyrethrum.



Fugure1: ***Map illustrating the Mugogo watershed***

3.2. Survey methods.

The following methods were used to collect the primary data. qualitative and quantitative

3.2.1. Sampling design

Environmental specialist, Natural resources offices were the key informants and they will provided information on the planting of trees, use of trees and knowledge of Agro forestry technologies in the study area.

3.2.2. Questionnaire

The semi-structured questionnaire that were used to collect data from the households. The questionnaire consisted of both open and closed ended questions based on research objectives.

3.2.3. Field observation

The researcher made observation in the study area. To confirm the different opinions from respondent. Field observation will be conducted to assess variables such as trees planted within the farm, species planted, estimation of farm size and type of Agro forestry technologies Adopted. In field observation the biophysical resources and the status of conservation measures within watershed were observed. Some physical soil and water conservation measures agroforestry) practiced in the Mugogog watershed.

Sample of soil was taken randomly based on slope variation from the three sectors at 20cm depth by Augur; the soil texture of the sites was tested in laboratory by hydrometer method. Generally, a total of 9 soil samples were taken from free sites (and one sample was mixed with five samples).

3.2.4. Key informant interview

A Random sampling was used to identify householder/Farmers for interview and to respond to the questionnaires. Primary data collected from small scale crop producers using semi-structure questionnaires with farmers, interviews with farmers and key informants as well as observations. Published and unpublished data will be also consulted.

3.2.5. Sample size

The total number of household in the location (N) constituted the sampling frame and the units of sampling will be the individual households. The sample size will be calculated based on the equation by Rees (1995)

$$\mathbf{S=}\frac{\mathrm{X2\ NP\ (1-P)}}{\mathrm{D2\ (N-1)+X2P(1-P)}}$$

Where

S = required sample

N = Population of household in the study area.

P = Sample proportion which is favored in the population to give 95% Confidence level.

D = Degree of accuracy which is reflected by the amount of error that can be tolerated in the fluctuation of sample proportion P.

X2 = Chi-square value corresponding to one degree of freedom relative to desired confidence.

3.2.5. Soil sampling

3.3. Data Analysis

The collected data (qualitative and quantitative) were subjected to descriptive analysis using STATA (version 16) and the relationship between variable were performed using correlation and regression analysis**.**

Chapter 4: Results and discussion

The collected data were based on the objectives study. It involves the presentation of the major findings and percentages and frequencies were used as means of analyzing and interpreting data.

4.1. Demographic characteristic

4.1. 1. Age and gender of household

The table below indicates that 32.39 % and 67.61% of respondent were female and male respectively. The results indicated that in watershed management there is gender imbalance where male were more dominant. This implies male was dominant compare to female in Mugogo watershed management therefore gender imbalance in watershed management impair implementation of designed practices .The results are similar to Kiptot *et al*.,(2014) who reported female could participate like male but resource scarcity and traditional culture reduce female participation in agroforestry practices.

Table 1: Representation of gender of respondents

Gender	Frequency	Percentage	n
Female	23	32.39	71
Male	48	67.61	

Also the results indicate that 33% of respondent had the mean age between 22-40 years

The table below indicates illustrate the age of respondents for watershed management where 46.47% belong 22-40 age class which were dominant, 32.39% of 41-50 age class and 26.76% for more than ages >51

Table 2: illustration of age of respondents

Age of respondents	Frequency	Percentage	n
22-40	33	46.47	71
41-50	23	32.39	
>51	19	26.76	

4.1.2. Education level of respondents

The survey indicates that 69.01 % of respondent had attended primary education, 16.90 were illiterate and 11.27 % had secondary education .The results revealed that community involving in watershed management had low education. The results are in line with Karki *et al*., (2016) found that forma education extension service and regular research output delivery increases agroforestry practices at household level. The results revealed that low education level of household affect the implementation of agroforestry practices in watershed management as it increase the analysis of farmers to the new agroforestry technologies also education could increase farmers access to information that are useful in watershed management.

Table 3: representation of household education

Education of respondents	Frequency	Percentage	n
University	2	2.82	71
Secondary	8	11.27	
Primary	49	69.01	
Illiterate	12	16.90	

4.2. Biophysical factors

4.2.1. Land form characteristic

The table below shows farm characteristics where household implemented agroforestry in Mugogo watershed. It indicates that many household had farm with moderate slope whereas fem of household had farm in flat area .land feature seems like an important aspect where farmers intend to plant agroforestry tree species on abandoned land. Similar results were found by Yadav *et al.,(*2019) asserted that agroforestry system such as agrisilviculture practices, agrisilviculture (AS), agrihorticulture (AH), agrihortisilviculture (AHS) and agrisilvihorticulture (ASH) differ according to land elevation.

