

**Impact of Climate and Environment Changes on the Sustainability of
the Coastal Areas: The Case of Ain Sukhna, Red Sea, Egypt**

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Abstract:

This paper investigates the impact of climate and environmental changes on the sustainability of the coastal area of Ain Sukhna, Red Sea, Egypt. Ain Sukhna sea shores and Galala mountain region have witnessed rapid change and modifications during the past 50 years. Climate changes are expected to impact this area through the increase in the amount and intensity of rainfall and the rise of seawater tides. Modifications applied to the topography of the mountains through grading and levelling are spreading excavation debris on the sides of the mountains creating a new hazard if swept away by the rainwater. The paper analyzes the design and construction of the coastal and mountain developments and assesses their capacity to withstand these changes. The negative impact of these changes is not only ecological but also physical and socioeconomic. Climate change impacts are becoming more instantaneous and intensified. Place-based strategies for reducing the negative impact of climate change are required to reduce the physical and ecological vulnerabilities and manage the impacts of climate change.

Keywords: Climate change, Environment Change, Sustainability, Coastal Areas, Ain Sukhna, Red Sea, Egypt

Introduction

Egypt has more than 3000 KM of coastal waterfront of different conditions and uses on the Mediterranean Sea. the Red Sea and Sinai Peninsula. According to the World bank Development Report on 2018, about 15% of the almost 105 million inhabitants of Egypt live in coastal zones. Waterfronts represent a dynamic and vibrant entity of the country that evolves according to the continuous development requirements. They differ according to their location, surroundings and characteristics. They could be either coastal parts of cities that have geographical features with a view over the

coast, where the sea always represents a major part of the societal culture and an element of the landscape through which the city is formed (Erkilic and Akpinar 2019), or coastal zone that has specific value and significance according to their surrounding natural and marine environments.

Ain Sukhna sea shores and Galala mountain region have witnessed rapid development and modifications during the past 50 years. Located approximately 60 kilometers south of Suez City and 120 kilometers east of the capital Cairo, it is considered one of the most important tourism attractions for Egyptians and foreigners due its proximity to urban areas. (Figure 1) The area is famous for its colorful coral reefs, rich marine life, beautiful scenery and fishing sites that have made this area one of the best scuba diving locations in the world. It enjoys excellent weather all year round. According to weather reports, the average minimum temperature in winter is 7° C while the average maximum temperature in summer is 34° C. The average annual rainfall is 17 mm and wind directions are NW, N, and W, with general speeds ranging between 11 and 20 km/hour. It is characterized by all year-round sunshine, clear sea water, beautiful sandy beaches, gentle waves, magnificent mountain scenes, and a spectacular coastal scenic drive along the sea shore. Recent archeological discoveries reveal that “the site was occupied extensively for more than a millennium during the pharaonic period, from the Old Kingdom to the New Kingdom used mainly to cross over to the southern part of the Sinai Peninsula on the other side of the Gulf of Suez.” (Tallet 2012)

Sukhna was famous as the best place for camping and one-day school trips until recent developments took place that occupied most of the virgin and public beaches. Mahgoub studied the recent touristic developments of the coastal stretch of Ain-Sukhna on the Red Sea coastal region of Galala Mountain, and their impact on the surrounding natural and cultural attractions (Mahgoub 2022). He indicated that since the 1967 War the region was designated a military restricted zone and was off-limits to civilian and public activities. It was part of the battlegrounds of the War of Attrition between 1967 and 1973 wars. After the reopening of the Suez Canal in 1975, and the signing of the peace treaty in 1977, restricted access to the area was lifted, and fishing, diving, and camping activities resumed. Since the late 1970s, the area has witnessed rapid construction of touristic facilities and resorts that produced negative impacts on the fragile natural and cultural heritage due to their proximity to the sea shores and destruction of valuable coral reefs. Between 1977 and 1997, early projects and development started with

traditional seafood eateries, small hotels, and modest vacation communities made of rows of one- or two-story chalets. Population continued to increase due to the construction of different types of developments that were established in the area including commercial, industrial, mineral, educational and touristic developments.



Figure 1. Location of Sukhna and Galal region.

