Vulnerability

vulnerability was defined as the degree to which a system is exposed and susceptible to the adverse effects of a given hazard.

Vulnerability = (Exposure) + (Resistance) + Resilience

Exposure: at risk property and population
Resistance: Measures taken to prevent, avoid or reduce loss
Resilience: Ability to recover prior state or achieve desired post-disaster state.

- **Types of Vulnerability**

- Physical vulnerability
- This refers to the potential losses to physical infrastructure such as roads, bridges, railways, radio and telecommunication mast and other features in the built environment.
- Also includes impacts on the human population in terms of injuries or deaths.

- **Social vulnerability**

- Social vulnerability refers to losses as experienced by people and their social, economic, and political systems
- Vulnerability refers to the extent to which elements of society such as children, the aged, pregnant and lactating women, single parents, physically and mentally challenged, the poor and destitute, social class, caste, ethnicity, gender, family systems, political systems, economic systems and cultural values degrade after being exposed to a hazardous condition.

- **Economic vulnerability**

- This refers to the potential impacts of hazards on economic assets and processes and includes vulnerability of different economic sectors.

- **Ecological/environmental vulnerability**

- This refers to the degree of loss that an ecosystem will sustain to its structure, function and composition as a result of exposure to a hazardous condition.

- **Vulnerability Assessment**

- This refers to the quantification of the degree of loss or susceptibility to an element at risk.
- Variations exist in the method of quantification of vulnerability based on the following:

a. Type of vulnerability being measured

b. The scale at which vulnerability is being measured

c. The type of hazard.

- ***Data needed for vulnerability assessment and their usefulness***

- Historical data on the magnitude of a hazard and the level of damage it caused
- Socio-economic data such as level of education, social networks, sanitation, income level, access to land, access to technology etc
- Level of exposure to hazardous conditions
- Data on policies, institutions and processes which influence capacity of individuals, households and communities

- **Approaches to Physical Vulnerability Assessment**

- There are a wide variety of ways to measure physical vulnerability.
- Two main methods are the empirical and analytical methods.
- The analytical methods rely on the use of geotechnical engineering software and are often limited to individual structures
- The empirical methods can be applied to groups of related structures.

Methods of measuring physical vulnerability

Group	Method	Description
Empirical methods	**Analysis of observed damage**	Based on the collection and analysis of statistics of damage that occurred in recent and historic events. Relating vulnerability to different hazard intensities.
	Expert opinion	Based on asking groups of experts on vulnerability to give their opinions, e.g. the percentage damage they expect for the different structural types having different intensities of hazard. This is meant to come to a good assessment of the vulnerability. Method is time consuming and subjective. Re-assessments of vulnerability after building upgrading or repair are difficult to accommodate.
	Score Assignment	Method using a questionnaire with different parameters to assess the potential damages in relation to different hazard levels. The score assignment method is easier to update, e.g. if we think about earthquake vulnerability before and after application of retrofitting.

