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Structural and Non-structural Measures Integration through Multi-hazard Risk Approach - Sohag Governorate as an Example

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Abstract Egypt, as a developing country, has a long history of facing natural risks. In most cases, the authorities depend on the reactive approach instead of the proactive one, which is the core of disaster risk management. This makes the structural measures to deal with the natural risks the main step without looking at the non-structural measures like land-use control and risk management planning. As a trial to help such countries enhance the application of disaster risk management, two cornerstones will be suggested: the first is the integration of structural and non-structural measures, and the second is the use of a multi-hazard risk approach. This approach will help to avoid single-risk measures by mapping all correlated risks and creating a risk zone map, guiding future planning strategies, and controlling land-use to avoid social and economic loss and mitigate the negative effect in the event of an unpredictable hazard. The application for the Sohag governorate at the regional level confirms the absence of risk management in the regional plans due to many imbalances, the most important of which is the failure to define the risk zones and match the suggested future land-use with the level of risks.

Keywords:. Sudden Hazards, Earthquakes, Flash Floods, Wadis Dams Collapse, Multi-hazard Risk Approach (MRA), Disaster risk management.

1 Introduction

There is no place on earth that does not face single or multiple types of natural hazard, a hazard known as the immediate occurrence due to the natural effects of abnormal circumstances causing losses to individuals and environmental and economic aspects. Many states exert different efforts to deal with natural hazards by applying structural and non-structural measures as a step to prevent and mitigate the hazards. Recently, some of them have started to find out the missing part of disaster risk management through many approaches. One of these approaches is the multi-hazard risk assessment, which helps to identify the different hazards in their exact location, find if there is a correlation between their occurrences, like the domino effect in some cases, and introduce a clear vision for the areas that might be vulnerable with the degree of this vulnerability. Unfortunately, some countries, especially the developing ones, focused on one measure without the other, which was mostly the structural one, and dealt with the risky areas from a single perspective by concentrating on the hazards that were most frequented without considering any other hazards that might happen or were correlated with the frequent ones, such as dams collapsing after flash floods or forest fires after earthquakes. So, this study is a trial to find out the integration between the structural and non-structural measures through using the multi-hazard risk approach as a way to help a developing country like Egypt moves forward towards better disaster risk management.

1.1. Research Problem

Countries differ according to the different approaches that they deal with in the areas exposed to risks. Some tend more towards the procedural and executive dimensions, as in the "reactive approach" to the aftermath of the disaster, and some countries move towards the "proactive approach," which attaches importance to the planning dimension that directs any executive procedure to make it more oriented and effective in disaster risk management. Egypt reliance as a country on structural procedures to protect itself from the different natural risks, so the problem is this research revolves around the unclear

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integration of non-structural and structural measures and how using the implied multi-hazard risk assessment approach to clarify this integration and avoid the unilaterally with interrelated risks.

It is widely acknowledged that both structural (technical method) and non-structural (planning approach) measures can be used to mitigate risk effects. Generally, it could be said that the non-structural measures are reduction measures, and the structural measures are more protective, so single sectorial measures must not be used to reduce the sudden risks. A comprehensive, integrated approach that combines both structural and non-structural risk mitigation measures should be linked to current urban planning and management policy and practices.

1.2. Research Goal

This study aims to propose a successful example for the integration of structural measures followed by the authorities and non-structural measures through the implementation of a multi-hazard risk approach. This will help the Egyptian planning departments concerned with regional development be more effective in determining how to deal with areas exposed to hazards or how to manage disaster risk in or before the event of a sudden hazard.

1.3. Research Importance

As developing countries mostly lack better disaster risk management due to focusing on the structural measurements for a single frequent hazard, this resulted in faulty and not inclusive handling of disaster areas, either before or after the hazard. This study will give an integrated perspective for the authorities dealing with natural hazards by putting together the structural and non-structural measures with a comprehensive view of natural hazards through the multi-hazard risk approach. The multi-hazard risk will be based on a top-down approach, as the risks will be followed from the national level to the regional level. This study will target the regional level; regional analysis would identify potential risk zones as a step to enable detailed local studies in the future. All of this is to help the concerned authorities enhance disaster risk management.

2 Natural Risks overall the World and Arab Region

Around the world, many natural risks are observed and highly documented according to the frequency of occurrence, the number of deaths and the damage costs. Natural disaster deaths can vary greatly from year to year; in some cases, there are very few fatalities before a major catastrophic occurrence that causes numerous fatalities. Globally, natural disasters have claimed the lives of about 45,000 people annually on average over the past ten years. This amounts to about 0.1% of all fatalities worldwide [9]. The number of fatalities from disasters now averages between 10,000 and 20,000 each year. This number can increase to tens of thousands in the deadliest years, which are typically those with significant earthquakes or cyclones.

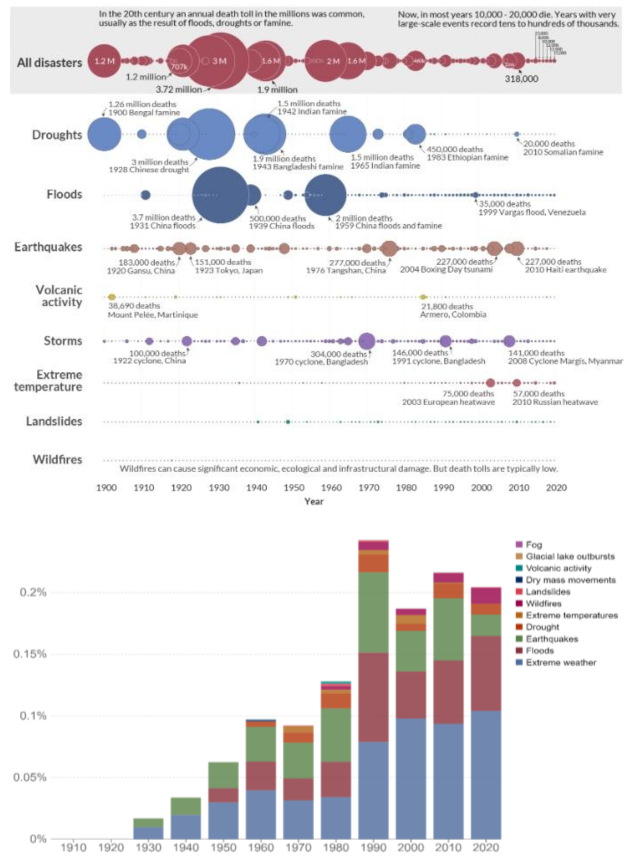

Fig. 1 Number of deaths from natural disasters over the world (up panel), and economic damages from disasters as a share of GDP (down panel).
Source: [9]

According to the United Nations, 43% of all natural catastrophes between 1995 and 2015 had a flood component. Over half (56%) of all victims of natural disasters of any kind were impacted by these occurrences, and nearly a quarter of them (26%) perished. The capacity of a community to sustain itself will decrease due to the high number of fatalities and financial losses. Since 1990, flooding has harmed more than 2.8 billion people globally, making it the phenomenon that has the greatest effect on the human population. However, due to the material destruction, it poses more of an economic risk than a life-threatening one for the community. For instance, compared to other natural disasters, floods result in much fewer fatalities than earthquakes but more economic losses than earthquakes as in **Fig. 1**.

According to [29], in the Arab countries' region, the trend of flash flood occurrence is clearly increasing, and from fifteen countries, only three face a low frequency of flash flood, and in the year of 2015, around nineteen extreme flash floods occurred in the region, which is mostly an arid region.

3 History of Egypt's Natural Risks

Egypt is one of the emerging nations in the dry region that experiences natural disasters, uncontrolled urban growth that alters the land-use and cover, and a greater rate of damage. Egypt, like many other countries, has parts of its territory that are vulnerable to certain risks, some of which occur frequently and others at irregular intervals. According to Al-Hakim [6], Egypt experiences a variety of natural hazards, the most common of which are earthquakes, which occurred approximately five times between 1950 and 1997, and destructive flash floods more than thirty-five times [7]. This is in addition to less common risks such as tsunami, which occurs twice a year. The collapse of wadis dams is also remarkable, as it happened three times in Upper Egypt in 2014 [8]. Another set of unsurprising risks, such as rising sea levels and beach erosion, particularly on Egypt's north coast, as well as the effects of climate change, are already in play. With all the above sudden risks within the purview of national and regional initiatives that nations want to build to boost rates of economic development and lessen regional inequities, there may be significant financial and human losses. Many recent scenarios predict a rise in the probability of sudden risks such as floods, which must be dealt with comprehensively to ensure highly effective interventions from the different concerned authorities. As a result of the preceding, the most common risks occurring in Egypt are flash floods, earthquakes, and wadis dams collapsing, and three threats will be discussed in the following lines.