Table 4: land form characteristic

Land characteristic	Frequency	percentage
Flat	20	11.36
Moderate	61	34.66
Gentle	45	25.57
Steep slope	50	28.41
	176	100

4.2.2. Farm size

The table below shows farm size of respondents and indicates that a large number of respondents had farm size less than 0.25 ha. Shortage of land indicating high agricultural intensification leads to low adoption of agroforestry in their farm. Similar result reported by Nyaga et al (2015) utilization of agroforestry tree species for small farm were not adopted by small farmer due to the ideology of reduction of cultivated soil and the competence of tree species with cropland that cause the reduction agriculture production .

Table 5: Show farm size

Farm size	Frequency	percentage
< 0.25ha	28	39.44
0.26-0.75 ha	23	32.39
0..76-1.5h	15	21.13
> 1.5 ha	5	7.04
	71	100

4.3. The contribution of local community and institutional stakeholder in Agroforestry model to the watershed management in the study area.

4.3.1. Community participation in Mugogo watershed management

Regarding to the contribution of Multi-stakeholder Agroforestry model to the watershed management in the study area, results indicates that 80.28% and 19.72 % of local community did not involve in Mugogo watershed management .Week participation increase low adoption of implemented practices by local community characterized by the existence degradation of watershed. The similar result reported by Bekele *et al* (2018) Land degradation and food insecurity are caused by bad management of watershed which reads to soil erosion by movement of soil particle used for agriculture activities to another place. The conservation activities of soil and water in the watershed have been promoted. Pradhan et al (2017) the adoption of long time implementation of the conservation policies, Watershed management, capacity building of farmers and resource protection are the strategies used for building capacity at local level in watershed.

Table 6: Community participation in Mugogo watershed management

Local participation	Frequency	Percentage	n
No	57	80.28	71
Yes	14	19.72	

4.3.2. Institutional contribution

The table below shows Institutional contribution in different agroforestry practices. The result indicates that 63.38%, 78.87%, 90.14%, 56.34% and 28.17% are for access to credit, training, funding, technical advice and land tenure respectively they were not receive institution support for improving agroforestry practices whereas 36.6%, 21.1%, 9.9%, 43.7% and 71.8% of respondents they were receive institution support. Except on land tenure where the dominants respondent shows they have land right on their farms. Great number of respondent they were not receiving institution support means there is no harmonized in watershed that cause the continuous water logging in lowland of mugogo watershed.

The similar result reported by Abbas et al (2017) government institution were the key factors for contributing in afforestation of trees species in crop land. Climate change is major challenges facing the world, to overcome these challenges different institution participate in different activities which are more benefit to the community and environment conservation (carbon sequestration, food, environmental protection, biodiversity conservation , increase agriculture production, woods, timbers.

Table 7: Institutional contribution in agroforestry

Institutional factors	NO	Percentage	YES	Percentage
Access credit	45	63.38	26	36.6
Training	56	78.87	15	21.1
Funding	64	90.14	7	9.9
Technical advise	40	56.34	31	43.7
land tenure	20	28.17	51	71.8

4.4. Agroforestry practices undertaken by Local community

The table below shows local community participation in different agroforestry practices. The result shown that 28.17% of respondents involved in plantation of agroforestry trees , 25.35% of respondents involved in nursery preparation and harvesting of agroforestry tree species while 21.13% of respondents they did silviculture practices such as thinning, pruning, weeding, improved cutting. These indicate that there is low adoption of agroforestry and implementation of government policies by local people live in Mugogo watershed which leads to continuous soil erosion, siltatation in lowland.

The similar result reported by Islam et al (2015) local community participation have been used bottom up approach for management agroforestry practices (tree planting, nursery preparation, silviculture and harvesting of agroforestry tree species) all these factors showed the social, economic and ecosystem outcome for participant in the watershed and the implementation of agroforestry practices were based on the decision of local commuity.Azizi, M. (2013) the implementation of different agroforestry activities by different stakeholders is the major contribution of watershed management and improvement living condition of local community. The processing of agroforestry trees species were the major contribution in the creation of off-farm employment like production of writing paper and various printing materials.

