CRP 514: city and regional planning

Section 2

Term 122

Term Paper:

Remote sensing and GIS applications to Landslides

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Table of Contents

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Abstract:

Landslide hazards can strongly damage the infrastructure of cities especially in the mountainous areas which have high steep topography and in some areas such as cliffs and slope that facing sea areas, the monitoring become very difficult or sometimes impossible and for this reason mainly the space brone and airborne remote sensing can be used as a technique for assessing and monitoring the area that be difficult to monitor. In the first case study which took place in Sharm El-Sheikh/Ras-Nasrani area in Egypt where many infrastructure have taken place, using high resolution images of QuickBird satellite in order to creating a map for the hazardous areas and slope stability map for the area and finally to develop slope stability by analyzing different factors that contribute slope stability. Historical data for landslide in Hong Kong used for estimating and analyze landslide hazard and generate various layers of information to assess landslide hazard map.

Keywords: Landslide, remote sensing, Sharm El-Sheikh/Ras-Nasrani, QuickBird, Hong Kong, hazard map.

1. Introduction:

A landside consider as a geologic phenomenon that can include the ground movement in different scales varying from small and local landslide to huge and regional ones and it have many types but the most common landslide are debris flows, rock fall, deep slope failure landslides, the main reason of landslide is the slope instability of earth's layers which can be triggered by earthquakes of continues rain fall or rock tension due to undercutting (http://en.wikipedia.org/wiki/Landslide). The rate of sliding also varies from very slow landslide to which occur particular in dry area or the areas that have thick vegetation cover that make the earth's layer stable, and it can take place in very high speed and this type of landslide is very hazardous and its mainly rock fall landslide which have very disastrous impact on the human lives in building infrastructure and many historical cases are been known to killed hundreds and damage most of city infrastructure and case immediate and delayed impact of those features. There are many Factors that control the potentiality of landslide which include: the weathering effect that weakening the earth's material, changes in the angle of the slope; overloading; changes and increasing of water content. (http://en.wikipedia.org/wiki/Mass_wasting).

2. Problem statement:

Landslide hazard have been known to destroy and damage severely the infrastructure of many cities throughout the world and killed hundreds of peoples, because the sudden slide of soil and rock material and there is no enough time to avoid its damage. The usual landslide map which depend on geographic position have a lot of limitations because it doesn't show many important factors such as slope of the map and zonation of hazardous areas. In this study I used reviewed paper to highlight the technique that can be used to create slope instability map and make a zonation map composed of different layers to assess the hazardous areas and find the best way to monitor landslide using remote sensing and GIS technique.

3. Objective:

Using Remote Sensing and GIS to analyze landslide hazard and applying Remote Sensing to solving geological problems regards to landslide and slope instability.

4. Methodology:

High resolution satellite with meter to less than meter (QuickBird satellite) has been installed and been used to collect corrected image of multi-spectral and panchromatic images. And to map the geological units of the area published geological data were used which is acquired by Enhanced Thematic Mapper Plus (ETM+). More detailed about the landslide and slope stability of the area of the study have been obtained by visual interpretation using the high-resolution QuickBird data and the result have been integrated to geographic information system (GIS) to identify the distribution of slope-instability hazardous zones on the larger scale.

The second case study depend mainly on the input data (published annually by the Geotechnical Engineering Office) of landslide in the study area and integrate the input data with GIS to generate slope map and zonal map which show the hazardous areas.

5. Literature review:

Fausto Guzzetti and others, 2012 have proposed Landslide inventory maps in term of identify and assess the extent of the landslide region using GIS and he conclude that landslide map can be generated using statistical and historical data and also generation of zonation map, risk analysis and landslide susceptibility map can be established based on multy temporal and seasonal maps and he recommended to standardized landslide maps.

 Cruden and Varnes, 1996; Dikau et al., 1996 discussed the main conditions that cause landslide which can be identified, and can be mapped. And they proposed that observable features have been recognized after the slope failure and those feature can be classified and mapped in the field or through remote sensing.

