

DEVELOPMENT OF WEB-BASED LOWER SHIRE ANNUAL FLOOD DISASTER RISKY AREA GEOPORTAL SYSTEM

MATIAS PISEN GIS-023-20

Dissertation Submitted in Partial Fulfillment of the Requirements

for the Award of the Bachelor of Science Degree in
Information and Earth Observation Science

MALAWI UNIVERSITY OF SCIENCE AND TECHNOLOGY

NDATA SCHOOL OF CLIMATE AND EARTH SCIENCES

EARTH SCIENCES DEPARTMENT

Date: 29 April 2025

DECLARATION

I, Matias Pisen, confirm that the research project titled "DEVELOPMENT OF WEB-BASED LOWER SHIRE ANNUAL FLOOD DISASTER RISKY AREA GEOPORTAL SYSTEM

" is my work. I have never submitted it to any other institution for academic purposes. Any information I have used or mentioned from other sources has been properly credited with complete references.

Signature: 

DISSERTATION APPROVED BY:

SUPERVISOR:

Dr. Jabulani Nyengere Signature: 

ASSESSOR Signature: _____

DISCLAIMER

This document describes work undertaken as part of a program of study at the Ndata School of Climate and Earth Science of the Malawi University of Science and Technology. All views and opinions expressed therein remain the sole responsibility of the author and do not necessarily represent those of the school.

COPYRIGHT STATEMENT

This copy of the dissertation has been supplied on condition that anyone who consults it is understood to recognize that its copyright rests with its author and that no Quotation from the dissertation and no information derived from it may be published without acknowledgement.

ACRONYMS AND ABBREVIATIONS USED

LSAFDRAGS: Lower Shire Annual Flood Disaster Risky Area Geo-Portal System

GIS: Geographic Information Systems

HTTP: Hyper Text Transfer Protocol

TA: Traditional Authority

DEM: Digital Elevation Model

TRI: Topographic Roughness Index

SPI: Stream Power Index

LULC: Land Use Land Cover

OSRM: Open Street Routing Machine

DBMS: Database Management System

SDSS: Spatial Decision Support System

SDS: Spatial Decision Support

ABSTRACT

GIS-based information is increasingly vital for the dissemination of flood information, aiding in early warning to flood-prone communities and informing the general public about the current flood conditions for responses. This study aims to develop a web-based system that visualizes and gives locations of flooded villages and essential structures such as hospitals, shelters, schools, markets, and safe routes. Apart from that, it also supports the spatial decision by using OSRM, which provides step-by-step travelling guidance and time estimates, which is a very important feature in disaster management. The system integrates remote sensing analysis techniques to identify flood risk areas and web web-based SDSS for optimal routing. Remote sensing data were processed to map areas prone to yearly floods based on flood criteria such as slope, elevation, land use and land cover, stream power index, topographic roughness index, curvature, and hydrology activities analysis. Risk areas were incorporated into the GIS routing and visualizations. The dissemination of flood incidents will be in three different modes, which include alerts, media content (videos and images), and as news. System testing demonstrated the web based geo-spatial technologies ability providing better spatial services to the flooding communities such as visualization of flooded or areas at risk of being flooded, travel guidance, optimization of routes, time estimates determination, location and proximity of structures in need from a victim position or any other marked starting point which are clearly geo-visualized. All these help to make spatially informed decisions, such as planning evacuation travel, travel guidance to unfamiliar destinations and time estimations which help in transportation. In addition to that proximity between or among places such as hospitals, shelters or schools which used as temporary shelters will be known along with their statistical details which aid in making better spatial decision and

prioritize allocation of resources. The geoportal proved to be an effective and powerful tool for disseminating flood messages and showing the flood areas and places which are useful during floods which help in flood disaster management and coordination in Lower Shire.

Keywords: Lower shire, Geo-Visualization, Route optimization, Travel guidance, Time estimation, Flood management.

Acknowledgement

First of all, I would like to thank Almighty God who made it possible to begin and finish this work successfully.

I expressed my deep sense of gratitude to my advisor Dr. Jabulani Nyengere for his invaluable support in all aspects of my work throughout this paper.

Special thanks must also go to Mr. D Mbeya and Harineck Tholo for sharing their insights and guidance's, which enriched my understanding of the matter.

I am also thankful to my classmates for their cooperative interactions and exchange of educational material even with academic advices for me to reach this far.

Table of contents

DECLARATION I
DISCLAIMER II
COPYRIGHT STATEMENT II
ACRONYMS AND ABBREVIATIONS USED II
ABSTRACT III
Acknowledgement IV
List of figures VII
Chapter 1: Introduction 1
1.1 Background 1
1.2 Problem statement 3
1.3 Main and Specific Objectives 3
1.3.1 Main Objective 3
1.3.2 Specific objectives include 3
1.3 Research Questions 3
1.4 significance of study 4
Chapter 2. Literature Review 5
2.1. Impact of easily accessible and centralized information of the system 5
2.2. Efficient information dissemination 5
2.3. Involving community in the system 5
2.4. Efficiency coordination with different stakeholders 6
2.5. Real-time information dissemination about flood disasters 6
2.6. visualization of critical resources 6
2.7. Route optimization, accurate travel guidance, and reliable time estimates. 7
2.7. Existing Systems 8
Chapter 3. METHODOLOGY 9

3.1 Study Area 9
3.3 Materials and Methods 11
3.3.1. Flood Risk Mapping 11
3.3.2 System Analysis and Design 23
3.6.6.7 SYSTEM FEATURES 38
CHAPTER 4: RESULTS AND DISCUSSION 41
4.1. Lower Shire Flood Risk Zonation 41
4.1.1 User 42
4.1.1.1 HOMEPAGE 42
4.1.1.2 System notification alerts or Notification 43
4.1.1.3 User Log in or sign up, If the user has no account, then can sign up by just click the toggle button of sign up. 44
4.1.1.3 Report flood incidents feature 45
4.1.1.4 Upload media content 46
4.1.1.5 News and updates 46
4.1.1.6 Visualization of currently flooded areas, areas at risk of being flooded and critical features including safe routes. 47
4.1.1.8 Accessing flood information in media content such as videos and images 50
4.1.1.9 Map view ,Users will be able to have an statistical overview and understanding of the lower shire traditional authorities independently just by clicking on map view button . 50
4.1.2ADMIN 52
4.1.2.1 Admin Log in 52
4.1.2.2 Admin dashboard 52
4.1.2.3 Manage incidents, ... 53
4.1.2.4 Manage users 54
4.1.2.5 Manage villages 54
4.1.2.6 Manage media uploads 56
4.1.2.7 Geoportal analytics and reports, this is designed to offer deeper insights into the systems data trends over time for both spatial and non-spatial data. 57
4.1.2.8 managing useful resources ,This is where all critical features needed during floods preparedness,response or recovery are managed such as adding new resource ,deleting and editing. 58
4.1.2.9 Manage feedback 59
CHAPTER 5: CONCLUSION AND RECOMMENDATION 62
5.1 CONCLUSIONS 62

5.2. RECOMMENDATIONS 62
CHAPTER 6. REFERENCES 64

List of figures

Figure 1 lower shire 9
Figure 2 elevation of lower hire 10
Figure 3 is a research design 11
Figure 4 shows processes involved in flood risk assessment 12
Figure 5 various criteria's output used in flood assessment and mapping 20
Figure 6 is Flood Risk Map in Lower Shire 23
Figure 7 is System Development Life Cycle used in the Research. Adopted from 24
Figure 8 indicating Use Case Diagram for Both Admin and Users 28
Figure 9 System Structure of the LSAFDRAGS 31
Figure 10 Database Entity Relationship Model 33
Figure 11 is a Home Page 43
Figure 12 is Notification Content 44
Figure 13 is the User Login or Signup to the System 45
Figure 14 User Reporting any kind of Flood Incident 46
Figure 15 Media Content being Uploaded to Geoportal System 46
Figure 16 News page about floods from system 47
Figure 17 Geo-visualization of Villages and Critical Features 48
Figure 18 is a OSRM functionality 49
Figure 19 Determining proximity of features at certain radius 49
Figure 20 image and videos about floods viewed from the geoportal 50
Figure 21 Traditional Authority flood status 51
Figure 22 b showing statistical details of one of TAs upon being clicked 51
Figure 23 Admin logging into the System 52

Figure 24 is the geoportal dashboard..... 53
Figure 25 is the admin feature for managing user reported incidences 54
Figure 26 above is the page in dashboard which used to manage user's activities. 54
Figure 27 is dashboard used for managing villages details and flood statuses..... 56
Figure 28 is uploaded videos and images in admin site 57
Figure 29 geoportal analytics & reports as an admin site for system performance and data trending visualization 58
Figure 30 Resources in the database where can be edited, deleted or adding new ones 59
Figure 31 is the feedback page for admin 60

LIST OF TABLES

Table 1 Data sources 16
Table 2 indicating criteria used, class value ,class rating and weight..... 21
Table 3 summarizing system user interface 36

Chapter 1: Introduction

1.1 Background

Floods represent a significant and destructive category of natural disasters worldwide. The United Nations Office for Disaster Risk Reduction (UNDRR) defines floods as "a serious disruption of the functioning of a community or society involving widespread human, material, economic, or environmental losses that exceed the affected community's capacity to cope using its own resources" (UNDRR, 2009). The Lower Shire Valley in Malawi is highly susceptible to frequent flooding, attributed to its topographical features, closeness to the Shire River, and variations in climate. Such catastrophic events result in the displacement of thousands, the destruction of livelihoods, and significant pressure on national response mechanisms (Government of Malawi, 2015; World Bank, 2020).

Disaster risk management in flood-prone areas such as Lower Shire necessitates the use of spatially explicit tools for hazard mapping, vulnerability assessment, and coordination of response efforts. Conventional methods, dependent on static maps and disjointed data, frequently do not deliver real-time insights or incorporate community-level feedback, thereby worsening delays in evacuation and resource distribution (GFDRR, 2018). Smith et al. (2016) highlight that the absence of dynamic, interactive platforms for visualizing flood risks and critical infrastructure constitutes a significant gap in disaster preparedness, especially in low-resource environments.

The Government of Malawi has prioritized disaster resilience via frameworks such as the National Disaster Risk Management Policy (2015) and the Malawi 2063 Vision, which highlight technology-driven solutions for climate adaptation (NPC, 2020). Persistent challenges include incomplete demographic data, outdated infrastructure mapping, and limited public access to real-time flood alerts. The 2018 National Statistical Office (NSO) census does not provide detailed population estimates for individual villages, which impedes effective evacuation planning and resource allocation (NSO, 2018, as cited in Malawi Vulnerability Assessment Committee Report, 2021).

Geospatial technologies, especially Web GIS, have become significant instruments in the field of disaster management (Huang & Cervone, 2016). The World Bank (2019) states that "Web GIS enables stakeholders to visualize, analyze, and disseminate spatial data in real time, bridging gaps between policymakers, responders, and affected communities." Systems that combine dynamic mapping, crowd-sourced data, and predictive analytics have demonstrated efficacy in reducing flood impacts in similar contexts, exemplified by Bangladesh's Flood Forecasting and Warning Centre (FFWC) platform (Islam et al., 2020). In Malawi, however, these systems are still underdeveloped, as most current platforms depend on static PDF maps or non-interactive datasets (Dodman et al., 2022). The Lower Shire Annual Flood Disaster Risky Area Geoportal System (LSAFDRAGS) mitigates existing deficiencies by offering a spatially enabled, user-focused platform for the visualization of flood risk and the coordination of response efforts. Utilizing methodologies from successful implementations such as Indonesia's InaRISK (BNPB, 2017) and the Philippines' Project NOAH (Lagmay et al., 2017), LSAFDRAGS incorporates real-time flood alerts, evacuation route mapping, and resource localization to enhance community and authority empowerment. The system utilizes Python libraries, including Folium and GeoPandas, to process geospatial data, such as flood-prone boundaries in GeoJSON format. It generates interactive maps featuring layered base maps (Google Satellite, OpenStreetMap), searchable markers for health centers and shelters, and tools for reporting community flood incidents.

This project is consistent with global frameworks, including the Sendai Framework for Disaster Risk Reduction (2015–2030), which promotes "people-centered early warning systems and inclusive risk communication" (UNDRR, 2015), as well as Malawi's commitment to Sustainable Development Goal 11 (Sustainable Cities and Communities). The system seeks to improve situational awareness, decrease response times, and strengthen community resilience in one of Malawi's most climate-vulnerable regions by addressing data gaps. This includes refining village-level population estimates through hybrid methodologies, such as the integration of satellite-derived settlement data with local surveys.

1.2 Problem statement

Lack of dynamic, accessible and centralized web-based system platform with visualizing tools for displaying flood-prone areas, giving real-time alerts, visualizing useful resources location, and a lack of community engagement in reporting which resulting into delays in evacuation and resource allocation s noted by Smith et al. (2016).

1.3 Main and Specific Objectives

1.3.1 Main Objective

The main objective of the system is to develop and implement web based geoportal system particularly for Lower Shire which will help much in disaster risk management and preparedness.

1.3.2 Specific objectives include

- ✓ Dissemination of Flood Risk Information:
- ✓ Geo-visualization of flood disaster-prone or affected areas and useful resources highly needed during flood.
- ✓ Promoting planning of evacuation & local traveling's through OSRM

1.3 Research Questions

The study will answer the following questions

- ✓ How can it be developed in such a way that it plays a role as a basic tool to disseminate flood information?

- ✓ How evacuation planning, travel guidance and time estimation be achieved?
- ✓ How system be designed with an aim of being unique from the rest of existing platform used to manage flood disaster?

1.4 significance of study

This system shall help to bridging the gap which is currently being encountered in Disaster Management as it will help in spatial decision making contributing in disaster proactive responses, preparedness and disaster management at large and this will be possible through:

Provision of Real-time Flood Alert Information. Once the flood issues have been reported then the information will be distributed to the lower shire community in various formats such as, media contents (videos & images) and news apart from alerts which will be sent about the area. Second significant is Visualization of useful resources and flooded and at-risk areas which Communities and authorities will be able to know where exactly to reach them and how proximity such areas or features are being found hence are able to make informed decision in time. Authorities will be able to plan about the evacuation Centre's, routes as well as getting travel guidance using OSRM. Visualization of safe routes with details along them used to guide the affected communities during evacuation, search & rescue team and various flood relief responders who bring different aids like foods, clothes and medicines to reach their destination with an easiness. Finally, there will be the minimal loss of number of people's live, reducing injuries and loss of people's belongings due to timely preparation to the disaster

Chapter 2. Literature Review

All Existing research that were done related to this research topic highlights a lot of benefits of geoportal systems in disaster and weaknesses of methods that are currently being used that do not bring any positive change to cut down the great loss of people's lives and properties each year. Below are benefits which geoportal system might offer in disaster management upon visiting various literatures.

2.1. Impact of easily accessible and centralized information of the system

Firstly, there is a lack of easily accessible and centralized information regarding disaster-prone areas, impeding response and preparedness efforts according to (Chinguwo, 2022) as geoportal has been most recommended to be reliable single platform offering multiple spatial data and spatial services (Akıncı, H., & Çömert, Ç, 2006)

2.2. Efficient information dissemination

First of all, inefficient information dissemination should be defined. "Inefficient information dissemination" means that information is not being shared or spread in an effective or organized way, leading to Difficulty in finding the information, wasting time searching for it, not getting the right information at the right time, Duplication of effort and Confusion or misunderstandings. This simply means that information is not being shared or communicated in a way that is quick, easy, and useful for everyone who needs it while with efficient information dissemination all the above explained problems are fixed making information reaching the targeted people right people at right time which aid them to make informed right decision. (GoM 2015b).

2.3. Involving community in the system

Paul et al. (2020) There is a lack of engaging and involving flood-related systems with the communities which undermines collaborative efforts and community resilience as

communities have proven to be impactful in providing very critical information as they are one's eye witnessing the severity of how situation is on the ground hence might be used to emphasize and validate the accuracy of the data. (Šakić Trogrlić,2017).

Sendai framework UNDRR (2015), also elaborates that "Early warning systems must engage communities to reduce mortality by 50% (Sendai Priority 1)

2.4. Efficiency coordination with different stakeholders

(Chinguwo, 2022) Lack of a direct link between National-level early warning systems and community-based early warning systems (poor coordination) for the current methods which are being used to disseminate useful information's which finally makes the critical information not reach the targeted area for effective flood response and preparedness to Lower Shire people .But this system shall give a chance to bring all stakeholders together which will make them to easily interact with communities on the same platform for easy coordination eliminating the issue of poor coordination.

2.5. Real-time information dissemination about flood disasters

There is also an issue of operational bureaucracy in government or non-government offices according to (Chinguwo, 2022), which limits the warning messages from reaching the desired groups of people at the right time. Due to the nature of office works in government and most non-governmental organizations documents of any kind of information regardless how important and urgency is it, flow in steps for authorization signatories or funds requesting process making process of managing disaster not being effective. (Chinguwo, 2022). To address that gap, as explained in the previous point, the system shall ensure good coordination between communities and various stakeholders, including both government and non-governmental organizations.

2.6. visualization of critical resources

Some literature also highlights that existing platforms do not offer comprehensive visualization tools, leading to difficulties in understanding the extent and severity of disaster risks even at national level ,from (GFDRR 2019; GoM 2019) the problem which

this system will fix by showing all the necessary resources needed in disaster management such as shelters location where is used to host the victims, hospitals where victims with various degrees of injuries can go and receive the treatment, market location where they can be involved in some of the marketing processes and showing of safe routes which victims or flood disaster responders can use.

The implementation, and usage of spatial technologically advanced systems like this system which I am implementing has proven that might be the best solutions to overcome all those weaknesses of current methods in disaster risk management as it meets what Sendai Framework demands, according to Sendai Framework (2015-2030) as Geoportals provide a single entry point for users to access and search spatial data, making it easier to find and use the data they need also known as "One-stop access" which means a single point of entry or a single platform where users can access all the necessary information, resources, or services they need, without having to search multiple sources or locations. this is according to (Akıncı, H., & Çömert, Ç,2006)

2.7. Route optimization, accurate travel guidance, and reliable time estimates.

According to (Smith et al., 2019). Flood events can quickly change road conditions, making it hard for emergency responders and people evacuating to find the safest and fastest routes. By using OSRM, the system can calculate the best routes in real-time based on current data from OpenStreetMap. This allows the system to suggest alternate paths when main roads are blocked or unsafe due to flooding. As a result, emergency services can respond faster and evacuate people more efficiently, potentially saving lives and reducing property damage. (Luxen & Vetter, 2011).

Additionally, OSRM provides accurate travel time estimates, helping government agencies and rescue teams plan resource use more effectively. It ensures that users get up-to-date information on expected travel times during rapidly changing flood situations. This real-time re-routing and time estimation greatly improve decision-making and responsiveness.

2.7. Existing Systems

Malawi Spatial Data Platform (MASDAP)

Its role is to share spatial data, including flood risk maps, infrastructure, and other layers. Its weakness is it has limited real-time data and hence relies on static datasets. For instance, during the 2022 flood, MASDAP could not provide real-time Shire Valley water levels. (MASDAP,2023).

Department of Disaster Management Affairs (DoDMA).

This is a government-led platform for disaster response coordination. Its weakness is it has centralized decision making, which means it excludes community input. The second limitation is a lack of visualization tools, which makes them rely on reports rather than interactive maps. Another factor is beurecracy in office nature jobs which makes flood message dissemination process to delay. An example in 2019, warnings about Cyclone Idai did not reach remote villages in Nsanje.Gom(2019)

Global Disaster Alert and Coordination System(GDACS)

This is an international platform for disaster alerts and coordination (GDACS,2023). Its limitation is that it focuses only on agencies, not grassroots participation (no community engagement). It makes use of only generic data. For instance, GDACS issued flood alerts for Malawi in 2023 but could not specify safe routes for Chikwawa community because it lacks hyperlocal insights.