3.1 Flash floods

The risk of floods is one of the greatest threats that Egypt has faced in the past century and the beginning of the twenty-first century. This is due to several factors, most notably the heavy exposure to large amounts of rain in various regions and at the level of urban and rural communities, as well as the global climate change that the world is currently experiencing. Most natural disasters, including floods, cause extensive destruction, financial loss, and the loss of life [14]. As low- and middle-income nations move to urban settlements, with a larger concentration of people and assets in various settlements, flash flooding is becoming more extensive and challenging to control. Flash floods occur in a variety of climatic regions around the world and are characterised by brief periods of intense rainfall, severe impacts, and damage to communities [1]. A flash flood is defined by the United Nations Educational, Scientific, and Cultural Organization (UNESCO) as a flood with a short duration and a relatively high peak discharge [2,3]. It happens quickly, within a short period of rainfall, and causes numerous disasters [4]. Flash floods are among the most lethal and destructive natural disasters on the planet, particularly in arid and semi-arid areas [5].

Due to the short-term strong rains on the slopes and highlands flowing to low-lying areas through valley routes, several governorates and metropolitan centres in Egypt are vulnerable to flooding [10,11].

Such hazards are likely to increase because of the effects of climate change. In Egypt, the majority of viable highway, road, and other infrastructure construction projects span wadis. People are building in areas with a high risk of disaster, like on wadis flood plains, due to the rapid growth in population, urbanisation, economic development, and tourism. In Egypt, recent increases in the frequency of flash floods have resulted in fatalities and substantial property damage. According to certain estimates, Egypt was afflicted by such severe floods from 1947 to 2020, causing an estimated 1.2 billion USD in annual economic damage. Even though they only happen two or three times every ten years, floods may be quite destructive and pose a risk to both people and property. The most recent major incident, which took place in March 2020, was ranked as the second-worst storm in the previous three decades, after the storm in 1994, even though it affected more governorates in Egypt. This incident compelled the closure of offices, schools, and highways as well as a stay-at-home advisory [12].

3.2 Earthquakes

Through the years, there have been various earthquakes in Egypt. The northern Red Sea, the southern end of the Gulf of Suez, and the area surrounding the Gulf of Aqaba are where the seismic risk is greatest in Egypt. One notable earthquake that killed 1,000 people occurred on November 27th, 885, in Cairo. Another one occurred on March 18th, 1068, but this one struck a larger area of Egypt and killed about 20,000 people. A third earthquake occurred on September 2nd, 1754, and it killed an estimated 40,000 people [23]. An unusual and destructive earthquake struck Cairo and northeastern Egypt on October 12th, 1992. This earthquake was about 18 kilometres south of Cairo. Despite being very moderate in size (measured at 5.9 on the Richter scale), it produced significant damage and numerous fatalities. There were around 500 fatalities, over 6,500 injuries, and about 8,300 damaged or destroyed buildings among these losses [24].

3.3 Wadis dams collapse

This risk could be caused by humans as the dams, which were built to protect Wadis from sudden floods where the most critical interventions are for storing large amounts of rain and reducing the devastating effects of dredging, may collapse. The risk of wadi dams collapsing is considered multiple effects of a hazardous phenomenon known as the domino effect. The importance of comprehending domino effects was amply demonstrated.

In fact, this is exactly what happened in 2014 when three dams in Upper Egypt collapsed, which had catastrophic effects on the surrounding areas. By 2021, Egypt will have constructed 160 dams, 307 artificial lakes, and 39 protective bridges, all of which were built on wadis. To combat the rainfall and flash floods, 93 barriers and industrial canals have also been put in place. A second phase will see the implementation of a variety of additional facilities, including 13 dams, 48 artificial lakes, 118 protection bridges, and 29 cooling basins.

The purpose of flood protection dams is to safeguard people and villages, important infrastructure, including highways, towers, electricity lines, and gas pipelines, as well as strategic locations. Some of these dams also benefit from the ability to capture rainwater, store it in man-made ponds for use as a source of freshwater by tiny settlements, and give nomadic communities stability by supplying subterranean wells with water to assure the longevity of the water source [8].

These dams' designs, however, are incompatible with the amount of water that has accumulated behind them, which results in their collapse and serious damage. This is what happened when the water rose above Al-Rawafa Dam in Wadi Al-Arish because of the January 2010 flash rains, causing enormous damage to the dam's body and serious devastation to its environs, same for Al-Hajer dam collapsed in Sohag Governorate because of 2016 flash rains [7].

When the stored water's shear stress is greater than the soil's resistance, the movement of soil particles is the primary cause of dam failure. The worst-case scenario for earth dam failure or breaching is minutes to a few hours (the least bad). The type of soil and how the building was done affect a dam's ability to resist erosion [8]. And the collapse of these dams is not only a structural defect; but there are many shortcomings in the procedures followed at the time of sudden floods and torrential rains that may contribute to the occurrence of these collapses, including:

- The ineffectiveness of advance planning to prevent a flood disaster and relying on the method of reaction during and after the disaster's occurrence, in addition to the lack of preparations required to confront the risks of floods, and the lack of a clear structure for procedures to reduce these risks [13].
- Despite being crucial for accelerating response times and lowering risks, there is a lack of reliance on the flood catastrophe early warning system [7].
- Lack of oversight in regions where flash floods are expected to occur leads to encroachment by people who construct inside wadis.
- a lack of thorough flood preparation for the infrastructure and the interested parties' inadequate preparation for dealing with natural disasters and their lack of expertise [7].
- Natural catastrophe information and maps are poorly documented, which results in shortcomings in how to deal with them scientifically [14].

4 Multi-hazard Risk Assessment Approach

The multi-hazard risk assessment approach has been raised historically as a result of the fact that single phenomena are not considered separately, such as hurricanes that cause storms and heavy rainfall that can again cause storm surges, flooding, and landslides. The explanation is that they fall under the purview of the notions being used. A multi-hazard risk assessment is an all-encompassing approach that can be used to minimise,

natural disasters [15].

The danger brought on by several hazards is referred to as multi-hazard risk. Comparatively, the phrase "multi-risk" refers to a variety of dangers, including economic, ecological, social, etc. Since these concentrate on the problems and difficulties that emerge in a multi-hazard environment as opposed to a single-hazard analysis and exposure does not alter, the exposure of the items at risk is not taken into consideration independently. So, it is essential for formulating effective disaster risk reduction strategies [16]. Risk assessment for individual hazards, qualitative multi-risk analysis, semi-quantitative multi-risk analysis, and quantitative multi-risk analysis are some of the steps that make up the overall multi-risk assessment process [17].

A multi-hazard risk assessment has several benefits. Two essential elements that make hazard analysis effective in regional-level planning exercises are addressed by assessments of multi-hazard vulnerability and risk, which permit both comparability studies and in-depth studies of the driving forces of risk [25]. The process of creating a catastrophe resilience strategy also begins with conducting a multi-hazard risk assessment [26].

A multi-hazard risk assessment approach also suggests where more in-depth research needs to be done and enables the identification of the places that are most in danger [27]. Communities need multi-hazard assessments more and more as exposures change over time. Such information can help to elucidate hazard interactions and the role they play in risk mitigation [25].
The use of a multi-hazard approach will help the concerned authorities enhance their capabilities for better disaster risk management by creating relevant data visualisations and presentations, which is one of the challenges of the approach. The visualisation of each individual risk or hazard separately, the reduction of multi-dimensionality to visualise a combined risk or hazard variable, such as overall risk or hazard, and the simultaneous presentation of multiple risks or hazards, making single-hazard outcomes comparable, are other difficulties that will help in finding the best modes of prevention [28].

The integration of structural and non-structural measures for all potential hazards in a region will help in more mitigation to reduce the negative effects of these risks. So, the mapping of the risks in addition to the reviewing of the structural and non-structural measures for different risks are the main cornerstones for achieving the comprehensive perspective of this study, see **Fig. 2**.