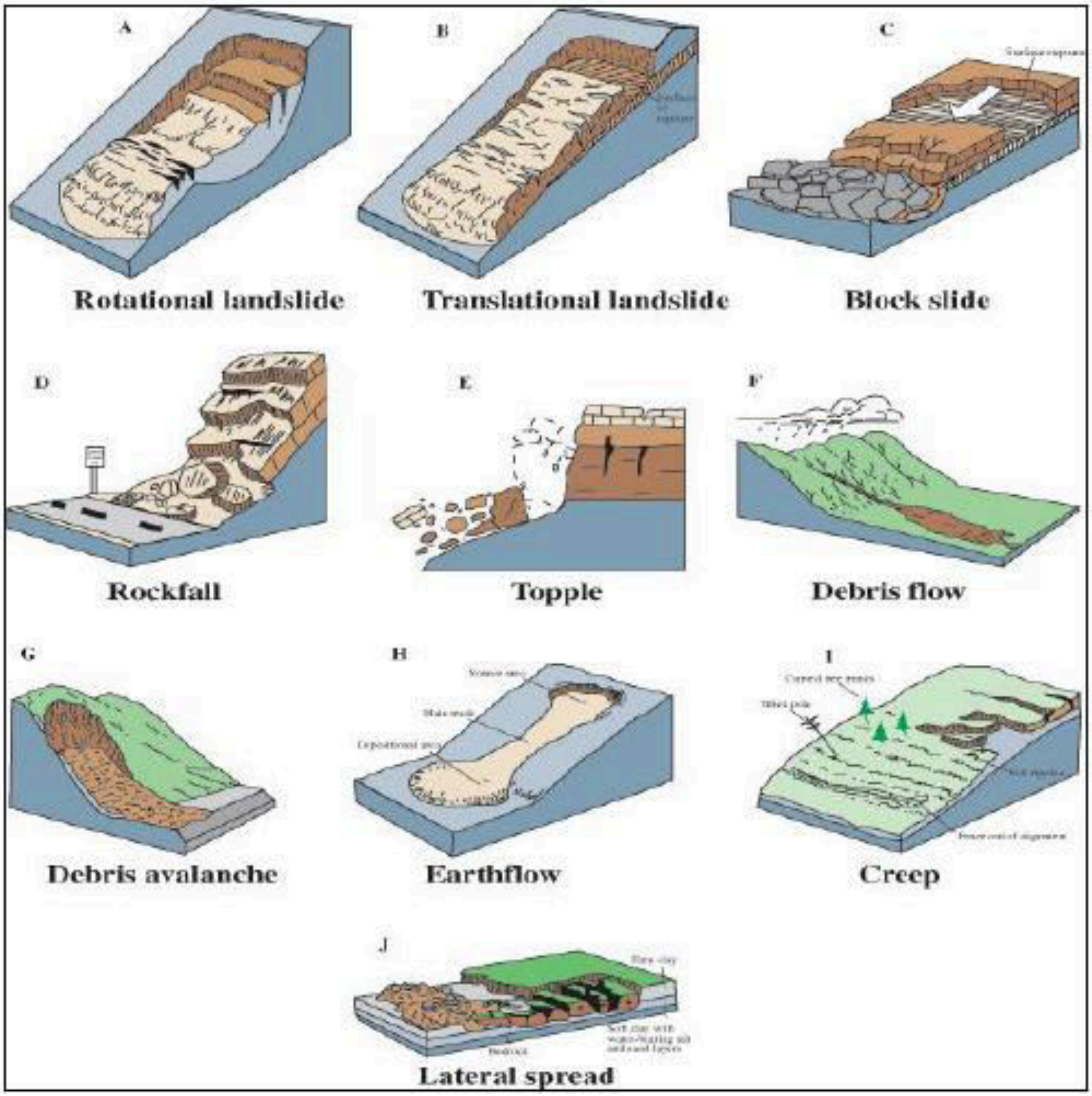
Mohammad Onagh and others, 2012 published paper that discuss Multiple Linear Regression method in susceptibility of landslide, landslide zonation and validation of landslide risk map with inventory map of the study area and they classified the areas of landslide to different zones depend on historical and statistical parameters to very highly landslide zone, highly landslide zone to moderately landslide zone and finally low landslide zone.

5.1 Types of landslides:

Classification of landslides depends on the many factors that include: the texture and the composition of the material, the slope steepness, the presence of air and water and the type of movement and velocity. A classification of the landslide have been proposed by Varnes (1978), which was based on their dominant behavior according to: types of material involved, rate of movement and type of movement. Different types of landslides are show in table 1 and figure 1.

Types of movement		Type of material		
		Bed rock	Soil	
			Course	Fine
Falls		Rock fall	Debris fall	Earth fall
Topples		Rock topple	Debris topple	Earth topple
Slides	Rotational	Rock slump	Debris slump	Earth slump
	Translational	Rock block side, Rock side	Debris block side, Debris side	Earth block side, Earth side
Lateral spreads		Rock spread	Debris spread	Earth spread
Flows		Rock flow Rock avalanche (Deep creep)	Debris flow Debris avalanche (Soil creep)	Earth flow (Soil creep)
Complex and compound		Combinations of two or more types of slope movements		

(Table 1)Types of landslides modified from Varnes (1978) classification of slope movements.



(Figure 1) schematic representation of major types of landslide movement. Varnes (1978).

Falls

Fall is a sudden vertical movement of material from a cliff by the pull of gravity, the falling Material can be a single rock dislodged from a steep slope or a sudden collapse of mass of rock falls down a slope by freely falling, rolling, bouncing and sliding until friction and decreasing slope angle at the base of the cliff halts its motion .

Slides

In slides, the rock blocks moving as coherent mass along weakness and failure planes. This kind of slide exhibit small amount of shear and deformed features such as patches. Some structure and trees exposed on the land surface sometime stay intact without contribution into sliding process, and the stratigraphy of the sediment and soil in most cases stay preserved (Varnes, 1975). Slides are the most common type of mass movements. They are shallow mass movements with a failure plane almost parallel to the surface of the slope.

Slumps:

It a type of slope failure which involves a downward and outward movement of rock or regolith on a concave up failure surface. Slumps can range from small displacements of one or two square meters to large complexes of hundreds or thousands of square meters.

Creep

Creep is the very slow (cm/year) down slope movement of weathering material. This movement is quasi-viscous, most often discontinuous. The movement of creep is restricted to the surface layer of the regolith. Depending on the materials involved, it can be grouped into rock creep, talus creep and soil creep.

Debris avalanche:

it a type of debris avalanche and mainly characterized by movement of the debris matrix chaotically which may include water and ice or both of them and they triggered by saturation of thick vegetation slope which results from many factors such as incoherent soil the debris slide have different rate of sliding than debris avalanches which characterized by rapid sliding. (http://en.wikipedia.org/wiki/Landslide).

5.2 Factors influencing slope stability:

Many factors affecting the slope stability which manly occur When the slope is in a critical state of stability the destabilization can be generated by a relatively sudden triggering event of natural (such as an earth quake, soil saturation) or human origin (e.g. an explosion). The most important factor controlling slope stability is explained in the following:

Force of gravity:

Water can reduce shear strength and thereby promoting the movement of rocks and sediment down slope under the pull of gravity. Positive pressure can be created by reducing the shear strength that produced in in the earth's material pore space and those pore space filled by the infiltrating of water to thee earth and case the area to be unstable and also the water Wight have influence on the stability of the layers. This lessens the friction between them and leads to failure (Sidle and Swanston, 1982).