Ushahidi Crowdsourcing Platform

Whose role is mapping crisis Meier, P. (2015) through community reports. Weaknesses with it include using fragmented data and limited scalability which requires technical expertise to customize for flood prone areas.

Chapter 3. METHODOLOGY

3.1 Study Area

The Lower Shire is composed of two districts Chikwawa and Nsanje which all made up 15 TAs. This is well known for its recurring flood which causes yearly devastating effect to lower shire communities. It is characterized by low lying topography with elevation ranging from approximately 10 to 100 meters above the sea level (GFDRR,2019). Receives an annual rainfall between 800 and 1,200mm as an approximate (World Bank, 2023). It also characterized by having densely population, with vulnerable settlements that face high exposure to flood hazards (Mwase et al., 2023). Shire River is the major river which run through and covers a lot of areas before ending into Zambezi river in Mozambique. There also other network of rivers which drain into it such as Ruo ,mwanza ,Makhanga ,Nkhate, Mapelera, Livunzu,Likhubula and Chidzimbi contributing the flooding force in Lower shire (Chinguwo, 2022).

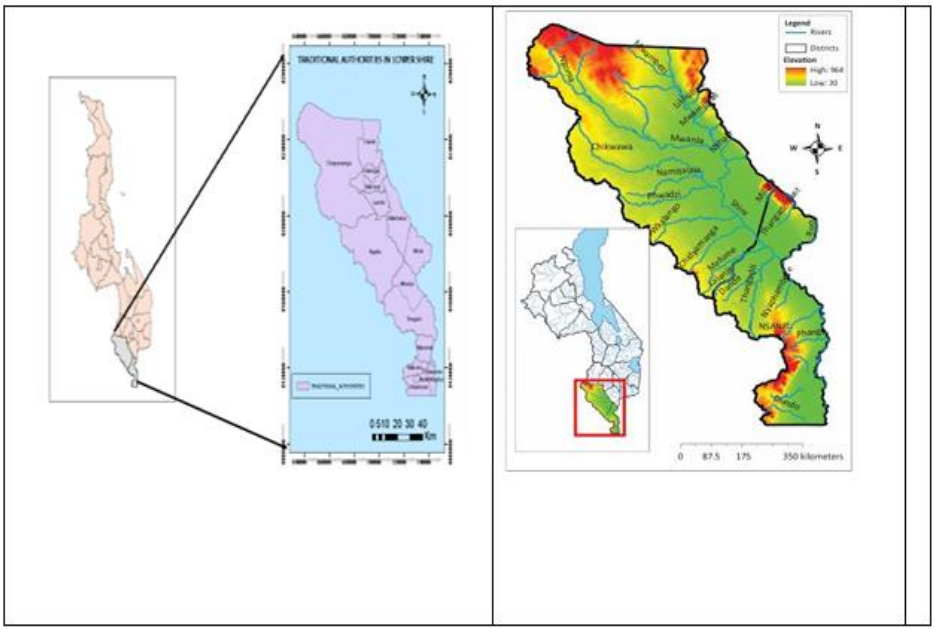


Figure 1 lower shire

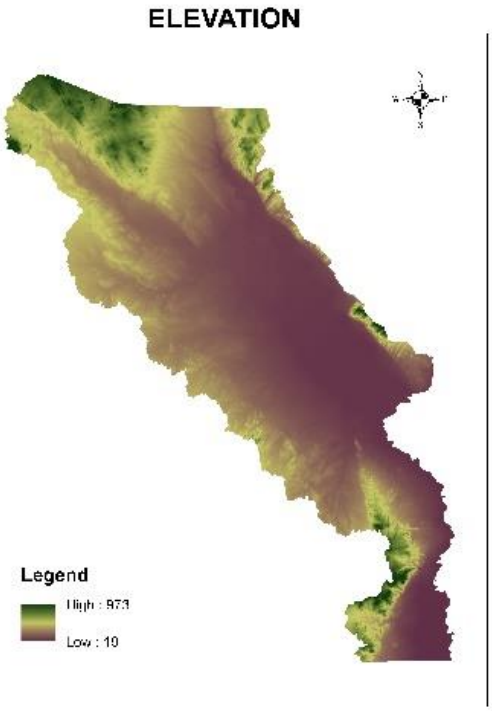


Figure 2 elevation of lower hire

3.2. Research Design

Three separate stages of the study were conducted. Data collection, cleaning, and obtaining specific needs and expectations from system users comprised the first phase. This involved comprehending their objectives, driving forces, technological expertise, behaviors, and thorough descriptions of the different ways users would engage with the system. In order to identify flood-risk areas, the second phase used the remote sensing data that had been collected to conduct flood hotspot analysis and flood risk assessment. Based on the flood risk zones determined by the spatial analyses and user system requirements collection carried out in the earlier phases, the final phase concentrated on designing and implementing the system. The system was tested after it was first put into use, and any issues or malfunctions found were fixed.

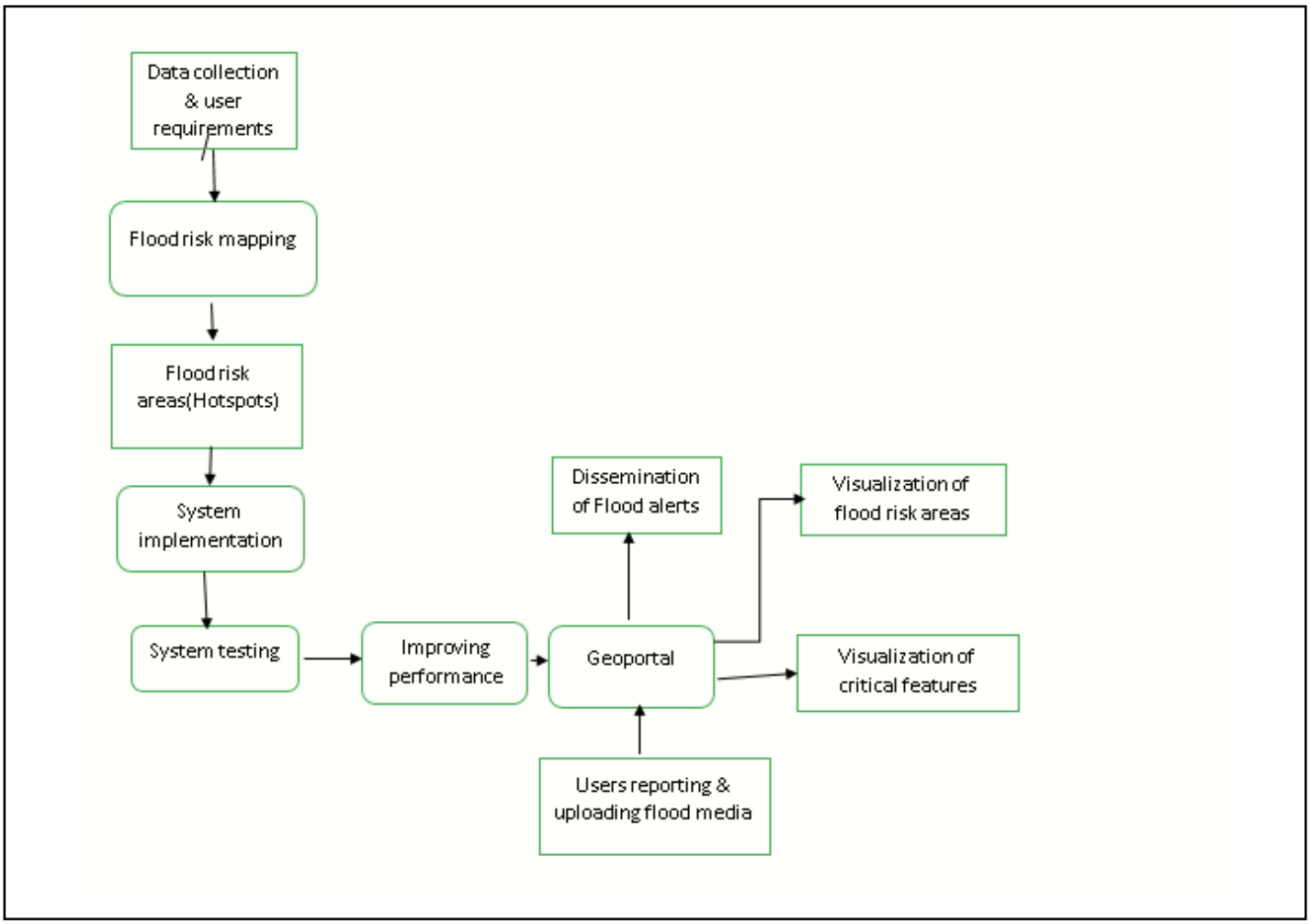


Figure 3 is a research design

3.3 Materials and Methods

3.3.1. Flood Risk Mapping

Flood mapping can be simply defined as an activity exercised to assess those areas which are prone or susceptible to be flooded. This takes a several steps to come up with accuracy and precision making the mapping processes to depict the reality or giving true reflection of what is on the ground or what definitely might happen (Thieken et al., 2016). Flood risk mapping is very critical element in GIS spatial data infrastructure as it integrates hydrological, topological and social-economic data to create actionable insights.

The following criteria used in the research The following criteria's used in the assessment (slope, elevation, LULC, TWI, TR I, SPI, curvature, aspect)

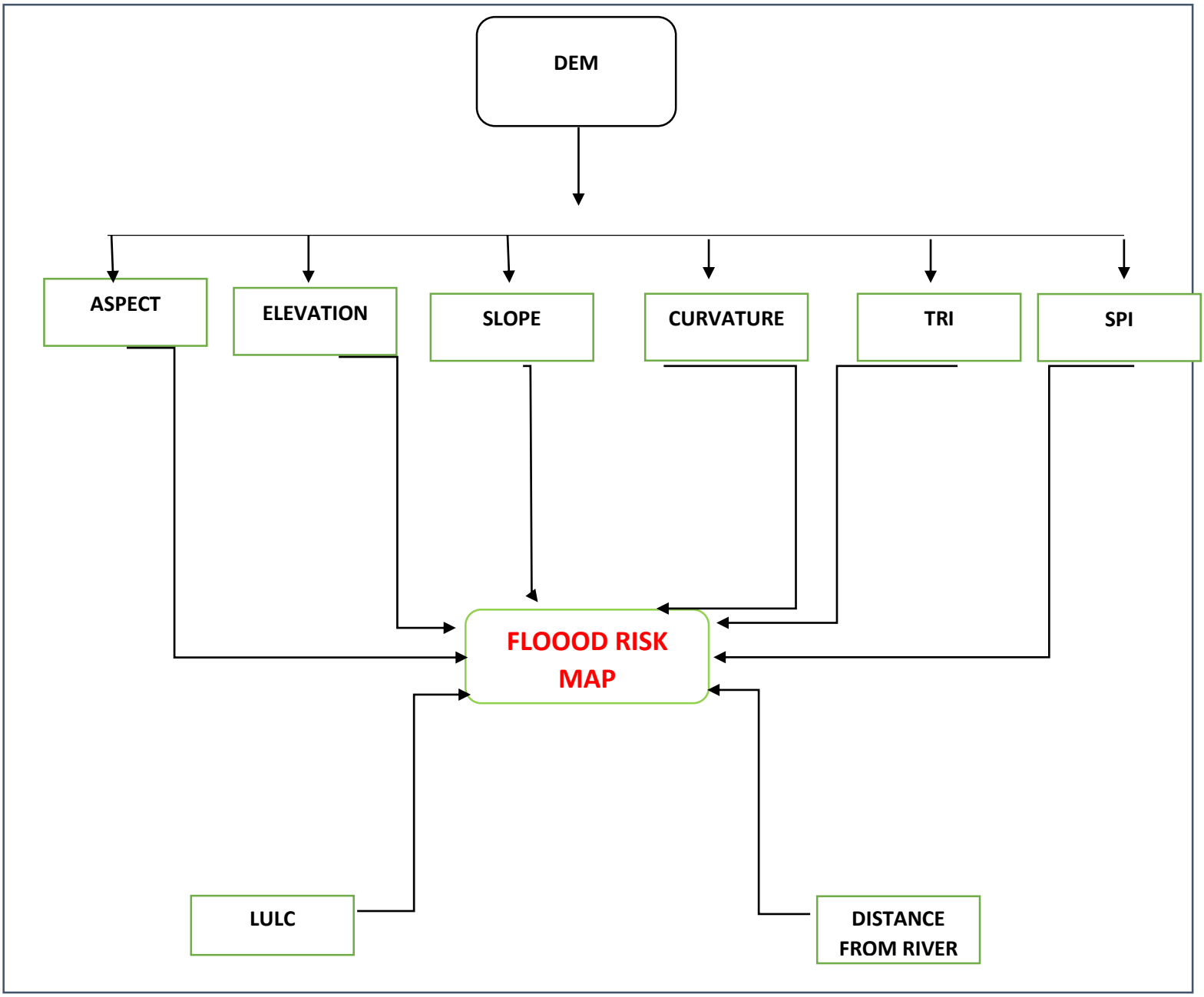


Figure 4 shows processes involved in flood risk assessment

3.3.1.1 CRITERIA USED FOR GENERATING RISK MAP

The study area was categorized into three classes based on actual values of the criteria used as follows:

3.3.1.1.1 SLOPE

Slope. This is one of the most important parameter which used in flood assessment (Rahmati et al., 2016). Slope is one of factor controlling runoff; steeper slopes facilitate rapid flow (reducing local flooding but affecting downstream areas), while gentle slopes promote accumulation of upward incoming water leading to floods in gentle or almost flat areas hence used as flood susceptibility indicator.

3.3.1.1.2 ELEVATION

With elevation as one of the used flood parameter to keep it simple Lower elevation areas especially in flood plains (e.g., valleys, riverbanks) are more susceptible to flooding due to natural topographic gradient which allow more accumulation of water as water naturally flows downward compared to higher areas elevated have low or minimal potential of being flooded (Vojtek & Vojteková, 2019).

3.3.1.1.3 LAND USE LAND COVER

This simply means how land is used and what covers it. As another criterion which used in flood assessment, this affect how much water goes into the ground (infiltration) and how much runs off on the surface. When an area has lots of hard surfaces(impervious) or very few plants, water can't seep into the soil well. This means more water flows over the surface, which increases the chance of flooding. Therefore, areas with activities leading to had surface has higher chances of flooding hence contribute a lot in determining flood risk areas (Sharma et al., 2018).

3.3.1.1.4 STREAM POWER INDEX

Stream Power Index (SPI), is a way to measure how much energy a flowing river or stream has to pick up, carry, and move sediment. In simpler terms, it tells us how "strong" the water is when it comes to eroding its banks and changing the shape of its channel. When the SPI is high, the water has more power to erode the riverbed and banks, which can

change the channel's shape and how sediment is carried along. These changes can affect flooding because altered channels may direct water differently or allow water to flow faster, sometimes increasing flood risks (Moore et al., 1991). This is coming in a different way with some criteria's used above because with this one it is done through mathematical calculation using Raster Calculator and formula which is used is as follows

SPI=Flow Accumulation ×Cell Size ×tan (Slope in Radians) ……(1)

3.3.1.1.5 TOPOGRAPHIC WETNESS INDEX

This is hydrological index used to quantify how likely an area is to accumulate water based on its slope and upstream contributing area which helps to model the surface saturation and water flow which are key in understanding flood potential (Beven & Kirkby, 1979).

Formula for TWI is:

TWI=ln($\alpha/tan(\beta)$)……(2)

α=upslope contributing area (m^2 per unit contour length)

β=local slope in radians

tan (β)=indicates how steep the terrain is

Areas with high TWI after mathematical operation are those with greater potential for water accumulation and saturation hence are at high flood risk WHILE areas with low TWI value are those which are steeper slopes or well drained regions therefore are low to flood risk.

3.3.1.1.6 TOPOGRAPHIC ROUGHNESS INDEX

Topographic Roughness Index **(TRI),** is a simple way to measure how "bumpy" the land is at a very small scale. This unevenness is what TRI captures. When the terrain has high roughness, water may slow down or be diverted into small depressions, affecting how it drains locally according to (Grohmann et al., 2011). However, while these tiny bumps and

hollows can change water flow in small areas, they generally don't have as strong an effect on overall flood risk compared to bigger factors like the general slope of the land or how the land is used but still play a smaller role in flood risk.

This one uses the mathematical calculations too with raster calculator and below is used formula

TRI= (Focal statistics mean – focal statistics minimum) / (focal maximum – focal minimum) …… (3)

3.3.1.1.7 ASPECT

According to (Moore et al., 1991) ASPECT, refers to the direction a slope faces—like north, south, east, or west. This matters because the amount of sunlight the slope receives depends on its orientation. For instance, in many places, south-facing slopes get more direct sunlight, which can dry out the soil faster, while north-facing slopes might remain cooler and moister. This variation in soil moisture indirectly affects flood susceptibility. If an area remains moist due to less sun exposure, it may already be near saturation, meaning it can't absorb much more rain during a storm and this increases runoff and potentially flood risk. Conversely, drier slopes might absorb more water until they become saturated. Additionally, the aspect influences the type of vegetation that grows on a slope, which further affects soil moisture and water absorption. To summarizing about aspect, it affects flood susceptibility by influencing local climate conditions, soil moisture, and vegetation all of which play a role in how much rainfall can infiltrate the ground versus how much becomes surface runoff.

3.3.1.1.8 CURVATURE

CURVATURE. This refers to the way a land surface bends. There are two main types which are Concave curvature (bowl-shaped) where Water tends to gather here, which can increase the risk of flooding (Zevenbergen & Thorne, 2017).. Convex curvature (dome-

shaped) is also another type: Water flows away more quickly, generally reducing flood risk. Therefore, Curvature tells us about small-scale surface shapes. Areas with concave curvature can collect water, potentially leading to localized flooding.

3.3.1.2 ADDITIONAL TECHNIQUES USED FOR VALIDATION

Proximity to water bodies was used for validation where areas near rivers, lakes, or coasts are at higher risk of overflow or storm surges hence determination of closeness to such water sources became useful in assessment. Flood historical data is another technique where Past flood events (e.g., Cyclone Freddy in 2023) highlight recurring risk zones, hence validating the result. Using remote sensing imagery technology. This involves using satellite images such as Landsat 8 and sentinel and even Google earth pro because GIS layers derived from these technologies enhance dynamic flood forecasting. Wang et al. (2018). The use of Demographic and socio-economic data aided in Assessing which areas are habited by people and what kind of properties are there simply because the area becomes flooded and be risk if there are people and properties which is exposed. This include knowing peoples dominant ages, income and housing type which help to identify their ability to cope up with the disaster. Cutter et al. (2003)

3.3.1.3 DATA SOURCES

Data Acquisition, gathering spatial data from satellite imagery (Landsat 8), digital elevation models (DEM), National Statistical Office (demographic data), existing flood hazard maps and conducting interviews.

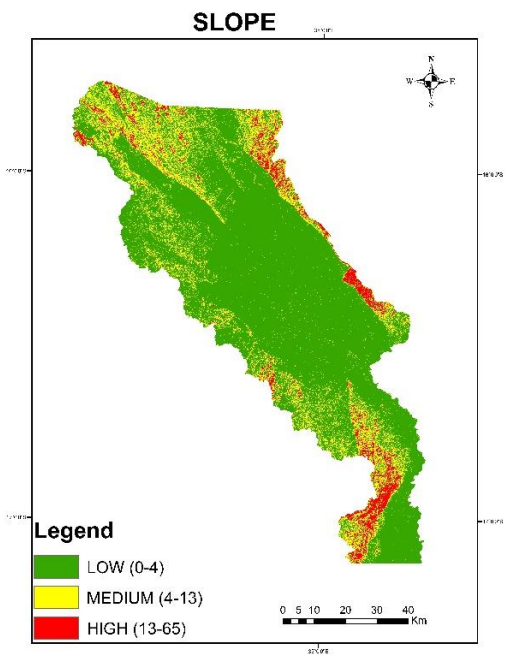
Sources of data.