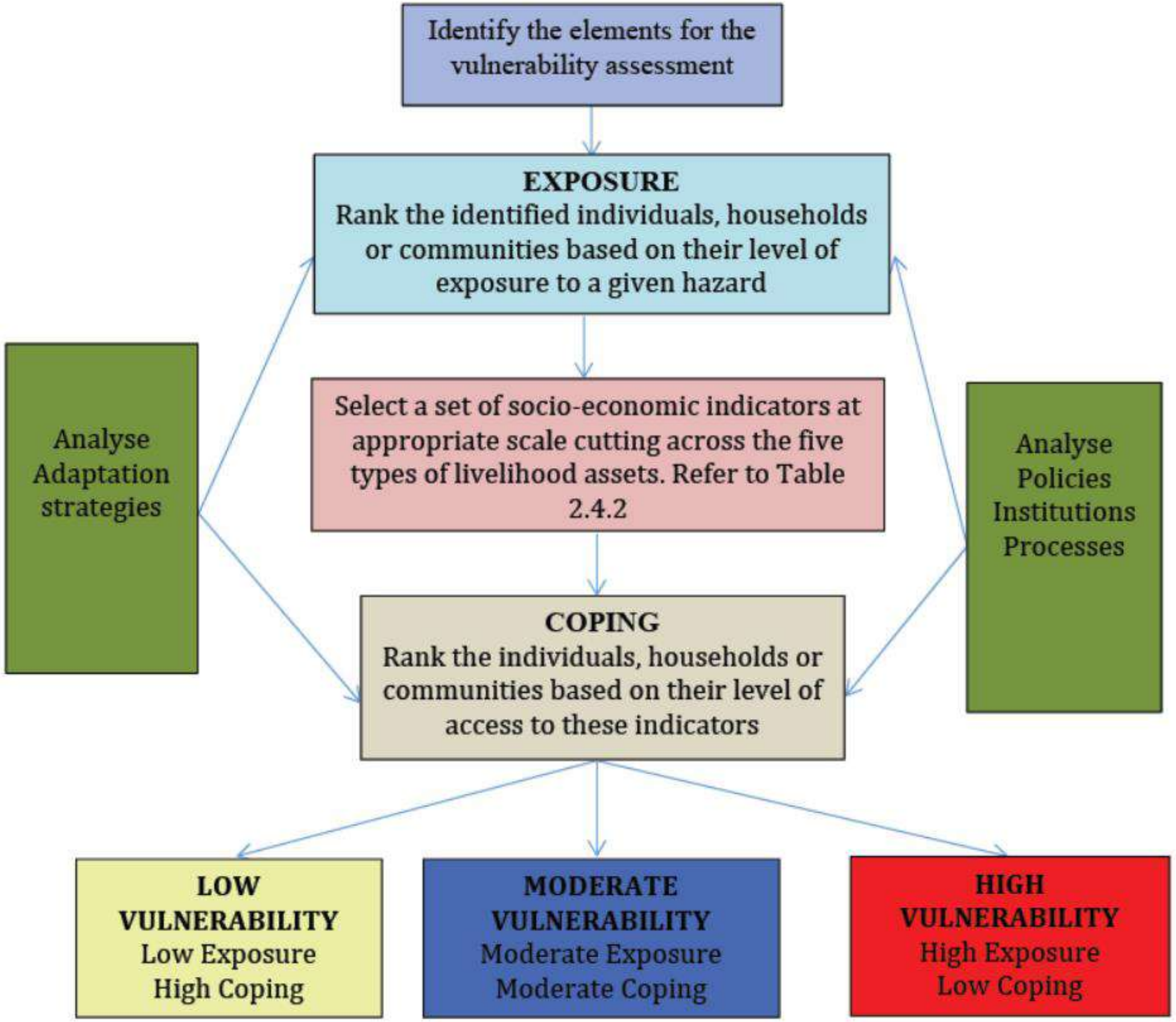
Methods of measuring physical vulnerability

Analytical models	**Simple Analytical models**	Studying the behaviour of buildings and structures based on engineering design criteria, analysing e.g. seismic load and to derive the likelihood of failure, using computer based methods from geotechnical engineering. Using, e.g. shake tables and wind tunnels, as well as computer simulation techniques.
	Detailed Analytical methods	Using complex methods. It is time consuming, needs a lot of detailed data and will be used for assessment of individual structures.

- **Methods of Measuring Socio-economic Vulnerability**

Socio-economic vulnerability is indicator-based and can be assessed by analysing the level of exposure and coping mechanisms of individuals, households and communities.

- **Method for assessing socio-economic vulnerability**



Socio-economic indicators

Human Capital	Natural Capital	Social Capital	Physical Capital	Financial Capital
Health	Land and produce	Networks and connections	Infrastructure • Transport - roads, vehicles, etc. • Secure shelter & buildings water supply & sanitation	Savings
			• Energy communications	
Nutrition	Water & aquatic resources	Patronage	Tools and technology • Tools and equipment for production • Seed, fertiliser, pesticides • Traditional technology	Credit/debt - formal, informal, NGOs
Education	Forest products	Neighbourhoods		Remittances
Knowledge and skills	Wildlife	Kinship		Pensions
Capacity to work	Wild foods & fibres	Relations of trust and mutual support		Wages
Capacity to adapt	Biodiversity	Formal and informal groups		Dividends
	Environmental services	Common rules and sanctions		Return on Investments

- **Methods of Representing Vulnerability**
- **Vulnerability indices**: Based on indicators of vulnerability
- **Vulnerability table**: The relation between hazard intensity and degree of damage can also be given in a table.
- **Vulnerability curves**: These are constructed on the basis of the relation between hazard intensities and damage data

➢ Relative curves: They show the percentage of property value as the damaged share of the total value to hazard intensity.