Seismicity:

Explosions, earthquakes or volcanic eruptions can increase shear stress and trigger slope failure. These phenomenons occurred naturally, but can be accelerated by human influence. Intense shaking can cause water pressure in the pore spaces of sediments, leading to liquefaction. The vibration released during earthquakes can cause failure of slopes which were previously stable through the influence of increased vertical acceleration. According to Muthu and Petrou (2007) the possibility landslide depend manly on trigger mechanism such as earthquakes which case the ground to shake and the landslide consider the main damager rather the earthquakes itself.

Land cover change:

Land cover change has been recognized throughout the world and it considered the most important factor that influence the occurrence of rainfall-triggered landslides (Cruden and Varnes, 1996). Deforestation increases the probability of landslides. Cities are especially vulnerable. In poor countries people have cut down trees and removed vegetation to build their houses. The roots of this vegetation bind the soil together and protect it from heavy rainfall keeping the slope stable but, if vegetation is removed the slope is exposed to risk of landslides. In many cases landslide is associated with de-forestation processes, but many factors integrate to generate triggering mechanism of sliding.

Geologic factors:

Geology is one of the important factors considered in slope stability analysis (Clerici et al., 2002). Depending on the type of regolith, there is strong relationship between geology of the material and slope instability of specific area. The Weathering process can case alteration to minrologic and mechanical properties of regolith which an important factor of slope instability in many settings (Maharaj, 1995; Chigira, 2002; Wakatsuki et al., 2005). Type of lithology and geological structures plays a great role in slope stability.

5.3 Landslide inventory mapping

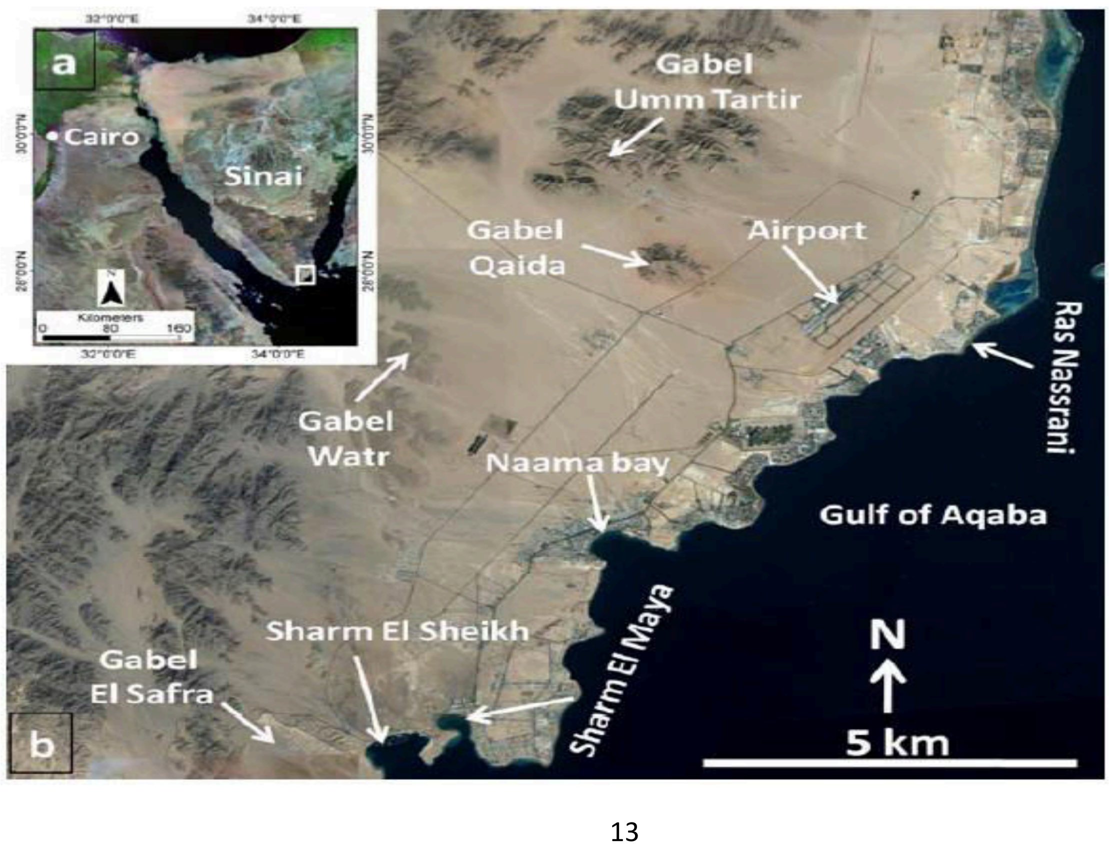
The most powerful way of studding landslide hazard to generate landslide inventory, the inventory technique consider the base of most of landslide mapping techniques (Dai et al., 2002). The main reason of landslide inventory and analysis is the prediction of future pattern and slop instability prediction depending mainly on the historical record of landslide in specific region. The inventory maps of Landslide show characteristics and locations of landslides that have been moved previously in the past but it not indicate any mechanism(s) that caused them to trigger. The maps of landslide can show the landslide location such as small scale maps and it also can show the source area of landslide such as large scale maps. To determine existing landslide hazard and undertake an estimation of future landslide occurrence, the understanding and explaining of the conditions and processes that controlling landslide factor are important. A map of existing landslides consider as a basic data re-source for understanding these processes and conditions. Existing landslides and their relationship with other key factors such as lithology, slope steepness and hydrology form the basis of a hazard assessment (Long, 2008).

Case Study 1: Remote sensing applications to geological problems in Egypt: case study, slope instability investigation, Sharm El-Sheikh/Ras-Nasrani Area, Southern Sinai.

By: Ahmed M. Youssef . Norbert H. Maerz . Abdallah Mohamed Hassan.

