

ANALYSING EFFECTIVENESS OF MITIGATION MEASURES OF FLOODS: CASE STUDY AT DWANGWA RIVER IN NKHOTAKOTA DISTRICT

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19 JULY, 2021

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DECLARATION

I Ephrida Nthala declare that this research project represents my own work and that it has never been submitted to this institution or any other institution for any academic purpose. All sources of information have been appropriate acknowledge.

Signature:

Date: July 2021

DISSERTATION APPROVED BY:

SUPERVISOR: VINCENT KATONDA Signature: _____

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ABSTRACT

Floods are the most widespread and frequent natural hazard in the world. Since Malawi experience floods in some areas and there have been reports of how vulnerable people are mostly affected especially people living in coastal, lower shire, and lakeshore areas. Dwangwa River being a main river as it receives high flow of water from different rivers. This influences the area to be more vulnerable to flood hazards. It is impossible to end the flood risks, but it is possible to work towards reduction of their impacts and reduce the losses, which they commonly cause. In response to these flooding problems, mitigation actions are applied to reduce the flood impacts. The sustainable development benefits of mitigation measure vary over sectors include economic, environment and social. Generally, mitigation improves the productivity of resources use, whether it is water, or land, yield positive benefits. The study has focused on analyzing the effectiveness of mitigation measures in Dwangwa area. Finally, the study revealed that applied measures in the area were effective as it reduces the flood impacts and discovered from diminish of loss and damages and even the volume of water in the river compared with past years without application of measures. The findings are useful to other district in Malawi of similar issue of flood hazard since those mitigation measures are applied in most of the countries of the world.

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First, I thank God for His kindness and grace for taking me this far. I thank God for allowing me to take one-step at a time and enjoy every fruit of His goodness, for wisdom and strength to make difference.

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ACRONYMS/ABBREVIATIONS

CRED	Center for Research on Epidemiology of Disaster
DC	District Council
DRM	Disaster Risk Management
EC	European Commission
FEMA	Federal Emergency Agency
MET	Meteorological department
MDGs	Millennium Development Goals
NGOs	Non-Government Organizations
SDGs	Sustainable Development Goals
SPP	State of Planning Policy
VCP	Village Civil Protection Committee
T/A	Tradition Authority
WB	World Bank

1. GENERAL INTRODUCTION

1.1 Introduction

Flood is the most devastating disaster in the present world, which causes damage to environmental, social, and economical factors. The Center for Research on Epidemiology of Disaster (CRED) defines a flood as a significant rinse of water level in streams, lakes, reservoirs, or coastal regions. Malawi discovered as a disaster-prone country, affected by several natural and human-induced risk factors, including floods, droughts, stormy rains, strong winds, landslides, deforestation, and environmental degradation (Stepanyan, 2014). The intensity and frequency of flood disasters have been increasing, due to a range of changes in land use, which triggers the changes in the hydrological system. Higher population growth, deforestation, climate change, urbanization, and environmental degradation, and reduction of wetlands cause a decrease in accumulation of water in a basin and increase runoff (Balasubramanian, 2016). It is impossible to end the flood risk, but it is possible to work towards prevention or reduction of their impacts, which they commonly cause. In addition, the other causal factor of floods is the vulnerability of community or society as they settled in the flood-prone area for example settled near the river. Floods create impacts on the environment, community and even damages the economic level of a country. Dwangwa is one of the areas that experience floods, the recent year which experience floods are February 2020, which involves damage to personal properties, crops, buildings, and leaving people homeless and even making Dwangwa Bridge impassable reported by Stanley Nkhondoyachepa, Malawi New) Agency. Due to damages and losses caused by floods, mitigation measures are applied to deal with the impacts of floods.

Effective flood mitigation is generally a combination of structure and non-structure measures aimed at reducing flood damage at all levels of rural and urban with the involvement of the community inadequate to handling issues and as they witness the flood issues. In this research, the use of afforestation, dyke, tunnels, pipes, and building designs as the mitigation measure was analyzed for their effectiveness. Generally, people focus on response activities and

implementing the flood risk management measures without analyzing their effectiveness, for example, the failure of dyke in Nsanje in Tengani village due to the poor work of the engineer, which led to a waste of resources reported by times. MW. The dyke construction was financed by World Bank (WB) which spent over K290 million which is a huge loss. The plan of introducing mitigation need to have the consideration of environmental impacts assessment. Environmental impacts assessment is mainly used at the level of specific developments and projects such as dams, industrial plants, transport infrastructure, and farm enterprises (Antonio, 2009) Some mitigation measures result in a negative effect, which may result in to decrease in the development of a country especially in economic status as they lose money on the construction process. Besides the existence of a problem that may occur, dam, tunnels, and reservoir increasing flood drain capacity would also be effective in increasing irrigation capacity and irrigated area and supplementing the groundwater for people's domestic and production purposes(EMP, 2012).

1.2. PROBLEM STATEMENT

Floods are the most widespread and frequent natural hazard in the world. Since Malawi experience floods in some areas and there have been reports of how vulnerable people are mostly affected especially people living in coastal, lower shire, and lakeshore areas. Dwangwa people are more vulnerable to floods as they settled close to the lakeshore. The area experience flood in past years, the recent year was between 14 -17 February 2020 that lead to more destruction, where 511 households were affected with 713 members homeless and 50 hectares of land were damaged reported by George F. Zibophe the Desk officer of Disaster Risk Management (DRM) in Nkhotakota District Council (DC). In response to these flooding problems, mitigation actions are applied of which there is no record of their effectiveness as the area continues to face the same problems. Therefore, the study was conducted to meet the knowledge gap between the mitigation measures used and their effectiveness in the area.

1.3. RESEARCH QUESTION

The key question to be addressed in the research are;

1. What are the loss and damage caused by floods in the area?

2. What are the local mitigation measure of floods at Dwangwa?

3. How has the water flow changed following the application of the measure?

1.3.1. RESEARCH HYPOTHESES

1. The floods caused no loss and damage in the area.

2. No mitigation measure can be implemented to reduce flood impacts.

3. No change in water flow with the measure.

1.4. MAIN AND SPECIFIC OBJECTIVES

1.4.1. MAIN OBJECTIVES

To analyze the effectiveness of mitigation measures of floods in the Dwangwa area.