Climate and Environment Changes

Egypt is highly vulnerable to climate and environmental changes impacts. Future projections indicate that Egypt will suffer from sea level rise, water scarcity and deficit in addition to an increase in the frequency and intensity of extreme weather events such as heat waves, flash floods, heavy rains, sand and dust storms. As indicated by the UNDP-UN 2018 report, water resources, agriculture and fisheries, health, housing and settlements, biodiversity, telecommunications, electricity, tourism, coastal zones, and coral reefs are among the industries that are anticipated to be most impacted (UNDP-UN 2018). As confirmed by Chi et al, in the next 100 years, features of climate change, such as sea level rise, altered rainfall patterns, and hurricanes, will have a significant impact on human life. More research is being done to find the best ways to adjust to the effects of the current and future climate (Chi et al. 2021).

The impact of climate change and related hazards such as floods, heatwaves, and sea level rise on human lives, cities, and their hinterlands depends not only on the nature of the hazard, but also on urban development, adaptation, and other socioeconomic processes that determine vulnerability and exposure. Spatial planning can reduce

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climate risk not just by influencing the exposure, but also by addressing social vulnerability. This requires that relevant information is available to planners and that plans are implemented and coordinated between sectors. (McMillan 2022)

The development of Sukhna started at the northern part and extended southward towards Zaafarana. The first hotels and resorts appeared in the north were Sukhna Hotel, al-Higaz resort and Portrait hotel. They were modest developments composed of rows of one- or two-story buildings containing one- or two-bedrooms units made of red brick, reinforced concrete and painted light colors. The large development called “Porto Sukhna” started in 2007 spreading over 2.5 million square meters extending up the mountain to 270 meters above sea level. The “Porto-style” transformed the traditional flat coastal development style in the region to a multistory wave-like building. It hosted significant development and recreational amenities, within vibrant facades, expensive pricey materials and unusual shapes.

The success of Porto Sukhna encouraged more luxurious developments and gated communities to be established in the area like La Vista and Telal. (Mahgoub 2022) Recently, development has started on the Galala Mountain Plateau following the construction of Galala Mountain Road and the establishment of Galala City, located 700 meters above sea level on the Galala al-Bahariya Mountains between Ain-Sukhna and Zaafarana, covering approximately 19,000 feddans. The city hosts Galala University that started operational in 2020 with 1500 students, and currently 5000 students, in 16 fields of studies and 37 programs, and is planned to grow to 25,000 students by 2030. Galala city hosts several residential communities, recreational, commercial and hotels. It is expected to have a huge economic, social and urban impact in the area.

Figure 2 illustrates the stages of development of Sukhna-Zaafarana coastal stretch. The development can be divided into three sectors. The first sector covers the area from Sukhna south of Suez city to Galala City. It contains the first examples of development; such as Al Hegaz and Portrait, and the latest; such as Galala Resort. Sector two contains the Porto Sukhna landmark as well as deconstruction developments. Lastly, sector three contains the luxurious resorts of Telal and La Vista developments. The last stretch of the coast towards Zaafaran is undeveloped providing future opportunities for development. Two hundred kilometers south of Zaafarana lies several

important tourism attractions; including Guna, Hurghada, Mersa Aalam and Sahl Hashish, that makes it an important node connecting Egypt to the attractive tourism developments along the Red Sea shores.

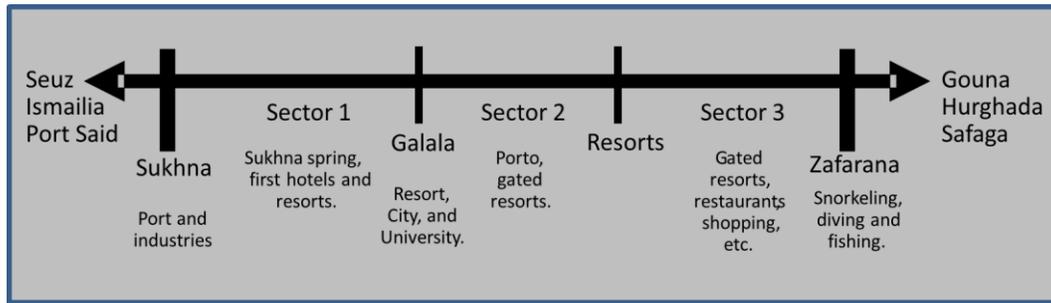


Figure 2. Stages and directions of Sukhna development.