1.1 Introduction:

Sharm El-Sheikh area consider one of the most attractive areas for tourist activities in Egypt, it locate on the red sea coast and the study are located between Ras-Nasrani and Sharm El-Sheikh. The morphology of the area of the study extend from northwest along basement complex and from the east along Gulf of Aqaba and many famous hills have been occurred in the area such as Gabel Qaida, Gabel El-Safra and Gabel Watr. The study area have different rock types ranging from Pre-Camberian rocks, Nubian Sandstones and recent sediments. The Landsat image (Figure 2) below describe the area of the study wich locate between Ras-Nasrani and Sharm El-Sheikh area.



(Figure 2) below describe the area of the study wich locate between Ras-Nasrani and Sharm El-Sheikh area. (Ahmed M. Youssef et al. 2009).

1.2 Methodology:

High Spatial resolution Satelite (meter to sub-meter) have been used in this study to collected corrected image of QuickBird which have 0.61 m for panchromatic band. The Multi-spectral and Panchromatic images of QuickBird in Ortho-ready standard have been acquired on the second of June 2007 and those images integrated with (Enhanced Thematic mapper plus (ETM+) data dated to 2001. And finally visual interpretation have been performed on the available data to get more detail out of it. The table below describe the technical properties of satellite sensors.

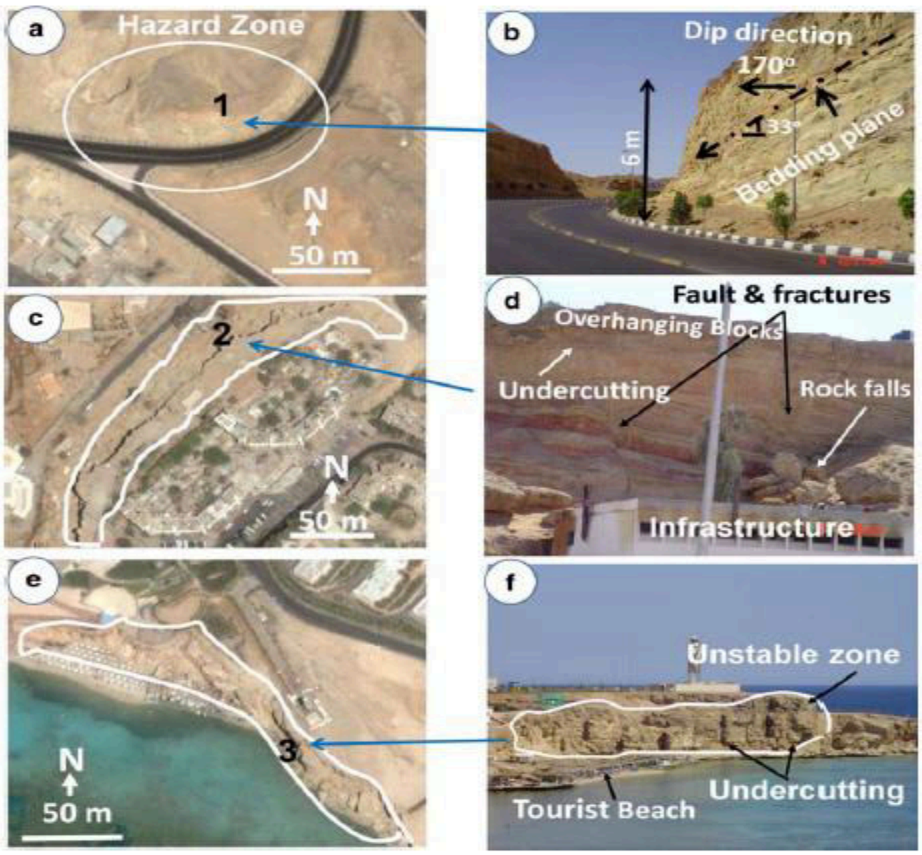
Satellite sensor, provider	Spectral bands	Spatial resolution/swath width (at nadir)	Average revisiting time, off-track viewing angle	Price per km^2 (USD)
QuickBird, DigitalGlobe	Panchromatic	0.61 m/16.5 km	1–3.5 days, ±30°	~24
	450–520 nm	2.44 m		
	520–600 nm	2.44 m		
	630–690 nm	2.44 m		
	760–900 nm	2.44 m		

(Table 2) technical properties of satellite sensors. (Ahmed M. Youssef et al. 2009).

1.3 Results:

The Identification of unstable slopes can be obtain by visual interpretation using high resolution image of remote sensing which allowed to detect many features such as beaches, buildings and the roads that can be affected by the landslide and fall of rocks(figure 3 explain example for visual recognition of unstable rocks in the area) and by combining the images of high resolution QickBird, a hazard map have been established based on the showing the main infrastructures, hotels, touristic villages and urban areas shown on the (figure 4) and its very clear that most of activities are mainly close to the coast-line and towards the desert.

(Figure 3) high resolution image and field image show risky area.



(Fig.4) Satellite image and the field image showing the result and real field data (Ahmed M. Youssef et al. 2009).