Table 8: Agroforestry practices undertaken by Local community

Community practices	Frequency	percentage	n
Nursery	18	25.35	71
planting	20	28.17	
Silvicultural practices	15	21.13	
Harvesting	18	25.35	
	71	100	

4.5. Adopted agroforestry system

To achieve the objective of assessing the adopted agroforestry practices in watershed management in the study area. The following table indicates that the dominant agroforestry practices were farm woodlot at 15.74% and live fences at 13.89%. In Mugogo watershed more population accept woodlot and live fences for protecting their farm. the similar result reported by Tafere *et al* (2018) the adopted of agroforestry by the respondents have been introduced slightly home garden technology followed by alley cropping, multipurpose trees and boundary planting which were more dominant. The adoption of agroforestry technology based on factors of size of the farm, age, labor, laws and intensives.

Table 9: **Adopted agroforestry system**

Agroforestry practices	**Frequency**	**Percentage**
Boundary planting	37	8.56
Windbreaks	13	3.01
Shelterbelt	17	3.94
Live-fences	60	13.89
Conservation hedges	42	9.72
Farm woodlots	68	15.74
Trees on pasture	35	8.10
Multipurpose and shrubs	46	10.65
Improve fallow	10	2.31
Fodder banks	23	5.32
Home garden	56	12.96
Alley cropping	25	5.79
	432	100.00

4.6. Agroforestry trees species on radical and progressive terraces along Mugogo watershed

The table below shows local agroforestry trees species on radical and progressive terraces along Mugogo watershed. The result indicates that 87.32% of land in Mugogo watershed is not covered with radical and progressive terraces and 12.68% of land in Mugogo watershed is covered with trees species on radical and progressive terraces. Land degradation due soil erosion is a main cause of poverty in livelihood who lives in Mugogo watershed. The increasing in soil fertility decline in Mugogo watershed is associated with climate change factor where high rainfall associated with unprotected upland contribute more sediment and silt in Mugogo wetland.

Refers to **Kiage, (2013)** he reported that soil erosion is main cause of Land degradation Sub-saharan Africa this is associated with high rainfall intensity, intensive agriculture on slop land without protection with agronomic and mechanical measures .

Table10: Status of agroforestry trees species on radical and progressive terraces along Mugogo watershed.

Radical and progressive terraces	Frequency	Percentage	n
No	62	87.32	71
Yes	9	12.68	

4.7. Agroforestry tree species on ditch and water ways along Mugogo watershed

The table below shows that 91.55 % of respondent agreed that in the catchment of Mugogo there were no ditches whereas 8.45 % of total land was managed by using ditches and waterways, those result is associated with economic factor, digging ditches requires cost and farmers did not do it in their farm, those percentage of ditches was done by government .Construction of water way in Mugogo watershed were also at low rate and again were highly associated with economic factor, by constructing water way, it require high investment and maintenance cost.

The presence agroforestry tree species on ditches and water ways these leads to improve soil structure by reduction of soil erosion, increasing infiltration rate by increase of ground water recharge. Similar result reported by as highlighted by Christopher (2017) suggest that ditches and waterway reduce excess nutrient and siltation that entered in the lake that cause harmful algal blooms, those conservation measure improve water quality by increasing infiltration rate and trapping sediment.

Table11: Status agroforestry trees species on ditch and water ways along Mugogo watershed

Ditch and water ways	Frequency	Percentage	n
No	65	91.55	71
Yes	6	8.45	

4.8. Major contribution of agroforestry

4.8.1. Contribution of agroforestry model to the farmer's livelihood in the study area

The table below shows general Contribution of agroforestry tree species to the farmer's livelihood at Mugogo watershed. The most dominant are 13.09% of Increase of agriculture production, 12.27% Increase soil biomass cover, 11.86% Enhance soil quality improvement, 11.66% Improved biodiversity (Habitat of flora and fauna), 10.63% Increase of water availability, 10.22% Climate change adaptation and mitigation, 8.79% Water quality improvement, 8.38% of Increased income generation activities, 6.95% Minimized the risks of natural disasters and 6.13% Underground water recharge. These results indicate the benefit of agroforestry in the watershed management and increase the well being of peoples living in the Mugogo watershed. Similar result highlighted by **Roshetko *et al* (2013)** smollholders farmers growing agroforestry trees in their farm. Agroforestry trees species contribute multidiverse services such as production of food for humans and for livestock, income generation, environment protection, stakes, mulching materials. **Cerda et al (2014)** Agroforestry contributing different product for well being of local community in quantitative and qualitative of agriculture production, generating income and biodiversity conservation and improving ecosystem services.