➢ Absolute curves: Show the absolute amount of damage depending on the hazard intensity

➢ Fragility curves: Provide the probability for a particular group of elements at risk to be in or exceeding a certain damage state under a given hazard intensity.

Hazard Mapping

- Hazard mapping involves a graphical representation of the location, magnitude and temporal characteristics of hazards on 2 or 3 dimensional surfaces.

- The objective of this it to represent the spatial and temporal characteristics of the hazard as well as its magnitude using graphical symbols.

Different Categories of Hazard

- Hazard can be categorized based on their origin, that is, whether they are natural, human-induced or technological.

- **Natural hazards** are phenomena experienced in the physical environment which are harmful to humans and caused by forces for which there is no control.

- Examples of natural hazards are floods, earthquakes, volcanic eruptions and hurricanes.

A view of urban flood at Kaneshie Market Complex, Accra in 2014

Volcanic eruption of Mount Etna, Italy in 2013.

- **Human-induced hazards** are changes of natural processes within the earth's system caused by human activities which accelerate or aggravate damaging events.

- Oil spills, atmospheric pollution, and major armed conflicts are some of such hazards.

Disabled oil vessel discharges oil into the Gulf of Mexico in 2005

- **Technological hazards** are dangers caused by technological or industrial accidents, infrastructure failures or certain human activities.

- Nuclear activities and radioactivity, dam failures, transport, industrial or technological accidents (explosions, fires, spills) are some of the technological hazards.

A collapsed building in Dkata, Bangladesh in 2013

The scene after fire at a fuel filling station in Accra, 2015

The scene of a train crash at Southhall, London in 2002

- Hazards can be single (such as volcanoes and earthquakes), sequential (such as flood) or combined (such as earthquake accompanied by tsunami) and, as a result, causing a flood or torrential rains leading to landslides in their origin.

- Each hazard is categorized by its location, intensity, occurrence, probability, duration, distance, speed of onset, spatial dispersion and temporal spacing.

- **Data Requirements of Hazard Mapping**

- Spatial characteristics such as location, distribution and dimension; temporal (duration and speed of onset) and magnitude are the major data requirements for hazard mapping.

Such information can be obtained through the following sources:

- ***Base maps***
- Base maps represent topographic layers of data such as elevation, roads, water bodies, cultural features and utilities.
- It must be plan metric, ie a representation of information on a plane in true geographic relationship and with measurable horizontal distances.
- It must orient the user to the location of the hazard.

- ***Remotely sensed images***
- Satellite images are sources of readily available information of locations on the earth's surface compared to conventional ground survey methods of mapping that are labour intensive and time consuming.

- Depending on the sensor type or capabilities (spatial resolution, spectral resolution, radiometric resolution and temporal resolution), different images may be obtained from different service providers to feed into the information extraction process.

- RADARSAT, TerraSAR-X, ALOS and LIDAR, for instance, are some of the sensors that produce Digital Elevation Model (DEM) depicting topography.

- GeoEye, QuickBird and ALOS-PRISM are preferred sensors for visual mapping as they are of high spatial resolutions.

- ***Field data***

- Ground surveying methods using electronic survey systems like Total Station, the global positioning systems (GPS) and Laser Scanners, have all greatly increased opportunities for data capture in the field.

- **Cartographic Representation of Hazard**

- Maps are the most operative way to convey actual and relative location.

- Hazard maps not to just convey the existence of natural hazards, but also to note their location, severity, and likelihood of occurrence in an accurate, clear, and convenient way.

- The application of cartography in hazard mapping will eventually lead to the creation of:

- ***Base map*** which contains sufficient geographic reference information to orient the user to the location of the hazard.

- ***Scale and coverage*** which draw the relationship between linear measurement on the map and the actual dimension on the ground.

- Small-scale maps show less detail for a large area and are applicable for regional development planning.

- Large-scale maps reveal more detail for a small area and are more suitable for local or community level development planning.