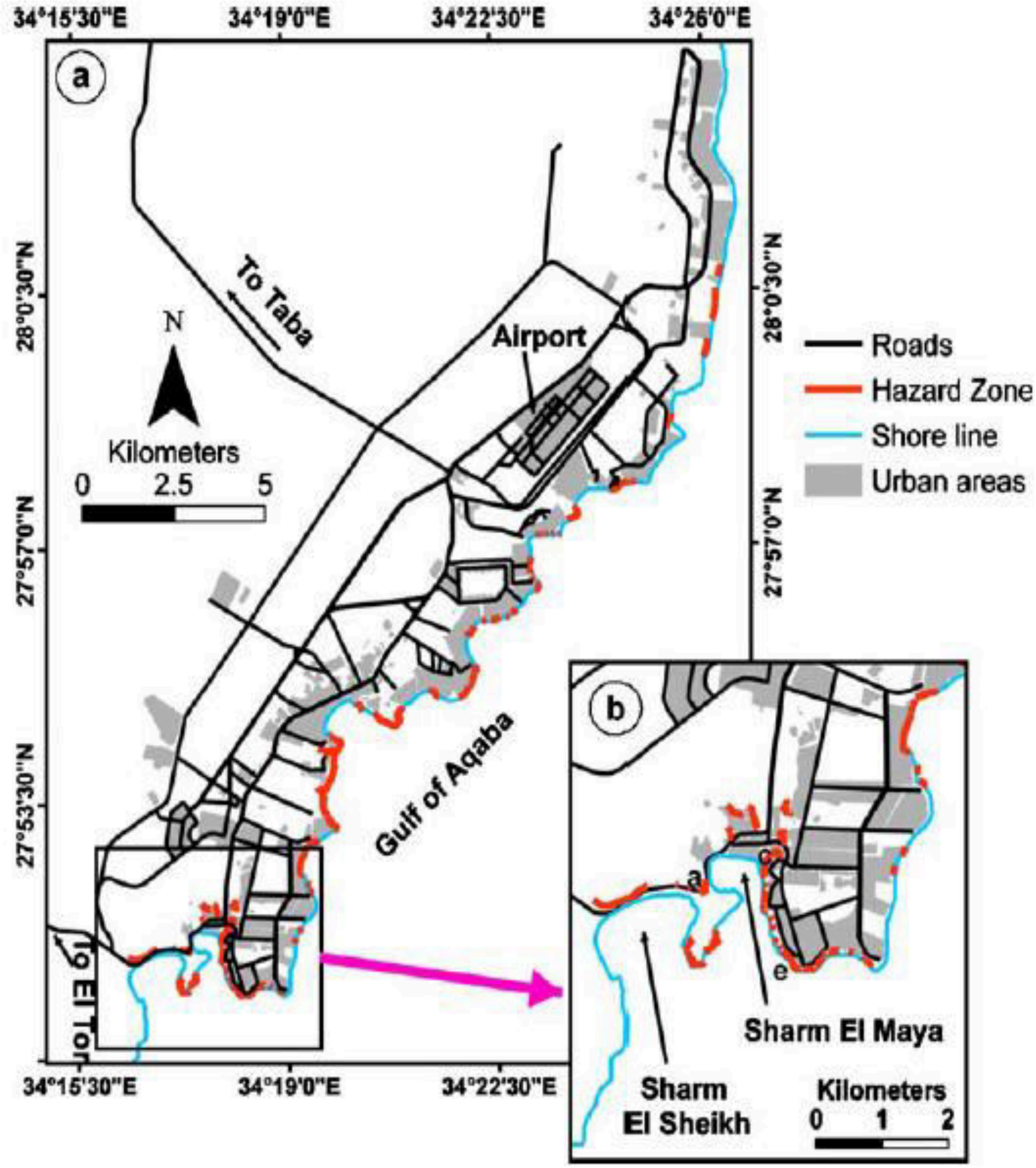


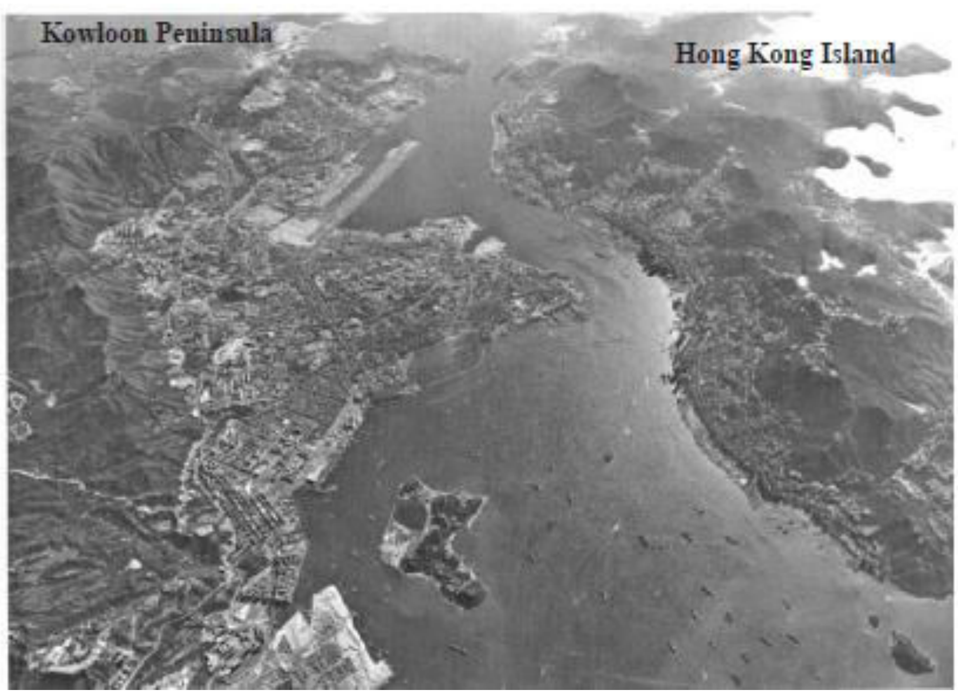
Figure 5 show the developed hazard map of the study area with the main infrastructures. (Ahmed M. Youssef et al. 2009).

Case Study 2: Landslide hazard analysis for Hong-Kong. using landslide inventory and GIS.

By: K.T. Chau*, Y.L. Sze, M.K. Fung, W.Y. Wong, E.L. Fong, L.C.P. Chan

2.1 Introduction:

The risk analysis and landslide hazard for a city icrease by the presence of mountain ranges which surrounding many of the recent cities and therefor landslide map to estimating landslide hazard is very important and useful (Anbalagan et al., 1993; Kienholz, 1978.). The study area is Lantau Island close to Hong Kong Island (figure 1) where the high building and the main infrastructure are there. And then the main objective of this study integration historical data of landslide with GIS and supported by the geological information of the area such as slope height and slope angle and finally to proposed zonation map of landslide hazard depending mainly on historical data and it spatial distribution.