Climate and Environment Changes in Sukhna Region

Climate Changes

The UN Paris agreement, adopted in 2015, sets out to limit warming to less than 2 degrees temperature increase above pre-industrial levels. However, the latest science warns that we should be aiming to keep warming below 1.5 degrees if we are to avoid the worst climate impacts. (TCPA, 2018)

Sukhna and Galala regions are witnessing climatic and environmental changes that threaten current and future developments in the area. Yearly temperature charts of Sukhna region indicate increase in temperature trend and anomaly since 1979, when mean temperature was 20.2 and trend was 19.3. In 2020, the trend has increased to 21.4 and the mean temperature has increased to 21.1. The results indicate that during the past 40 Years temperature change between 1979 and 2020 have increased: (meteoblue 2022) (figure 3)

- Trend: $21.4 - 19.3 = + 2.1$
- Mean: $21.1 - 20.2 = + 0.9$

The implications of this temperature increase include:

- Increase in air temperature
- Increase in sea water level
- Change of rain fall pattern and intensity of rain water flooding

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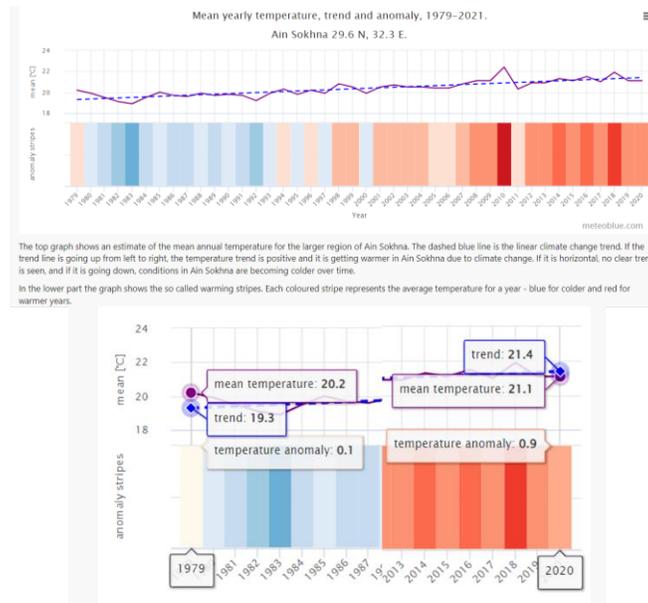


Figure 3. Yearly temperature change in Sukhna (Source: meteoblue 2022)

The following charts illustrate the changes of precipitation trends and anomaly. In 1979, the mean precipitation was 9.1 while the trend was 22.2. In 2020, the mean precipitation has reached 57.8 while the trend was 20.6. The results indicate that during the past 40 years precipitation change between 1979 and 2020 was: (meteoblue 2022) (Figure 4)

- Trend: $20.6 - 22.2 = - 1.6$
- Mean: $57.8 - 9.1 = + 48.7$

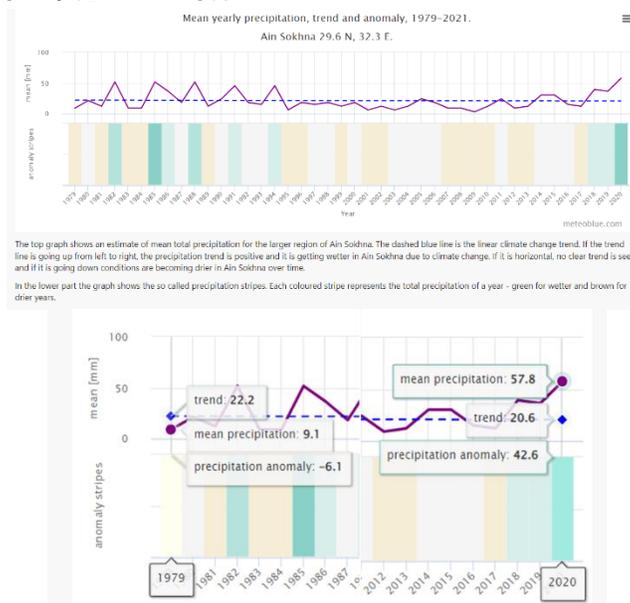


Figure 4. Yearly precipitation changes in Sukhna. (meteoblue 2022)

While increase in temperature amounted to nearly complete 1 degree centigrade, the amount of rain decreased. Yet, rain intensity increased in specific days creating more rain flooding hazards and damages. The overall results indicate that the weather in Sukhna is getting warmer and the amount of precipitation is decreasing while its in-tensity is increasing. (Figure 5)