1.4.2. SPECIFIC OBJECTIVES

1. To evaluate the loss and damage caused by floods in the area.

2. To determine local mitigation measures in the area.

3. To determine effects of different mitigation measures on the River flow.

1.5. SIGNIFICANCE OF THE STUDY

Mitigation measures play a key role in Disaster Risk Management (DRM).In presence of correct understanding of the effectiveness of mitigation measures, which are present in the Dwangwa area, the suffering from impacts of floods will decrease and the farming system would be productive. The analysis of effective mitigation measures is useful in bringing information gap in addressing the significant measure to be used to deal with flood risk. This also provides the data to the experts in disaster management to improve the measures action with the understanding of problems faced during the usage of action and revise the measure.

It is also important as the study will provide information to the government which helps form the disaster risk management plan and policy.

Moreover, the study will contribute the data on Millennium Development Goals (MDGs 111) to increase approaches on Agriculture and Food Security, and Transport infrastructure. Also, contribute ideas on Sustainable Development Goals (SDGs) especially in goal number 9, which involves Industries, Innovation, and Infrastructure.

2.0. LITERATURE REVIEW

2.1. FLOODS

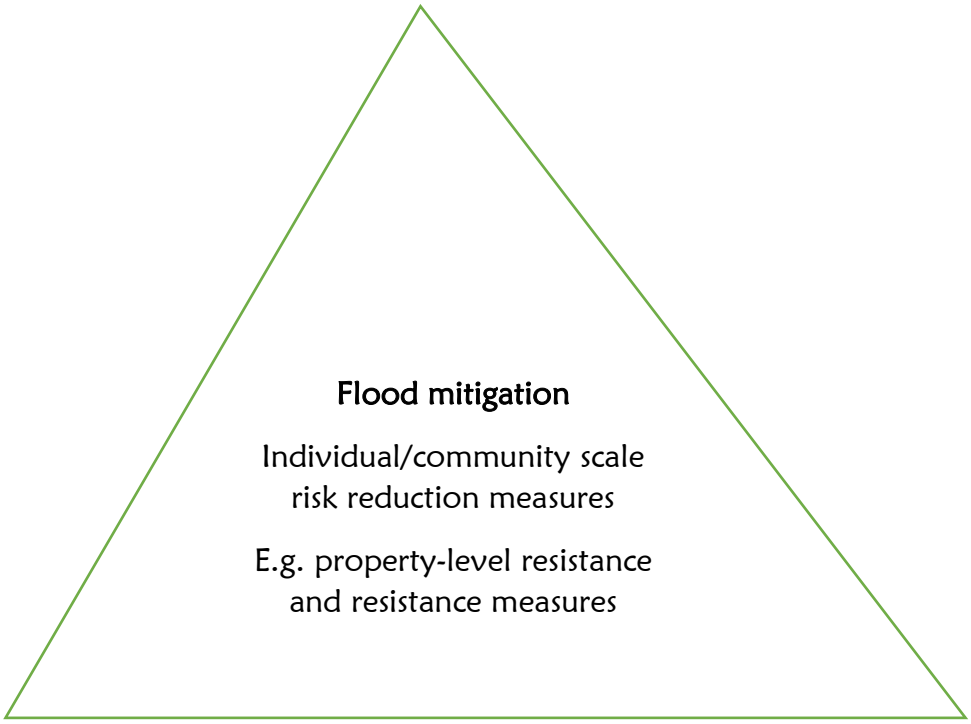
A flood is a natural hazard that is defined as the overflow of a large amount of water beyond its normal limits, especially over what is normally dry land(Samuels, 2013). There are many types of floods. To mention a few, coastal flooding which often occurs in coastal areas which bear brunt of severe storms, river flooding which is one of the most common types of inland flooding occurring when a water body exceeds its capacity, and flash flooding. Malawi suffers from two different types of floods. On the one hand, it experiences flash floods that arise due to excessive rainfall in a short period. Flash floods can be defined from various aspects as hydro meteorological phenomena, natural hazards or geomorphic agents. From a hydro meteorological aspect, flash floods are best described as events involving "too much water in too little time" This means that exceptionally high amounts of rainfall, combined with very efficient and rapid runoff on relatively small catchments, are typical of flash floods. As geomorphological phenomena flash floods are short-duration events caused by an abrupt rise in the discharge of a river or stream, which may have remarkable geomorphic impacts through erosion and sedimentation(Lóczy et al., 2012)

On the other hand, Malawi suffers from riverine floods which happen when the river exceeds its capacity due to heavy rainfall over an extended period (I.Management). Flooding results in loss of life, population displacement, damage to properties, and disruption of economic activities. Flooding is of particular concern here in Malawi and for many developing countries

vulnerable to high levels of rainfall. Intense precipitation over a short duration or by normal rain over a longer period is commonly triggered by floods. Flood management is one of the most important activities in water resources planning for minimizing the potential damages and supporting the sustainable development of communities(Yazdi & Neyshabouri, 2012). For example, the European Commission Floods Directive 2007/60 /EC asked member states to draw up a map, plans for flood management, and create measures for protection, prevention, and preparedness. Therefore, the most appropriate and effective mitigation interventions must be identified and prioritized. Then, the benefits of these measures over the long term must be assessed to choosing the most effective strategies to manage the flood risk.

2.2. MITIGATION MEASURES

Federal Emergency Agency (FEMA) defines mitigations as structure and non-structure actions that are applied with aim of reducing or eliminate long-term risk to hazard. Structural and non-structural measures have been implemented to cope with the resultant flood damages. Structural measures are strategies to control floods using a variety of structures, such as seawalls, dams, levees, and channels. Non-structural measures, as their name suggests, are not built, and they include directing land use away from hazardous areas, flood risk mapping, educating citizens by disseminating information on floods and flood-risk areas and protecting sensitive areas using early warning systems. Structural measures to prevent flood damage are based on estimations of predicted damages, and their effectiveness can be quantitatively determined.