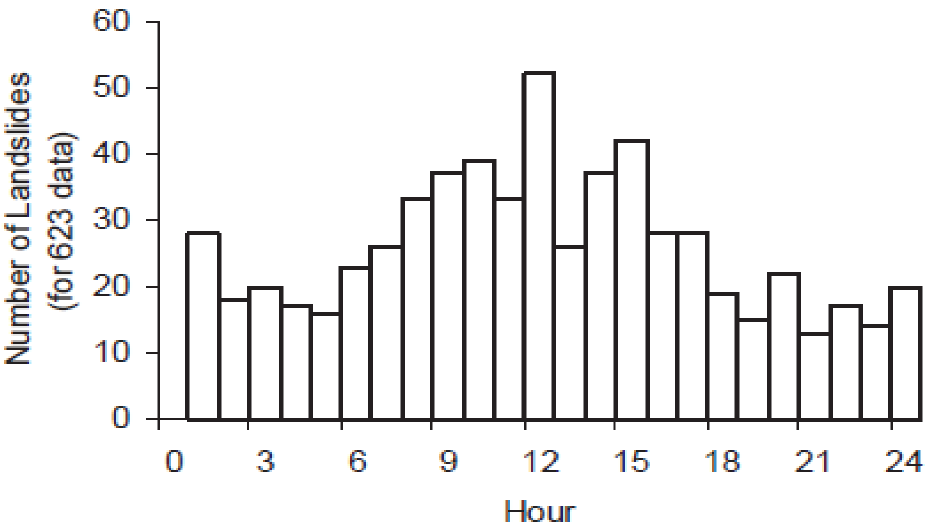
(Figure 6) Aerial photograph of Hong Kong Island (after Fyfe et al., 2000).

2.2 Methodology:

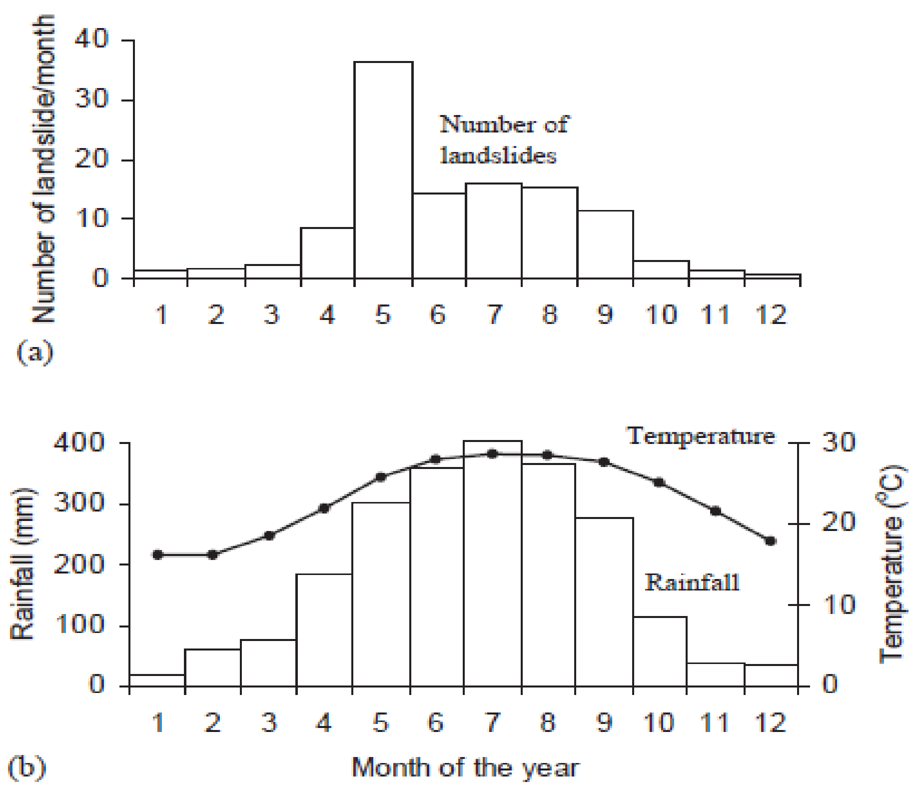
Landslide sometime is very hazardous phenomena which can cause injury, death and complete destroy of the cites and its infrastructures, if their location close to the human activities. The study area have underwent many landslide events as a debris flow and the (figure 2) below show different landslide events.

(Fig. 7). Landslides history in Hong-Kong (K.T. Chau et al., 2004).

Diurnal frequency of rock fall have been established for Hong Kong by Chau et al. (1998) by using data form 1995-1949. The (figure 3) represent a plots for the diurnal landslide distribution by plotting the data from 1996 to 1948. And the investigation showed that the landslide occure mainly during the daytime from 7 morning up to 6 evening and the peak-landslide hours took place at noon. And in the daytime the human activities reach the peak.