Table 12: Contribution of agroforestry model to the farmer's livelihood in the study area

livelihood improvement	**Frequences**	percentage
income generation	56	15.73
timber production	60	16.85
stakes for climbing beans	65	18.26
Soil fertility improvement	47	13.20
Fire wood	67	18.82
crop yields improvement	61	17.13
	356	100.00

4.8.2. Benefits of agroforestry practices

The table below shows the benefit of agroforestry practices in Mugogo watershed. The result shw that 13.09% is for Increase of agriculture production, 12.27% for Increase soil biomass cover, 11.86% Enhance soil quality improvement, 11.66% Improved biodiversity, 10.63% Increase of water availability, 10.22% Climate change adaptation and mitigation, 8.79% Water quality improvement, 8.38% Increased income generation activities, 6.95% Minimized the risks of natural disasters, 6.13% Underground water recharge, these benefits improving living condition of loval community and environment conservation, the acceptable agroforestry in Mugogo waresged have more benefit for improving living condition of local farmers and environmental conservation.Similar result highlighted by **Gao et al (2014)** agroforestry suggested to produce ecological and socio-economic benefit and with the integration of public institution there are increase of agriculture production, **Liang et al (2019)** agroforestry and soil and water protection are the major contribution to ecological benefit including carbon sequestration, soil fertility improvement, soil pollution prevention, green house gas mitigation. Climate change adaptation and mitigation, Increase soil biomass cover, improved biodiversity, Enhance soil quality improvement, minimized the risks of natural disasters, Increased income generation activities all are more powerful for improving the living condition of population and environmental conservation.

Table 13: Benefit of agroforestry practices

Benefit of agroforestry practices	Frequences	Percentage
Increase of water availability	52	10.63
Water quality improvement	43	8.79
Minimized the risks of natural disasters	34	6.95
Increase of agriculture production	64	13.09
Increase soil biomass cover	60	12.27
Enhance soil quality improvement	58	11.86
Increased income generation activities	41	8.38
Improved biodiversity (Habitat of flora and fauna)	57	11.66
Climate change adaptation and mitigation	50	10.22
Underground water recharge	30	6.13
	489	100.00

4.8.3. Direct benefit of agroforestry to the local community

The table below shows the result of well management of watershed had the direct positive impact to the local community. The most dominant benefit of agroforestry tree species to the people 22.49% Stakes for climbing beans, 21.11% Crop yields improvement, 20.76% Timber production, 19.38% Income generation, 18.82% Fire wood. Similar result highlighted by **Thorlakson *et al* (2012)** climate change is the ones for causing the increase of temperature on the earth, high rain fall intensity (flooding), draught and extremes weather variation. To overcome these challenges agroforestry were the solution that provides more goods and services for the world population (fermers) while preserving the environment. **Elevitch *et al* (2018)** agroforestry is the system of increasing food production which leads to social, economic and environment benefit. In agriculture agroforestry contributing to five environment concerns: carbon sequestration, biodiversity conservation, soil fertility improvement and health, water quality improvement and ecosystem conservation.

Table14: Direct benefit of agroforestry to the local community

Farmers livehoold	Frequencies	percentage
Income generation	56	19.38
Timber production	60	20.76
Stakes for climbing beans	65	22.49
Soil fertility improvement	47	16.26
Crop yields improvement	61	21.11
Fire wood	67	18.82
	356	100.00

4.9. SWOT Analysis on agroforestry model for Mugogo watershed management

4.9.1. Strength of agroforestry model

The table below summarizes household's overview on strength for agroforestry in watershed management .it shows that 71.83% and 28.17% of respondent agreed that soil is suitable and no suitable for agroforestry respectively .the other strengths identified were different Organizations intervening in distribution ,provide training for household and availability of seedlings. The similar result reported by Elevitch *et al* (2018) agroforestry is the system of increasing food production which leads to social, economic and environment benefit. In agriculture agroforestry contributing to five environment concerns: carbon sequestration, biodiversity conservation, soil fertility improvement and health, water quality improvement and ecosystem conservation.

Table15: Strength of agroforestry model

Suitable soil	Frequency	Percentage	n
No	20	28.17	71
Yes	51	71.83	

Table16: ***Illustration of soil suitability for agroforestry***

4.9.2. Weakness of agroforestry model for Mugogo watershed management

The table below shows that 66.19% and 33.80 % of respondents mentioned that lack knowledge was the most challenge for using agroforestry model in Mugogo watershed management. The others factors identified as limitation were Lack of planting materials, Lack of man power, Water availability, Land tenure, Lack of knowledge/skill Lack of technical assistance, Lack of capital, Pests and diseases, Initial costs of input, Limited land. These factors cause the low adoption of agroforestry in the watershed. Similar results are reported by **Noordwijk *et al* (2017)** overflow of river are the main cause flood that reflect relocation human being and different activities during rainy season climate. For effective maintaining and restoring ecological services that play role for adaptation of climate change, it requires different stakeholders for quantifying the effectiveness of activities such as agroforestry, mulching, construction of water ways, buffer zone and organic farming in the specific social, ecological, economic and environment context.