Table 1 Data sources

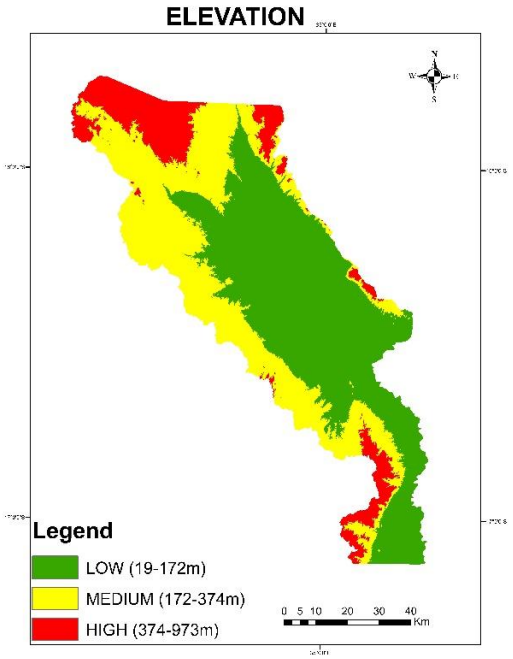
DATA TYPE	DESCRIPTION	SOURCE
Land Cover Land Use	This was 30 by 30 resolution dataset used for land classification which provides high-resolution,	Landsat 8

	open, accurate, and timely land use maps are essential for decision-makers across various industries and in developing countries.	
DEM	The SRTM data offers high-resolution digital elevation models for about 80% of the Earth's land surface between 60°N and 56°S. Key specifications include: WGS84 geographic horizontal datum, EGM96 vertical datum, vertical units in meters, a spatial resolution of 1 arc-second (approximately 30 meters), raster size of 1-degree tiles, and a C-band wavelength of 5.6 cm (Farr et al. 2007).	United States Geological Survey (USGS)
Villages/settlements	The data which provide residential areas in lower shire. There are 1790 villages in lower shire	National Statistics Office
schools, hospitals	Active Primary Schools and 48 hospitals .	National Statistical Office
Roads	Defined linear features which are found on open	OpenStreetMap

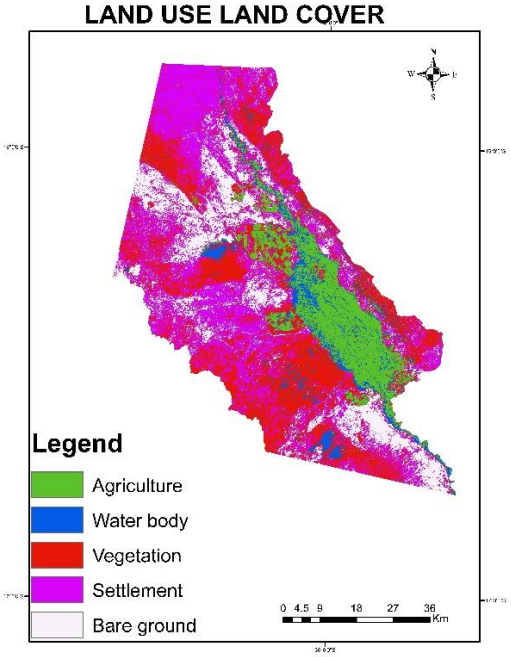
	street map and used as roads	



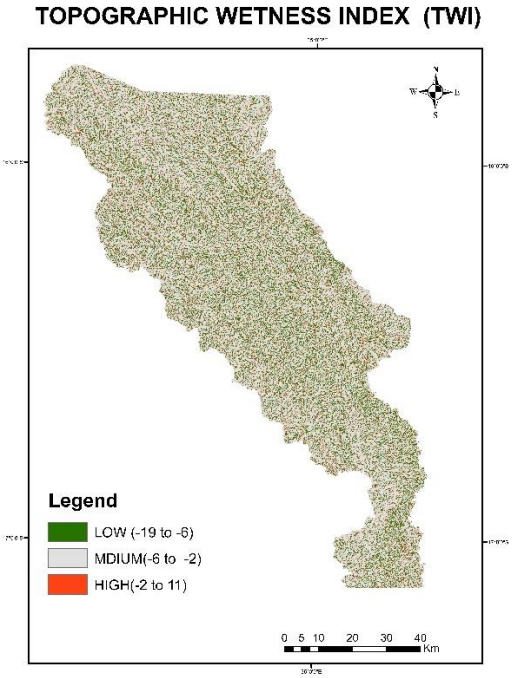
a



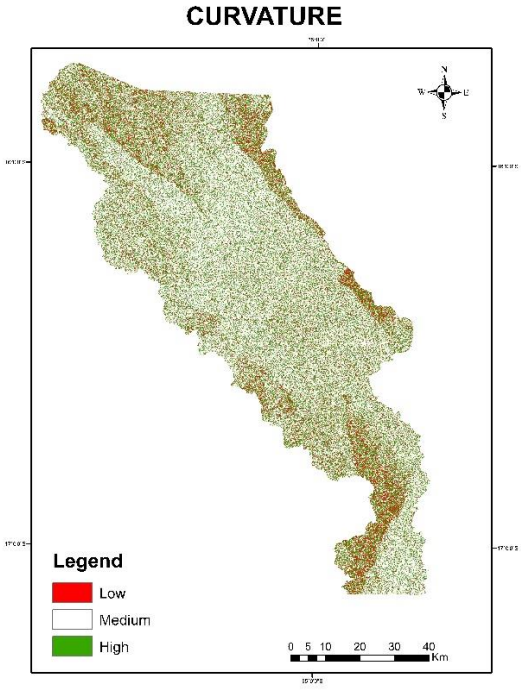
b


LAND USE LAND COVER
Legend
Agriculture
Water body
Vegetation
Settlement
Bare ground
0 4.5 9 18 27 36
Km

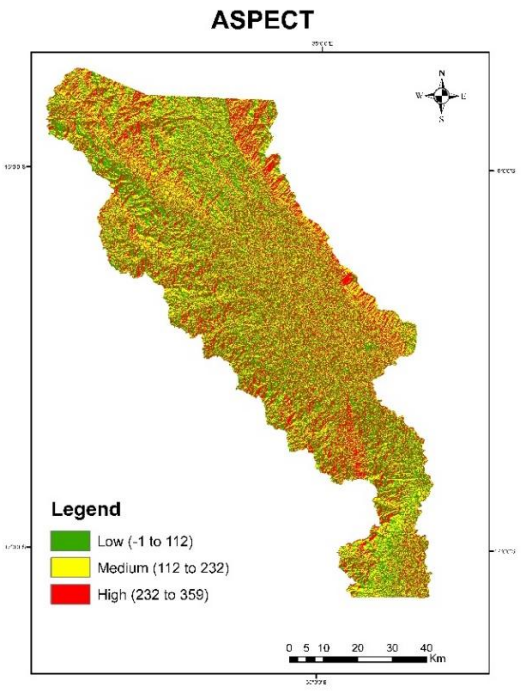
c


TOPOGRAPHIC WETNESS INDEX (TWI)
Legend
LOW (-19 to -6)
MDIUM(-6 to -2)
HIGH(-2 to 11)
0 5 10 20 30 40
Km

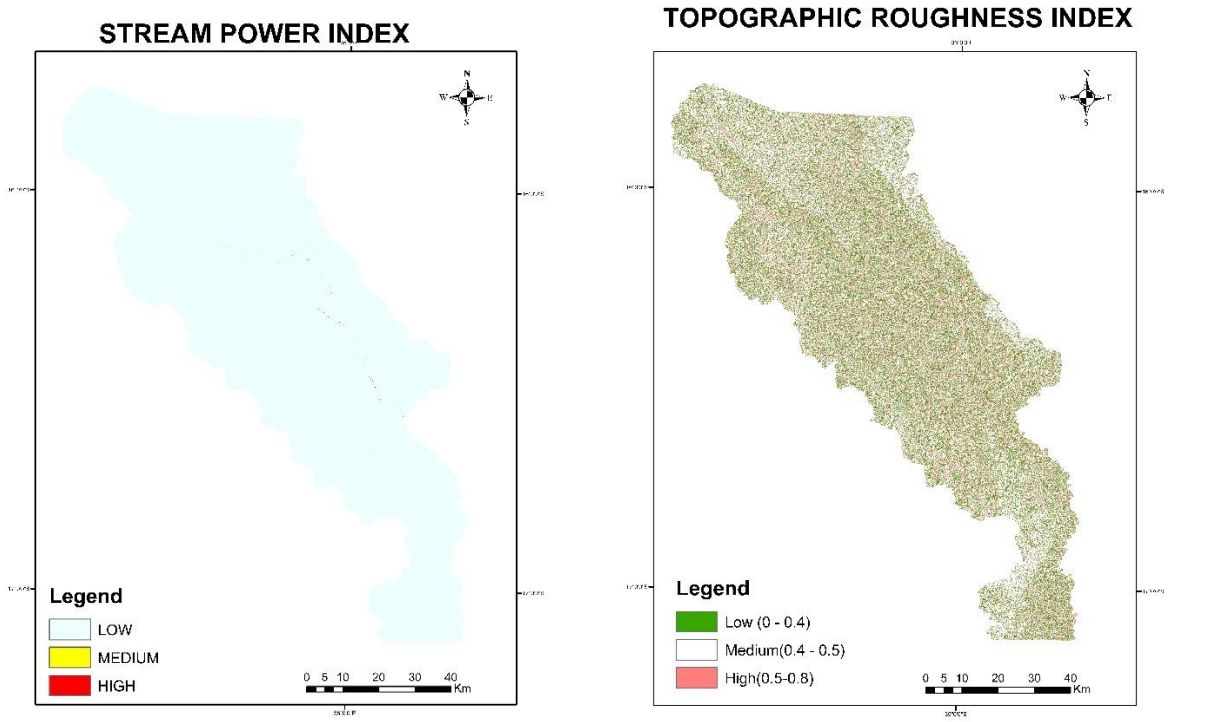
d


CURVATURE
Legend
Low
Medium
High
0 5 10 20 30 40
Km

e


ASPECT
Legend
Low (-1 to 112)
Medium (112 to 232)
High (232 to 359)
0 5 10 20 30 40
Km

f



g h

Figure 5 various criteria's output used in flood assessment and mapping

3.3.1.4 FLOOD RISK ZONES IDENTIFICATION

Analytical Hierarchy Process (AHP) is used, to assign the weight to criteria's depending on their influential percentage to flooding. AHP is a structured, decision-making framework used to assign weights to multiple criteria based on their relative importance. So below is the AHP with weight assignment for flood susceptibility parameters.

Table 2 indicating criteria used, class value ,class rating and weight

Number	Criteria	Class	Range	Class rating	Weight (%)
1	Slope	0	High	3	25%
		0 - 89.64683084	Moderate	2	
		89.64683085 - 89.99977112	Low	1	
2	Elevation	19 - 172.3882353	High		20%
		172.3882354 - 374.4117647	Moderate		
		374.4117648 - 973	Low		
3	LULC	Water body	High	3	15%
		Agriculture	Moderate	2	
		Settlement	Low	1	
4	STREAM POWER INDEX	0 - 846,424.9804	High	3	12%
		846,424.9805 - 3,462,647.647	Moderate	2	
		3,462,647.648 - 19,621,670	Low	1	
5	TOPOGRAPHIC WETNESS INDEX		High	3	10%
			Moderate	2	
			Low	1	
6		0.111083984 - 0.425267119	Low	3	8%

	TOPOGRAPHIC ROUGHNESS INDEX	0.425267119 - 0.568632238	Moderate	2	
		0.568632238 - 0.888916016	High	1	
7	ASPECT	-1 - 112.1510034	Low	3	5%
		112.1510035 - 232.3739445	High	2	
		232.3739446 - 359.6688232	Moderate	1	
8	CURVATURE	-168,479,998,000 - -3,893,086,216	High	3	5%
		-3,893,086,215 - 1,473,878,297	Moderate	2	
		1,473,878,298 - 287,711,985,700	Low	1	
9					

With all that information in the table above, the allocated weights were based on the influential percentage to floods, which upon combining them using weighted overlay the final flood risk map is produced which upon validating with flood historical data and other GIS and remote sensing techniques the resulted output proven to represent the truth on the ground hence such areas are being targeted for flood alerts and all services offered by the system.

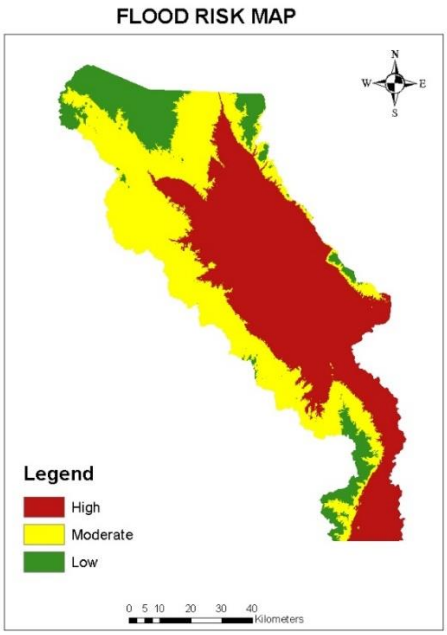


Figure 6 is Flood Risk Map in Lower Shire

3.3.2 System Analysis and Design

3.3 2.1. System Methodology

The system was developed utilizing a prototyping approach, which involved the initial creation of a basic, functional model of the product. This preliminary version was then subjected to user testing, allowing participants to provide feedback on their experiences. Based on the insights gathered, the system underwent a thorough evaluation and refinement, leading to the construction of a second prototype designed to address identified issues and incorporate additional features. This methodology was selected due to its rapid implementation capabilities, facilitation of swift adaptations in response to user input, and its efficacy in mitigating risks by identifying potential issues early in the development process, ultimately resulting in significant time and cost savings. The primary objective of this approach was to ensure the system's practical utility rather than merely its aesthetic appeal, thereby reducing operational costs.

The project commenced with a clear definition of its scope, followed by the formulation of a system proposal that included assessments of its technical, financial, and practical viability. During the analysis phase, the team meticulously identified the system's requirements by examining current workflows through interviews and surveys. Additionally, an evaluation of existing systems and processes was conducted to identify gaps and potential areas for enhancement.

The design of the system was informed by non-functional requirements, encompassing critical components such as hardware, software, and network specifications.

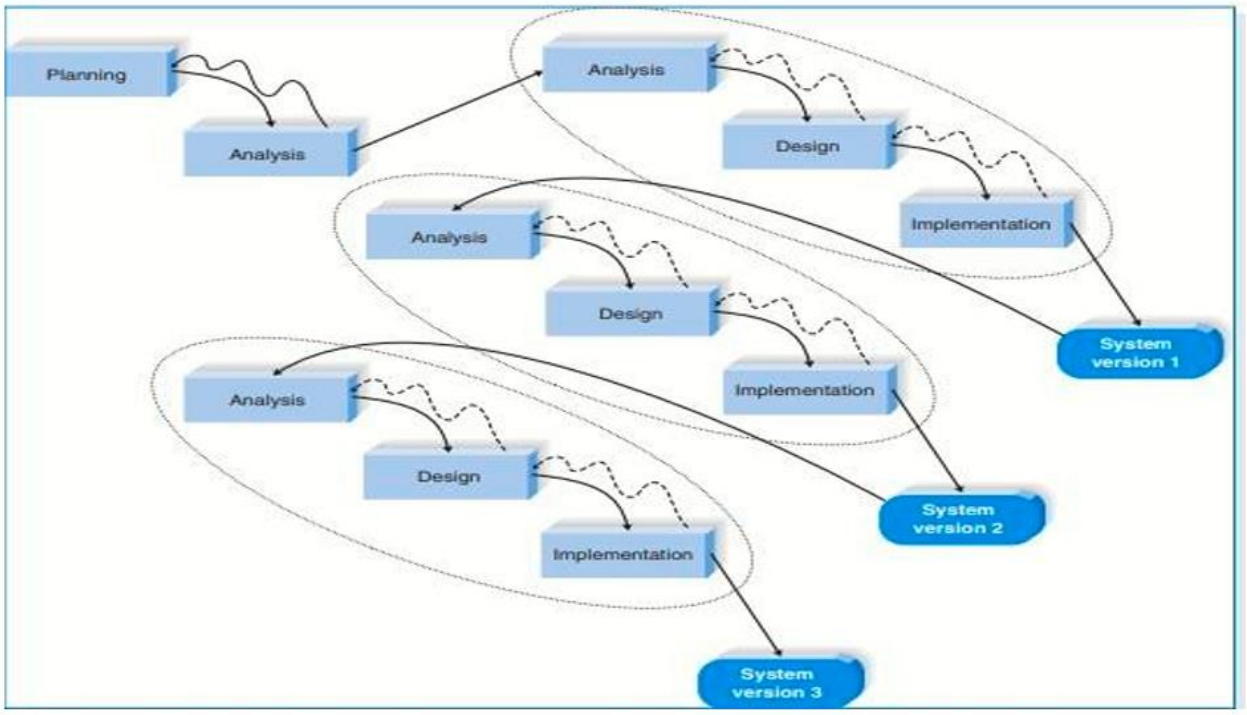


Figure 7 is System Development Life Cycle used in the Research., Source: Dennis, 2011

LSAFDRAGS required thoroughly system planning and feasibility analysis to ensure its viability therefore below is an evaluation of key feasibility aspects of this geoportal system.

3.3.2.1.1 System planning

This means defining the project scope, objectives and requirements of LSAFDRAGS.

LSAFDRAGS objective was developing web-based platform for real time flood alerts, flood areas visualization, evacuation route optimization and promoting community engagement. Resources or requirements for the system included Open-source tools (geosrver, OSRM, PHP, MySQL), spatial datasets which include (DEM, Landsat 8, lower shire villages shape file, schools shape file, markets shape file, hospitals shape file and evacuation centers) and stake holder's collaboration (e.g. Local communities)

Apart from that the research also structured into phases such as data collection, flood risk mapping, system design and iterative prototyping.

3.3.2.1.1.1 Feasibility Analysis

3.3.2.1.1.2 Technical feasibility

Technical feasibility assesses whether the proposed technology can meet the system requirements. In this project, various tools and technologies were considered, including open-source frameworks such as Leaflet.js and Geopandas, Docker for OSRM routing services, and XAMPP for backend hosting. These tools are cost-effective, widely supported, and align well with the project's needs. In addition to tool selection, key technical challenges were also addressed. Real-time data integration for flood alerts and community reports was achieved using PHP and MySQL. Cross-browser compatibility was ensured by testing the system on browsers such as Chrome and Edge. Scalability was supported by designing a cloud-ready architecture using Apache server setups and spatial databases. Based on the reliance on open-source technology, cost-effective toolsets, and successful prototype testing, the LSAFDRAGS system was found to be technically feasible.

3.3.2.1.1.3 Economic feasibility

Economic feasibility evaluates Cost-Benefit balance. LSAFDRAGS has minimal development costs due to free software's, existing datasets and operational data from community-driven updates. The explained minimal costs compared to its benefits which include reduced loss of lives or properties through early warnings. There will be efficient resource allocation through use of optimized routes for responders and long-term savings by aligning with

Malawi's disaster resilience goals. Search and rescue team and those who come with flood relief items reach targeted areas with an easiness

3.3.1.1.4 Legal Feasibility

This is to ensure that the system is in compliance with Malawi laws, regulations and data policies. LSAFDRAGS analysis base on legal feasibility include, Data sources, where there is proper attribution for OpenStreetMap, Landsat 8 and NSO data. Community data where there was ethical handling of user-reported data through privacy consideration in user requirementsand lastly, Policy alignment where there was assurance that it supports Malawi National Disaster Risky Management Policy (2015) and Sendai Framework.