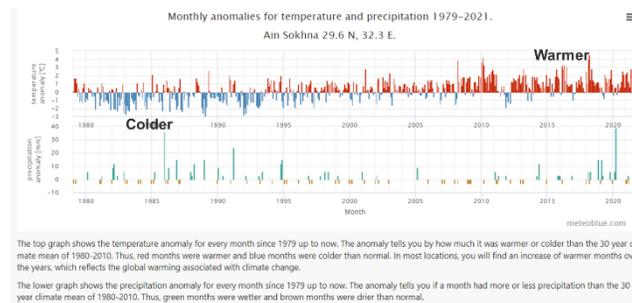


Figure 5. Monthly anomalies of temperature and precipitation in Sukhna. (meteoblue 2022)

The analysis of climate change in the region indicates a continuous trend of temperature increase during the past 50 years and change in precipitation patterns. Continuation of these changes can create great hazards to the vulnerable natural environment and urban development. It can also be hazardous to the increasing population of tourists, workers, students and visitors to the area. An analysis of the urban environment conditions is necessary to understand the expected impact of the climate changes and required responses. As indicated by Alwreikat, “the impact of climate change on ecological, physical, human-managed systems, food safety, land production, agriculture, water quantity, and human health is significant.” (Alwreikat 2022) In addition to the current hazards due to environmental and urban changes discussed below, climate changes pose a new threat to the area.

Environmental Changes

Construction of hotels and touristic villages in Sukhna began in the late seventies. It started from the north side close to Suez city and Cairo-Suez Road. Touristic villages were built on alluvial fans resulted from the accumulation of sediments produced by rain water floodings. They continue

to be in a threat of future rain floodings if not protected and secured properly. On the other hand, as indicated in a report published by The Government of New Brunswick,

Land development can affect the risk of flooding in a number of ways. First, development tends to replace soil and vegetation with impervious surfaces such as roof tops and asphalt. This means that rainfall that used to soak into the ground will flow directly into rivers and streams, increasing the amount of flow. Second, buildings, infilling with earth and other structures placed within flood plains can obstruct the passage of floodwaters. Finally, the potential for flood damage is greatly increased when, through lack of awareness or disregard for the potential danger, unsuitable development takes place in areas that are already subject to flooding. (Government of New Brunswick n.d.)

Figure 6 illustrates examples of tourism development along the coast of Sukhna constructed on alluvial fans. As argued by Abu Rayya, due to the increased tourism activities along the Gulf of Suez, tourism facilities were constructed on alluvial fans, ignoring the natural hazards of rain runoff and placement of these structures on the path of torrential flows that might cause many property and human losses. (Abu Rayya 2022) (Figure 7) The leveling of the surfaces of the alluvial fans did not consider natural land inclinations that allow the runoff rain to reach the sea. They also did not consider the weak nature of the soil of these alluvial fans that results in its disintegration and buildings' failures. (Figure 8)



Figure 6. Examples of Developments along the coast of Sukhna



Figure 7. Porto Sukhna site development from 1985 to 2021 as seen in Google maps.



Figure 8. Example of a rain flooding path resulting and alluvia fan currently used for tourism development.

Recent developments are being constructed on higher levels of the mountain. As described by Mahgoub, the natural environment has undergone significant change. For development, the mountains are being terraced (Mahgoub 2022). Figure 9 illustrates how the debris of the leveling and excavations activities thrown to the sides of the mountains creating a new hazard since they could be carried by rain water during heavy rains and unpredictable changes in rain flood paths.



Figure 9. Debris resulting from the leveling of the mountains are creating a new hazard

Tourism Development: Planning and design of compounds and touristic villages

The Red Sea is a unique environment with deserts rich in history abutting sea whose remarkable coral reefs are among the best in the world. With its striking environment and touristic potential, sunny climate, and short flight distance from major population centers in Europe, the Egyptian Red Sea coast has tremendous potential for economic development and benefits for the nation and region. (Gohar 2016)