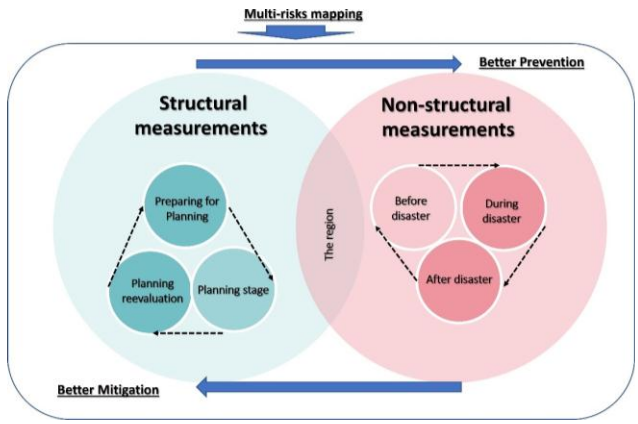

Fig. 2 Structural and non-structural measurements integration through multi-hazard risk assessment approach for better disaster risk management
Source: Author

4.1 Mapping the multi-hazard risks

One of the major steps in the multi-hazard risk approach is mapping all risks to create integration between all types of effects, and as mentioned previously, this could be one of the challenges of applying this approach. This step is dependent on the collection of regional data. This include defining the study area and knowing important information such as administrative boundaries, the number of settlements, and the population. Reading the region's data history of natural disasters in general and the most frequent in particular, in the case of Egypt as mentioned before, three main sudden hazards will be in focus: "flash floods, earthquakes, and wadis dams collapse," so the map will define the main wadis and if there are any dams for sudden flood protection and its current structural evaluation, in addition to the history of earthquakes and the range of the affected areas if any.

4.2 Structural and non-structural measures

4.2.1 The structural measures

Structural measures often consist of various works and interventions targeted at either reducing peak risks or mitigating the effects, as well as large-scale public works projects that need moderate to extensive planning and design work. formal permission from one or more government departments or agencies, as well as the requirement for moderate-to-large capital expenditures, operational commitments, and maintenance obligations. Detention/retention facilities, channel improvement to lessen the impact of flooding in flood hazard areas, building banks or dams, upstream storage and diversion works, channel modifications or enclosures, dikes and floodwalls, bridge and culvert alteration or replacement are examples of structural measures used primarily to control the quantity of urban surface water resulting from the flash floods. Sedimentation basins, artificial or restored wetlands, and other structural methods are mostly employed to control the quality of urban surface water. For earthquakes, one of the best measures is designing and building structures code that can survive powerful ground tremors, which is the primary strategy Egypt took to prevent earthquake damage. Since 1986, Egypt has had an earthquake building code, which entails knowing the characteristics of the ground motions that have been documented during earthquakes to forecast future ground motions [21]. Hospitals, emergency services, and locals can practice for an earthquake by holding drills in public places, but this strategy is not taken into consideration. This way, people can be prepared and know what to do in the event of an earthquake [22].

4.2.2 The non-structural measures

Risk management planning

To deal with any disaster and cope with its risk, there is a need to divide the process into different stages and find out what needs to be executed from planning procedures to prevent or mitigate the risk at every stage. Many studies have discussed those stages, as Blackwell and Maltby [33] believed that preparatory, incident, and post-incident measures could be taken to manage risks such as flood risk. Moe and Pathranarakul [19] classified natural disaster management (NDM) into five stages: prediction, warning, emergency relief, rehabilitation, and reconstruction. The main activities in NDM can be divided into four main categories: mitigation, preparedness (pre-disaster), response (during a disaster), and recovery (post-disaster).

Seddeek and Elsayed [20] pointed out that the planning framework to deal with natural disasters should be divided into three main phases: the pre-disaster phase, the disaster phase, and the post-disaster phase. So, the planning measures will use the same pillars to divide the planning time to deal with the disaster of flash floods or dam breaks. Blackwell and Maltby [33] saw the preparatory stage that is equivalent to the pre-disaster stage and should contain in the case of flash floods (runoff reduction, preventive flood risk reduction), and to do that we need to find the next data and information for the study region. To help mitigate hazards risk, non-structural methods provide a range of options, from land-use planning and regulation to land purchase and relocation, hazard prediction and warning systems, emergency response plans, and a risk insurance programme [18]. Non-structural measures aim to protect people from risks through better managing urban growth and planning, which enhances the application of disaster risk management.

Land-use control

Controlling development through land-use planning is one of the best ways to reduce the risk of sudden hazards and mitigate their negative effects. The UN's International Strategy for Disaster Reduction [35] claims that populations exposed to natural hazards are more vulnerable because of insufficient, incorrect, or nonexistent land-use planning. In the case of flash floods, urban areas are the most susceptible to flood-related calamities, but there are insufficient safeguards in place to lessen the impact of flooding on nearby residents. The decision about the long-term use of land belongs to spatial planning. Although it is not directly accountable, spatial planning plays a crucial role in disaster risk mitigation. According to Fleischhauer [34], spatial planning could play four different roles in lowering the risk of disasters:

• Determine the dangers associated with land-uses in highly susceptible places, especially with a history of disaster occurrences, in order to prevent future development in these areas.

• Determine and identify sensitive or significant societal or environmental elements to categorise various land-use settings in hazard-prone locations. Every disaster has its own acceptable risk for various types of land-use.

Many variables and datasets are incorporated into spatial and land-use planning. Initially, cadastral data is included in a map of topography and natural characteristics. The spatial awareness of all other elements, including buildings, infrastructure locations, open areas, coastal regions, green belts, nature preserves, and watercourses, is then gradually developed upon this basic map. Policymakers can effectively plan for community needs and handle potential dangers and risks thanks to this layering strategy.

4.3 Multi-hazard Risk Assessment Application Proposed Methodology

To To apply the Multi-hazard Risk Assessment with the integration of structural and non-structural measures with the goal of dealing with any disaster and coping with its risk, there is a need to divide the process into three different stages. The first is Mapping the multi-hazard risks; in this stage, the historical different risk events by region should be reviewed. The next step is delivering geographic resolution-appropriate GIS maps to ease the use of the Qualitative Method to Identify potentially affected regions using multiple risk maps. The second stage will revolve around risk management planning, including locating villages and cities in the vulnerable location in addition to determining the risk area map for the initial evacuation. Land-use control will be the third stage, as the Map of regional land Use, type, and density will be illustrated outside and inside of risk zones, which is strategically important for economic land use planning. This will help in upgrading the urban plans of areas within the risk zones and will lead to a link with future development and vision for cities and regions (see **Fig. 3).**

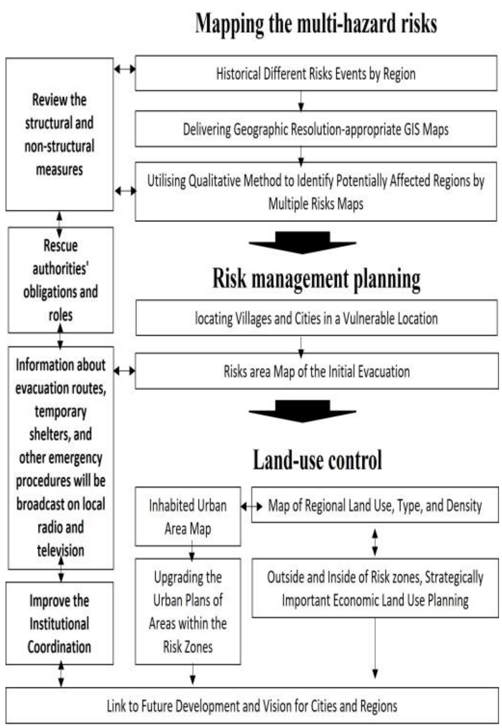

Fig. 3 Multi-hazard Risk Assessment Application Proposed Methodology
Source: Author

5 Study Area Description (Sohag Governorate)

5.1 The location

Sohag Governorate is one of the rural governorates of Egypt, and its capital (Sohag) city is located 467 km south of Cairo. Geographically, the governorate is a narrow strip of land on both sides of the Nile Rver, with a length of 125 km see **Fig. 4**. The cultivated areas extend from 16 to 25 km. The administrative borders of the governorate are between longitudes 31.22 and 32.85 east and latitudes 26.01 and 27.03 north. The total area of the governorate, including the inhabited and uninhabited areas, is 11218.5 km2.