3.3.1.1.5 Operational Feasibility.

This assesses if the system can be integrated into workflows. This ensured that there was compatibility where it works on smartphones, tablets and desktops. it also considers user Multilanguage interface (Chichewa integration) for local communities since there will be people of different education levels. Training admin dashboard for authorities to manage the data. The LSAFDRAGS proven to be operational feasible due to its usability testing and alignment with user needs.

3.3 2.2. SYSTEM ANALYSIS

System analysis is a crucial phase in the development of a geoportal system, where the intricacies of the problem are examined and deconstructed to gain a comprehensive understanding of its components, processes, data flow, user requirements, and stakeholder expectations. This thorough analysis serves to clarify project requirements while assessing the technical, economic, and legal viability of the solution, ultimately ensuring that the geoportal system performs the necessary tasks effectively and efficiently.

3.3.2. 2.1. Requirements Gathering

Using questionnaire and interviews the insight requirements specification analysis was done, which involved how flood reports are collected and disseminated in lower shire. Which tools do they use and how strong the coordination is with authorities. User roles, responsibility and access levels were also analyzed.

3.3.2. 2.2. user requirements

The system will be used by both administrators and end users this is to allow the administrators to manage content such as deleting, adding, validating reports from users and making necessary changes to the contents. This will only need to have admin account for authorization in system as administrator which provide all privileges and responsible for managing whole content. while the end user which include the community people and local authorities will be able to view maps with flooded areas, optimal routes operation, visualization of location of various resources helpful during floods, determining proximity of resources from certain point of interest and calculating distances , reporting the flood disaster issues , uploading the media content as a way of informing the community and public about flood current situation , accessing news about lower shire floods published on the platform and sending feedback based on system performance..

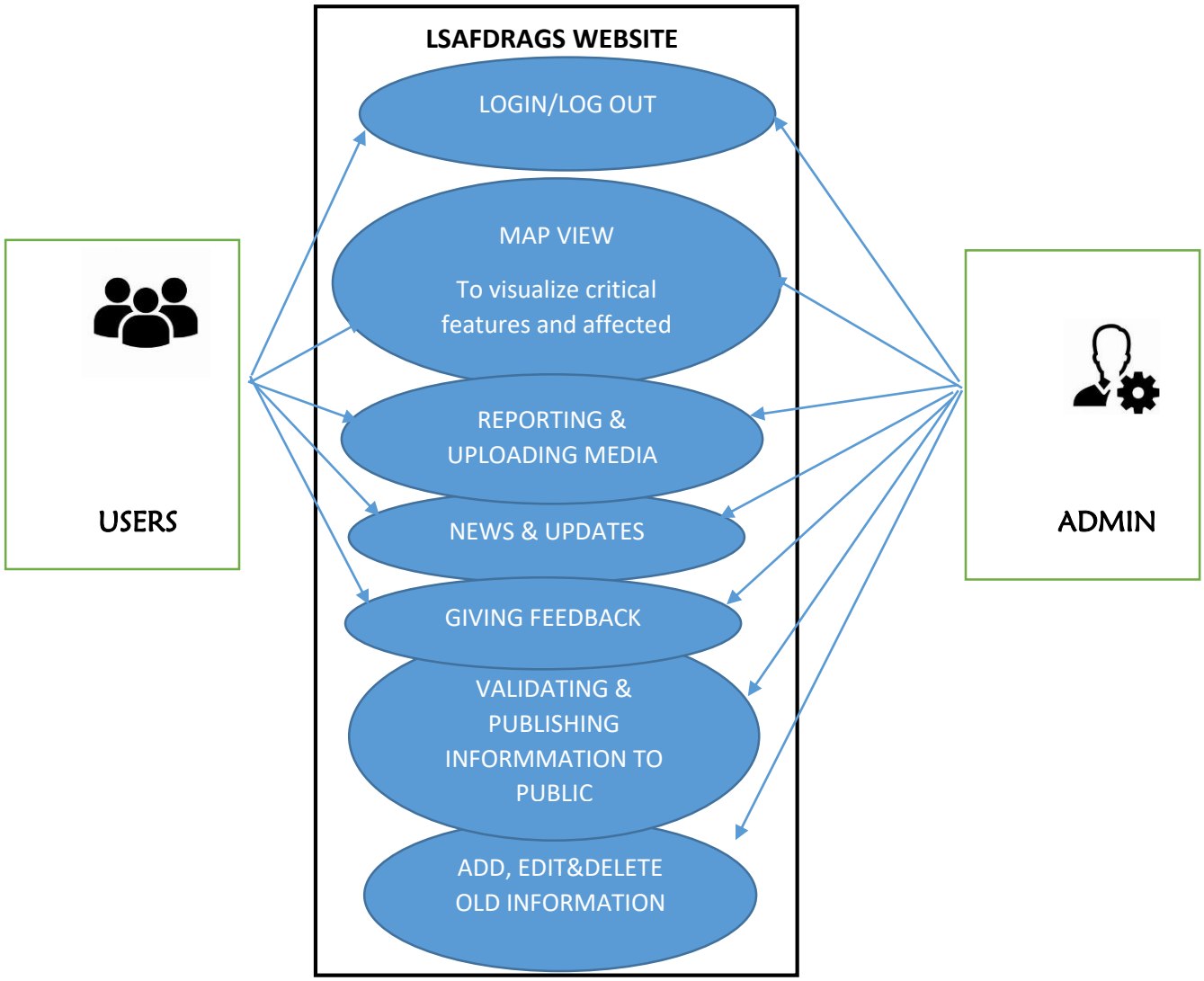


Figure 8 indicating Use Case Diagram for Both Admin and Users

3.3.2.2.3. functional requirements

The system is designed to efficiently store all relevant and updated information regarding flood issues in Lower Shire, including the names and locations of victimized villages and necessary resources. To ensure data authenticity and security, it includes authentication measures that control who can view and perform administrative operations, restricting access to public users while allowing only admins to log in and

manage content. The integration of a dynamic and interactive base map utilizes both Open Street Map and Google Maps; Open Street Map provides detailed labeling of critical infrastructure, roads, and rivers, while Google Maps offers a realistic representation of ground features, making it easier for users with limited familiarity to navigate by toggling between the two layers. Furthermore, users can search for targeted features or villages, and the system will respond accordingly, informing them if the requested item is not available. It connects to a database that stores all necessary data, providing both spatial and non-spatial information upon request. Data updates are managed exclusively by administrators, who possess full privileges to delete outdated information, add new data, and validate reports from users regarding flood issues before making them publicly accessible.

3.3 2.3. SYSTEM DESIGN

First of all was to understood what the users needed, then planned how entire system would work including having the right gadget, tools and programs. The system was designed based on how it stores data, how everything connects and how data flows through it.

3.3.2.3.1. System Architecture

The LSAFDRAGS system utilizes a modular client-server architecture for flood disaster management, structured into four layers: a user-friendly front-end built with HTML5, CSS3, and JavaScript for map interaction and reporting; a back-end in PHP and Python for processing requests and managing authentication; a MySQL database for storing spatial and non-spatial data served via GeoServer; and integration with external services like OSRM for evacuation route calculations. User inputs are captured, validated, and stored efficiently, while administrators monitor and manage content through a dashboard.

3.3.2.3.2. User Interface Design

The goal was to make the web-based spatial decision support system easy and natural to use. wire framing and prototyping to plan the layout, parts, and how users interact with the system was used. symbols included on each button so that symbols may sometimes help users to understand the functionality of that particular button or feature with an easiness. Apart from that in some situation Chichewa language was integrated on some functionality of the system by considering that it will be used by people of different educational and knowledge levels, making them all be able to use this system with an easiness. The focus was on building a responsive web system that works well on all devices without errors or display problems. The design followed a method by Sugumaran and Sugumaran (2007), which includes separate pages towards archiving one goal of the system in Lower Shire for flood disaster.

3.3.2.3.3 Application Server

Application server plays a central and critical role by acting as the brain between this geoportal front end interface, database and other services like maps, routing and analysis engines. This includes handling business logic, serving dynamic content, connects to the database, user management or authentication, processes map or GIS data requests and API integration.

3.3.2.3.4. Server side

This is everything that runs behind the scenes on the server not in the browser including the application server itself. Such operations make use these technologies which include PHP for processing logic and pages, MySQL for storing and managing resource data, Apache (XAMPP) acts as application server that interprets PHP and serves pages

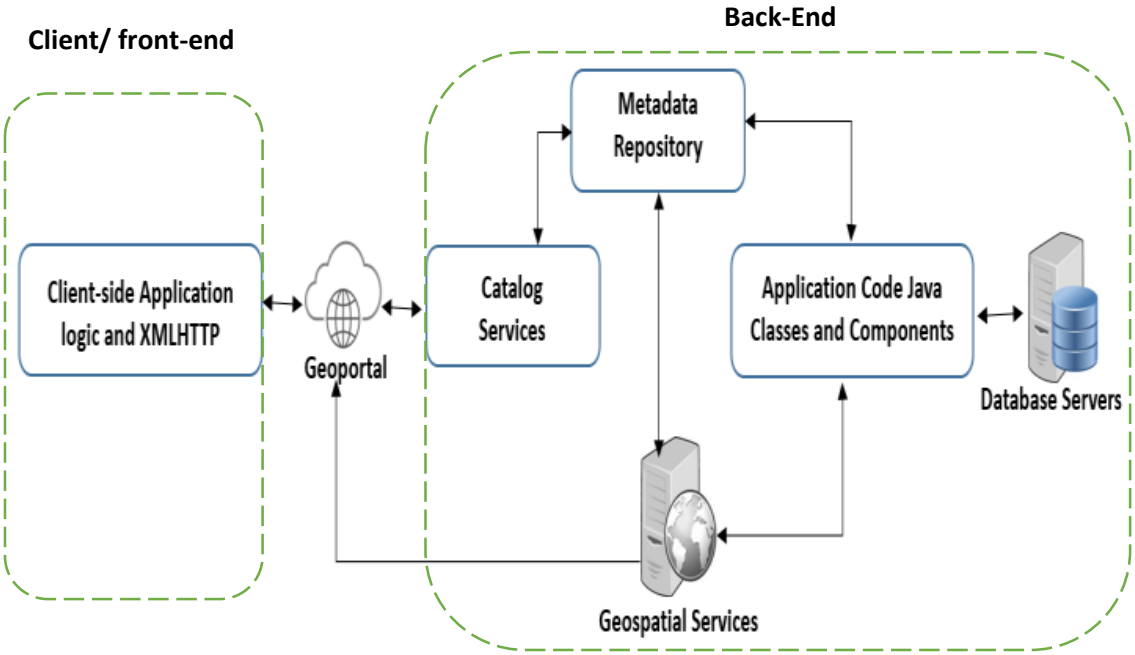


Figure 9 System Structure of the LSAFDRAGS

3.3.2.3.1. 1 Front-end Side & Back-end side

A web-based Geoportal system consists of several interconnected components that work together to provide users with an interactive experience. The front-end of the system includes a web browser, such as Google Chrome or Mozilla Firefox, where users interact with the Geoportal. To enhance the development of maps and spatial data displays, developers use JavaScript libraries like OpenLayers and Leaflet. On the back-end, the web server manages HTTP requests and serves web pages, while the application server executes server-side logic and integrates with databases to deliver business functionalities. Specifically designed to manage spatial data, the map server, like ArcGIS Server or GeoServer, generates and serves the map content, while a spatial database, such as PostGIS or Oracle Spatial, stores and manages extensive spatial datasets. Additional components further enrich the system, including GIS data formats like shapefiles and GeoTIFFs, and APIs and services that offer supplementary features for geocoding, routing, and spatial analysis. To secure the system, mechanisms for security and authentication, such as user credentials and SSL/TLS encryption, ensure safe access. Together, these elements create a robust and

scalable web-based GIS system that allows for effective management and visualization of geographical information.

3.3.2.3.5. Database Design

The system database is designed to efficiently manage both spatial data, such as the location of critical features, and non-spatial data, including village statistics, victim counts, and death tolls. It utilizes a structured database like MySQL for attribute data storage, with a backend developed in PHP and Python to handle user requests and dynamic updates. For spatial data serving and route optimization, it integrates GeoServer and OSRM (Open Source Routing Machine).

3.3.2.3.5.1 DATABASE ENTITY RELATIONSHIP MODEL

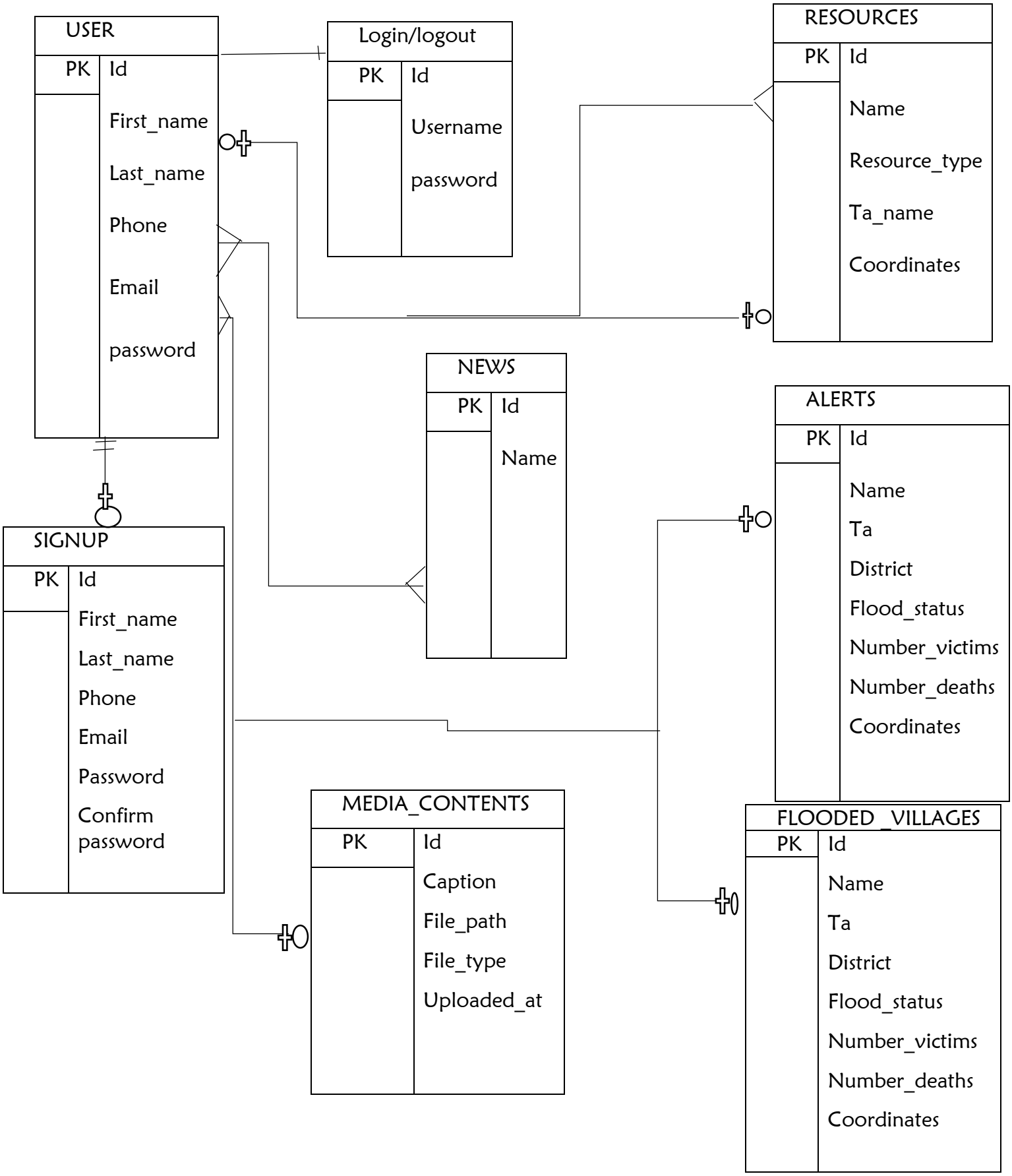


Figure 10 Database Entity Relationship Model

3.3.2.3.6. SYSTEM IMPLEMENTATION

3.3.2.3.6.1. Required details

Being a geoportal, it means its main aim is to visualize and disseminate location-based information, which includes, Location of affected villages, Location where critical resources are found, like, Evacuation centers (shelters), Hospitals /health centers, Markets, Schools (used as temporary shelters and coordination hubs), Safe routes location and names

Some non-spatial information, which is also important and required to be shown in the system, includes, estimated population of each affected/targeted village, Number of victims in each reported affected village, Number of deaths in each village, if available, Overall number of schools, hospitals, and evacuation centers

Videos & pictures of the current flooding situation with some explanation

News and updates

Due to limited availability of resources (money & time) interviews and data collection were done in detailed only to some traditional authorities even although some of the data like about village demographic was not latest which will not give true reflection on the ground but for the sake of system demonstration it is working effectively and does the intended tasks.

3.3.2.3.6.1.1 System requirements

Database

For storage of both spatial and non-spatial information

Website

The website should allow performing basic necessary website requirements, such as authentication and system administration, as well as displaying pages such as the homepage and other related web pages relevant to the functionality of the system.

Some of the pages will allow users to visualize data in the web as website should support web mapping to be able to display the spatial data visualizations

cross-browsers compatibility

The website's compatibility was tested to ensure that its compatible to web browsers such as Google Chrome, Mozilla Firefox, opera, Microsoft Edge and to ensure consistent performance and functionality in all the trusted browsers

Operating system compatibility

The system is compatible with major operating system such as windows, Linux, Mac OS, Ubuntu, Android and IOS.

Docker for supporting OSRM

Docker is the containerization platform that lets an individual to run application in an isolated environment. (*Luxen & Vetter, 2011*) in this case it hosts the OPEN SOURCE ROUTING MACHINE data. This is very help as most of the public servers in Africa do not host open street routing data because of inaccuracy and incompleteness. When an individual clicks starting and ending points in the geoportal system it will give an optimum route to be followed. It provides not only the best path but also useful details such as estimated travel time and step-by-step directions which is helpful in the world of GIS particularly in evacuation guiding. **UNOOSA (2022)**.

3.3.2.3.6. FRONT-END

3.3.2.3.6.1 User-Interface Design

The website was designed to have several pages all of them working towards achieving the main objective, the pages play a role in data visualization, timely flood information dissemination, reporting, early warning, admin dashboard among others.

Below is the table illustration of intuitive and user-friendly user-interface of the geo-portal.

Table 3 summarizing system user interface

USER INTERACTIVE BUTTONS	FEATURE DESCRIPTIONS
Map View	Click to visualize the map of targeted area of lower Shire with a open street map and google map used as layers for base map
Search & navigation button	Searching for predefined options of areas of interest for detailed information to each area (T/A)
Uploading media	Button which upon clicked will allow users to upload video or image bearing flood information.
News & Updates	Button which users will use in order to be feed with latest news and updates about floods in lower shire (Chikwawa & Nsanje)
Reporting an incident	Users will use this for reporting of any new affected village(s) ,number of victims, number of deaths and location of the area in terms of latitude and longitude.
Feedback	With this button people will be given a chance of reporting issues, describing their experiences or suggesting improvements which will help to improve the system.

3.3.2.3.6.2. software sourcing

The following free and open source software are ones which I used to came up with the full working system to the implementation stage.