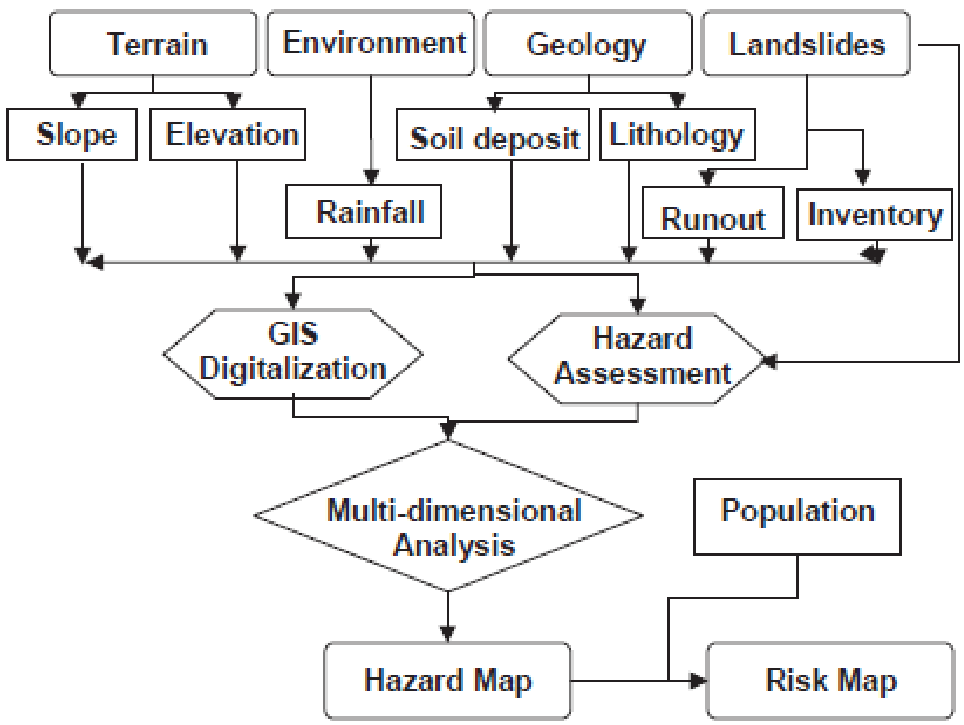


(Figure 8) landslide frequency in Hong Kong (1948– 1996). (K.T. Chau et al., 2004).



(Figure 9) .a. explain the seasonal variations of Hong Kong landslides (1984–1996). B. rainfall seasonal distribution with temperature variations. (K.T. Chau et al., 2004).

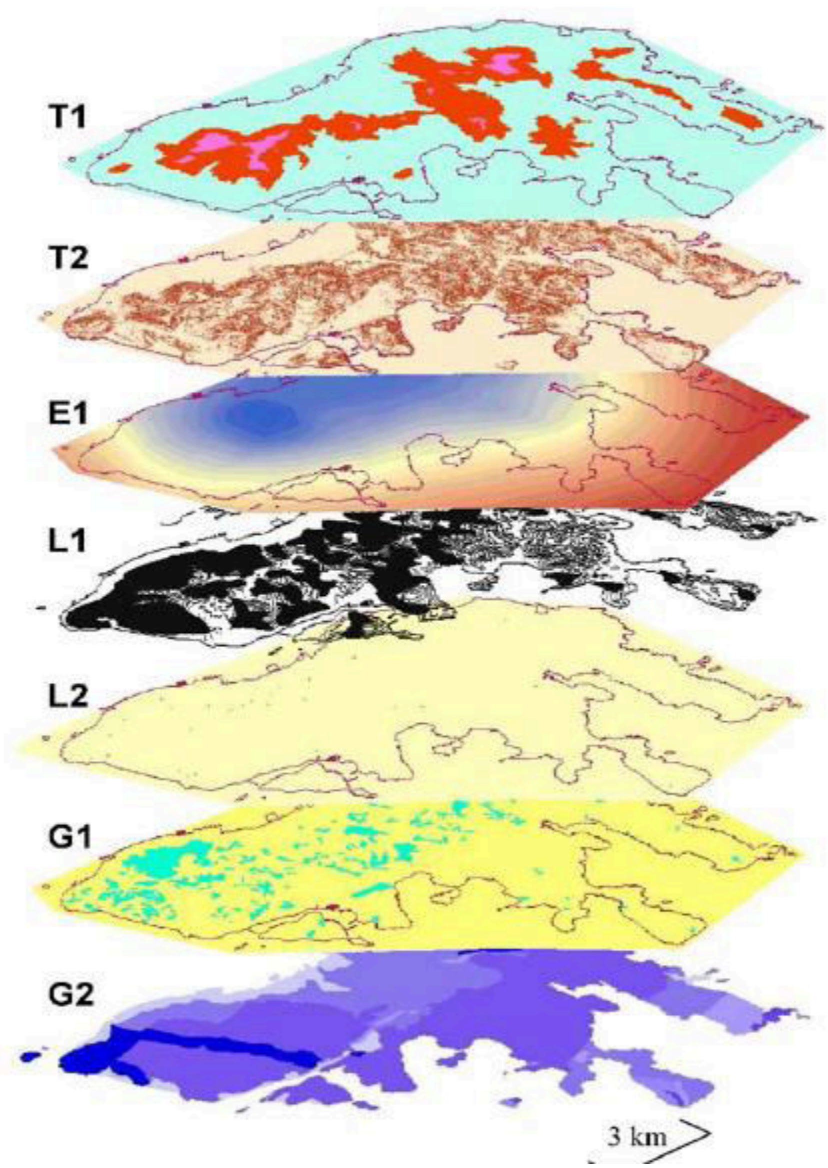
The hazard map that formed casually based only on the landslide data have shown many limitations but the zonation depend on different factors that related directly to the landslide such as hydrology, lithology, vegetation, geomorphology and the climate, so the challenge in the zonation map is to integrate all those factors to generate the zonation map of landslide. More reliable estimation need to include and incorporate different layers and integrate it with GIS system ArcGIS 8.2 have been used in this study. In this present study seven layers through the flow chart below wich explain the main input of data which is environmental effect, terrain data and land-slide information to generate different layers.