Large-scale flood defense and mitigation measures: Large-scale project designed to minimize the likelihood/magnitude of risk through resisting or accommodating water e.g. flood dykes, dams, and flood retention basins

Figure 1 : **showing flood risk management in mitigation** (Suykens et al., 2016)

Dyke construction

Dyke construction play role in the reduction of flood risk. Here in Malawi, many districts have been developing the dyke construction to reduce flood risk for example in Nsanje. Illovo Company and population of Dwangwa area protected by the dyke. Illovo has been able to

flourish economically and is one the best company that increases the development in Malawi. The company takes the advantage of Dwangwa River for irrigation and the agriculture system in Dwangwa has been profitable for example the sugarcane farming and even rice cropping. Although the river is helpful to their farming, as the Dwangwa river is a tributary of Lake Nyasa the water enters with high pressure leading to floods, which cause floods. Due to flood effects in 2020, they decided to construct dyke to protect and reduce the flood impact. The dyke height design was constructed linked with water level and the flows. The design height of a dyke is the water level whose chance of occurrence is linked to the level of protection that has been chosen to protect the regions(Dijkman & Loucks, 2004)

Dams and reservoirs

Dams and reservoirs play important role in flood mitigation and are the most important structure measure. In the field of Integrated Flood Management, dam and reservoir are considered as a viable and effective alternative, especially when there is an extensive settlement on the floodplain, which make it impossible to restrict land uses or implement other non-structure. Dams and reservoirs are effective structure measure since they can store the large flow volume and significantly reduce peak flows(Group, 2010)

Levees and floodwalls

These are structures constructed by engineers out of organic materials such as stones in the flood plain and parallel to the river or along coastal beaches to prevent the flood from extending farther in a landward direction(S, Changnon, W.Ackerman, G.white, et al. 1998)

Open water channel flow

Open water channel flow is a flow of liquid (water) in a conduit with a free surface. That is a surface on which pressure is equal to local atmospheric pressure(J. Southard, 2009). These are not entirely included within rigid boundaries; a part of the flow is in contract with nothing at all, just space. The surface of the flow thus formed is called a free surface, because that flow boundary is freely deformable, in contrast to the solid boundaries (Southard, 2006). The

boundary conditions at the free surface of an open-channel flow are always that both the pressure and the shear stress are zero everywhere. However, a flow can have a free surface but not be an open-channel flow. Closed-conduit flows that consist of two immiscible fluid phases of differing density in contact with each other along some bounding surface is not open-channel flows, because they are nowhere in contact with open space, but they do have a freely deformable boundary within them (Southard, 2006). Such flows are free-surface flows but not open-channel flows, although they are usually called stratified flows because the density difference between the two fluids gives rise to gravitational effects in the flow. On the other hand, open-channel flows are by their definition also free surface flows (Southard, 2006).

Construction techniques

One major approach for mitigating flood damage requires construction techniques that can resist the ravages of flooding waters. Construction techniques are often specified in building codes. These codes can have provisions that apply to construction in flood-prone lands. The general safety of buildings is covered in construction codes and structural systems. In the United States, residential codes have been used for over one hundred years and the first model used was in 1905 published by the National Board of Pine Underwriters(Compendium, 2009). Poorly constructed buildings are unavoidably destroyed by floods, with great costs in property and sometimes lives. It is widely recognized that it is cheaper in the long run (in the economic, social, and political senses of the world) to prevent or mitigate disasters than to fund recovery.

Land use planning

Land use planning is an effective method to reduce the impact of flood hazard. Land use planning is a tool that can be used to permeate both structural and non-structural methods of reducing flood risks. Land use planning has the potential to reduce people's exposure to hazardous environments by allocating specific spaces for specific uses. Relocation is taken as the best option of reducing vulnerability to risk of floods. Development and implementation

of flood risk reduction plan is also taken as way in land use planning. This involves of hazard map which are used for the spatial planning of flood risks (Gondwe et al., 2017)

The State Planning Policy (SPP) is the key component of Queensland's planning system. The SPP express the interest in land use planning and development, including avoidance or mitigation of the risk. Promoting this avoidance or mitigation through plan making and developing decision of state and local government can significantly reduce the likelihood and severity of impact of floods.

Watershed management

Watershed management includes methods to create, enhance and maintain vegetation (Green Infrastructure) to reduce runoff and provides flood control in the watershed. This enhances the infiltration, which reduces the runoff. With less water flowing into the river and sewer system, flood risk could naturally reduce. These measures change the land uses and affect the flood characteristics(Yazdi & Neyshabouri, 2012). This also demonstrates a significant reduction in discharge and an increase in evapotranspiration(Submitted & Fulfillment, 2011).The Green Infrastructure solution provide a complementary approach that reduce the flow of storm water by connecting it to adjacent natural storage and overflow system. This cannot only help reduce flood impacts but also produce environmental and health benefits. In addition, they provide source of supplementary income that facilitates agriculture and provide direct economic benefits. The Green Infrastructure solution involves bios wales, green roofs, rain gardens, rainwater harvesting, mangroves and wetlands(UFCOP,2016).

Flood forecasting

Through the application of meteorological and hydrological data in models, it is possible to predict some stream flows and coastal storm surges. when linked to an effective communication and response system, advanced actions can be taken to reduce loss of life and property damage(Changnon et al., 1983). This helpful as the community and country are aware of upcoming events enhance well preparations. Therefore the responsible authorities

Meteorological department of Malawi (MET) should provide timely and reliable flood warnings, flood forecasting, and information(EC. Europa, 2003).

Isolation of people leaving in flood-prone areas

Moving a flood-prone building to higher ground is the surest and safest way to reduce its risk from flooding(Dijkman & Loucks, 2004). The government mostly does this; they replace the community with a better place. Individually can also be done without relying on government action, where one can decide for his/her life, property safety. Resettlement of the people works better with effective planning as people are provided with land and support by the government or NGOs. However, here in Malawi, the government fails to isolate the community to non-prone areas because the people believe with thoughts of losing their land.

Mitigation in Malawi: Dwangwa area

Mitigation is also defined by Lindell and Prater as pre impact action that protects passively against casualties and damage at the time of hazard impact and includes community protection works, land-use practices, and building construction practices(Genovese & Thaler, 2020). Experts of meteorology, hydrology, geomorphology and engineering mostly carry out flood management and protection(Balasubramanian, 2016). Mitigations, which are applied in Dwangwa mostly, involved the Illovo Company whose provide more measure to protect their farm, which is also helpful in form of irrigation, as well the community benefits from the measures that are carried out. The Dwangwa community also uses it is own mitigation measure in response to flood effects and to reduce the flood risk. Currently Dwangwa area uses dyke, tunnels, building code, vetiver and green dyke bearing as mitigation measure to reduce the floods impacts.