Python ,Sublime text, Xammp and Docker

3.3.2.3.2.1 Justifications on the choice of software and languages used

The choice of software and programming languages for the project was based on their flexibility, efficiency, and open-source nature, each serving a specific purpose. Python was selected for data processing, particularly for handling GIS datasets, and as a back-end framework using Django. To aid in development, Sublime Text was utilized as a lightweight text editor that supports multiple programming languages and offers powerful syntax highlighting, making it ideal for web development. For local server hosting, XAMPP, which includes Apache, PHP, and MySQL, was chosen to facilitate development and testing. Bootstrap was incorporated as a front-end framework to simplify responsive web design, ensuring compatibility across different screen sizes and devices. Docker works as a containerization tool, allowing efficient deployment and operation of applications in isolated environments, which is essential for integrating services like OSRM for routing functionalities. The Apache server was chosen for its stability, security, and robust community support to process user requests and deliver dynamic content effectively. On the programming side, HTML (Hypertext Markup Language) was used for structuring web pages and defining elements such as buttons, forms, and content sections, since it is the standard markup language that integrates seamlessly with CSS and JavaScript. CSS (Cascading Style Sheets) enhanced the system's visual appeal, ensuring a user-friendly interface, with Bootstrap assisting in styling and responsiveness. JavaScript was essential for adding interactivity, enabling dynamic form validation, map integration using Leaflet.js for GIS mapping, and AJAX for seamless server communication, thus improving user experience by allowing real-time data fetching without refreshing the page. PHP (Hypertext Preprocessor) was chosen as the server-side scripting language to handle form submissions, process user inputs, and

interact with the MySQL database, being well-integrated with Apache and widely used for building dynamic web applications. MySQL was selected for efficiently managing both spatial and non-spatial data, valued for its scalability, efficiency, and compatibility with PHP and Apache.

explanation of how all the components work together

The user interacts with the system through web pages built with HTML and CSS, enhanced by Bootstrap, where buttons, forms, maps, and menus are displayed. To add interactivity to the interface, JavaScript handles events such as clicking buttons, selecting from dropdown menus, and drawing on maps; for instance, when the "feedback" button is clicked, JavaScript sends user input to the server. Meanwhile, PHP runs on the Apache server using XAMPP to receive data from the client-side via form submissions, processing this data and interacting with the MySQL database, which stores comments, incident reports, and media uploads. MySQL manages all data, ensuring that user submissions and other dynamic information are securely saved and retrievable when needed. On the front end, libraries like Leaflet (and Folium in Python) display maps and spatial data, pulling information from the backend or directly from static files to visualize layers such as flood boundaries or resource locations. Ultimately, the user's actions on the interface trigger JavaScript events that call PHP scripts on the server, processing the data and updating the MySQL database, with the updated data then reflected back on the interactive maps, creating a continuous loop from the user to the backend and back again.

3.6.6.7 SYSTEM FEATURES

3.6.6.7.1 Map navigation controls

Map navigation controls were included to allow users to pan, zoom, and interact with the map easily. Providing options for both mouse-based and touch-based interactions to accommodate different devices and user preferences.

3.6.6.7.2 Integration of Open Street Routing Machine Functionality

OSRM functionality was integrated into the mapping application to calculate and display optimal routes from one place to another (where facilities are found) it also displays time taken to reach the desired destination and the direction window. This functionality utilized routing algorithms to determine the shortest and constraints free routes such as avoiding terrain. Despite that it also includes distance estimation from one point to another hence help in making choice of using fastest as well as safest route, making the search and rescue team or local travelers to have informed decision of the destination.

3.6.6.7.3 Searching area or feature of Interest

This feature is enabling users to search for the places of interest and exploring to them by having inner details about such places.

3.6.7.4 Calculating the radius from the targeted point

This help to determine the number of villages and critical features including safe routes found within that range of radius. This also helps to determine the proximity of critical features from one point of location.

3.6.6.7.4 web mapping Legend

This will help to interpret the meaning of symbols and colors used on the map hence users are being able to identify features and flood status of villages such as flooded, area at risk and safe.

3.6.6.7.5 Popping up message

This functionality is being able to provide specific details about the clicked feature E.g. the location details

3.6.6.7.6 providing coordinates (location) of every place

When the user clicks at each point of the map he or she will be able to get the location of that pin pointed place.

3.6.6.7.7 ability to switch between different layers.

The system was designed to have two different layers, open street layer's which is labelled hence be able to provide information about the place by acting like address leading the person to reach the place where he or she is not familiar with while on other hand with google map layer which has no label but provide the realistic view of the ground feature which makes users to identify places and features with an easiness since no any interpretation is needed

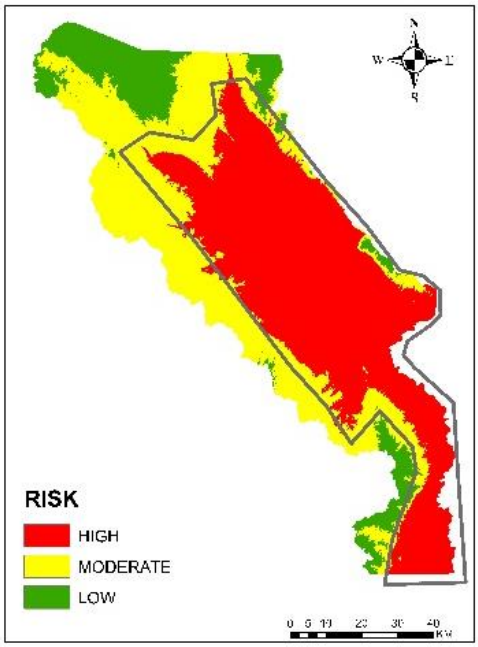
3.6.6.7.8 Allowing the feedback from the users

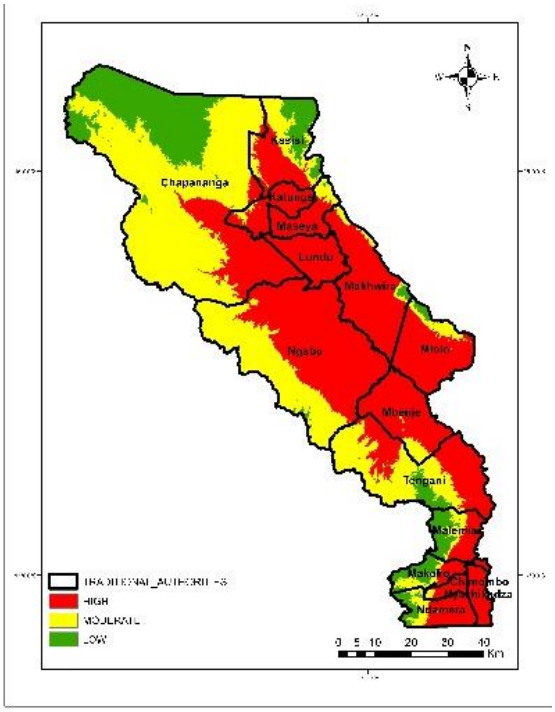
This feature helps to continuous improve or maintenance the functionality of the system for optimum and best performance of the system.

CHAPTER 4: RESULTS AND DISCUSSION

4.1. Lower Shire Flood Risk Zonation

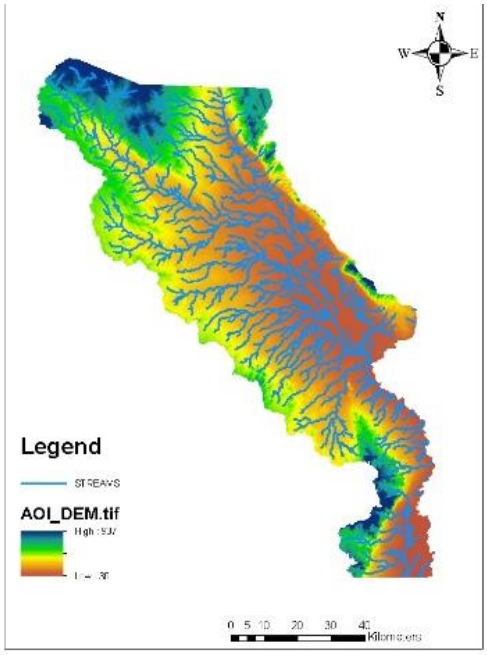
The areas which are flood prone in lower shire were identified and demarcated in a specified location known as flood zone which ranges from high risk areas medium up to the areas which are safe from being flooded.

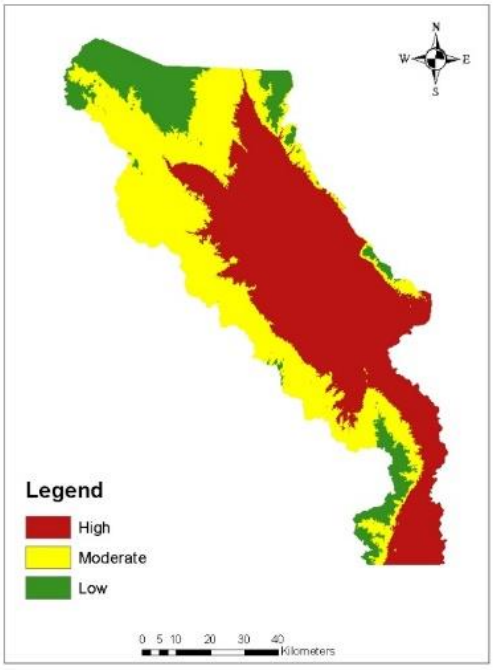


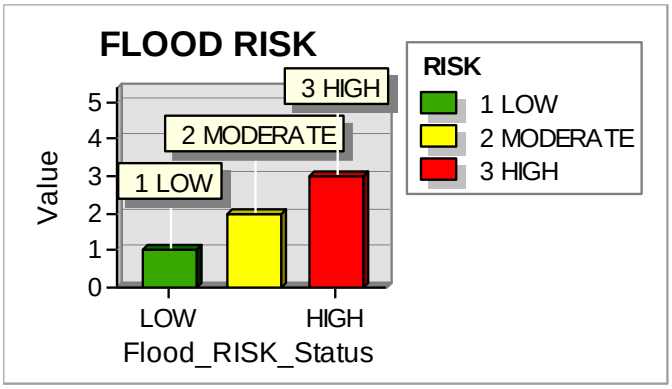


4.2 Flood Hotspot analysis

This is where there was a statistical operation of hotspot analysis of rivers and other tributaries which contribute highly to floods in lower shire. Upon validating such areas found to be clustered within the flood risk mapped zone, guarantee the result that such areas are really susceptible to annual floods







Therefore, after combining flood risk zone with its hotspot it is indicating that most of the flood hotspot area is within the flood risk area which is also the largest portion in lower shire taking over 60% of the area.

The LSAFDRAGS being centralized platform of disseminating and accessing all kinds of flood information with inclusion of spatial decision support. It is composed of the following features from both users and admin sites.

4.1.1 User

4.1.1.1 HOMEPAGE

This is where the user can interact with the system through the availability of basic system functionality features.

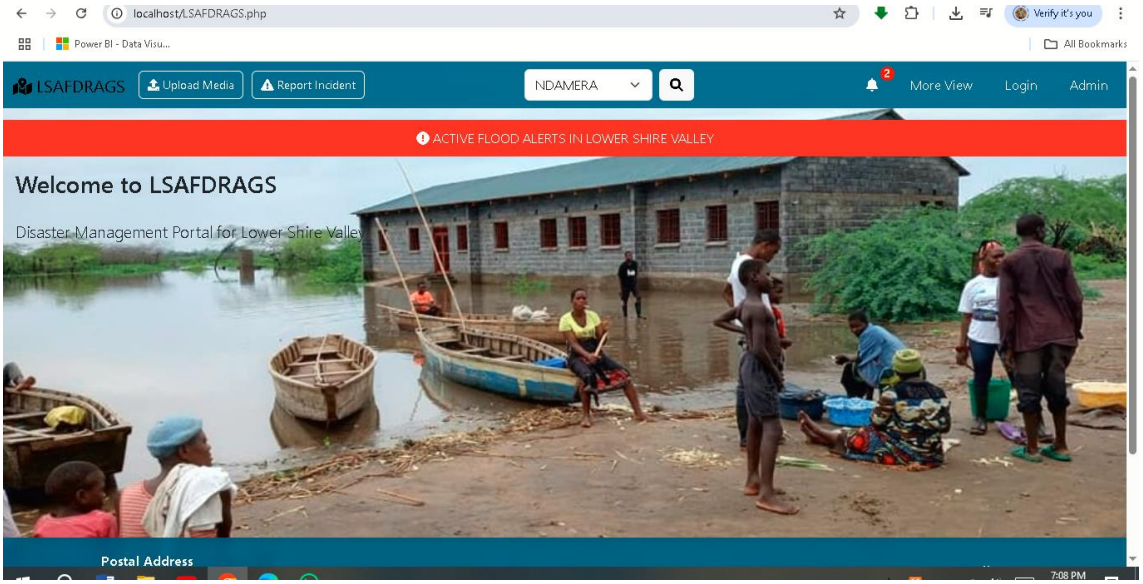


Figure 11 is a Home Page

The home page is composed of the following features based on the purpose of flood management.

4.1.1.2 System notification alerts or Notification

This is the bell icon in the navigation bar which gives an instant alerts based on the current flood situation on the ground. This alerts include number of villages which are flooded, number of victims, number of deaths if available and village name which is currently impacted. As illustrated below when the person clicks on an alert notification, an individual will be taken to the notification page with more details to the affected village(s)

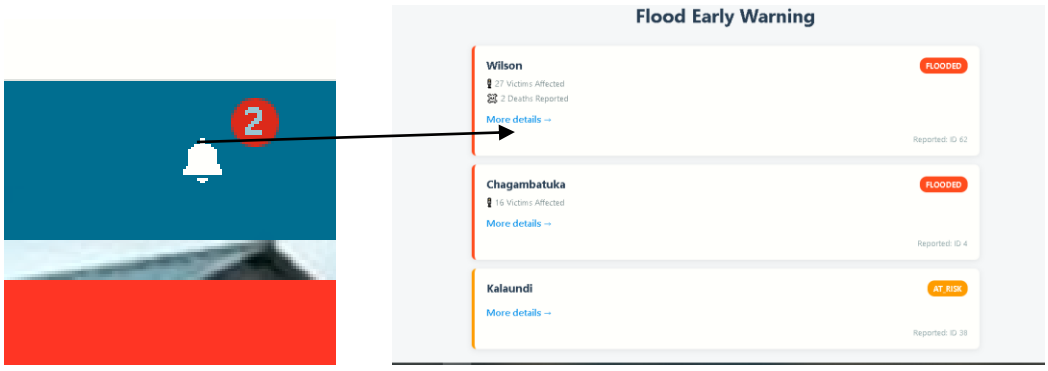
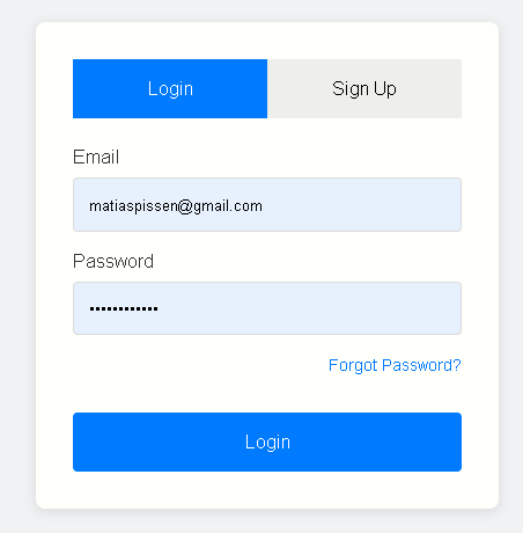
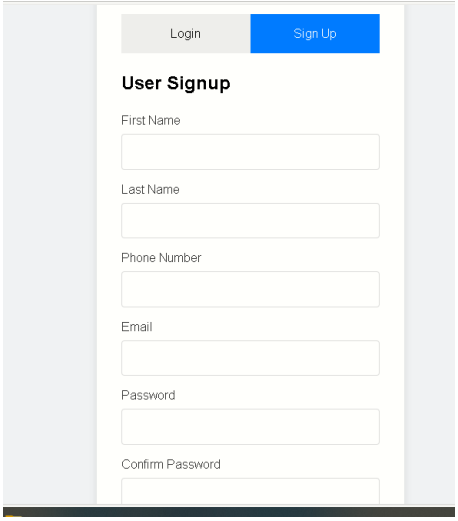


Figure 12 is Notification Content

4.1.1.3 User Log in or sign up, If the user has no account, then can sign up by just click the toggle button of sign up.





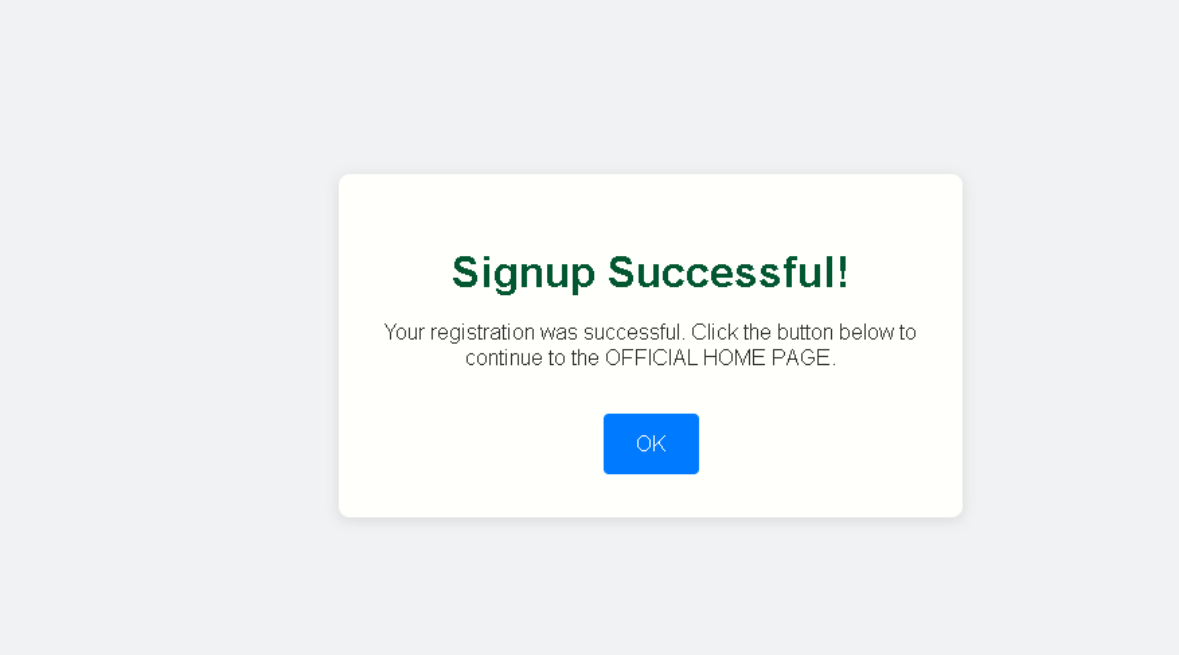


Figure 13 is the User Login or Signup to the System

4.1.1.3 Report flood incidents feature

This is the home page feature which is placed at highly visible enough, a feature which to report about the flood issues. For the location it will automatically ask the user to accept the turning on of the garget location to capture the position/location of that particular place into the system the form automatically.