- The choice of scale for a hazard map may consider the following issues:

  - Number of hazards to be displayed at a go;
  - The hazard elements necessary to be displayed;
  - Range of relative severity of hazards to be shown;
  - The area of interest to cover;
  - The use of the map with other planning documents;
  - Function of the map

- ***Types of symbols***

- Symbols are used to represent reality
- Symbols are selected for their legibility and clarity and/or map production characteristics.
- Location can be depicted using one of these basic geometric symbols – point, line or an area.
- Points are more preferred for displaying volcanoes, while areas have been used for showing flooding.

- **Approaches to Hazard Mapping**

- In these approaches the key factors of consideration in the spatial analysis is appreciating that:

▪ all components of a hazard assessment vary in space and time;

▪ as the consequences of hazards are usually large, it is prudent to include vulnerability and risk reduction strategies in the process.

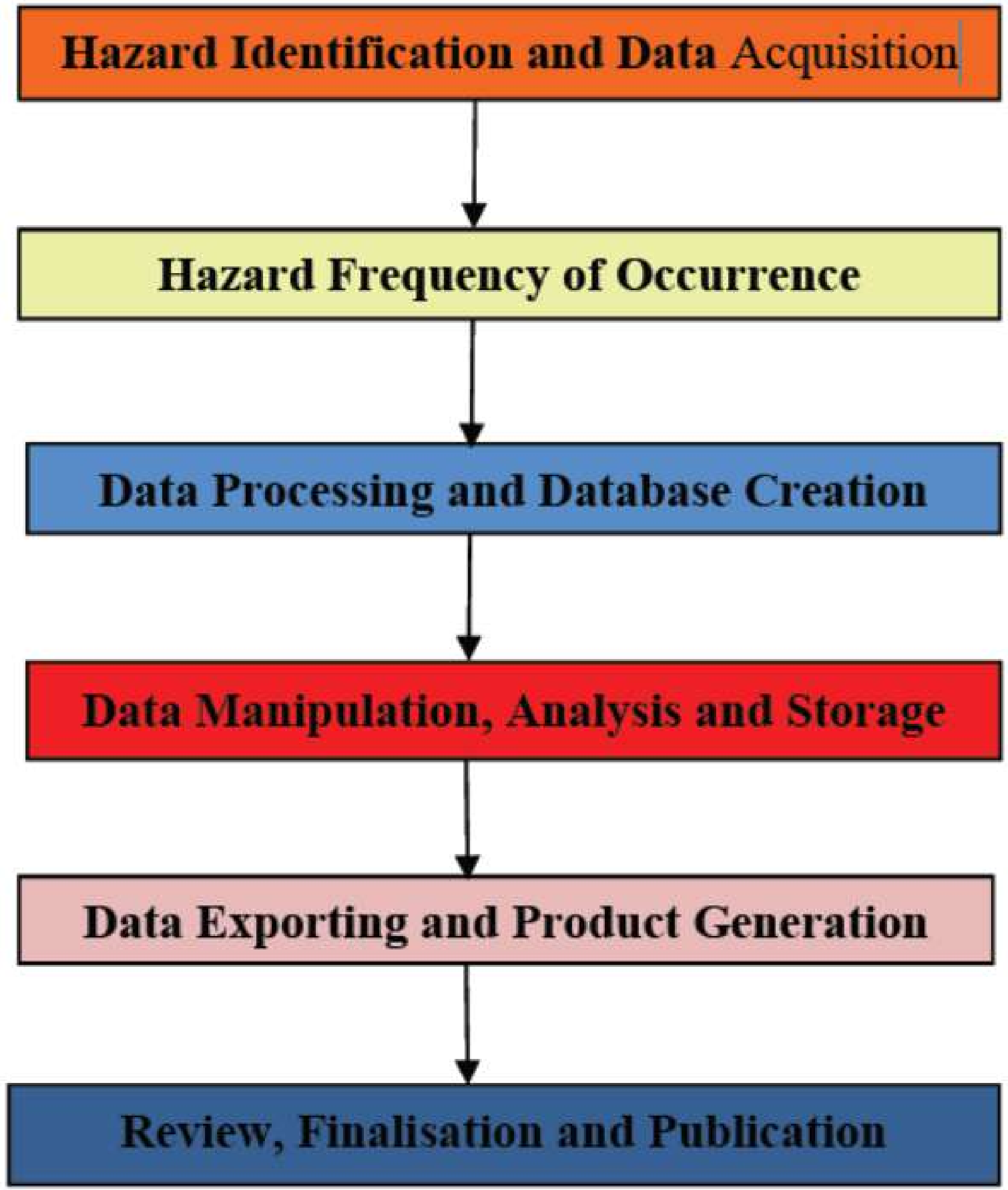
- ***Hazard mapping using GIS***

- GIS provides an excellent basis for processing and presenting hazard information in the form of maps.