3.0. MATERIALS AND METHODOLOGY

3.1. AREA OF STUDY

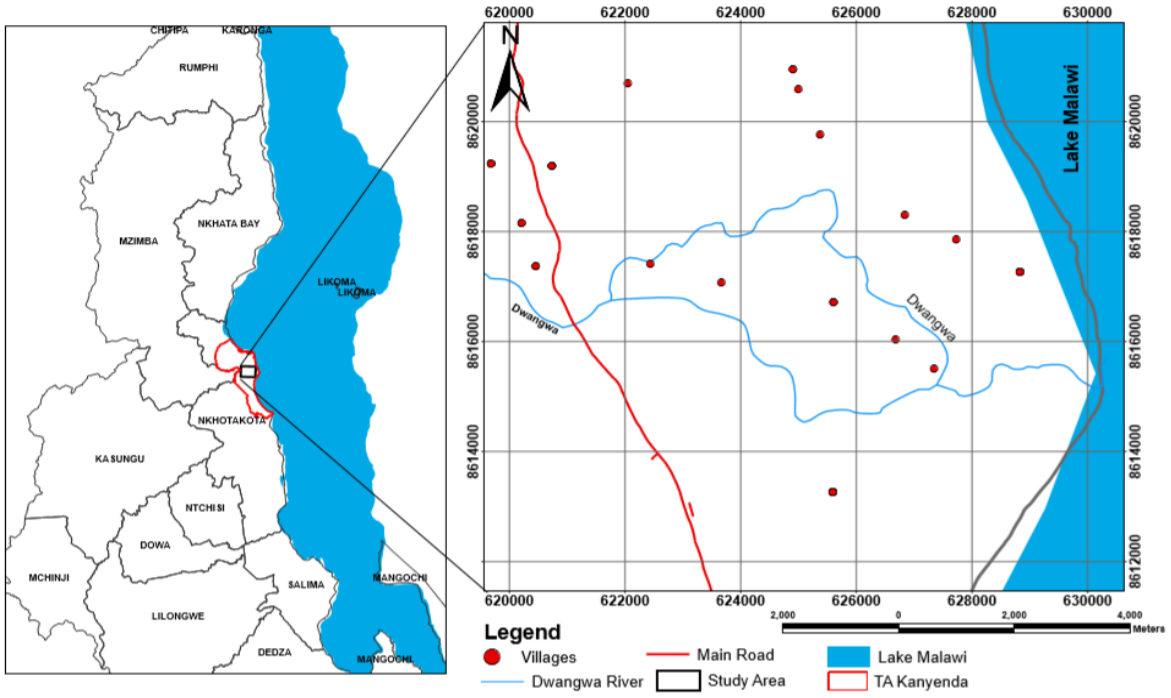


Figure 2 ***Map showing Dwangwa River***

The study was conducted in Group village headman Nyanje, Tradition Authority (TA) Kanyenda in the central region of Malawi in the Nkhotakota district. This area is allocated along the Dwangwa River and gets flooded due to several tributaries that carry water into the Dwangwa main River. Its source is in the Kasungu National park.

3.2. RESEARCH DESIGN

In this study, data was collected using direct observation, whereby the local mitigation measures in the area were observed as well as loss and damage incurred due to the floods. In addition person interview where by a questionnaire was used to hear villagers view. A questionnaire was done in village headman Nyanje. Ninety-six adults mostly those who were a victim for flood damage whose age was ranged between 20 to 80 answered it. Illove worker, the Desk Officer of Disaster risk Management in Nkhotakota George F. Zibophe, and the Village Civil Protection Committee (VCP), interviewed the center information. To ensure the reliability of collected data. This study uses both qualitative and quantitative methods. A qualitative method was used to find out different opinions and their understanding of the

effectiveness of their mitigation measure compared with the loss and damage they experience during floods. Quantitative using secondary data where the rainfall data and water flows were collected from Illovo station with a purpose of comparing the years of introduction of measures with the changes of water flows, where fasten of water flow with short time may result to floods.

3.3. DATA COLLECTION

The study involves the use of both primary and secondary data. In which primary data was collected using informant interviews and personal observation.

Secondary data

Secondary data which was used involves water flow and loss and damage to compare with mitigation measure used in the area.

Primary data

Direct observation and interviews were used.

3.4. SAMPLE SIZE AND SAMPLING TECHNIQUE

The sample size was picked using a random systematic sample using the formula of

$$\text{Sample size} = \frac{\frac{z^2 \times p(1-p)}{e^2}}{1 + \left(\frac{z^2 \times p(1-p)}{e^2 N}\right)}$$