Table 16: Weakness of agroforestry model on mugogo watershed management

Lack of knowledge	Frequency	Percentage	n
No	24	33.80	71
Yes	47	66.19	

4.9.3. Opportunity for agroforestry model for Mugogo watershed management

The table below indicates that 83.09 % of respondents agreed that multipurpose functions of agroforestry were the most opportunities to implement agroforestry. There are others functions George *et al* (2012) sustainable development of new agriculture landscape there is a need of agroforestry. Agroforestry bundling carbon sequestration with biodiversity conservation handles different problems. Agroforestry in dry land is a solution for biodiversity loss and climate change mitigation. Guteta& Abegaz; . (2016) the influence of scaling up of agroforestry natural fertilizer transfer, Presence of multipurpose tree, crop resilience during drought, Ease and speed of eliminating weeds, Serve as windbreak.

Table 17: Opportunity of agroforestry model on Mugogo watershed management

Afs as Multipurpose	Frequency	Percentage	n
No	12	16.90	71
Yes	59	83.09	

Also the supports from government have been identified by respondents to be more efficacy to enhance the use of agroforestry in watershed management.

4.9.4. Threat of agroforestry model for Mugogo watershed management

The survey indicated 81.6% of respondents agreed that that disease outbreak were the most threat for agroforestry model whereas 18.30 % had disagreed.

Table18: Threat of agroforestry model on Mugogo watershed management

Diseases outbreak	Frequency	Percentage	n
No	13	18.30	71
Yes	58	81.6	

4.10. Factors influencing low agroforestry model on Mugogo watershed management

The table below represent many factors that influencing low adoption of agroforestry practices in mugogo watershed. The result indicate that 25% of Lack of technical skills, 18.5% Weak extension services, 15.5% Cost of seedling, 15 Lack of off farm income, 12 Lack of access to credit. According to the result obtained indicate that in Mugogo watershed there is low adoption of agroforestry practices which leads to soil erosion and environmental degradation that contributing to the increase of siltation in the low land of mugogo that were indicators in the reduction well being of local community through low agriculture production, environmental degradation by climate change. To overcome these challenges through multistakeholders (local community, public agencies, non government organization, youth) must increase extension services, training, practices by explaining the benefit of agroforestry for improving the living condition of local community, environment and for the state.

The similar result highlighted by **Bargués et al (2014)** the constraint of water scasity on living condition of peoples live in tropical dryland. The scarcity of water in dryland environment discouraging the development of planted trees that need large water consumption.

Table 19: Factors influencing low agroforestry model on Mugogo watershed management

Factors	Frequency	Percentage
Lack of technical skills	50	25
Cost of seedling	31	15.5
Lack of access to credit	24	12
Lack of off farm income	30	15
Weak extension services	37	18.5

4.11. Soil texture

Soil samples were collected from the three different sectors (that are in two districts where Mugogo watershed located based on slope that is from top, middle, and bottom slope.**Table 20**:

Table 20. Represent soil texture

Sites	Slope	%sand	% clay	%silt	Soil class
MUKAMIRA	Upland	71.1	15.1	13.8	Sandy loam
	Middle land	69.4	18.7	11.9	Sandy loam
	Lowland	68.3	21,1	11.6	Sand Clay loam
KINTOBO	Upland	67.3	16.5	16.2	Sandy loam
	Middle land	59.2	22.1	18.7	Sand Clay loam
	Lowland	58.9	23.2	17.9	Sand Clay loam
BUSOGO	Upland	69.8	18.4	11.8	Sandy loam
	Middle land	60.2	21.6	18.2	Sand Clay loam
	Lowland	59.8	22.8	17.4	Sand Clay loam

The result showed that the percentage of clay content increase from top down in Mugogo watershed in terms of loam. , this increase was in associated with erosion , siltation as clay particles are quick transported by water erosion, this result was in line with (**Tabien *et al*, 2016**) illustrated that there was high correlation between slop and nutrient content where low land have high nutrient than upland due to erosion that transport soil nutrients on the hill side to lowland.