- GIS is very useful in arranging a high volume of data necessary to produce a hazard map.

- The three-dimensional representation available in modern GIS offers opportunity to model hazard.

GIS mapping of hazards



- ***Participatory mapping***

- Participatory mapping is a technique that allows for the integration of local level participation and knowledge in the map production and decision taken process.

- It is an interactive process that draws on local people's knowledge and allows them to create visual and non-visual data to explore social problems, opportunities and questions.

- In participatory mapping, the main objectives are to:

- collect evidence assets of the study area and issues during the mapping process;
- interpret the study area mapping experience and related experience to answer questions that have been developed about the study area;
- develop a presentation that synthesises the participatory mapping experience and presents the conclusion and possible questions for further investigation.

- **How to Conduct Participatory Mapping**
- Outlines the nature and essence of activities to be done.
- Organize the activities of participatory mapping in two blocks – preparation and implementation.
- The preparation involves ‘scouting’ and ‘designing survey instrument, materials and directions’.
- The implementation may be organised into sessions- preparation of participants; undertake participatory mapping field trip; make presentations and carry out debriefing exercises.

- **Utilisation of Participatory Mapping**

- To create maps that represent resources, hazards, community values, usage, perceptions, or alternative scenarios
- To gather traditional knowledge and practices and to collect information for assessments or monitoring
- To identify data gaps.
- To inform other data collection methods
- To evaluate existing programmes, plans and activities
- To facilitate the decision-making process
- To assist with data gathering for research

- To empower stakeholders
- To conduct trend analysis
- To educate stakeholders about issues and interrelationships of resources outside their immediate areas of concern

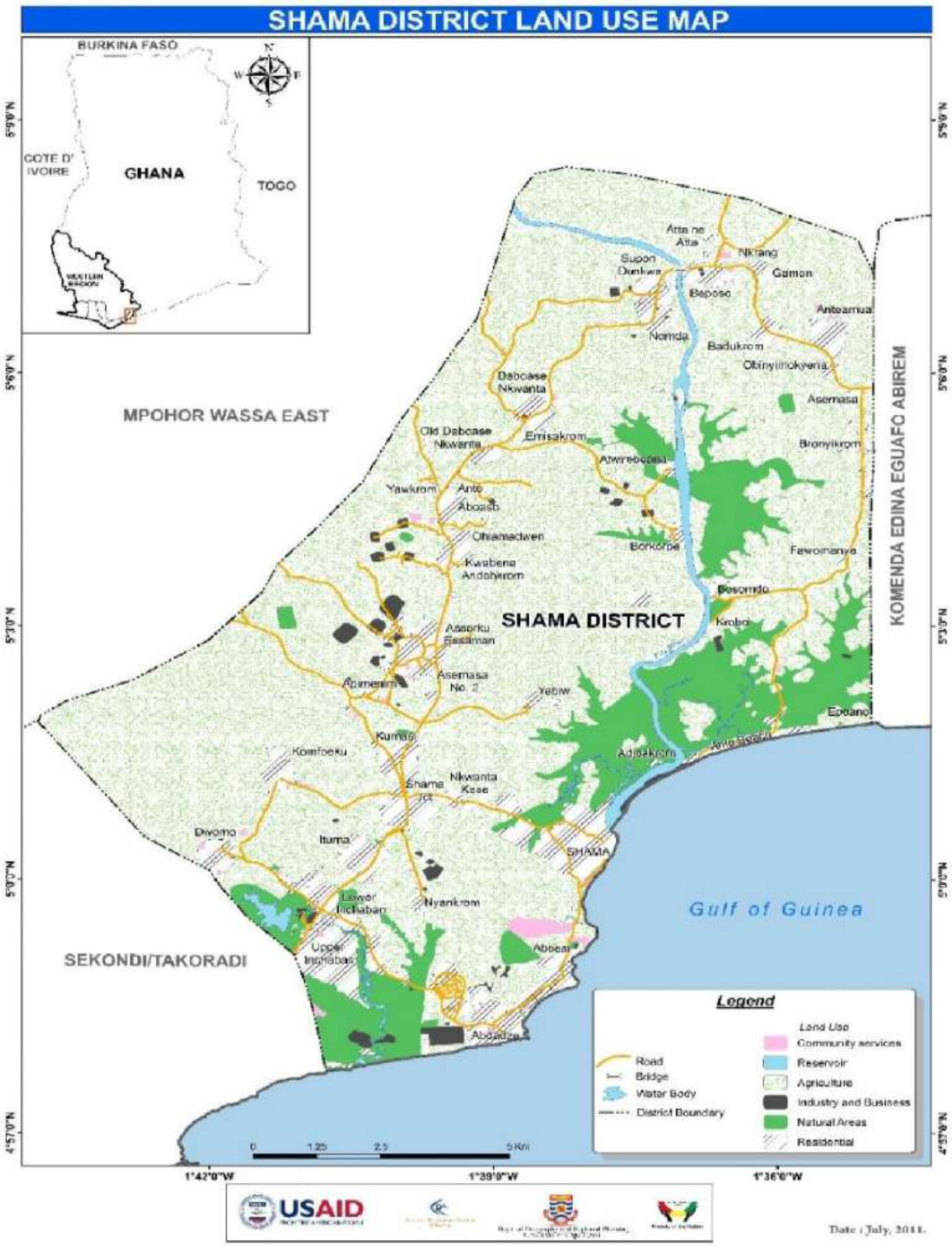
A scene of a participatory mapping activity