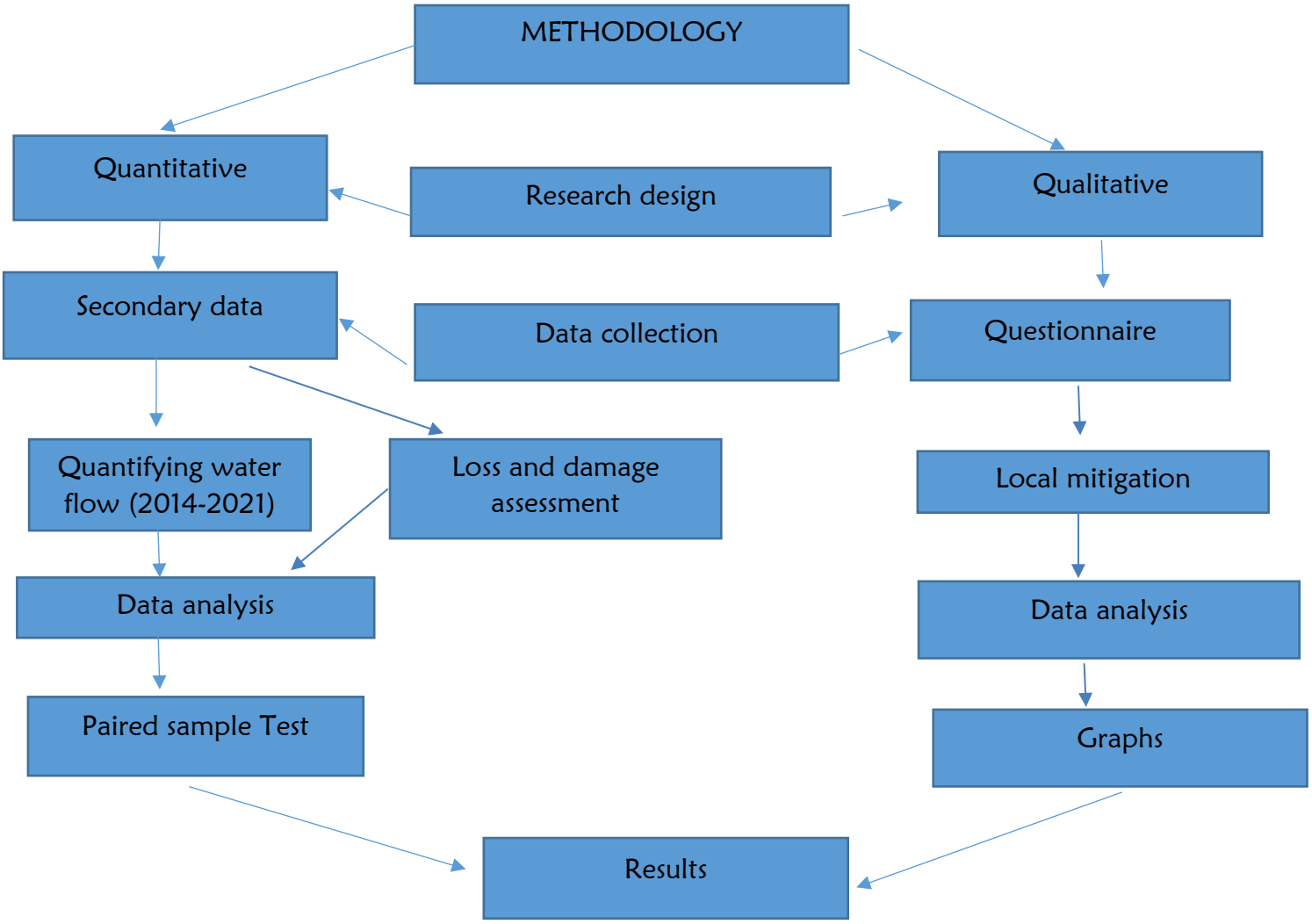
Where N= population size (in this study this will represent a total number of households), n= sample size, and e= marginal error or acceptable sampling error and z=z-score.

The sample size of the study will be calculated based on the total number of households in the study area. For this study, considering the population size and available resources, the calculation of sample size will be adopted with a 90% confidence interval. This means the allowable precision level is 10%, which in this case represents a marginal error of 0.1. Given

a population of 116,546 of people in Kanyenda, the sample size that has been calculated is 96.

3.5. DATA ANALYSIS

The water flows and loss and damage were analyzed using Excel 2016 and SPSS statistical data interpretation software. Graphs will be plotted to show the results.



3.6. Limitations

- Unavailability of data
- Limited finance.
- Unable to cover the planned sample due to covid problem.

4.0. RESULTS AND DISCUSSIONS

4.1. EVALUATION OF LOSS AND DAMAGES

4.2. RESULTS

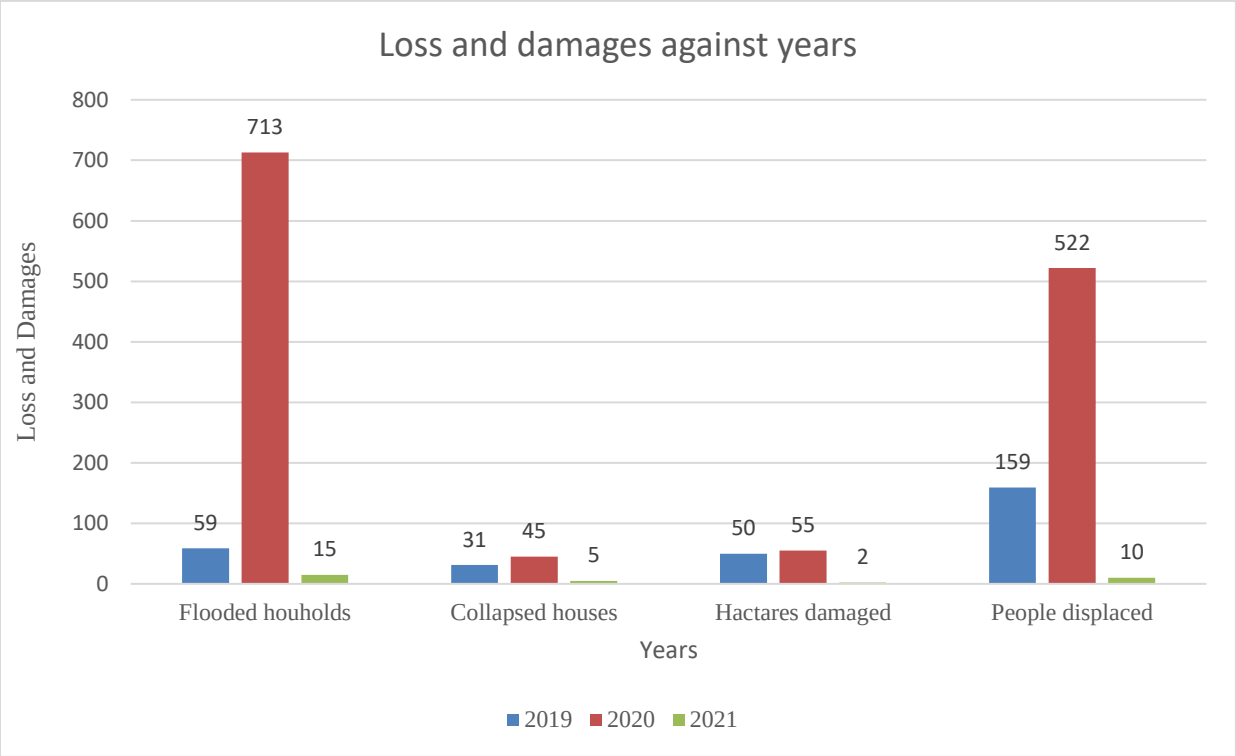


Figure 3: Evaluation of loss and damage

The results as presented in figure 3 indicates that the number of flooded households, collapsed houses, people displaced and hectares damaged were increased in 2020 compared with the year of 2019 and 2021 this occurred since they experienced more rainfall of 478mm (max) with 1163.01m^3/s (max) of water flow in 2020 as shown in appendix. The researcher discovered that because of much rainfall in 2020 and much damages, people were enforced to maintain the constructed dyke, their houses and relocate to safe places that resulted to

least loss and damages in 2021. In addition, in 2019 the loss and damages were not much because they experienced less rainfall.