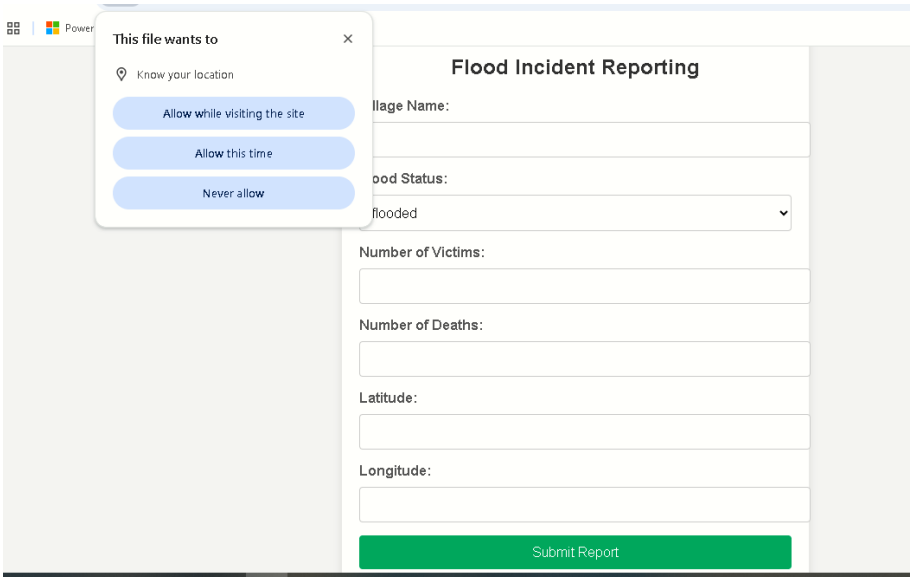


Figure 14 User Reporting any kind of Flood Incident

4.1.1.4 Upload media content

This is the feature which authority officers can upload videos or images and share to inform others.

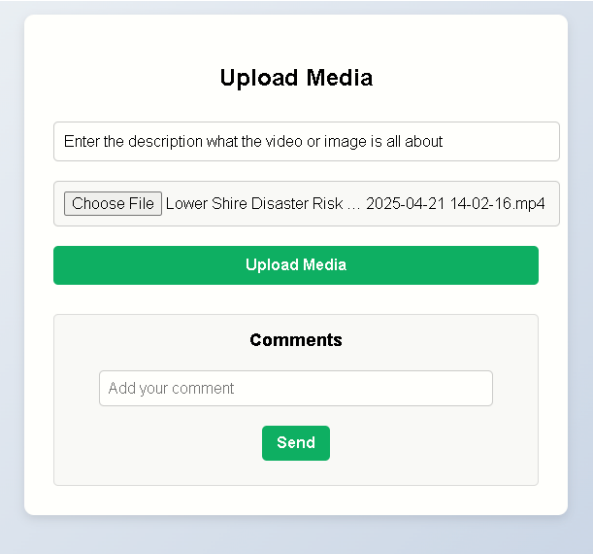


Figure 15 Media Content being Uploaded to Geoportal System

4.1.1.5 News and updates

On news and updates that's where information about floods in lower shire will be accessed. This can include affected areas, areas with probability to be flooded as warning to the community, evacuation planning, type of support needed and many more flood related news.

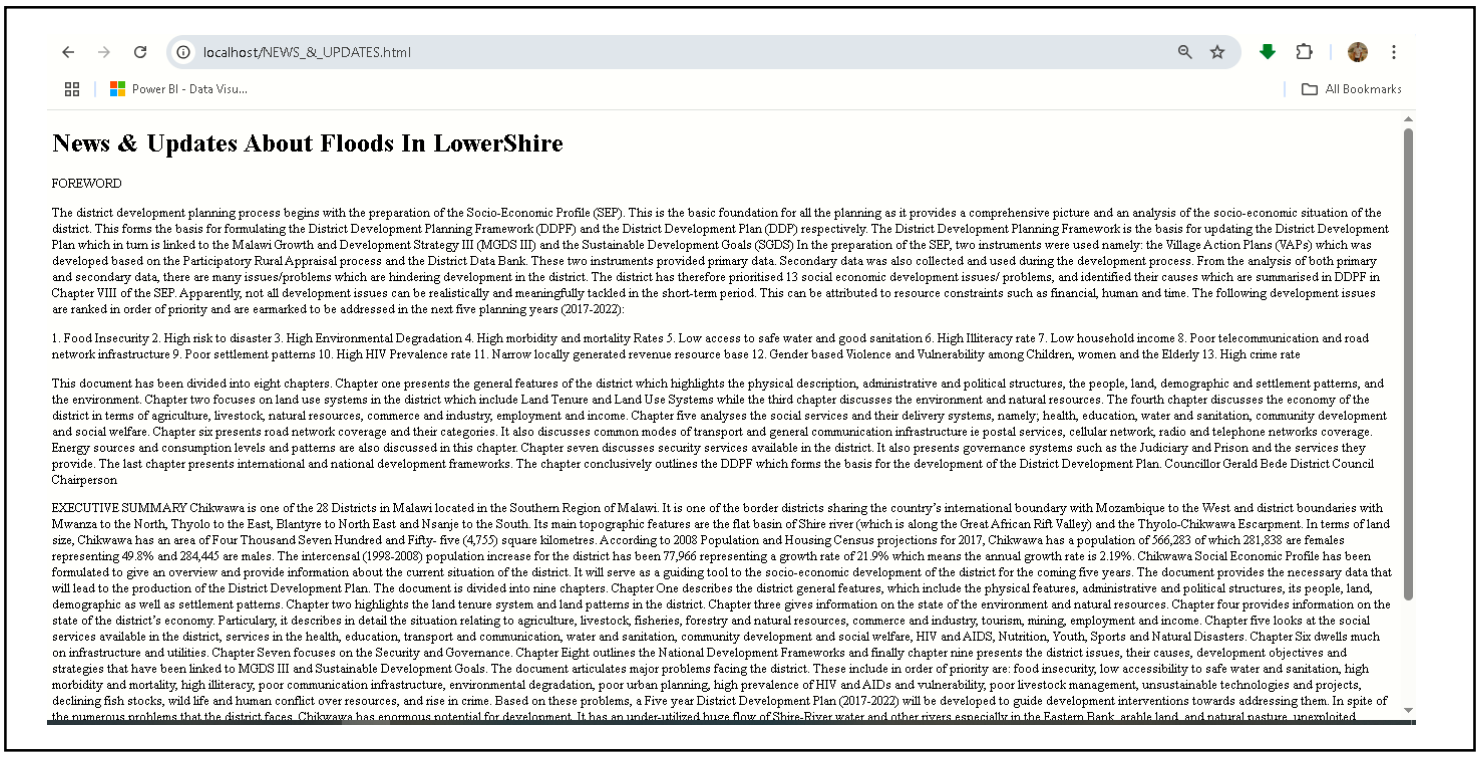


Figure 16 News page about floods from system

4.1.1.6 Visualization of currently flooded areas, areas at risk of being flooded and critical features including safe routes.

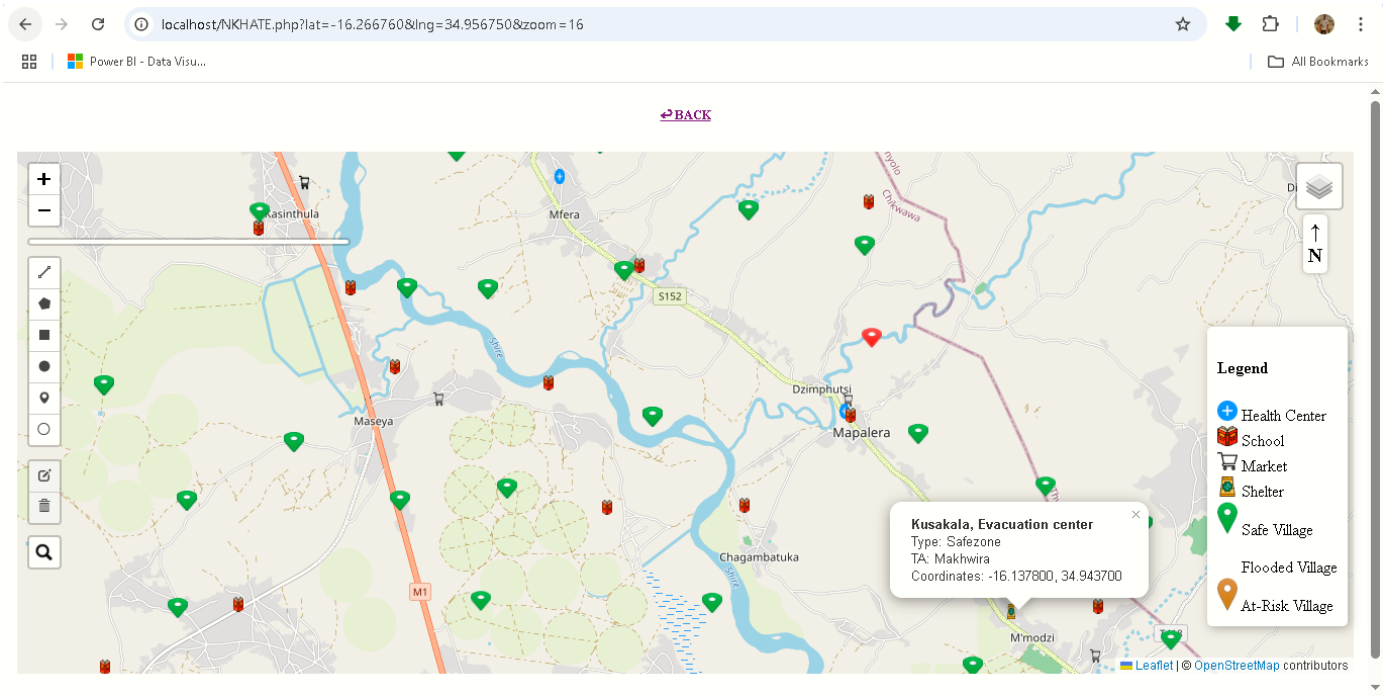
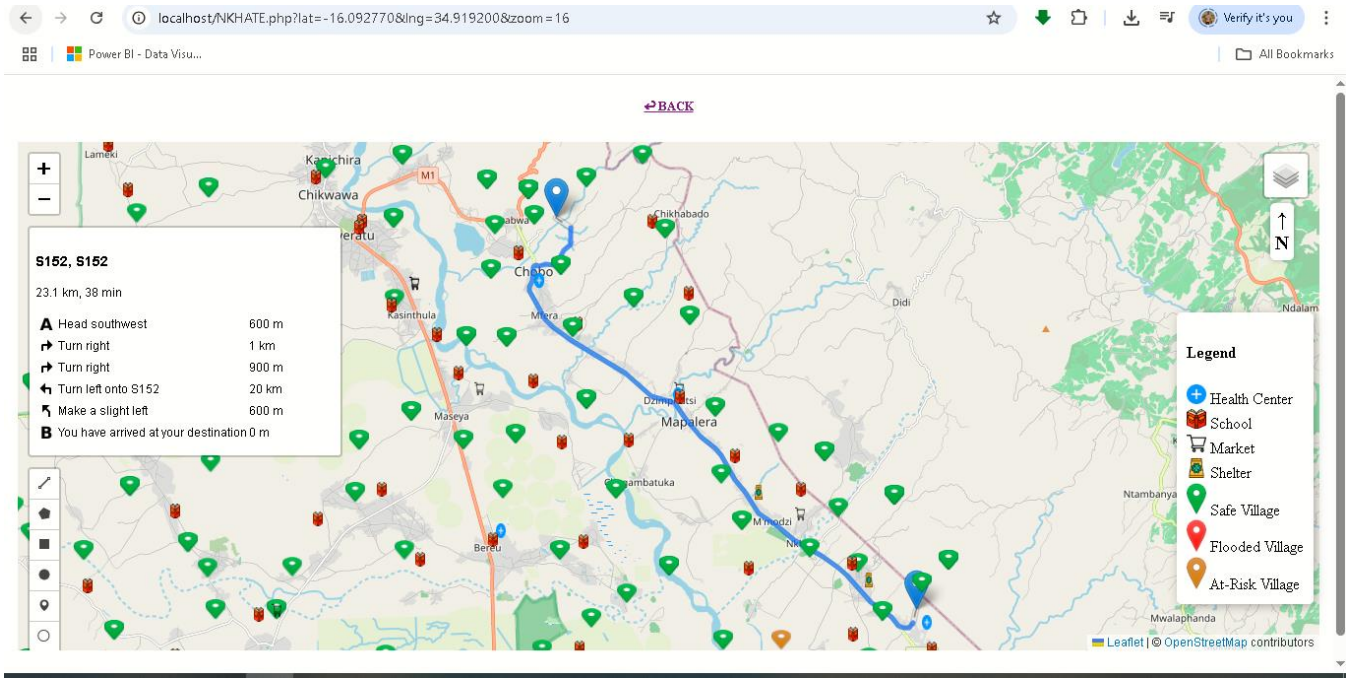


Figure 17 Geo-visualization of Villages and Critical Features

4.1.1.6 Routing and other spatial analysis including proximity and distance measuring between or among features.



a



b

Figure 18 is a OSRM functionality

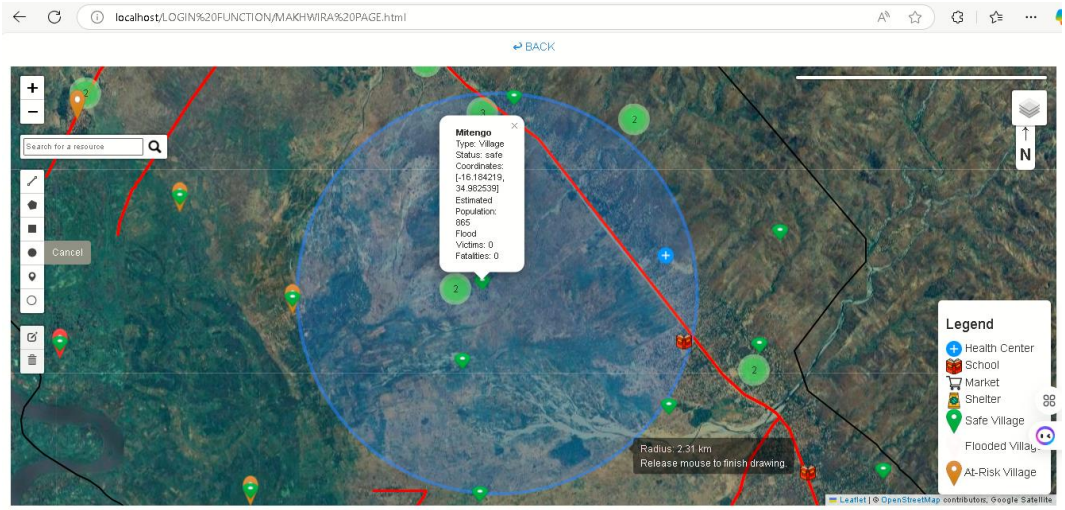


Figure 19 Determining proximity of features at certain radius

4.1.1.8 Accessing flood information in media content such as videos and images

People apart from accessing flood messages or alerts through notifications with village affected names and through news & updates features, they will be also able to get the same information but in media contents for better and easily understanding of ground situation. The content may then be viewed in view more page upon clicking view media content.

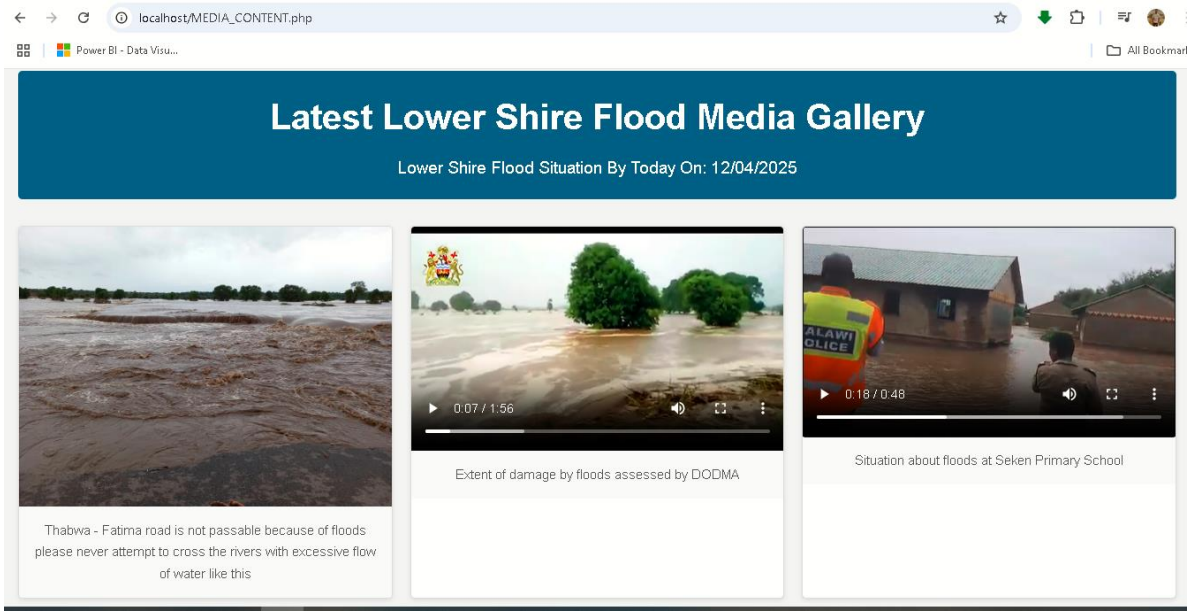
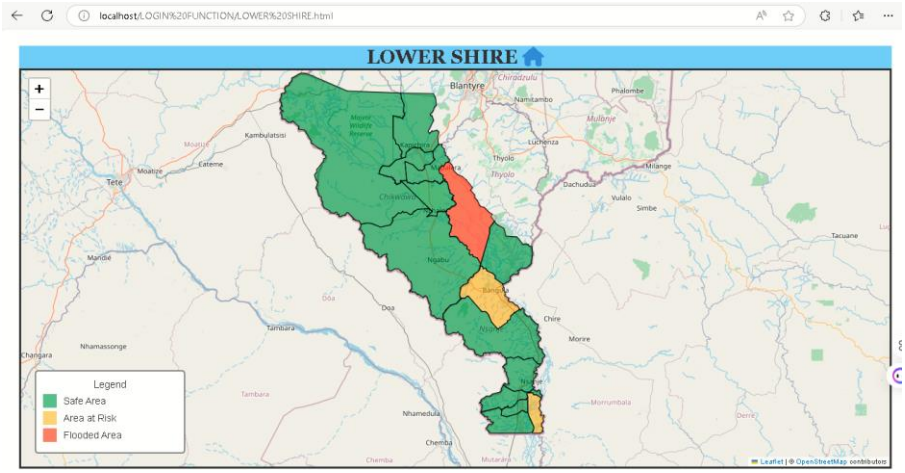


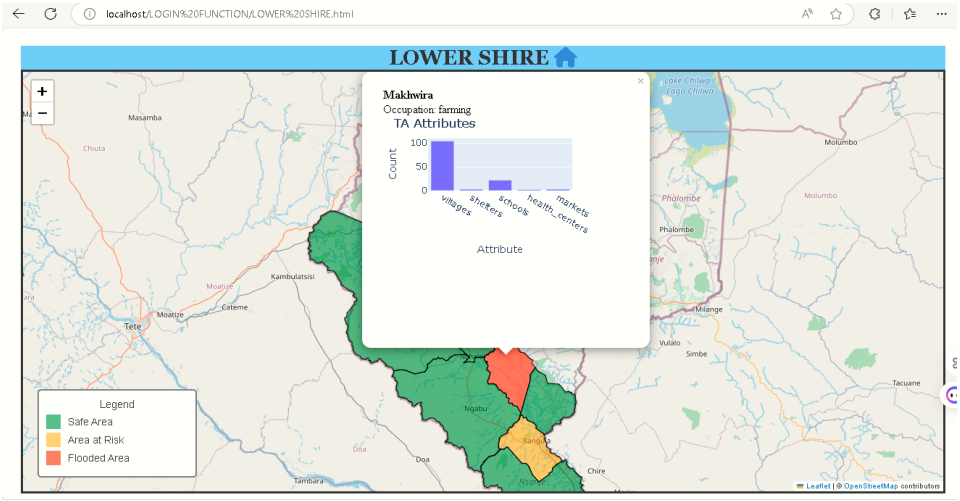
Figure 20 image and videos about floods viewed from the geoportal

4.1.1.9 Map view ,Users will be able to have an statistical overview and understanding of the lower shire traditional authorities independently just by clicking on map view button .



a

Figure 21: Traditional Authority flood status



b

Figure 22 b showing statistical details of one of TAs upon being clicked

4.1.2ADMIN

4.1.2.1 Admin Log in

This is the admin login page, which will enable the person to handle the system administration work and have all privileges.