- **Applications of Hazard Maps**

- Hazard maps have various applications that may be broadly captured as in;

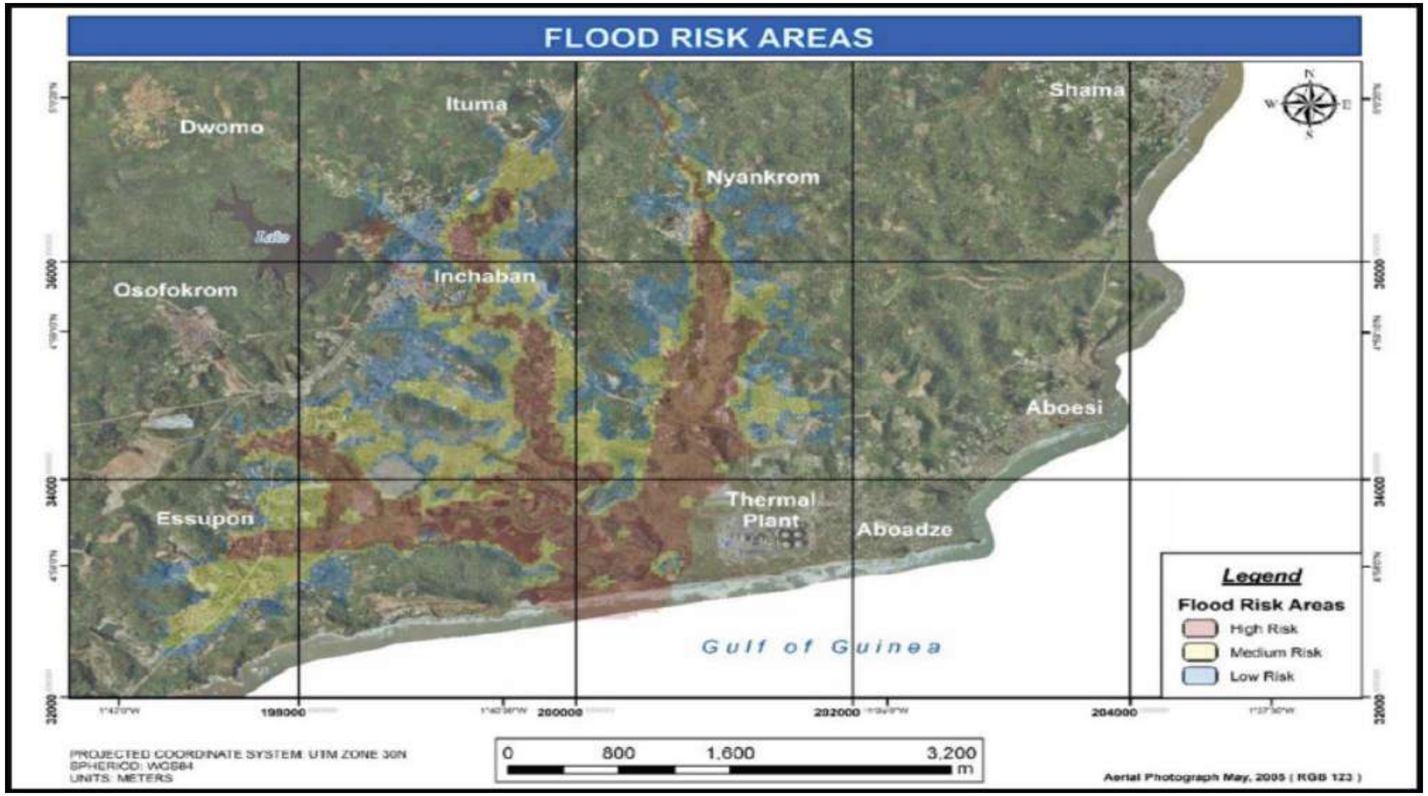
➢ Spatial planning
➢ Risk reduction measures
➢ Instruments used in emergency planning
➢ Raising awareness among the population.