The Sukhna area was famous as camp ground for schools and family one-day trips during the end of the 20th century. Its virgin beaches and sloping mountains touching the sea water was attractive for local and international tourism. It was also famous as an excellent diving and fishing spot close to urban areas. Tourism developments along the costal stretch between Sukhna and Zaafarana has started after the 1973 war and the signing of the peace treaty between Egypt and Israel in the 26th of March, 1979. The Eighties and Nineties witnessed the construction of the first touristic villages and hotels in the area around the hot spring – Ain Sukhna – site east of the coastal road overlooking the sea. The planning focused on providing chalets and apartments with basic services and swimming pools. The second stage of development extended south and included five stars hotels and higher standard chalets, apartments and villas. One gated community, La Siesta, was constructed in a strategic location on higher level hills west of the road. This project encouraged other developments to utilize the mountain hills west of

the road instead of only utilizing the flat available lands east of the road. (Figure 10)



Figure 10. Examples of the planning of tourism development in Sukhna

The area became attractive for developers to construct luxurious gated communities. The second part of the stretch from Porto-Sukhna to Zaafarana contains several luxurious gated communities constructed by Telala, La Vista, Long Beach and other real estate developers. The planning focused on providing distinctive vast landscape, private gardens, large number of swimming pools and entertainment facilities. The coastal road was moved away from the sea on higher levels to allow larger areas for development close to the sea. Several commercial strips were constructed hosting supermarkets, restaurants, furniture stores and other shops. (Figure 11)



Figure 11. Examples of the architecture of tourism development in Sukhna

In addition to the hazardous locations of the touristic resorts on alluvial fans along the coast, many structures are located in the path of flash floods

paths. Figure 12 illustrates example of a development locating the tourism development planning perpendicular to the natural flow of rain water paths. Rows of villas and chalets are obstructing the natural flow of rain water towards the sea that results in the accumulation of water and structural damages.



Figure 12. Illustration of a tourism development planning and the natural flow of rain water paths. Yellow lines indicate rain water path while red lines indicate construction development.

Another hazard indicated by AbdelMaksoud et al study is the quality of the rock formation on which on which many of the currently under construction touristic villages are located. The rock formation is partially comprised of very weak micrite limestone exceeds the recommended limit of 20% of the total formation. (AbdelMaksoud et al 2022)

Unfortunately, projects aimed at attracting tourists have been built on deteriorating rocks, increasingly becoming of poorer rock quality. The results showed that parts of the study area become vulnerable to natural hazards due to its tectonic history and particular rock formation. (AbdelMaksoud et al 2022)

Discussion

As indicated by Gohar, “Since the late seventies there has been recognition of the environmental significance of the Red Sea area, but attempts to do environmental planning started only in the 21st century.” (Gohar 2016) During this period, many damaging practices negatively impacted the natural and built environment in the area. The following is an

analysis based on the field observations and surveys conducted by the researcher.

Rapid Development

There are many sudden natural hazards that cause change in the study area, as they differ from one place to another depending on the natural factors that cause them, and the degrees of their severity and their impact on the areas they are exposed to may vary, and among these sudden natural hazards that humans do not control are rockslides and torrential rains that conflict with the study area. It has negative effects on development projects in the study area. (Hagras 2021)

The Sukhna-Zaafarana stretch is witnessing rapid increase in development activities; touristic facilities, industrial factories, educational institutions, commercial and residential communities. The new projects are following the same strategies of older projects focusing construction on alluvial fans or reclaimed land from the sea. The new approach to utilize high level lands for construction after leveling and grading is increasing in several locations. Yet, excavation and leveling products are deposited on the sides of the mountains creating a new hazard during flash floods. (Figure 13)



Figure 13. Permanent construction of high walls and land infill of sea beaches is destroying the marine life and causing coral reefs degradation.

Increase in Population

The rapid increase in the number of different types of developments in the region is causing rapid increase in activities, population and need for services; including affordable housing, commercial amenities and public transportation for the increasing number of workforces. Increasing numbers of students and staff from Galala University are opting to reside rented apartments and chalets

of Porto Sukhna and other touristic villages. While this increase in population is improving the economic vitality of this low occupancy and seasonal tourism region, it is applying burden and heavy demand on the already limited resources of services; including transportation, commercial and housing. Unplanned transportation parking areas and street vendors serving the passengers and drivers are spreading informally in the area. The new McDonalds restaurant, with its famous sign, became a significant meeting point for busses commuters, mini-busses passengers and drivers. (Figure 14)



Figure 14. Informal transportation and busses parking near McDonalds sign

Landscape Irrigation

The landscape design of the residential gated communities applies an English-style landscape of large green lawns and grass that require large amounts of water from irrigation. Whether this water is recycled or not, huge amounts of freshwater are being injected into the ground with unforeseen consequences. As indicated by Abu Rayya, residual irrigation water is gathering on the limestone causing rock erosion (Abu Rayya 2022). (Figure 15)



Figure 15. Landscape irrigated by excessive water.