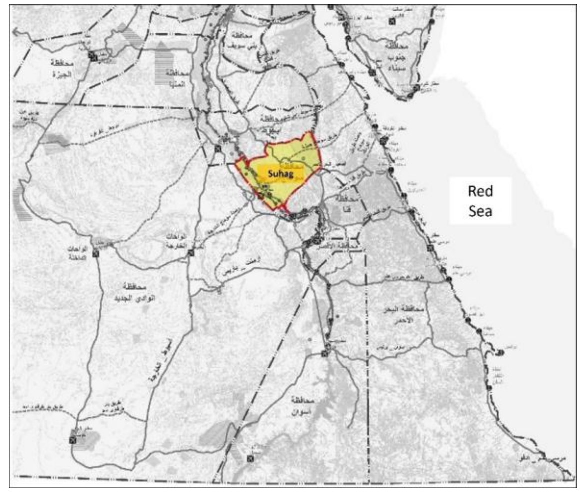

Fig. 4 Location of Sohag governorate
Source: [32]

5.2 Population and settlements

The governorate of Suhag is one of five governorates in the South Upper Egypt region, and it came first in population and second in area compared with the other region governorates. In 2017, the total population of the governorate was 496,409 inhabitants, and this number was divided into 21.2% for the urban population and 78.2% for the rural population. There are 11 cities within the 11 city-region Markaz," 270 villages, and 1574 hamlets. The governorate ranked as having the highest percentage of population under the poverty line (59.6%) at the scale of the region and ranked second at the national level after Assuit governorate. This indicates a complicated social and economic situation in case of a natural hazard occurrence, as will be stated in the next lines.

5.3 The history of natural hazards

The history of natural hazards in Suhag emphasises the frequency of destructive flash floods. According to Mostafa [14], the governorate faced nine destructive flash floods between 1975 and 2018. In all, 9 times, many deaths are recorded, with not less than 6 villages and 2,000 buildings partially destroyed, in addition to huge losses in agricultural land. As a domino effect of the flash flood, in 2014, the governorate witnessed the collapse of one of three dams built for flood protection, resulting in huge losses of reclamation land and livestock. Earthquakes are not remarkable as a hazard in the governorate.

6 Results

6.1 Mapping of natural risks

6.1.1 Flash floods

As shown in **Fig. 5**, flash flooding is the most effective risk and the most frequent in Sohag. This is because many of the wadis in the west and east are classified as dangerous due to the frequency and strength of the floods. According to [31] the governorate has 49 wadis in total, 25 in the east side of River Nile and 24 in the west, the total number ranging from low risk to very high-risk level. In **Table 1** around 14 wadis could be illustrated in names as their risk level ranges from medium to high, most of them are in the east side of the governorate and less of them in the west side.

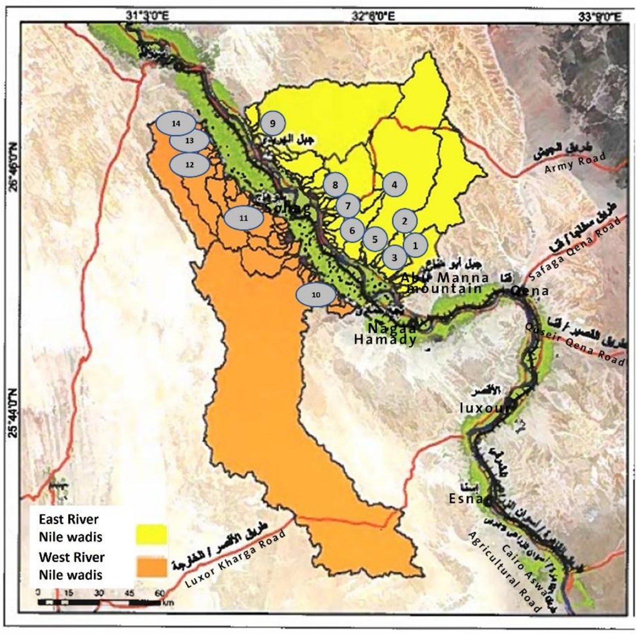

Fig. 5 Main wadis in Sohag governorate correlating with flood risk level
Source: Author depending on [31]

Table 1 Main Wadis in Sohag governorate

The side	NM	Wadis name
Eastern side	1	El-matahra
	2	Abo Nafogh
	3	Between Abo Nafogh and Qasab
	4	Qasab
	5	Between Qasab and Qaleat Ammar
	6	Al-ahawyaa
	7	Al-Nazeraa
	8	Naqb Ayuwb
	9	Abu_Shih
Western side	10	Sohag Airport and wadi after the airport
	11	Group of Wadis between taj aldiyr and Abu_retaj
	12	Group of Wadis between Aljubirat and Darab_alghanayim
	13	Group of Wadis between Darab_alghanayim and wadi sarija
	14	wadi sarija

Source: Author depending on [31]

6.1.2 Earthquakes

There is no direct effect of earthquakes as all of the governorate area is out of the range of earthquakes.

6.1.3 Wadis dam’s collapse

One of the most significant wadis in Egypt's Eastern Desert is Wadi Abu Shih, which has seen numerous flash floods. In the downstream area, it is distinguished by numerous sub-basins as in **Fig. 6**, numerous urbanised regions, and agricultural reclamation initiatives.

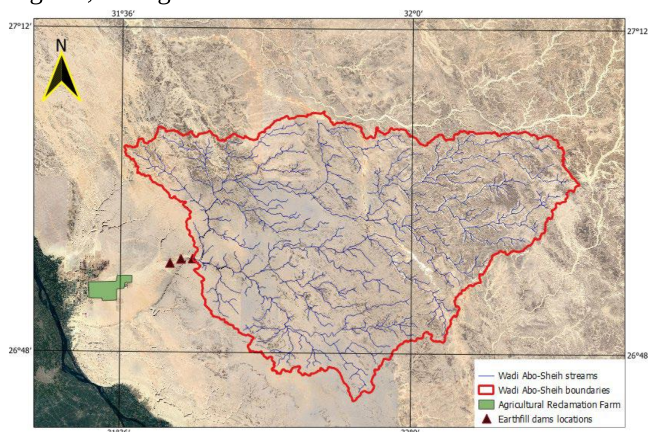

Fig. 6 Wadi Abu_Shih’s dams location
Source: [8]

Agriculture reclamation began in 2000, and the extension of agricultural lands increased to cover a considerably wider area in front of the outlet of the wadi, which is prone to flash floods. The downstream delta of the wadi is very vast and contains many new sites of urbanisation. The government built three mitigation dams since this wadi's downstream development was crucial. Unfortunately, the first dam was breached at the abutment following the 2014 flash flood. Enhancing the design codes for integrated management should take into account the effects of climate change and rising urbanisation, and assessing wadi management in light of events is crucial.

6.2 Risks’ structural measures

The next structural measures for natural disasters could be applied anywhere because they are considered a central intervention at the national and regional levels, and some additional measures may be designed in response to unique circumstances or depending on the severity of the disasters. There are no specific structural measures for natural disasters designed specifically for the Sohag governorate.

6.2.1 Structural measures for flash floods

Table 2 Structural measures in case of flash floods

The pre-disaster	During the disaster	The post-disaster
- Purification of the existing Wadis in preparation for receiving the flash floods. - Establishing a set of protection means such as dams, diversion channels and culverts to reduce the risks of potential floods. - Purification and maintenance of canals and drains where flood water is likely to enter and keeping on the efficiency of the drainage stations. - Reducing the water levels in the canals and drains to which the flood waters come, in order to absorb the flowing water.	- Conducting an aerial survey by air forces to monitor the flow of torrential rains and reconnaissance the affected areas and using airdrops for rescue teams in isolated areas and using loudspeakers to alert citizens of dangerous places. - Rescuing those trapped by flash floods and providing first aid to the injured. - The evacuation of the affected and threatened areas. - Use the equipment to open roads and fences to open a stream for floods away from residential places. - Taking public health measures and medical care to prevent the spread of epidemics. - Establishing camps in open areas, fully equipped, to shelter the affected people. - Distributing food, blankets and clothes, and disbursing financial aid to those affected.	- Inventory of deaths and injuries - Withdrawal of flood water by machines, to reduce its level until life returns to normal. - Draining the accumulated flood water by using an artificial wadi. -Taking measures to remove rubble and repair the infrastructure to restore the normal situation of the affected areas. - Re-housing the affected people. - Inventorying economic losses (completely and partially destroyed buildings and housing, collapsed infrastructure, destroyed crops and supplies, dead livestock).