4.3. TYPE OF BULDING MATERIALS

4.4. RESULTS

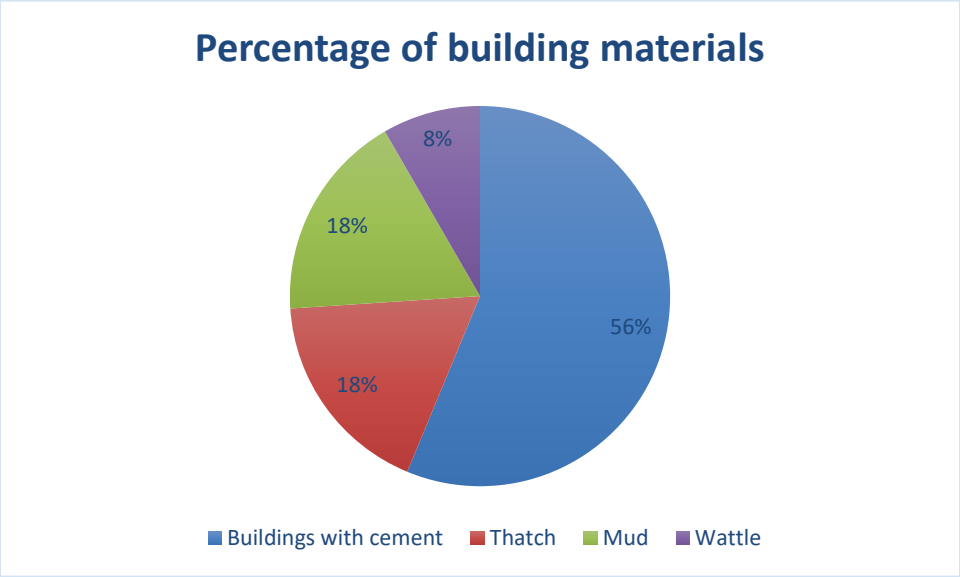


Figure 4: **Percentage of building materials**

The type of building material is the determinant of what kind of loss and damage can happen. Poorly constructed buildings are unavoidably destroyed by floods. This may result to great costs in property and sometimes lives. The findings as illustrated in figure 6 revealed that 56% of people built their houses with cement that play significance role on reducing the loss and damages as it increase the resilience of people during and after the floods. This represents that a greater number of people that used cement as a building material. The researcher also discovered that use of thatch, mud, wattle increases the loss, and damages as their buildings were unable to withstand the impacts of the floods.

4.5. LOCAL MITIGATION MEASURE OF FLOODS

4.6. RESULTS

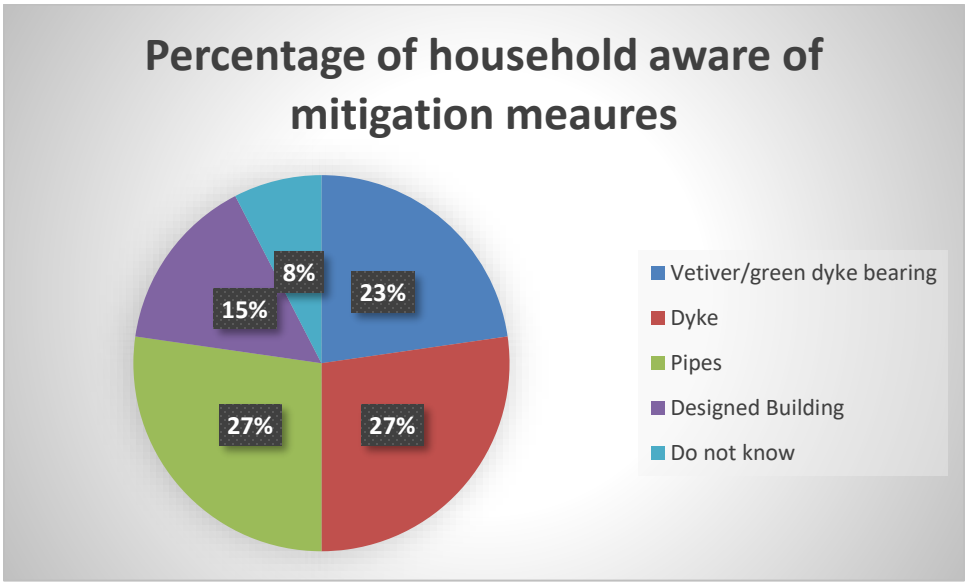


Figure 5shows percentages of local mitigation measures

The researcher discovered that the mitigations applied in Dwangwa mostly, involved the Illovo Company who provided more measures to protect their farm, which was also helpful in form of irrigation, as well as the community benefitted from the measures that were applied. The Dwangwa community also used their own mitigation measure in response to flood effects and to reduce the flood risk.

The findings as illustrated in figure 6 reveal that Dwangwa area uses dyke, pipes, building code, vetiver and green dyke bearing as mitigation measures to reduce the floods impacts. The highest percentage (27%) of people were aware of using dyke and tunnels as mitigation measures hence they controlled water from damaging their farms and collected the water for irrigation. Lower number of people used the building codes and vetiver and green dyke bearing. The researcher discovered that the least number of people were not aware of using the mitigation measure as they lacked knowledge because they did not participate in community based disaster risk management.



Figure 6: showing the dyke



Figure 7: showing nature based solution (vetiver).



Figure 8: showing green dyke bearing fruits (bananas)

4.7. SIGNIFICANCE AND PROBLEMS OF THE MEASURE TAKEN

The mitigation measure sustainable development over sectors include economic, environment and social. On economic part, include the growth and distribution of income, employment and availability of jobs and competitiveness of the economy within globalizing markets. From the results, the use of dyke, and pipes, Illovo has been able to flourish economically and this increases the development in Malawi. The company takes the advantage of Dwangwa river for irrigation using tunnels, pipes that harvest water from the river and the agriculture system in Dwangwa has been profitable for example the sugarcane farming and even rice cropping.

Although the measure is taken plays a good work, few numbers of households whose settled away from dyke Illovo constructed they experience more effects of floods. The water flows to their area with more pressure this is mostly done as the dyke covers only Illovo farm leaving their part of the area where they insist from government for provision dyke to their area.