- **Spatial planning**
- Hazard maps provide a basis for communal and district spatial planning processes



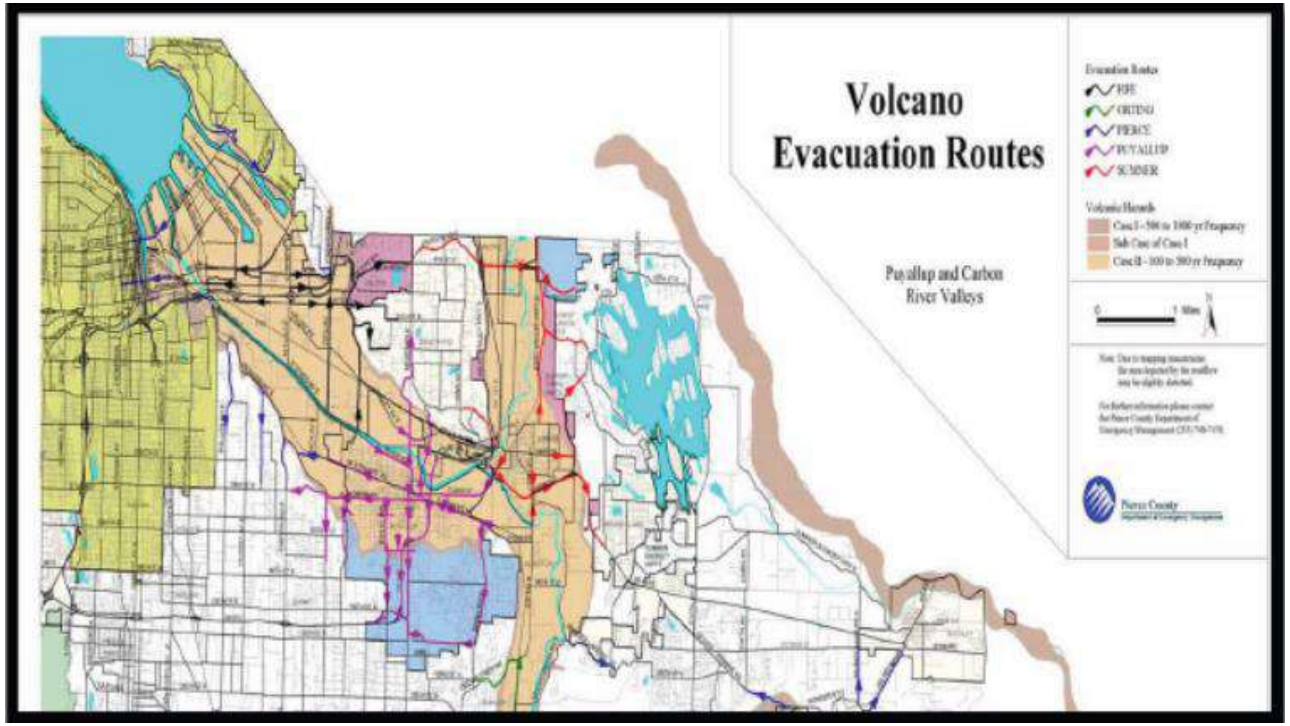
Land use map of Shama district, Ghana

- **Risk reduction measures**
- Hazard maps assist in the localisation and dimensioning of hazard protection measures.