Source: Author depending on [7, 14]

6.2.2 Structural measures for earthquakes

Table 3 Structural measures in case of earthquakes

The pre-disaster	The post-disaster
- The urban authorities and municipalities are committed to issuing building permits for buildings that comply with the earthquake code only. - The destruction of building do not follow the earthquake code.	- A list of fatalities and injuries - Taking action to clear the debris and fix the infrastructure in order to get the affected areas back to normal. - Locate transitional housing for those affected. - Rehousing the impacted individuals. - Recording financial losses (completely and partially destroyed buildings and housing, collapsed infrastructure, destroyed crops and supplies, dead livestock).

Source: Author

6.2.3 Structural measures for wadis dams collapse

Table 4 Structural measures in case of wadis dams collapse

The pre-disaster	During the disaster	The post-disaster
- Conduct periodic visits to dam sites to ensure their structural integrity. - Observing any up normal activity in areas around the dams through the aerial survey.	- Announcing the collapse of the dams and informing people to evacuate the affected places to other more safety locations. -Use the tools to open fences and roadways to direct floodwaters away from residential areas. -Providing medical attention and public health measures to stop the spread of epidemics. -Building fully furnished camps in open spaces to house the impacted people. - Giving out food, clothing, blankets, and financial aid to individuals in need.	- Establish a temporary water barrier to decrease water runoff. - Studying the reasons for the collapse for future evaluation. - start the reestablishing of collapsing dams with better standing factors.

Source: Author

6.3 Risks' non-structural measures

6.3.1 Map of the regional land-use

Land-use control is considered a main cornerstone of disaster mitigation as it could help in scouring the most dangerous and risky areas by planning settlements in areas exposed to flash floods [14]. The importance of land-use control emerges from the stream water mechanism during the occurrence of a flash flood, as water levels abruptly rise and the flow velocity may be very high. The force of the water has the potential to move boulders, uproot trees, and destroy bridges and buildings that are in its path. Flash floods frequently flow at extremely fast rates, and a water level of just a dozen cm can be quite dangerous. Water at a depth of one metre and moving at a speed of one metre per second can constitute a destructive threat to an adult, so the accuracy of land-use map determination helps in decreasing the potential risk. Figure 8 shows that most of the main wadis, whether on the eastern side or the western side of the governorate, face a case of non-control land-use as many rural settlements are existing in the wadis' paths, alongside many agricultural lands that are transformed, which means a huge economic loss in the case of flash floods in these wadis.

Also, as shown in **Fig. 7**, which illustrates the regional land-use, which does not reflect the precise land-use in the areas of the main wadis and to determine the land-use in the risky areas, a more detailed land-use map is required at the regional level with a spatial resolution of not less than 1:25000 to clearly identify all the detailed areas that might be affected by the flash flood, as shown in **Fig. 7**.

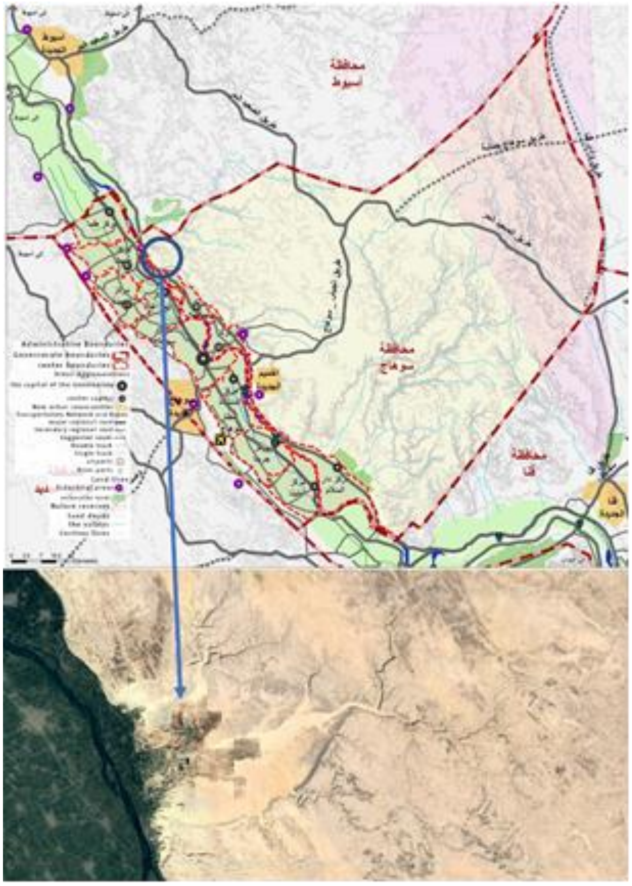

Fig. 7 Land-use map at a spatial resolution of 1:100,000 with no reflection on wadis areas (up panel) and land-use map at a spatial resolution of 1:25,000 with direct reflection on wadis areas (wadi Abu_Shih) (down panel)
Source: [32], author

6.3.2 Risk management planning

Preparing for Planning

- Collecting the main data for each hazard, like rainfall data in the case of a flash flood, is very important to building waterfall scenarios using different prediction models. The rainfall data could be observed by satellite products or reference data.

- Mapping of the natural factors affecting the occurrence of the disaster: just as topography and slope mapping, which is a very important factor in affecting the region's vulnerability to flooding since the runoff from heavy precipitation is likely to be faster and greater when topography and slope are more elevated and sharper, Also, geologic data It's very important, especially in the range of earthquakes and flash floods, which can be combined with the soil data type by using a watershed modelling system and a digital elevation model to determine the watershed precision, see **Fig. 8**.

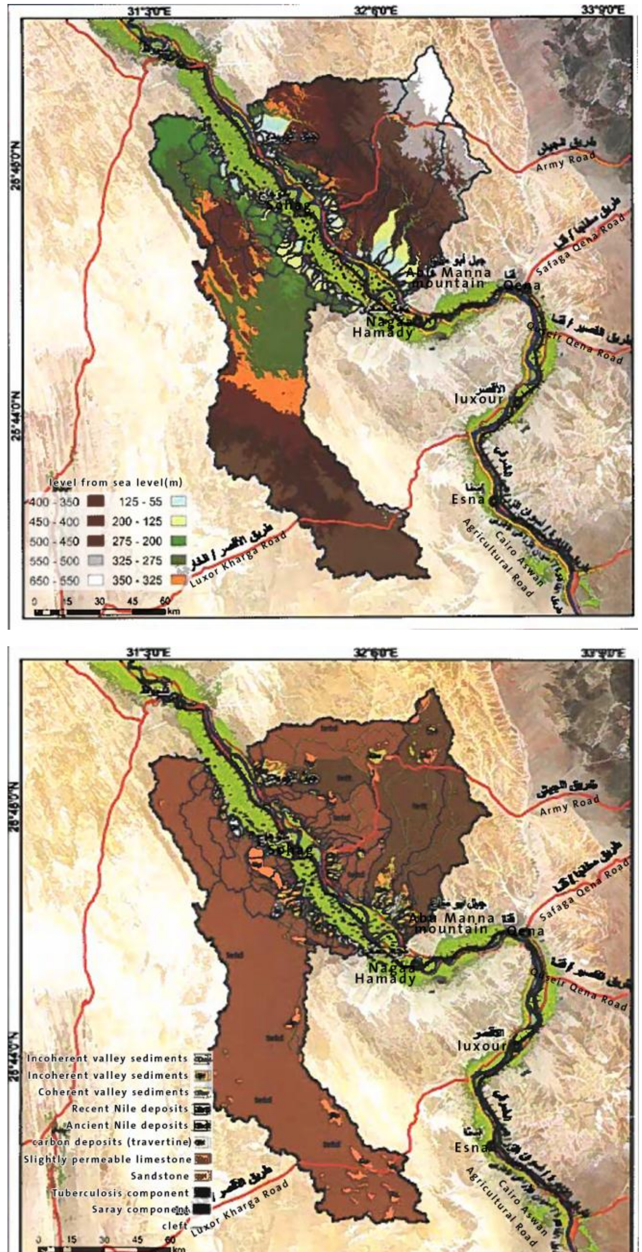

Fig. 8 Topography of Sohag wadis (up panel) and its geology (down panel) (flash flood risk), Source: [31]

- Mapping of Hazard Areas: Hazard intensity determination is a step towards determining hazard levels and presenting hazard scenarios in the form of hazard maps, see **Fig. 9**. The most important factors that affect flash flood hazards in each watershed are annual rainfall, area of the watershed, basin slope, drainage density, and land-use.