The use of vetiver grass has been regarded as a low-cost technology for soil and water conservation according to the Village Civil Protection Committee (VCP) of Nyanje area. Some of the respondents said that the vetiver plays the role of feeds for their animal.

Vetiver also enhance the water quality for irrigation purposes when compared with other soil conservation technologies and could be a dynamic tool for mitigating the environment (Oshunsanya & Aliku, 2017).

4.8. DETERMINE EFFECTS OF MITIGATION MEASURE ON THE RIVER FLOW

Paired T-test output at a confidence interval of 95%.

	Year	Mean difference	Std. deviation	t	Sig. (2-tailed)
Pair 1	2014 - 2021	-3405024.00	6988105.67	-.975	.402
Pair 2	2015 - 2021	-8525304.00	4929660.93	-3.459	.041
Pair 3	2016 - 2021	-5953608.00	6096271.16	-1.953	.146
Pair 4	2017 - 2021	729648.00	2082695.91	.701	.534
Pair 5	2018 - 2021	-2106432.00	4320678.88	-.975	.401
Pair 6	2019 - 2021	-3783024.00	4596998.94	-1.646	.198
Pair 7	2020 - 2021	8000208.00	16259289.23	.984	.398

Table 1: shows paired T-test output at a confidence interval of 95%.

As indicated in Table 1 above, since the implementation of different measures in 2021, there is a statistical significance in mean differences between 2015 and 2021 in river discharges. So

the mitigation measures were effective in reducing river discharge from the comparison of the mean differences of 2015 and 2021 with a p value equal to 0.041 which is less than 0.05 at 95% confidence interval. However, there was no statistical significance in mean differences of river discharge from the years 2014, 2016, 2017, 2018, 2019 and 2020 with 2021. This explains the fact that the mitigation measures over the mentioned years did not significantly affect the river discharge. Therefore, suffice to say, the implementation of the mitigation measures did not affect the river discharge. The extent of flooding potential was reduced through some flood mitigation measure, while other measure increases the potential flood threat. The ability to reduce the flood peaks depends on the capacity and operation of mitigation measure. The operation of mitigation measure need to balance. From the results, the researcher discovered that the mitigation measure applied in the area was not balanced. The measures require adequate maintainance to turn the effectiveness.

5.0. CONCLUSION AND RECOMMENDATIONS

The study was designed to analyse the effectiveness of mitigation measures of floods in Dwangwa River in Nkhotakota T /A kanyenda. The study was done with available data obtained from Dwangwa Illovo meteorological station and questionnaire from people of Kanyenda. The data used in the study include loss and damages from 2019 to 2021, local mitigation measures applied in the area and the water flow 2014 to 2021. The much loss and damages occurred in 2020 evidenced of high mean volume of water in the river. The least loss and damage was in 2021 since the occurance of floods was not much. This results from loss and damage indicate that dyke, designed building, harvesting water using pipes and vetiver indeed able to reduce flood extent.

The mean volume for each year from 2014 was compared with 2021 mean, which is the year after the implementation the maintained flood mitigation measures in 2020 to determine the significance of the mean differences. The significance was determined by checking the corresponding p-value presented. The significance shows that the mitigation measures over the mentioned years did not significantly affect the river discharge. Therefore, the results revealed that the implementation of the mitigation measures did not affect the river discharge. This is to say, other mitigation applied did not reduce the water flow and the volume, for

instance the vetiver application might not reach the level of affecting the river discharge. However, harvesting of water using pipes play much role to reduce water flow though other mitigation measure did not, this reveals that the mitigation measure were not effective. In addition, the researcher discovered that due to usage of same station on collecting data of water flow lead to wrong results as some measure were applied far from station.

These findings will help in disaster management to improve the measures action with the understanding of problems faced during the usage of action and revise the measure. It is also important, as the study will provide information in improving the disaster risk management plan and policy.

5.1. RECOMMENDATIONS

Future studies on analyzing the effectiveness of mitigation measures of floods should consider the measurement of water level. This will enable the determination of the water level thresholds, which triggers to floods impact. In order to achieve the significance of applied mitigation measures, there are ways to be done to improve the results. These include improved housing construction by implementing house construction guidelines, improving land use planning and updating the building codes used in construction. Introducing and constructing the open water surface channels or pipes that empty water from the river hence reducing the amount of runoff. Encourage government and Non-Governmental Organizations (NGOs) to improve the comprehensive DRM awareness. Additionally, avoiding deforestation practice by reinforcing policies that protect the environment. Lastly improving and strengthening the Government and institution arrangement in DRM on provision of finances on construction of structural measures like dyke in reduction of floods impacts.

6.0. REFERENCES

Antonio, E. (2009). Profiles of tools and tactics for environmental mainstreaming: Environment Impact Assessment (EIA). A Product of the Environmental Mainstreaming Initiative, 1. http://www.sciencedirect.com/science/article/pii/0921344995000658%5Cnhttp://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Profiles+of+Tools+and+Tactics+for+Environmental+Mainstreaming#0

Balasubramanian, A. (2016). Floods as Natural Hazards. August 2005. https://doi.org/10.13140/RG.2.2.18898.96962

Changnon, S. A., Ackerman, W. C., White, G. F., & Ivens, J. L. (1983). A Plan for Research on Floods and Their Mitigation in the United States: Final Report to the National Science Foundation.

Classification of Open-Channel Flows. (n.d.).

Compendium, A. (2009). Literature Reviews on Mitigating Flood Disasters in the Belize River Valley.

Dijkman, J., & Loucks, P. (2004). Flood management options for The Netherlands Flood management options for The Netherlands. June 2014. https://doi.org/10.1080/15715124.2004.9635225

EMP, (2012) Environment Management for subproject "upgrading the dyke".

Genovese, E., & Thaler, T. (2020). The benefits of flood mitigation strategies: effectiveness of integrated protection measures. AIMS Geosciences, 6(4), 459–472. https://doi.org/10.3934/geosci.2020025

Gondwe, J., Manda, M. A. Z., & Kamlomo, D. M. (2017). Discriminatory land use planning and flood risk management in Karonga Town , Malawi. April 2018. https://doi.org/10.14687/jhs.v14i4.4706

Group, E. W. (2010). " Dams and Flood in Europe . Role of Dams in flood mitigation ."

Lóczy, D., Czigány, S., & Pirkhoffer, E. (2012). Flash Flood Hazards. January. https://doi.org/10.5772/28775

Management, I. (n.d.). Exploring vulnerability and impact of floods in Malawi A first step towards impact-based forecasting Maud Broeken Dissertation presented as partial requirement for obtaining the Master ' s degree in Statistics and Information Management.