4.12. **Physical observation**

Mugogo watershed attach on 3 sectors (Busogo, Mukamira and Kintobo) that are located in 2 distric (Musanze and Nyabihu). Mugogo watershed is hilly and lowland terrain. Agriculture in mugogo watershed are dominated by Irish potatoes, maize, climbing beans and wheat and on hill side they are dominated by forest. In the farm of population also they are dominated with agroforestry tees species (Alnus accuminata, grevelia robista…). During rainy season lowland of mugogo has led to serious environmental degradation due to overexploitation of the soil and extensive erosion which results in soils being washed down the hillsides causing extensive sedimentation of the main rivers and water logging.

FIGURE 3: ***Water logging and siltation in Mugogo lowland***

To overcome these challenges facing Mugogo there was a project called RV3CBA project on Mugogo rehabilitation worked on contruction of waterway in mugogo lowland, plantation of agroforestry trees species, Radical and progressive terracies were made on the one part of Kintobo sector but still now there is the case of erosion, siltation.

Mugogo caves outlet

All Water in mugogo watershed travels in Kinoni River and drained in the outlet that called the caves. The water enters into the caves located in Mugogo lowland and enters in contact with the groundwater aquifer.

Figure3: S*how the structure of caves that drain water in mugogolowland*

The sediment from the hill side was deposit in the caves that also is the cause of waterlogging in the lowland. The farmers haven't capacity to recover the caves.

Chapter v: Conclusion and recommendation

5.1. Conclusion

Multistakeholders in agroforestry are one of the solutions for improving farmer's behavior where integrated different of Agroforestry practices are used in modern and tradition land use system**.**

The implementation of the plan aiming at reducing hazards in Mugogo lowland are required with different stakeholders participation and a strong institutional framework not only for the flood plain area but also for the entire watershed contributing to the Mugogo lowland area. To overcome many challenges facing mugogo watershed, agroforestry on the farms, on ditches, buffer zone on Kinoni River are the solution for soil structure improvement, increase of soil fertility, increase of agriculture production and environment conservation while improving living condition of local community and for state.

Government, local leaders, non government organization and private entities for better management of Mugogo watershed there is a need of intervention or participation for controlling water way by removing the sediment and on the caves for controlling water logging in the lowland of mugogo.

5.2 Recommendation

For proper management of Mugogo watershed government of Rwanda and different stakeholders must make attention on sustainability of implemented watershed management practices for achieving food security, environment protection.

- ✓ Improved cooking stove is one way for reducing deforestation and climate change mitigation, these practices must integrate in district performance contract and make sure that institutional like schools, prison, hotel and Restaurant use improved cooking stoves and other source of energy instead of using biomass energy.
- ✓ Government must protect Mugogo watershed by planting agroforestry trees on bench and progressive terraces , for all land fitted with terraces as sustainable solution of erosion control in Mugogo watershed.
- ✓ Trainings and extension on agroforestry techniques for environmental management.
- ✓ All activities done for managing Mugogo watershed must take into account local communities as main stakeholders in Mugogo watershed protection
- ✓ Agroforestry system must be increase in Mugogo watershed by planting different species fitted with agro-ecological zone especially *percia American* for solving issue of malnutrition and food security in this region
- ✓ Siltation and sedimentation enter in caves and block the water to enter underground, the proper solution of this issue was to make ditches in upland, waterway and different workers for removing sediment in the cavers.
- ✓ Rain water harvesting was at low rate in Mugogo watershed, Government must take responsibility for support poor family for getting rain water harvesting equipment and before giving construction permit of new building, people must have at least one tank.

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APPENDICES

QUESTIONNAIRE FOR PARTICIPANT

Participant n°

My name is **TUMUSENGE Eric**. I am an postgraduate student undertaking a master degree in college of Agriculture and veterinary medecine, **University of RWANDA**. As a requirement by the university, for the completion and award of my degree, I am conducting a study on "**Effect of multi-stakeholder in agroforestry practices to enhancing watershed management for sustainable farmer's livelihoods in highland of north-western of Rwanda***"*.

I am going to extensively explain about this research and invite you to voluntarily participate. I am going to give you time to decide on whether you will participate in the research. You are free to consult before making any decision.

Name of respondent:…….....

Telephone number:……**Date**:……

A: Demographic characteristic

SOCIO FACTORS

1. Sex
   - Male
   - Female

2. Age:
   - Below 20 yrs
   - 21 – 30 yrs
   - 31-40 yrs
   - 41-50yrs
   - 51 and above

3. Marital Status
   - Single
   - Married
   - Divorce

4. Educational Level.
   - No formal Education ☐
   - Informal Education ☐
   - Primary Education. ☐
   - Middle school Education ☐
   - Secondary school Education ☐
   - Tertiary Education ☐

SECTION C: GOVERNMENT INTERVERNTIONS

5. Does your culture forbid the cultivation of any plant/tree species or rearing any animal species?

   - Yes ☐
   - No ☐

If yes, specify…….....