Planning stage

Planning for loss prevention

- Risk zonal mapping: depending on the risk classification, the risk zonal map should guide the planning direction and determine the planning approach to sustain the future of any development in the region.

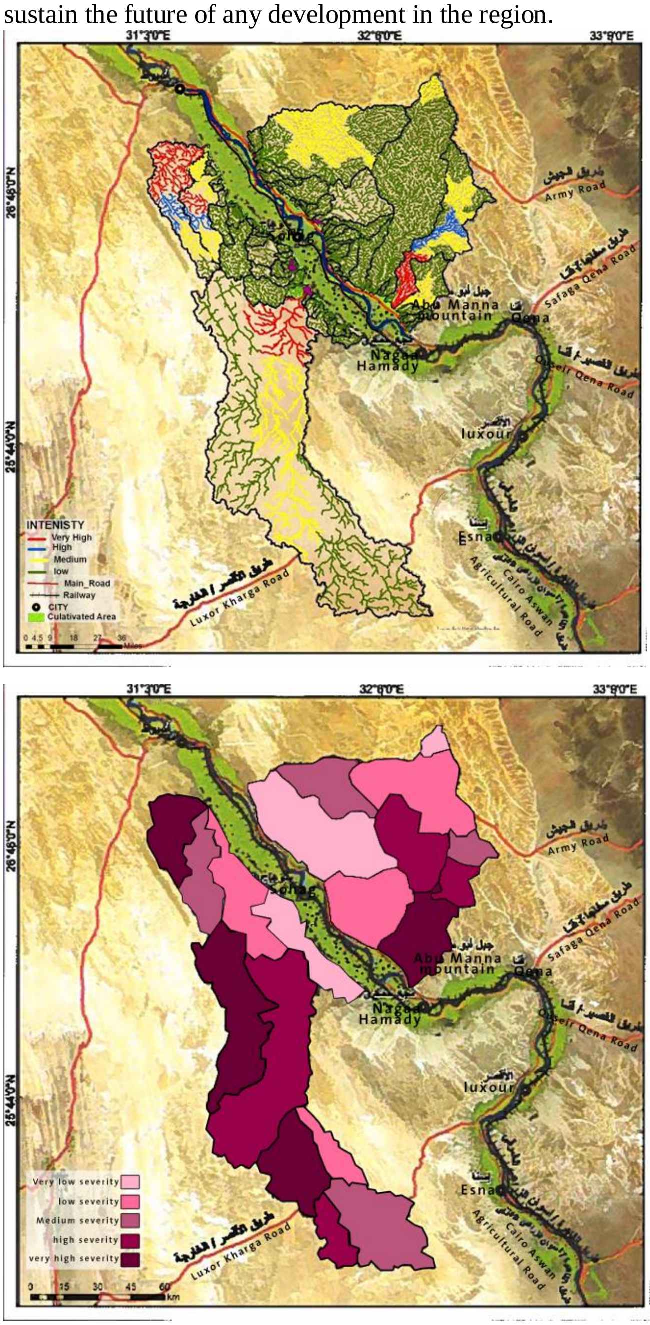

Fig. 9 Hazard intensity map (up panel) and risk zones map (down panel) (flash flood risk)

Source: [30], Author depending on [30, 31]

- Current land-use and risk evaluation: it's very important to find the effect of the risk zones on the current land-use and different settlements; this will allow planners and decision-makers to decide the level of intervention to reduce the risk of economic and social losses, see **Fig. 10**.

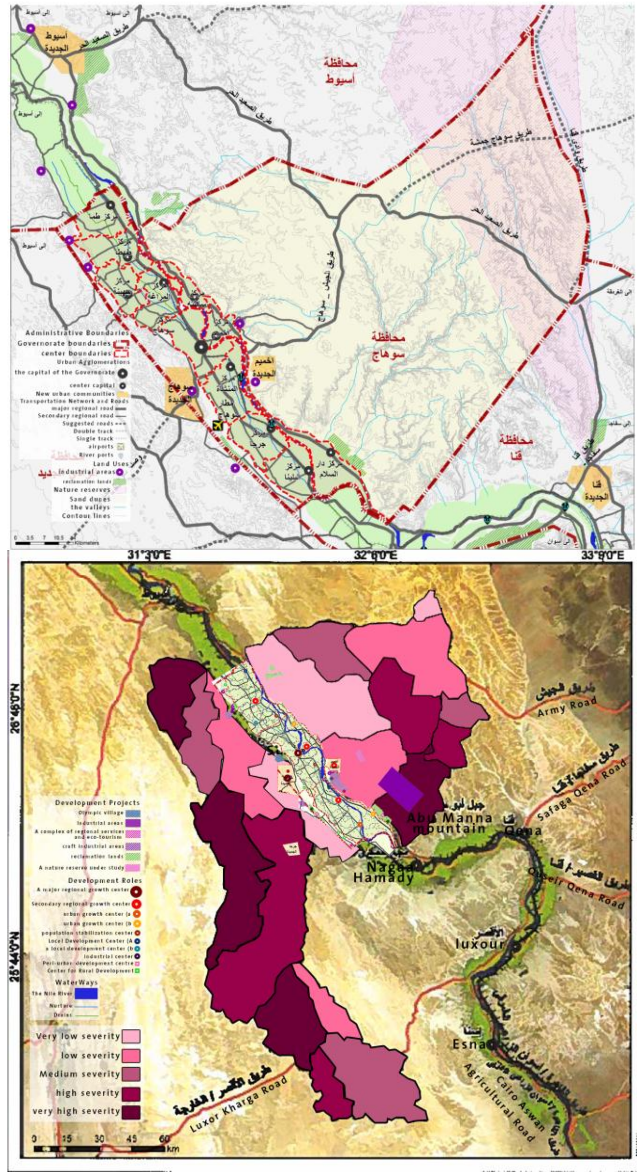

Fig. 10 Regional land-use map (up panel) and the link between the land-use map and flash flood risk map (down panel)
Source: [32], Author

- Intervention map: In this stage, the integration between the structural measurements, like the projects of protection from flash floods, whether by using dams or non-structural measurements like the suggestion of open areas, or in high-risk areas, by population transfer to another safe area away from the danger, takes place. In the case of flash floods, many areas will be affected due to the expansion of uncontrolled land-use inside the wadis. In

Table 5, the main wadis will be presented correlated with the land-use and the type of intervention that is needed.

Table 5 types of intervention needed in case of flash flood in the main wadis in Sohag governorate

Wadis name	Flood risk level	The land-use in the risky area	Type of needed intervention
El-matahra	Medium to high	Rural settlement is existing on the wadi path	Establishing an underground canal to catch the water away from the settlement.
Abo Nafogh	Medium to high	Rural settlement is existing on the wadi path	Change the surface water path away from the settlement.
Between Abo Nafogh and Qasab	Medium	Rural settlement is existing on the wadi path	Change the surface water path away from the settlement.
Qasab	Medium	Agriculture area is existing in the wadi path	Preventing the establishment of any structural facilities in agricultural areas
Between Qasab and Qaleat Ammar	Medium to high	Rural settlement is existing on the wadi path	Establishing an underground canal to catch the water away from the settlement.
Al-ahawyaa	Medium to high	Agriculture area is existing in the wadi path	Preventing the establishment of any structural facilities in agricultural areas
Al-Nazeraa	Medium to high	Agriculture area is existing in the wadi path	Preventing the establishment of any structural facilities in agricultural areas
Naqb Ayuwb	Medium	Many rural settlements are existing on the wadi path	Establishing a dam to protect the settlements from flood water.
Abu_Shih	Medium	Agriculture area is existing in the wadi path	Preventing the establishment of any structural facilities in agricultural areas
Sohag Airport and wadi after the airport	Medium	Penetrates the airport area	Establishing an underground canal to catch the water away from the settlement.
Group of Wadis between taj aldiyr and Abu_retaj	Low to high	Many urban (new Sohag city) and rural settlements are existing on the wadi path	Use the wadi path inside the new city as a green area without any construction and create a puffer zone on the both sides of the water path.
Group of Wadis between Aljubirat and Darab_alg hanayim	Medium to high	Many rural settlements are existing on the wadi path	Establishing an underground canal to catch the water away from the settlement.
Group of Wadis between Darab_alg hanayim and wadi sarija	Medium to high	Many rural settlements are existing on the wadi path	Establishing an underground canal to catch the water away from the settlement.
wadi sarija	Medium	Many rural settlements are existing on the wadi path	Change the surface water path away from the settlement.