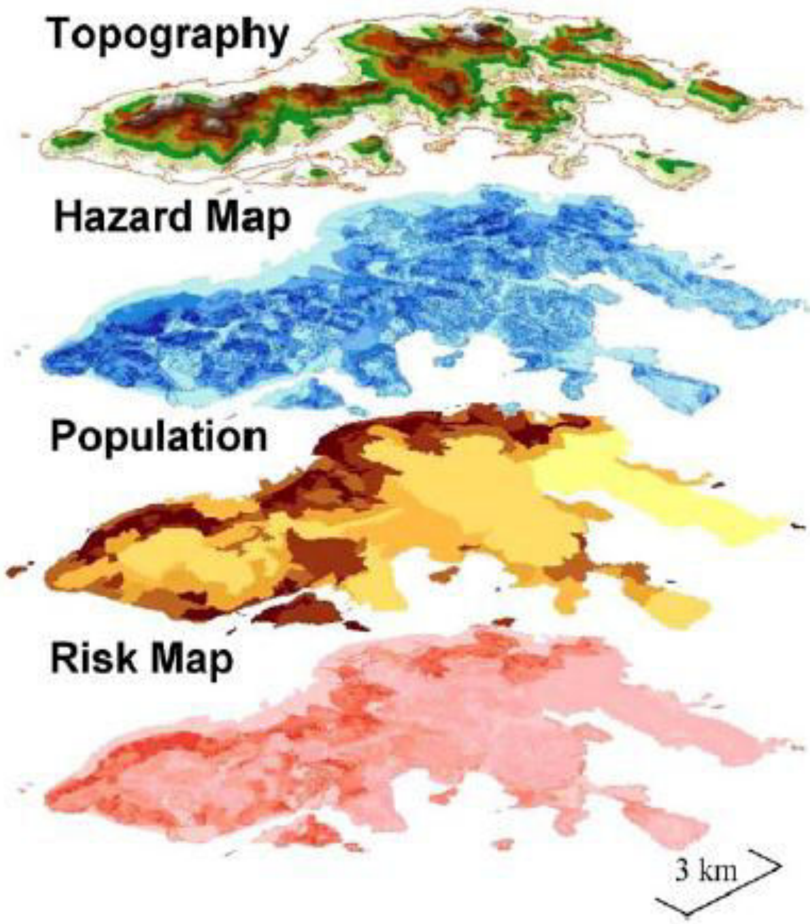
(Figure 10) explain flow chart of risk anaylsis and landslide hazard based on GIS. (K.T. Chau et al., 2004).

2.3 The results:

The landside record and information history for many factors such as temperature, rainfall, slope and lithology integrated with GIS used to generate hazard map of the area of the study and the result have been shown below.



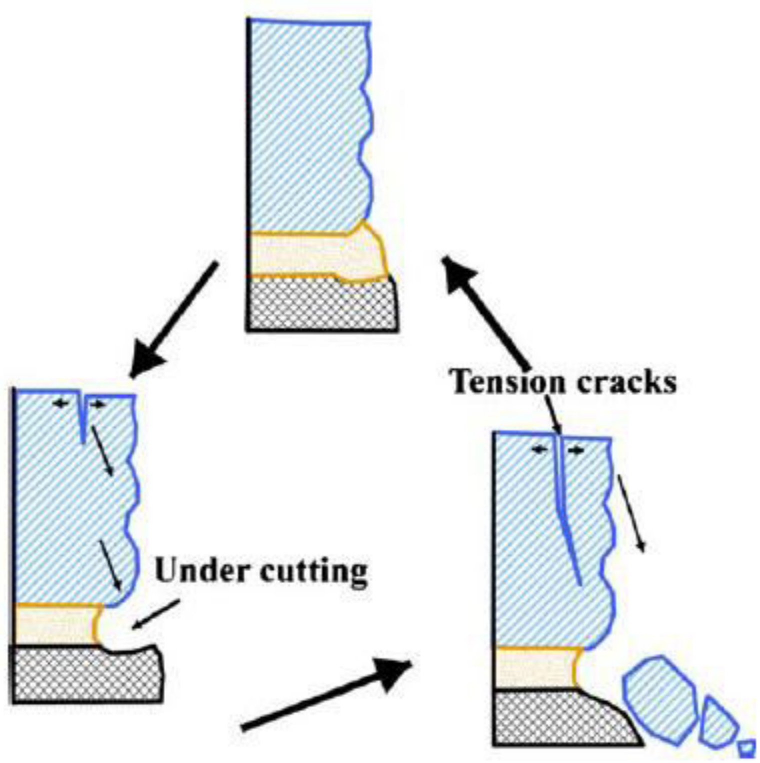
(Fig. 11). The Seven GIS layers maps have been used in generating landslide hazard map for the study area the legend: T1= the elevation T2=the slope; E1=rainfall map; L1=potential run-out L2=landslide inventory map G1=map of soil deposition; G2=geology map.). (K.T. Chau et al., 2004).



(Fig. 12). Hazard map and the risk map. (K.T. Chau et al., 2004).

Conclusion and discussion:

Landslide hazard assessment using high resolution sensors (QuickBird) images have been applied to Sharm El-Sheikh area and it proved that slope instability can be investigated using high resolution satellite images and the results have been coupled and proved by field assessments and hazard map have been created with model of slope instability have been found in the area which proposed that the undercutting phenomena (figure 13) by the wind action and wave along the coast area make the area very weak to reconstruction.



(Figure13) mechanism of slope failure. (K.T. Chau et al., 2004).

The hazard map also can be generated using the historical information of landslide in specific area such as Hong Kong and it proved to very good assessment more than using the usual hazard map because the integration of GIS gives a powerful tool in slope instability assessment.

Recommendations:

To avoid constructions failure due to instability of the area and presence of close mountainous area which have high probability of sliding, remote sensing images must be used in such a projects and integration of GIS to generate Hazard map is very powerful tool which generate many layers also very useful. Remedial work must took place in the hazardous area immediately before starting constructions, the hazard map using GIS gives very good information about landslide and must be applied for the areas that have large probability of slides.

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