6. What is the source of farming knowledge?
   - Inheritance ☐
   - Extension ☐
   - School ☐
   - Media ☐

Others, specify……

SECTION B: ECONOMIC FACTOR

7. Indicate Household Asset
   - Animals ☐
   - Land ☐

Others (specify)……

8. What is the value of total household assets?
   ……..

9. What is the size of your farm in hectares? ……

10. Do you own the land
    - yes ☐
    - No ☐

14. If yes, how did you own the land? A. Purchased ☐

B. Inherited

Others (specified)……

If no, what type of land tenure are you engaged in?

- Public land ☐
- Shared lease ☐
- Rented ☐

Others(specified)……

15. What type of livestock do you keep?…….

16. What is the number of animals kept? .....

17. How many years have you been farming? .....

SECTION C: GOVERNMENT AND INSTITUTIONAL INTERVERNTIONS

18. Are you a member of cooperative group?
- yes ☐
- No ☐

19. Do you receive any institutional support?
- yes ☐
- no ☐

If yes, specify institution(s) that provide(s) support?

- Ministry of Agriculture ☐
- Forestry Department ☐
- NGO (specify if NGO)……...

Others, specify…….

20. What type of support do you receive?

- Technical information supply ☐
- Inputs support ☐
- Technical training ☐
- Credit facilities ☐

Others (specify)……

22. Do you have access to extension service?
- Yes ☐
- No ☐

If yes, how often?

- Weekly ☐
- Fortnightly ☐
- Monthly ☐
- Quarterly ☐

Others, specify……..……

23. Do you have access to climate information?
- yes ☐
- No ☐

24. What is your source of climate information?

- Extension agent ☐
- Fellow farmers ☐
- Research institutionns ☐
- Media ☐

Others (specify)……..……

SECTION D: BIO-PHYSICAL FACTOR

24. What is the nature of farm land?

- Flat ☐
- Gentle slope ☐
- Steep slope ☐
- Undulating ☐

25. Do you own the land you cultivate on?
- Yes ☐
- No ☐

If yes, how did you own the land?
- Purchased ☐
- Inherited ☐

Others (specify)……..……

26. What is the source of farming water?

- Rainfall ☐
- Stream/river ☐
- Well ☐
- Dam ☐

Others (specify)……

SECTION E: STRENGTHS, WEAKNESSES, OPPORTUNITIES AND THREATS (SWOT).

27. What are the Strengths in the adoption of agroforestry technologies?

- Suitable soil, ☐
- Organizations‟ help ☐
- Geographic position ☐
- Availability of seedlings ☐
- Borehole ☐
- Family Labour ☐

Others (specify)……..……..

28. Do you have access to credit facilities? .....

29. What are the weaknesses in the adoption of agroforestry technologies?

- Lack of planting materials ☐
- Lack of man power ☐
- Water availability ☐
- Land tenure ☐
- Lack of knowledge/skill ☐
- Lack of technical assistance ☐
- Lack of capital ☐
- Pests and diseases ☐
- Initial costs of input ☐
- Limited land ☐

Others (specify)……

30. What are the opportunities in the adoption of agroforestry technologies?

- Presence of multipurpose tree ☐
- crop resilience during drought ☐
- Ease and speed of eliminating weeds ☐
- Serve as windbreak ☐

Others, specify…….……..……..

31. What are the threats in the adoption of agroforestry technologies?

- Illegal lumbering of tress ☐
- Prey attack on farm animals ☐
- Diseases outbreak ☐
- No land for permanent trees ☐

Others, specify…….……..……

32. What are the types of agroforestry technologies adopted?

i.Fodder banks
ii.Windbreaks
iii.Farm woodlots
iv.Improved fallows (taungya)
v.Boundary planting
vi. Trees on pasture
vii. Plantation/crop combinations
viii. home gardens
ix. Alley cropping
x. Orchards or tree gardens
xi. Shelterbelts
xii. Conservation hedges
xiii. Live fences

Others, specify…….

33. Which tree species do you plant under the agroforestry system? ……..

34. What is the reason for planting the species stated above? …….

Thanks for your participation!!!!!