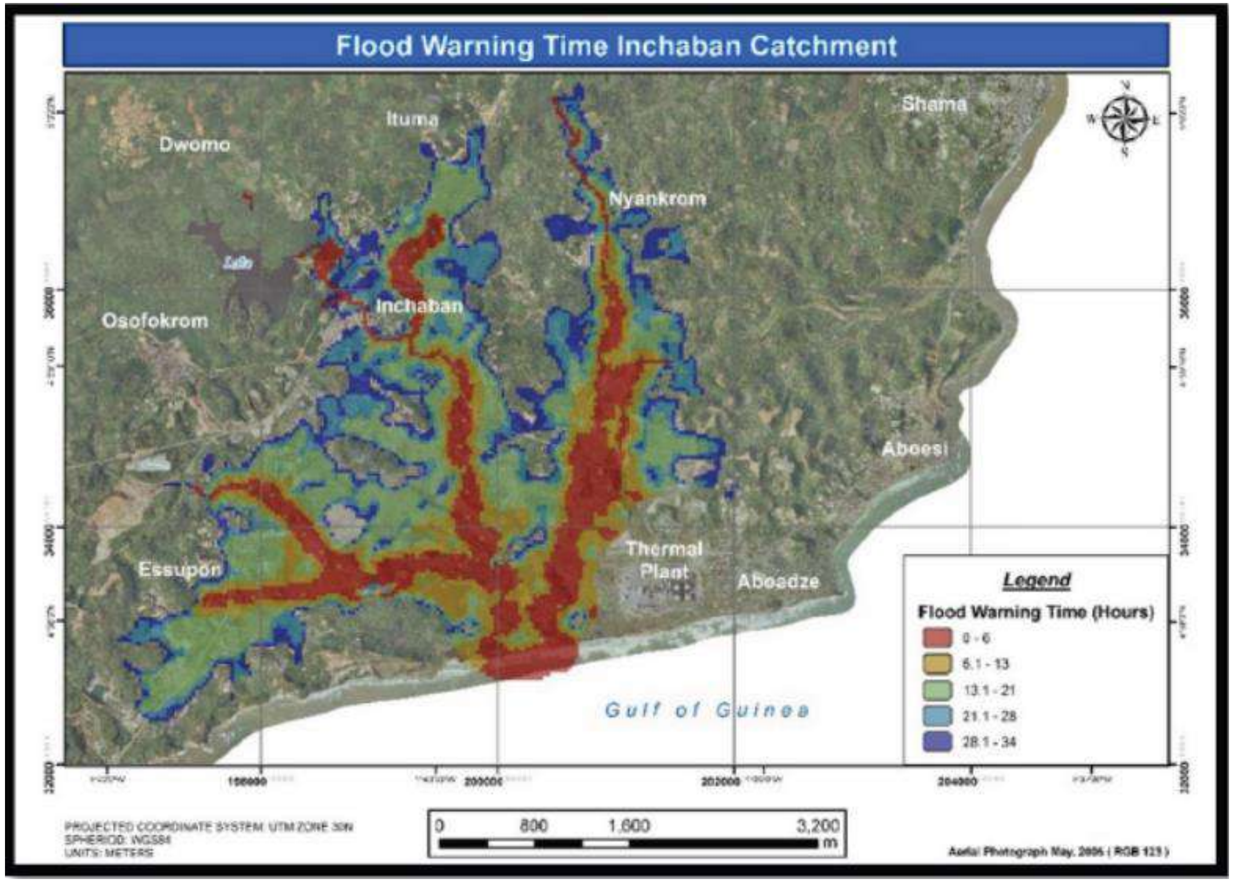
Flood risk map of Inchaban and surrounding settlements

- **Instruments used in emergency planning**
- Hazard maps indicate where the biggest risks arise and the events most likely to occur. This information can be used as a source of orientation in emergency planning.



A hazard map used for emergency planning

- **Raising awareness among the population**
- It helps to demonstrate potential risks to the population and to increase awareness of eventual protective measures.



Flood warning time map of Inchaban and surrounding settlements