Source: Author

Planning in case of disaster occurs:

- Coping maps: in case of a sudden hazard, after taking in advance all ways of protection, the planning should take into consideration providing predetermined safe areas that are close to risky areas to evacuate the people. The evacuation routes should be clearly identified, and safe shelters should be found for terrified persons.

Planning reevaluation:

- As people and settlements are more dynamic and they are fast moving, the land-use map should be updated every five years at most, with a full evaluation of the protection projects after updating the climate data, especially for high-risk zones that are highly habituated to population growth and economic development.

7 Discussion

The Suhag Governorate's application of MRA reveals numerous imbalances, particularly in the non-structure measurements. Despite the Suhag Governorate's approval of a GOPP regional strategic plan, which was unveiled in 2016 and updated in 2021 to include all new development dimensions, the study failed to consider risk management planning for the reasons listed below; for more information, see **Fig. 11**:

- The in-depth analysis of wadis, whether in the east or on the left bank of the Nile, was not considered by the regional strategy.

- The recent land-use study took place on a large scale, which was ignored to find out the extent of land-use expansion in wadi areas.

- There is no mention of the level of risk associated with the different wadis, which will help in risk evaluation and the planning of land-use in the risky areas.

- There is no focus on the urban settlements that could be affected by sudden flash floods through specific studies or by reviewing the history of flash flood accidents to examine their recent location.

- The suggested locations for the land-use in 2030 are chosen in high-risk zones (see **Fig. 11** example 1 where new industrial zone suggested in high severity risk zone), which will lead to more economic and social loss compared with the current status.

- Many new rural settlements in high-risk zones (see **Fig. 11** example 2) are being suggested without introducing any means of protection or intervention in case of hazards.

- The structure measures for the sudden hazard in Egypt are missing the inclusion of new technology, especially in developing early warning systems and messaging residents in risky areas through social media or mobile devices.

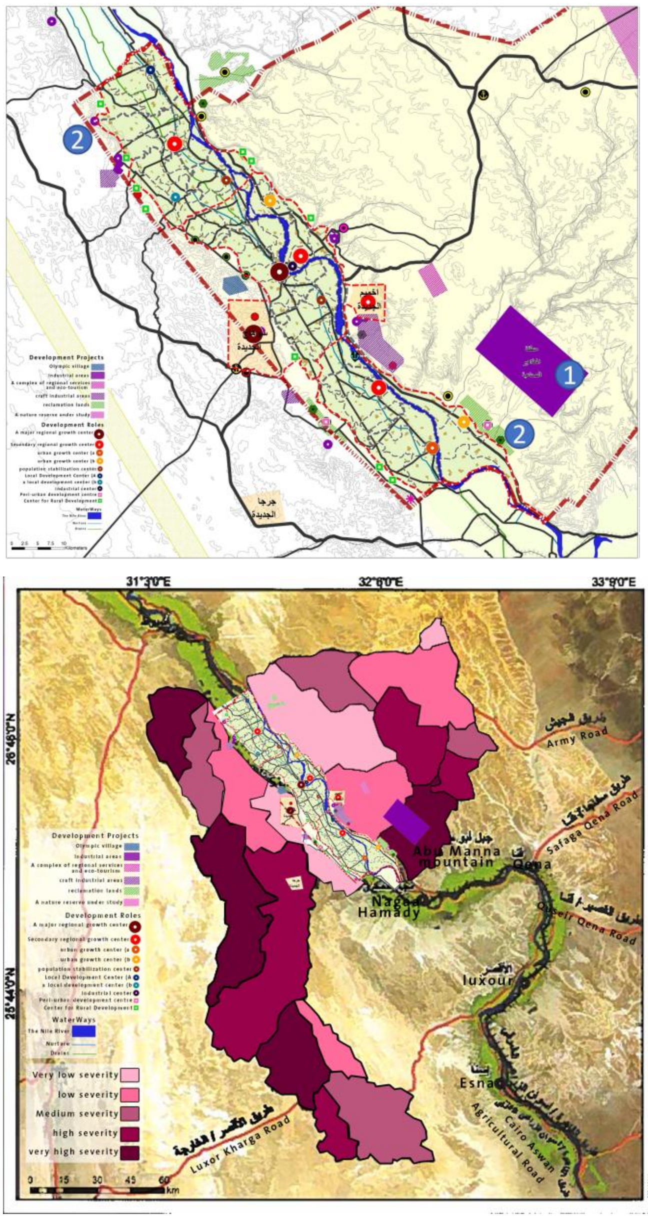

Fig. 11 Sohaj 2030 strategic plan without matching risk zone map (up panel) and Sohaj 2030 strategic plan matching with risk zone map (down panel)
Source: [32], Author

8 Recommendation

- According to the specific determination of vulnerable settlements in case of sudden floods, a long-term plan should be developed to deal with them to make the authority ready at any time to take the proper action.

- Establishing a flood risk assessment system for each risk zone and mapping flood risks; reviewing architectural plans for the urban area to identify vulnerable areas to secure; drawing escape maps; and building evacuation facilities in high-risk areas.

- Preparing guidelines for the implementation of structural measures to reduce the risk of sudden hazards and providing workers training centres for measures implementation training.

- Controlling the land-uses on a regional scale through detailed maps to demarcate the dangerous zones and define the permitted uses of these zones

- The non-structured measures should come out with the participation of civil society organizations, stakeholders, the private sector, and relevant government institutions, as it is extremely important for the success of the sudden risk management process.

- Generalise the use of the multi-hazard assessment approach for natural risks in Egypt, which helps to determine the roles and responsibilities of the parties related to natural disasters and coordinate between them, taking into account the responsibilities and follow-up to implement the correlated tasks.

- Training officials in local administrations and municipalities on how to manage sudden risks, implement emergency plans, and manage crises.

- For multi-hazard assessments, taking hazard relationships into account is a crucial topic. Due to an incorrect assessment of the actual hazard situation, the disregard of this factor may instead result in the appearance of unexpected and wholly unknown outcomes.

- In these local zones, thorough and comprehensive investigations are conducted. The current investigation was conducted using a top-down strategy. This will first apply to local (>1:10,000) and regional (1:10,000 and 1:50,000) scales.

- Information about faults, soil, and geology would be at the regional scale. The local level would be used to gather physical and population data.

9 Conclusion

Egyptian authorities rely on a reactive rather than proactive strategy in dealing with the natural risks depending on the structural measures, without considering the non-structural measures like land use regulation and risk management planning. Two pillars will be recommended as an experiment to aid authorities in improving the application of disaster risk management: the integration of structural and non-structural measures and the employment of a multi-hazard risk strategy. By mapping all linked risks, developing a risk zone map, directing future planning strategies, and managing land use to prevent social and economic loss and lessen the negative impact in the case of an unanticipated hazard, this strategy will assist in avoiding single-risk measures. At the regional level, numerous imbalances are found; the most significant is the failure to designate the risk zones and match the planned future land use with the level of hazards. The proposal for the Sohag governorate showed the need to determine the vulnerable settlements in case of sudden floods and establish a flood risk assessment system for each risk zone in addition to mapping flood risks and demarcating the dangerous zones.

References

[1] D., Penna, M., Borga, D., Zoccatelli, "Analysis of flash-flood runoff response, with examples from major European events. Treatise on Geomorphology", Academic Press, San Diego, CA, vol. 7, Mountain and Hillslope Geomorphology, pp. 95–104, 2013, DOI: 10.1016/B978-0-12-374739-6.00153-6

[2] X., Lin, "Flash floods in arid and semi-arid zones" UNESCO, Paris, p 6. 1999, available at https://unesdoc.unesco.org/ark:/48223/pf0000118882

[3] K., Halbert, C., Nguyen, O., Payrastre, & E., Gaume, "Reducing uncertainty in flood frequency analyses: A comparison of local and regional approaches involving information on extreme historical floods," Journal of Hydrology, vol. 541, pp. 90–98, 2016, http://dx.doi.org/10.1016/j.jhydrol.2016.01.017

[4] H., Hapuarachchi, Q., Wang and T., Pagano, "A review of advances in flash flood forecasting," Hydrological Processes , vol. 25, pp. 2771 – 2784, 2011, http://dx.doi.org/10.1002/hyp.8040

[5] J., Mashaly and E., Ghoneim., "Flash Flood Hazard Using Optical, Radar, and Stereo-Pair Derived DEM: Eastern Desert, Egypt," Remote Sens., vol. 10, pp. 1204, 2018.