Characterization of respondents based on Mugogo watershed position

Based on Mugogo lowland characterization, which is an agricultural area in Busogo sector of Musanze district, is downstream part of Kinoni river watershed stretching from Nyabihu district in its upstream. It is drained by Kinoni river and runoff from surrounding uplands which, over time deposited layers of sediments from upstream, triggering prolonged flooding. The survey has considered this delineation and 39.43% and 60.56% of respondents from Musanze and Nyabihu districts.

Table 4: Illustration of respondents based on Mugogo watershed delineation

District	Sector			Percentage
	BUSOGO	MUKAMIRA	KINTOBO	
Musanze	28	0	0	39.43
Nyabihu	0	25	18	60.56

Table. Spatial distribution Household at Mugogo watershed

SOIL TEXTURE TRIANGLE

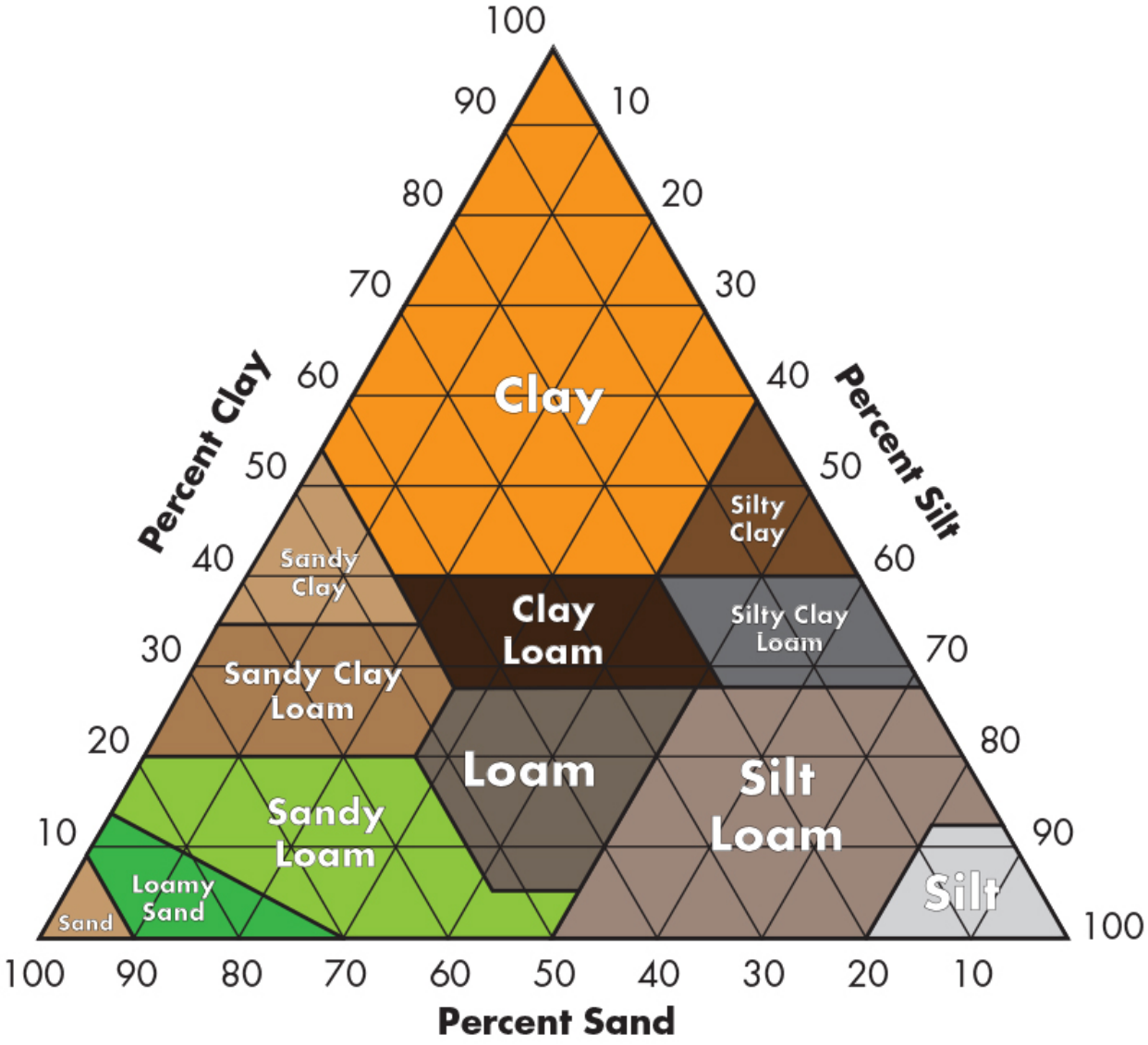

Figure4. ***Illustrating soil texture***