Oshunsanya, S., & Aliku, O. (2017). Vetiver Grass : A Tool for Sustainable Agriculture World ' s largest Science , Technology & Medicine Open Access book publisher. September. https://doi.org/10.5772/intechopen.69303

Samuels, A. (2013). Flooding. Journal of Planning and Environment Law, 7, 808–809. https://doi.org/10.5040/9781501397585.0009

Southard, J. (2006). Chapter 5 Open-Channel Flow. Special Topics: An Introduction to Fluid Motions, Sediment Transport, and Current-Generated Sedimentary Structures, 157–183.

Submitted, D., & Fulfillment, P. (2011). Land use/Land cover Change and its Impact on Flood Occurrence: A Case Study of Upper Jhelum Floodplain.

Suykens, C., Priest, S. J., Doorn-hoekveld, W. J. Van, & Rijswick, M. Van. (2016). Dealing with flood damages : will prevention , mitigation , and ex post compensation provide for a resilient triangle ? 21(4).

UFCOP,(2016) The role of Green Infrastructure Solutions in Urban Flood Risk Management.

Water Directors. (2003). Best Practices on Flood Prevention , Protection. Ec.Europa.Eu, 1–29. http://ec.europa.eu/environment/water/flood_risk/pdf/flooding_bestpractice.pdf

Yazdi, J., & Neyshabouri, S. A. A. S. (2012). A Simulation-Based Optimization Model for Flood Management on a Watershed Scale. https://doi.org/10.1007/s11269-012-0167-1

7.0. APPENCICES

Appendix A. Loss and damages experienced in T/A Kanyenda

2019	Loss and damages
	59 Flooded households
	31 Collapsed houses
	159 People displaced
	50 Hectares damaged
2020	
	713 Flooded households
	45 Collapsed houses
	522 people displaced
	55 Hectares damaged
2021	
	15 Flooded households
	5 Collapsed houses
	10 People displaced
	2 Hectares damaged

Appendix B. Data of monthly water flow in Dwangwa River

2014	Min (m^3/s)	Mean (m^3/s)	Max (m^3/s)
January	13.19	44.58	133.57
February	0.00	163.66	767.68
March	19.62	66.62	424.35
April	8.00	16.40	38.25
2015			

Jan	0.00	0	0.00
Feb	0.00	0	0.00
Mar	11.06	41.60	232.91
Apr	4.66	12.61	32.21
2016			
Jan	0.90	34.81	320.52
Feb	12.11	71.86	224.15
Mar	11.06	33.64	109.15
Apr	8.10	32.96	559.52
2017			
Jan	0.17	130.96	604.25
Feb	32.21	141.61	462.68
Mar	32.21	172.55	424.35
Apr	13.19	37.56	146.84
2018			
Jan	14.31	63.20	299.67
Feb	11.06	88.20	260.36
Mar	14.31	126.52	489.28
Apr	12.11	73.46	914.66
2019			
Jan	8.10	84.46	644.89
Feb	26.75	92.68	153.74
Mar	24.23	72.01	545.04
Apr	10.04	24.01	52.14
2020			
Jan	0.00	309.25	803.06
Feb	64.19	409.46	1163.01
Mar	26.75	86.78	260.36

Apr	0.00	13.79	38.25
2021			
Jan	35.14	122.07	342.17
Feb	35.16	102.94	207.20
Mar	115.00	192.84	387.90
Apr	0.00	31.05	97.99

Appendix C: Paired T-test output at a confidence interval of 95%

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
					95u% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	2014 - 2021	-3405024.000	6988105.673	3494052.837	-14524659.540	7714611.540	-.975	3	.402
Pair 2	2015 - 2021	-8525304.000	4929660.929	2464830.465	-16369494.606	-681113.394	-3.459	3	.041
Pair 3	2016-2021	-5953608.000	6096271.157	3048135.579	-15654135.810	3746919.810	-1.953	3	.146
Pair 4	2017-2021	729648.000	2082695.910	1041347.955	-2584385.952	4043681.952	.701	3	.534

Pair 5	2018 - 2021	-2106432.000	4320678.878	2160339.439	-8981596.266	4768732.266	-.975	3	.401
Pair 6	2019 - 2021	-3783024.000	4596998.939	2298499.470	-11097875.145	3531827.145	-1.646	3	.198
Pair 7	2020-2021	8000208.000	1625928 9.232	8129644.616	-17871949.472	3387236 5.472	.984	3	.398

Appendix D. Data of monthly rainfall

Years	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sept	Oct	Nov	Dec	Avg
2014	148.2	348.8	286.9	174.4	6.4	56.9	1.2	0.0	0.0	6.1	2.5	171.0	1,202.4
2015	398.4	173.6	100.3	116.5	49.4	0.0	0.0	0.0	0.5	7.0	0.0	114.0	959.7
2016	325.7	156.0	335.7	100.3	32.2	0.0	2.4	0.0	0.0	0.0	26.5	198.4	1,177.2
2017	170.0	273.7	227.2	222.0	5.4	5.5	0.0	3.0	0.0	0.0	103.0	285.6	1,295.4
2018	247.6	175.9	234.9	321.3	34.2	0.9	4.2	0.0	0.0	1.5	31.4	303.0	1,354.9
2019	213.9	290.4	102.0	163.7	21.6	0.0	0.5	0.0	0.0	10.7	114.3	420.7	1,337.8
2020	359.9	478.1	238.8	28.2	19.0	3.5	0.7	6.5	0.0	54.5	17.8	159.1	1,366.1
2021	263.5	260.5	415.0	83.9	21.6								

Appendix E. Questionnaire

1. What are the loss and damage caused by the floods?

2. What are locally mitigation measure they use in the area?

3. What type of infrastructures are always damaged/ affected by floods

4. Does modern materials or local material build your House?

5. What problems do they experience with the measures taken?

6. In your everyday life, what is the importance of the measure?

To Illovo

1. What measures do you use to protect your farm from floods……
   ……
   ……
   ……
   ……
   ……
2. What problems do they experience with the measures taken? In terms of expenditures and to the environment……
   ……
   ……
   ……
   ……
   ……
   ……
3. what are the importance of the measure taken ?.....
   .....
   .....
   .....