Architectural Design

The architectural design of all the buildings do not consider the natural environment in terms of building orientation, openings, materials, or passive cooling systems. The design focusses on proving a sea view for every unit regardless of orientation and direction. The area is affected by irregular building activity, early development buildings and structures that have been abandoned. Informal sea food sales kiosks and restaurants are dispersed along the coastal road. (Mahgoub 2022) (Figure 16)



Figure 16. Examples of buildings designed without consideration of the environment

Vehicular Transportation

The area suffers from heavy trucks traffic along the coastal road. Trucks carrying construction materials along the coastal road are creating pollution, noise and hazards of accident. They spread construction materials on the road endangering other vehicles and pedestrians. Trucks are causing air, land, visual and audial pollution deteriorating the original noiseless site attractions. (Figure 17).



Figure 17. Vehicular traffic on the coastal road is noisy and dangerous to pedestrians.

Conclusions

This study aimed at identifying expected impact of climate change and environmental modifications in Ain Sukhna and Galala region. Results indicated that increase of human and development activities taking place in the area are creating several problems and hazards to people and the environment. It investigated the expected implication of climate change on the natural and built environment. The research findings identified the following as major threats to the area:

- Debris resulting from modifications and leveling of hills and mountains.
- Landscape plants and irrigation systems excessive use of irrigation water.
- Destruction of the marine life and coral reefs degradation due to pollution and coastal modifications.
- Vehicular traffic along the coastal road creating hazards and pollution.
- Unplanned development, parking and bus stops along the coastal road.

The study helps to better understand the impact of climate change on the region and ways to avoid drastic implications. “Climate change is a global issue that is already being felt locally.” (Schweizer 2013, 59) Each location is affected by climate change in a different manner depending on its specific environment and severity of changes. As suggested by Abbass, "Climate change is a long-lasting change in the weather arrays across tropics to polls. It is a global threat that has embarked on to put stress on various sectors." (Abbass et al 2022) However, as Chi et al indicated, adapting to climate

change is not an easy task, and adaptation may cause additional vulnerabilities, which are referred to as maladaptation. (Chi et al 2021)

Towards a Place Based Strategy

This paper suggests the application of Place Based strategies for reducing the negative impact of climate change on the physical and ecological environments. Research has shown that climate change will resonate with diverse audiences when: (1) it is situated in cultural values and beliefs, (2) it is meaningful to that audience, and (3) it empowers specific action. (Schweizer 2013) It is recommended to engage visitors, users and local communities through awareness plans to reduce energy consumption, water use and recycling. To reach large audience, cultural values, such as language, beliefs, and social networks should be considered when preparing these plans. Events and activities can be planned during seasonal vacations and weekends. A dedicated mobile application can be developed for visitors and users providing climatic updates and education. Schweizer recommends that “future education and outreach initiatives to develop integrated place-based activities such as climate camps, citizen science programs, and mobile and website tools that are locally relevant, empowering, and engaging for diverse audiences.” (Schweizer 2013, 59)

The best way to reduce risks to human safety and property damage from flooding is to identify locations that are prone to flooding (flood hazard areas) and avoid them when planning new buildings, roads and other vulnerable structures. Good planning practice indicates that land in areas that regularly flood should be limited to uses that are not greatly affected by flooding. These include parks, golf courses, recreation areas and parking lots, or uses such as agricultural or forestry or conservation.

Buildings that are already located in flood hazard areas can be “floodproofed”, which means adding temporary or permanent features to a building or its surroundings that reduce the potential for damage due to flowing or standing water. The power to regulate the use of flood plain lands within municipal boundaries rests with the local municipal council. Measures such as zoning by-laws, and building permits can be used to control and direct land use within the flood hazard areas. Galala University is establishing an Environment and Development Observatory that will make use of its expertise and resources, particularly the Geoinformatics laboratory, to continuously

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monitor these changes and publish newsletters on the status of the area and any potential dangers.

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