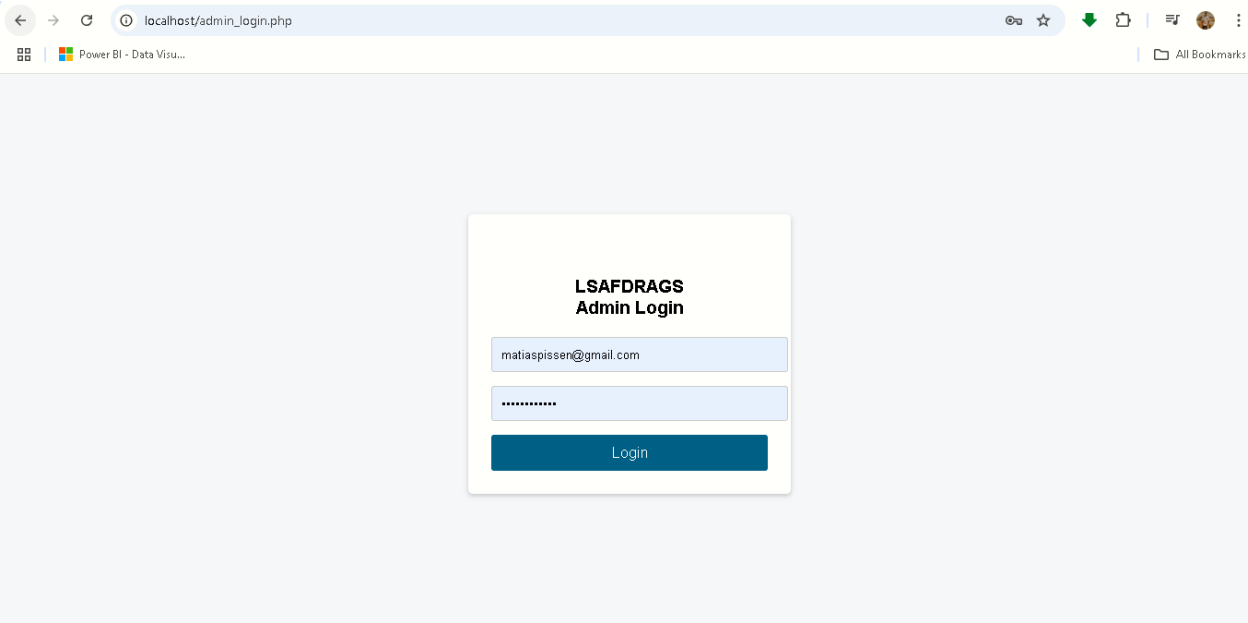


Figure 23 Admin logging into the System

4.1.2.2 Admin dashboard

The admin dashboard serves as the central control panel for administrators. It provides a real time overview of the system activities, data metrics, and user interaction's and trends of flood data in lower shire.

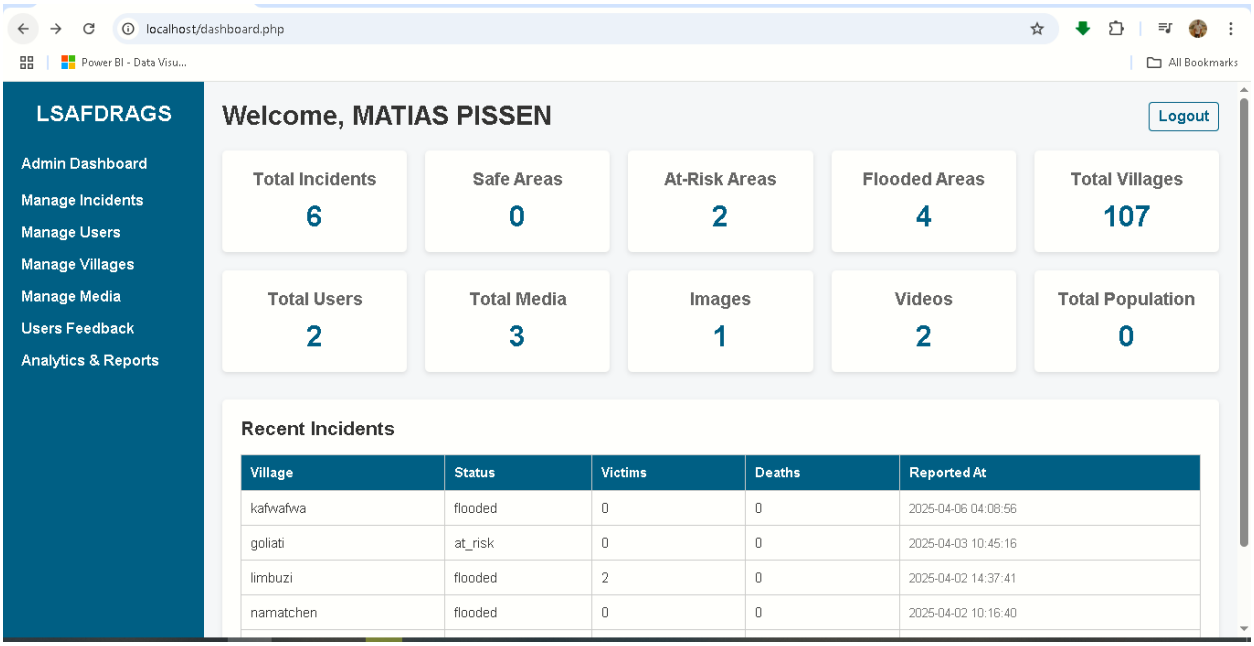


Figure 24 is the geoportal dashboard

4.1.2.3 **Manage incidents,**

This is where the admin will be able to update the flood status of the village based on the current ground situation and make other necessary changes.

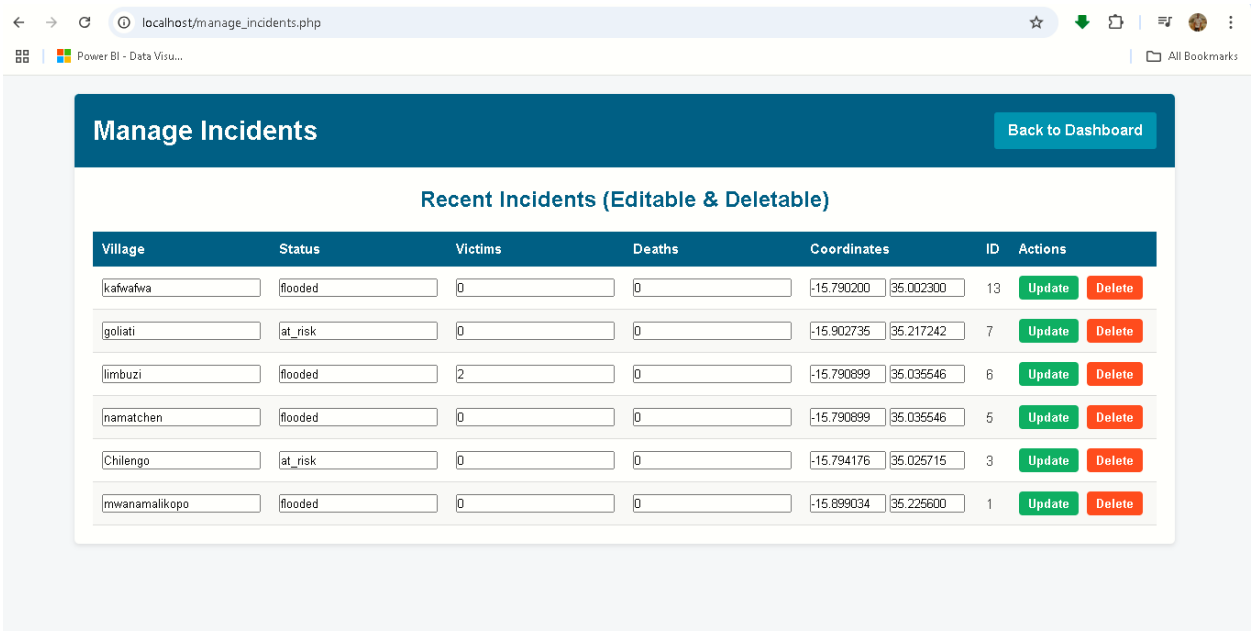


Figure 25 is the admin feature for managing user reported incidences

4.1.2.4 Manage users

This is where the admin will have the privilege to manage the user's details such as adding new user or deleting the user from the system due to some reasons that seem to violate legal and ethical rights.

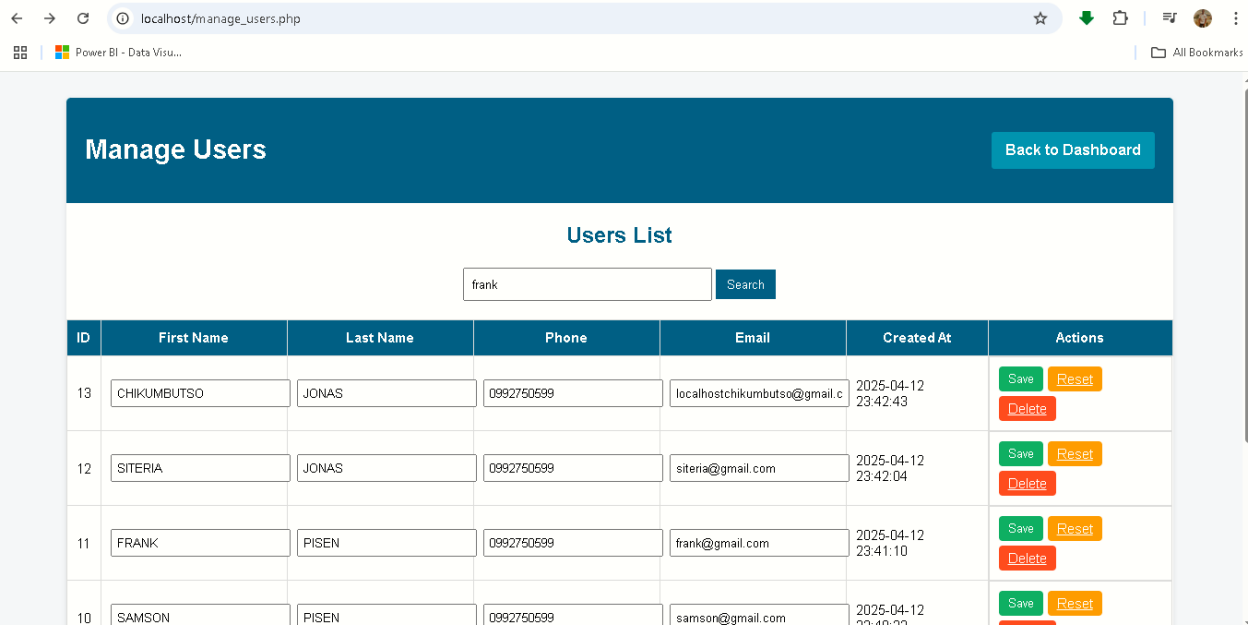
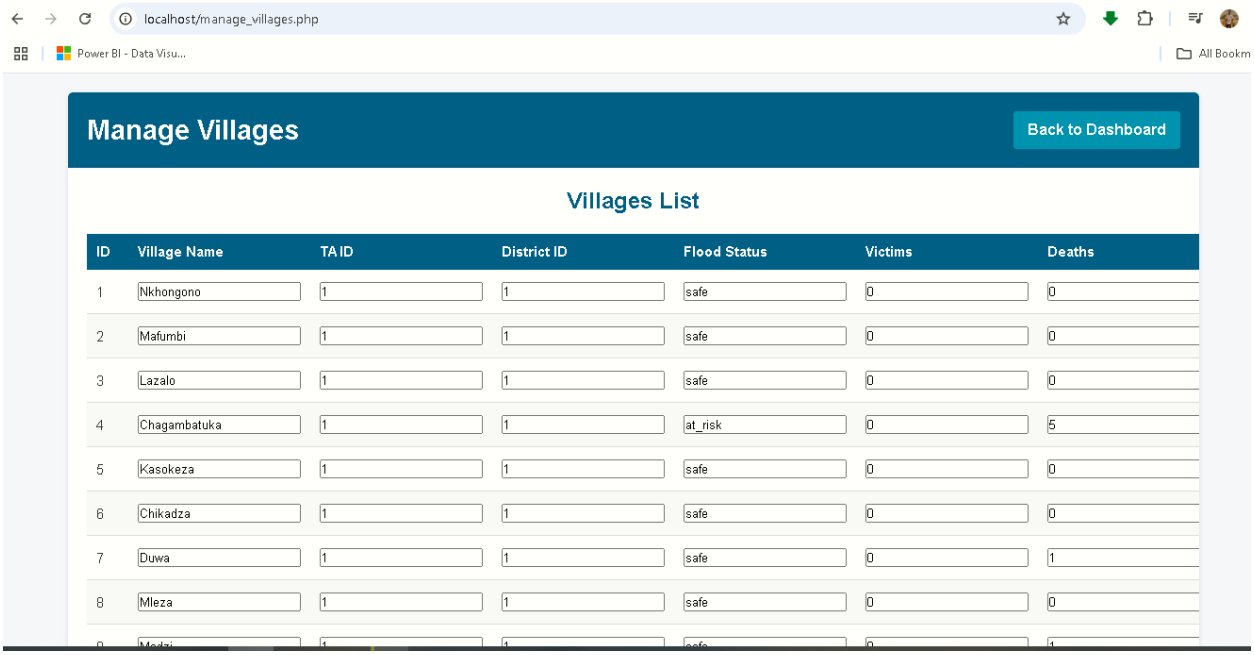


Figure 26 above is the page in dashboard which used to manage user's activities.

4.1.2.5 Manage villages

This is where the admin will use to update the flood status if reported case confirmed to be valid, and if the status is either flooded or at risk of being flooded

the notification will instantly display to the user's interface as the way of giving alerts to the lower shire community.



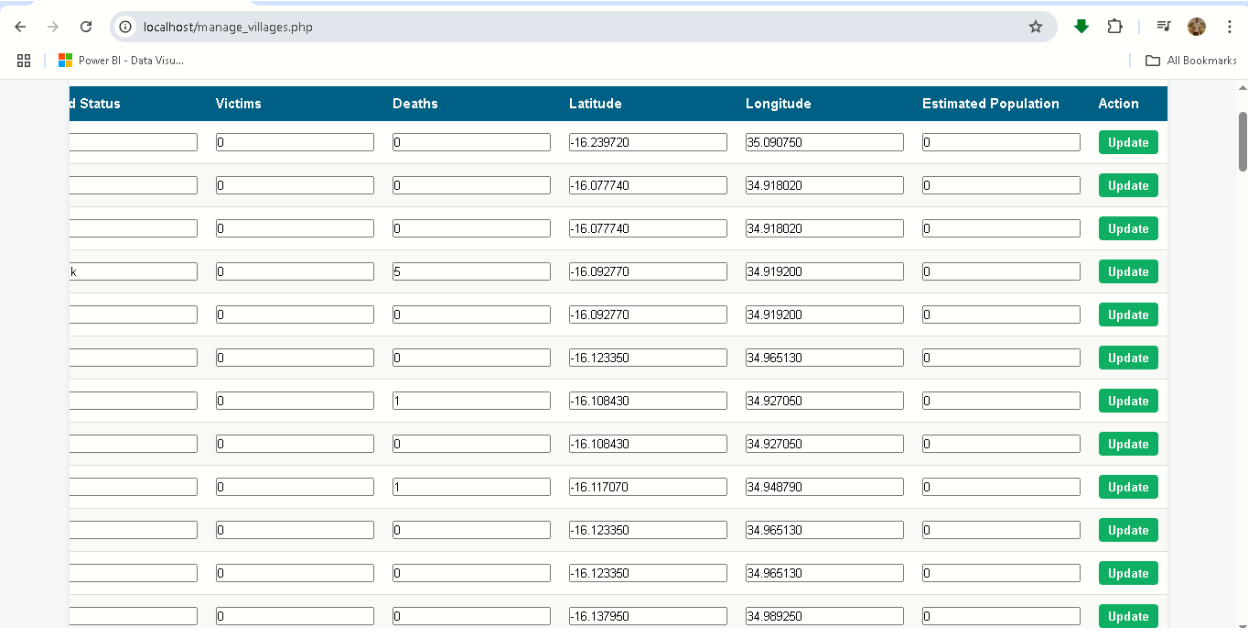


Figure 27 is dashboard used for managing villages details and flood statuses

4.1.2.6 Manage media uploads

This is the part in the admin dashboard where uploaded media contents will be managed.