[6] Al-Hakim, Bahauddin Abdul-Majid, "Natural Hazards in Egypt," The Second Annual Conference on Disaster and Crisis Management, Cairo: Crisis Research Unit, Faculty of Commerce, Ain Shams University, pp. 548-474, 1997, Retrieved from http://search.mandumah.com/Record/109923

[7] Karim Ahmed Fouad., Ahmed Mahmoud Yousry., Ghada Mahmoud Hassan, "Global planning procedures in facing the risks of floods in the built environment and their compatibility with the Egyptian situation," Conference on Contingency planning and Adaptative urbanism, Cairo, Faculty of Urban and Regional Planning, Cairo University, 2022.

[8] Ahmed Adel Saleh, "DAM BREAK ANALYSIS USING HEC-RAS: CASE STUDY OF WADI ABU SHEIH, EGYPT," Conference on Contingency planning and Adaptative urbanism, Cairo, Faculty of Urban and Regional Planning, Cairo University, 2022.

[9] https://ourworldindata.org/natural-disasters

[10] A., lnazer, A., Salman, & S., Asmoay, "Flash flood hazard affected Ras Gharib city, Red Sea, Egypt: a proposed flash flood channel,' Nat Hazards, vol. 89, pp. 1389–1400, 2017, DOI 10.1007/s11069-017-3030-0

[11] Water Resources Research Institute (WRRI), "Storm 2017 Damage on Ras Ghareb City in Red Sea governance" Report, Cairo, 2017.

[12] M., Baldi, D., Ami, I., Al Zayed, G., Dalu, "Climatology and Dynamical Evolution of Extreme Rainfall Events in the Sinai Peninsula—Egypt," Sustainability, vol. 12, pp. 1–20, 2020, https://doi.org/10.3390/su12156186

[13] Abdrabo, K. I., Kantoush, S. A., Saber, M., Sumi, T., Habiba, O. M., Elleithy, D., & Elboshy, B, "Integrated methodology for urban flood risk mapping at the microscale in ungauged regions: A case study of Hurghada, Egypt," Remote Sensing, vol. 12, pp. 3548, 2020, http://dx.doi.org/10.3390/rs12213548

[14] Muhammad, Wissam Mostafa Imam, "Planning and urban policies and mechanisms to confront environmental disasters - Positive dealing with floods in Egypt", PhD thesis, Faculty of Regional and Urban Planning, Cairo University, 2019.

[15] Mladineo, N. et al, "Methodology for the Assessment of Multi-Hazard Risk in Urban Homogenous Zones," Applied Sciences (Switzerland), vol. 12, no. (24), 2022, doi: 10.3390/app122412843.

[16] https://blogs.egu.eu/divisions/nh/2021/10/04/natural-hazards-101-multi-hazards-and-multi-hazard-risk/

[17] Liu, Z. et al, "A three-level framework for multi-risk assessment", Georisk, vol. 9, no. (2), pp. 59–74, 2015, doi: 10.1080/17499518.2015.1041989.

[18] Colombo, A. G., Hervás, J., & Vetere-Arellano, A. L, "Guidelines on Flash Flood Prevention and Mitigation" European Commission Joint Research Center. Italy, 2002, available at https://reliefweb.int/report/world/guidelines-flash-flood-prevention-and-mitigation

[19] T. L. Moe and P. Pathranarakul, "An integrated approach to natural disaster management: Public project management and its critical success factors," Journal of Disaster Prevention and Management, vol. 15, no. 3, pp. 396–413, 2006, doi: 10.1108/09653560610669882.

[20] Muhammad A. Seddeek, Maha M. Elsayed, "From Regional to Local Level: An Integrated Planning Framework for Cities Facing Tsunami Risk – Alexandria Case, Egypt", Civil Engineering and Architecture, vol. 10, no. (6), pp. 2230-2245, 2022, DOI: 10.13189/cea.2022.100602

[21] https://www.britannica.com/science/earthquake-geology/Methods-of-reducing-earthquake-hazards

[22] Prediction, protection and preparation - Earthquakes - AQA - GCSE Geography Revision - AQA - BBC Bitesize, https://www.bbc.co.uk/bitesize/guides/zp46sg8/revision/6

[23] Ahmed Badawy, "Historical seismicity of Egypt," Acta Geodaetica et Geophysica Hungarica, vol. 34, no. (6), pp. 119 – 135, 1999.

[24] El-Sayed, A., Arvidsson, R. & Kulhánek, O, "The 1992 Cairo earthquake: A case study of a small destructive event," Journal of Seismology, vol. 2, pp. 293–302, 1998, https://doi.org/10.1023/A:1009717023043

[25] Buck, K. D. and Summers, J. K, "Application of a multi-hazard risk assessment for local planning," Geomatics, Natural Hazards and Risk, vol. 11, no. (1), pp. 2058–2078, 2020, doi: 10.1080/19475705.2020.1828190.

[26] DFID, "Multi-Hazard Disaster Risk Assessment (v2)", DFID UKaid, pp. 1–6, 2012, Retrieved from

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/204933/Multi-hazard_risk_assessment_guidance.pdf

[27] Eshrati, L., Mahmoudzadeh, A. and Taghvaei, M, "Multi hazards risk assessment , a new methodology," International Journal of Health System and Disaster Management, vol.3, no. (2), p. 79, 2015, doi: 10.4103/2347-9019.151315.

[28] Kappes, M.S., Keiler, M., von Elverfeldt, K. et al, "Challenges of analyzing multi-hazard risk: a review," Nat Hazards, vol. 64, pp. 1925–1958, 2012, https://doi.org/10.1007/s11069-012-0294-2

[29] Sameh A. Kantoush, Mohamed Saber, Mohammed Abdel-Fattah, and Tetsuya Sumi, "Integrated Strategies for the Management of Wadi Flash Floods in the Middle East and North Africa (MENA) Arid Zones: The ISFF Project," Natural Disaster Science and Mitigation Engineering, DPRI Reports, Springer, https://doi.org/10.1007/978-981-16-2904-4

[30] Radwa Bakr, Doaa Amin, Khaled Gaber, "Guideline for Atlas Flash Floods" Civil Engineering and Architecture, vol. 10, no. (5), pp. 2108-2127, 2022, DOI: 10.13189/cea.2022.100530.

[31] Water Resources Research Institute (WRRI), "Wadis Atlas of Sohag Governorate," Ministry of Irrigation and Water Resources, Cairo, Egypt, 2015.

[32] GOPP (the general organization of physical Planning), "The Strategic Plan of Suhag governorate 2030," Cairo, Egypt, Unpublished report, 2016.

[33 Blackwell, M. S. A., Maltby, E., Gerritsen, A. L., Haasnoot, M., Hoffmann, C. C., Kotowski, W., Leenen, E. J. T. M., Okruszko, T., Penning, W. E., Piorkowski, H., Platteeuw, M., Querner, E. P., Siedlecki, T., & de Swart, E. O. A. M" ,Ecoflood guidelines : how to use floodplains for flood risk reduction," Ecoflood Project , https://d3n8a8pro7vhmx.cloudfront.net/yyccares/pages/20/attachments/original/1498666598/EU__Ecoflood_Guidelines__HOW_TO_USE_FLOODPLAINS_FOR_FLOOD_RISK_REDUCTION_compressed.pdf?1498666598

[34] Fleischhauer, M, “The Role of Spatial Planning in Strengthening Urban Resilience," In: Pasman, H.J., Kirillov, I.A. (eds) Resilience of Cities to Terrorist and other Threats. NATO Science for Peace and Security Series Series C: Environmental Security. Springer, Dordrecht, 2005, https://doi.org/10.1007/978-1-4020-8489-8_14

[35] UN, "International Strategy for Disaster Reduction," United Nations Documents Related to Disaster Reduction, 2004, available at https://sdgs.un.org/statements/un-international-strategy-disaster-reduction-unisdr-8377