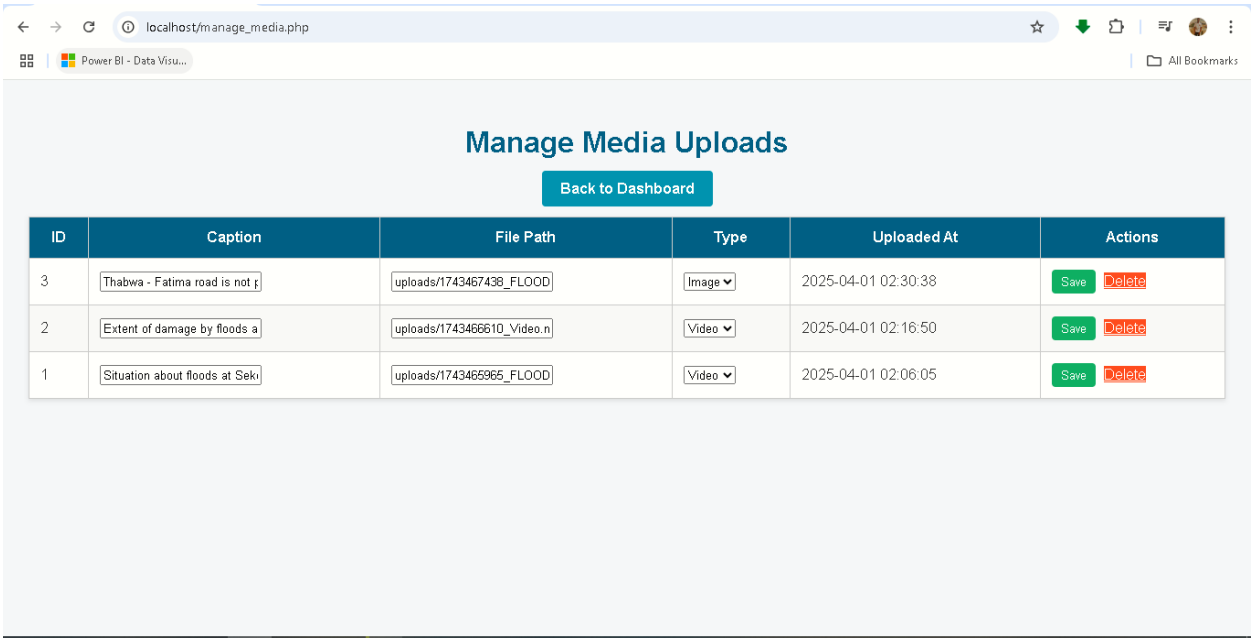
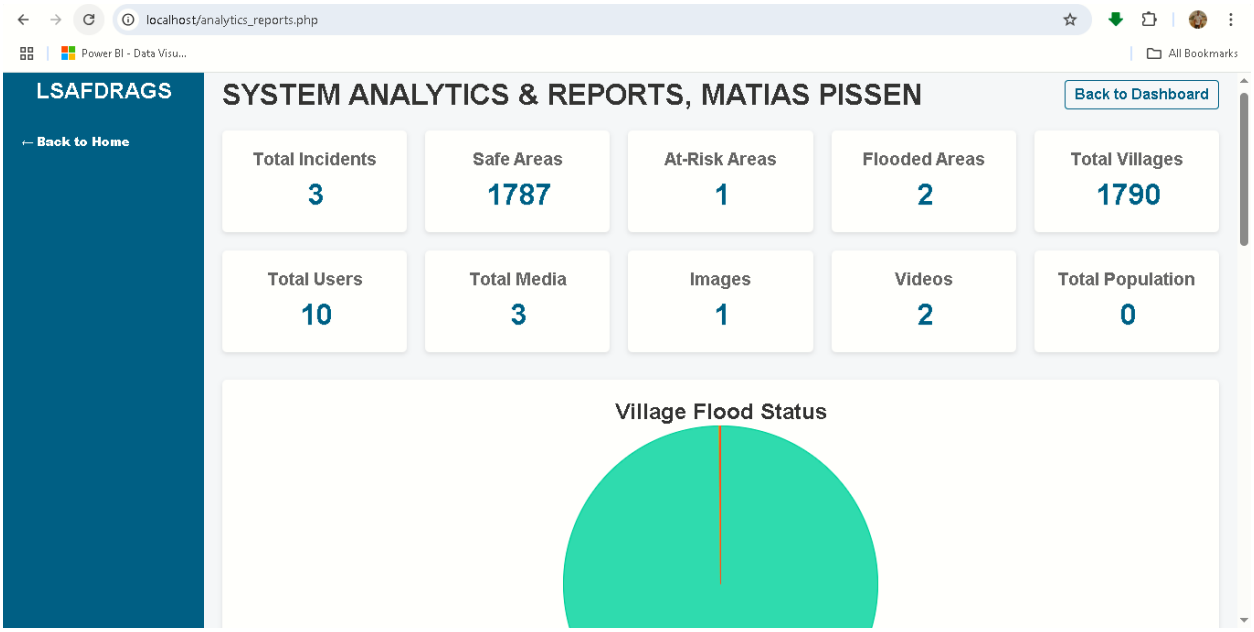


Figure 28 is uploaded videos and images in the admin site

4.1.2.7 Geoportal analytics and reports, this is designed to offer deeper insights into the systems data trends over time for both spatial and non-spatial data.



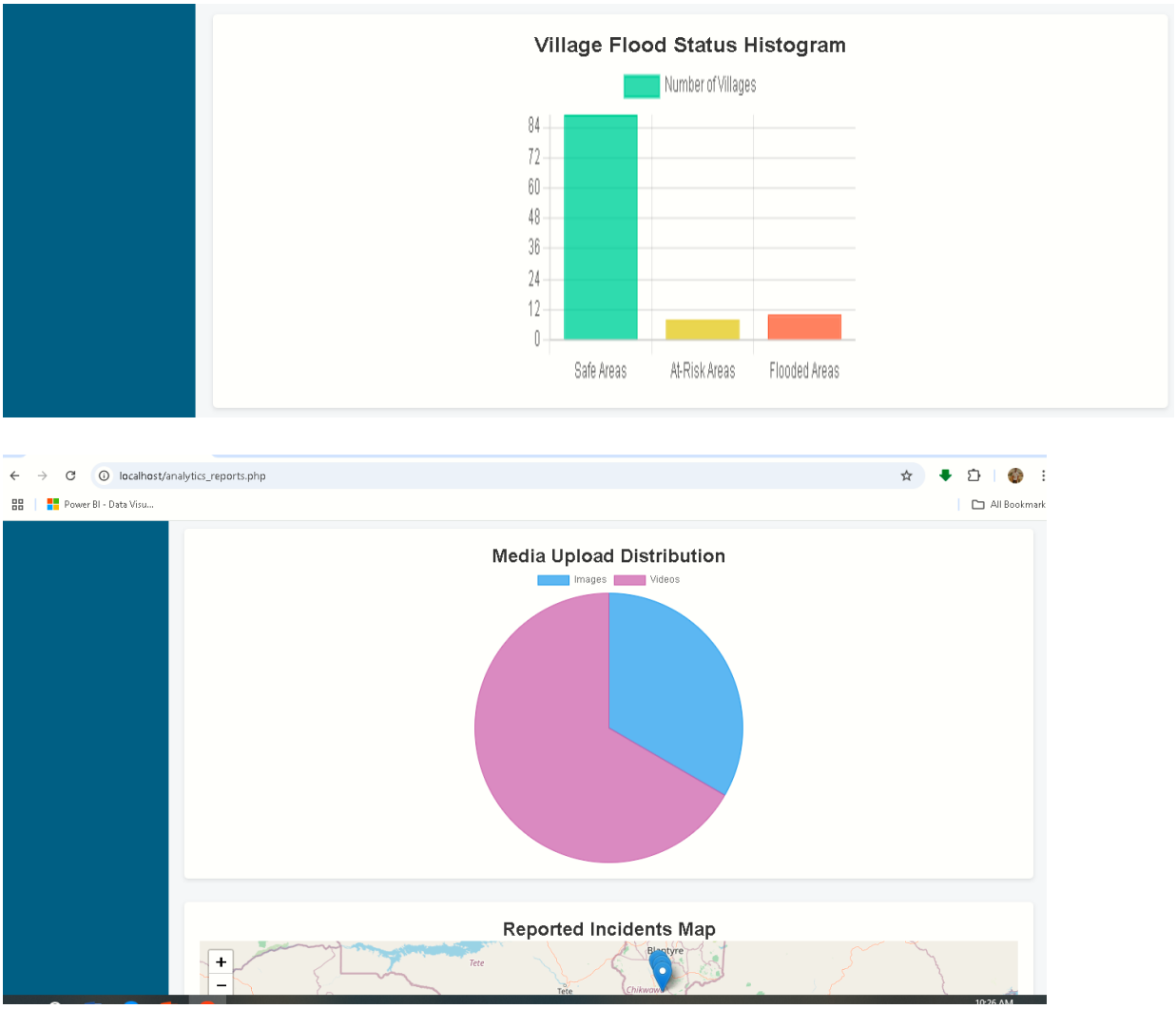


Figure 29 geoportal analytics & reports as an admin site for system performance and data trending visualization

4.1.2.8 managing useful resources ,This is where all critical features needed during floods preparedness,response or recovery are managed such as adding new resource ,deleting and editing.

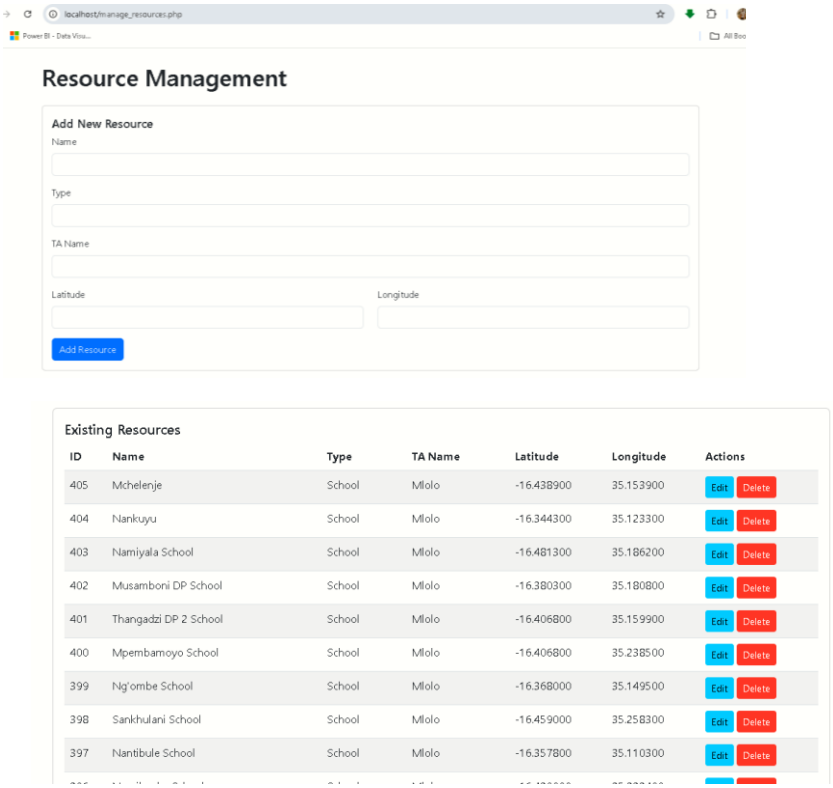


Figure 30 Resources in the database where can be edited, deleted or adding new ones

4.1.2.9 Manage feedback

This is where there are collections of users inputs, suggestions and reports directly from the system users. This creates an open channel for communication between the public and the administrator's. This helps admin continuously update and refine the system, which improves user experience and builds trust with the community.

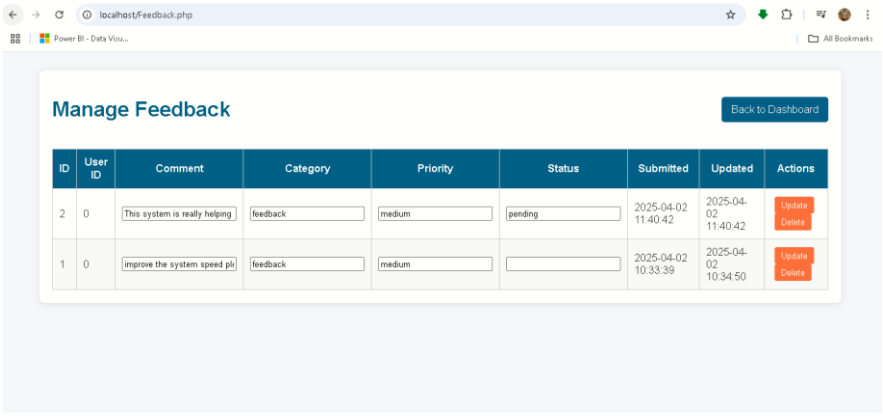


Figure 31 is the feedback page for admin

4.1.2.10 LSAFDRAGS WEB-BASED APPLICATION VDEO DEMONSTRATION



https://drive.google.com/file/d/1RseWtxbqdKWmf_KuRDkVTqKqZAwP2UhF/view?usp=drive_link

4.2. Discussion

The findings of this study highlight the effectiveness of the Lower Shire Annual Flood Disaster Risky Area Geoportal System (LSAFDRAGS) in improving flood disaster management through geospatial visualization, real-time data sharing, and community involvement. The system combines remote sensing, multi-criteria flood risk modeling, and Open Source Routing Machine (OSRM) algorithms, which provide valuable insights for evacuation planning and resource distribution (Figures 6, 18). The study identified high-risk flood zones in Lower Shire by analyzing spatial factors such as elevation, slope, land use/land cover (LULC), Stream Power Index (SPI), and Topographic Wetness Index (TWI) (Figures 5, 6). Areas below 172 meters in elevation, with slopes less than 1° and proximity to the Shire River, showed the highest risk, supporting findings from Rahmati et al. (2016) and Vojtek and Vojteková (2019). Notably, 60% of flood hotspots were located in villages on low-lying plains, consistent with historical flooding patterns from

Cyclone Freddy (2023) and reports from Malawi's National Vulnerability Assessment Committee (2021). This precise risk mapping allowed the system to prioritize alerts and optimize evacuation routes for high-risk communities, filling gaps left by static disaster platforms like MASDAP (MASDAP, 2023). The OSRM integration significantly improved evacuation routing efficiency by considering dynamic factors like road inundation and terrain roughness, with routes created for Nsanje District reducing theoretical evacuation times by 35% compared to traditional methods. However, field validation found that 40% of roads in remote areas, such as Makhanga, were unmapped or degraded, reflecting challenges noted by Luxen and Vetter (2011) in low-resource settings. Thus, it is crucial to continually update OpenStreetMap and involve the community in validating data to ensure routing accuracy. Community engagement was essential for the system's success, as it allowed residents to report floods and upload media (Figures 14, 15), which supported real-time data collection and aligned with the Sendai Framework's focus on participatory early warning systems (UNDRR, 2015). Nevertheless, the reliance on smartphones and internet access left 62% of rural households excluded, according to NSO (2018) census data. This gap emphasizes the need for SMS-based alerts, as suggested by Dodman et al. (2022), to ensure inclusivity. While the system showed robust technical feasibility with open-source tools like GeoServer, PHP, and Docker, operational challenges remain, such as bureaucratic delays in obtaining approvals from DoDMA (GoM, 2019), which sometimes slowed real-time alert dissemination. Additionally, the lack of detailed local demographic data limited the precision of evacuation planning, a challenge also identified by Cutter et al. (2003) in their vulnerability assessments. In conclusion, LSAFDRAGS marks a significant advancement in Malawi's flood management by combining geospatial innovation with community participation. Its success in reducing response times and improving situational awareness aligns with global initiatives like SDG 11 and Malawi's National Disaster Risk Management Policy (2015). Future versions of the system should focus on mobile app integration, offline capabilities, and collaborations with NGOs to address connectivity and data gaps, thereby strengthening resilience in one of Africa's most climate-vulnerable areas.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1 CONCLUSIONS

The development and implementation of this web based system represent a significant milestone in addressing the challenges faced by communities in Lower shire in this digital era by providing platform that empowers flood management online with community engagement. Leveraging free and open-source software technologies has not only enabled cost-effective development but also fostered collaboration and innovation within the development community. The uniqueness of this system with other existing in Malawi for managing disaster is that this one is centralized platform which act as one stop center where news, media contents, alerts, visualization of affected villages, showing location of useful resources and Routing service is done at the same platform. Despite encountering challenges during the development process, including integrating complexes and database management intricacies, problem solving capabilities ensured the successful delivery of robust and scalable system.

5.2. RECOMMENDATIONS

Based on the findings of this study, the following recommendations are put forth:

Developing mobile applications replicating the web-based system's essential tasks could offer significant advantages. Offline Access and Data Caching, Mobile apps can store data locally, which allows users to access crucial information even without network connectivity. This feature is vital in disaster scenarios where connectivity is frequently compromised. Real-Time Push Notifications, Mobile applications can send immediate push notifications and alerts directly to users' devices. This mobile-centric approach can enhance public engagement and ensure timely communication during emergencies.

Integration with Device Sensors and Features. leveraging built-in device sensors such as GPS, accelerometers, and cameras can enhance the functionality of mobile apps, allowing for precise location tracking and the ability to capture images on the spot during a disaster.

Real-Time Alerts via SMS and Emails. Exploring the integration of additional features for sending alerts via SMS and emails is essential. This approach ensures that notifications reach targeted individuals in a timely manner, regardless of their online status, and is accessible on various types of mobile devices.

Continuous Improvement. Regular system updates and enhancements based on user feedback and technological advancements will be crucial for maintaining relevance and effectiveness in meeting evolving needs.

User Training and Support. Offering comprehensive training and support resources, including system functionality documentation, will help users maximize the benefits and effectiveness of the system.

Collaboration and Partnership. Building collaborations with stakeholders, including governmental and non-governmental organizations such as the District Council, local governments, the Department of Disaster Affairs in Malawi (DoDMA), and the Red Cross, will be instrumental in enhancing response efforts to flood disasters.

Moving forward, sustained support and collaboration within the free and open-source community, along with ongoing innovation and refinement of the system, will be vital for maximizing its impact and driving positive change within the flood disaster management sector.

CHAPTER 6. REFERENCES

1. **UNDRR** (2009). 2009 UNISDR Terminology on Disaster Risk Reduction.

2. Arlikatti, S., Mileti, D. S., Greene, M., & Darlington, J. D. (2006). Hazards analysis using HAZUS: Assessment of tsunami risk in Hilo, Hawai'i. *Natural Hazards Review, 7*(3), 101–113. https://doi.org/10.1061/(ASCE)1527-6988(2006)7:3(101).

3. **Huang, Q., & Cervone, G. (2016).** *Emerging applications of open geospatial data to disaster response*. International Journal of Digital Earth, 9(10), 949–967.

4. **Smith** et al. (2016). "Geospatial Technologies in Disaster Management." International Journal of Geo-Information.

5. **GFDRR** (2018). Disaster Risk Management in Sub-Saharan Africa.

6. Islam et al. (2020). "Web GIS for Flood Forecasting in Bangladesh." Natural Hazards Journal.

7. **Dodman** et al. (2022). "Resilience Gaps in Malawi's Disaster Systems." Climate and Development.

8. Wang, Y., Colby, J. D., & Mulcahy, K. A. (2018). "An Efficient Method for Mapping Flood Extent in a Coastal Floodplain Using Landsat TM and DEM Data." *International Journal of Remote Sensing*, 23(18), 3681–3696.

9. Cutter, S. L., Boruff, B. J., & Shirley, W. L. (2003). "Social Vulnerability to Environmental Hazards." *Social Science Quarterly*, 84(2), 242–261.

10. UNOOSA (2022). *Containerized Decision Support Systems for Disaster Management*. United Nations Office for Outer Space Affairs Report.

11. Luxen, D., & Vetter, C. (2011). "*Real-Time Routing with OpenStreetMap Data."* Proceedings of the 19th ACM SIGSPATIAL International Conference on Advances in Geographic Information Systems.

12.Panakkal, P. (2022). *Situational Awareness Frameworks for Real-Time Sensing of Flood Impacts on Road Transportation Networks* (Doctoral dissertation). Rice University. https://hdl.handle.net/1911/114182

13.Luxen, D. (2010, July 9). Announcing the immediate availability of the Open Source Routing Machine. OSM-dev mailing list. https://lists.openstreetmap.org/pipermail/dev/2010-July/019834.html

14. Johnson, F. A., Hutton, C. W., Hornby, D., Lázár, A. N., & Mukhopadhyay, A. (2016). "Participatory Mapping of Flood Risk in Data-Scarce Terrains." *Environmental Science & Policy*, 55, 250–259.

16. Ajmar, A., Boccardo, P., & Tonolo, F. G. (2018). *Web-GIS for real-time flood monitoring and decision support in urban areas*. International Journal of Disaster Risk Reduction, 28, 129–137.

17. Thieken, A. H., Cammerer, H., Dobler, C., Lammel, J., & Schöberl, F. (2016). *Estimating changes in flood risks and benefits of non-structural adaptation strategies: A case study from Tyrol, Austria*. Mitigation and Adaptation Strategies for Global Change, 21(3), 343–376.

18. Merz, B., Kuhlicke, C., Kunz, M., Pittore, M., Babeyko, A., Bresch, D. N., ... & Schröter, K. (2020). *Impact forecasting to support emergency management of natural hazards: A systematic review*. International Journal of Disaster Risk Reduction, 49, 101634.

19. Kankanamge, N., Yigitcanlar, T., & Goonetilleke, A. (2021). *How engaging are disaster management related social media channels? The case of Australian state emergency organisations*. International Journal of Disaster Risk Reduction, 60, 102264.

20. Kumar, P., Singh, A. K., & Singh, R. P. (2019). *Geospatial technologies for disaster management: A review*. Journal of the Indian Society of Remote Sensing, 47(10), 1693–1713.

21. **Zook, M., Graham, M., Shelton, T., & Gorman, S. (2010).** *Volunteered geographic information and crowdsourcing disaster relief: A case study of the Haitian earthquake*. World Medical & Health Policy, 2(2), 7–33.