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Identification of Tsunami Hazard Zones in Krabi Coastlines using GIS Techniques

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Abstract : One of the natural coastal disaster tsunami hit the various coastal areas of Southern Thailand including krabi by devastating human lives and infrastructure in 26 December 2004. This research focused to identify tsunami hazard zones in such tsunami affected region krabi, using Geographical information systems (GIS) techniques. This research is applied, qualitative, GIS based and field oriented. The tsunami hazard criteria were initially developed including tsunami hazard parameters. The developed criteria were justified using Saaty scale of importance method as weight of comparison matrix method. The five different classes of tsunami zones were predicted using various GIS techniques such as extracting the data layers, converting the data layers from vector to raster format, classification and reclassification of various raster format data layers into required classes and map calculation by adopting the assigned weight of the different parameters, were utilized. The different parameter such as mangroves, elevation, road and river were utilized. The predicted tsunami hazard zone model was developed into five categories naming as very high tsunami hazard zones, high tsunami hazard zones, moderate tsunami hazard zones, low and very low tsunami hazard zones by identifying the tsunami hazards different areas in these types of categories with their appropriate definition of such predicted regions for utilization in future. It is assured that this tsunami hazard model will save human lives and infrastructure in future it may be incorporated for redevelopment for the region.

Key words: Krabi, GIS, Land use planning, Spatial Analysis, suitability Analysis

1. INTRODUCTION

The terrible tsunami waves triggered by earthquake , inundated the coastal lines of Indian ocean on 26 December 2004 with significant magnitude of 9.3 (*Suppasri., et al., 2011*) which destroyed the human lives of socio economic set up of the different coastlines of southern Thailand including other various countries. Though the epicenter of that occurred earthquake was Banda Ache, north of Sumatra islands in Indonesia but the tsunami waves travelled to different seacoasts of Thailand possessing about more than two thousand km of coastlines including the various coastal areas of Krabi and other provinces by killing more than five thousand people (*Thanawood, et al., 2006*).

As the vulnerability rate of developing countries remain higher than the developed countries in terms of getting losses and destruction from the natural disasters especially tsunamis because of the difference in their attitudes during such types of disasters as developing countries remain proactive while the developing countries adopt reactive approaches. The identification of probable natural hazards in advance is one of the parts of the pro-activity for mitigation of their losses in future. The disaster management institutes adopt the various methods such as risk assessment, identification of natural hazards zones and developing evacuation routes to minimize the troubles by adopting quick response and recovery (*Papathoma., et al., 2003*).

The identification of hazards process uses various steps such as collection of previous occurred hazards events data, developing hazard parameters, using weighting and rating method to prioritize the factors weights to identify the various hazard zones (*Flax., et al 2002*). The drawback of weighting method is that it has always been criticized due to its subjectivity for assigning the weight to the different parameters, which can be compensated by using Saaty scale of importance method. (*Malczewski.1999*). Hazard assessment is the fundamental step for evaluating the risk as it is the important component of the risk variable (*Wegscheider., et al., 2011*). As the hazard is the probable natural damage to be happened in future.

The disaster management authorities utilize the various sources to cope up the disasters including the technological use of geoinformation technology in mitigation for developing the different hazards models by identifying the various levels of hazards in advance for reducing the occurring losses in futures to the human lives and infrastructure. GIS helps to develop various hazard risk and the vulnerability models utilizing the different data layers depending on their required parameters, criteria and assigned weights during processing such data. GIS is widely utilized by using different data for detecting hazard locations using its different techniques such as overlaying, proximity analysis, buffer techniques and map algebra (*Chakraborty), et al., 2005*).

This research paper aims to identify various tsunami hazards in krabi coastlines using GIS techniques in coastline of capital city of Krabi in province of Krabi in southern Thailand, where tsunami

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occurred in December 2004. This developed model would prove helping to the different decision makers be to become pro-active for redevelopment and rehabilitation of this region in future by avoiding such type of natural brutal disaster.

2. Study area Krabi Coastline Overview in perspective of tsunami hazard.

Krabi **(as shown in Fig.1)** is one the most famous and fascinating province of south Thailand at the distance of 814km from Bangkok (*Marchand., 2006*). It consists various coastal areas such as Ban khlong Hin, ban na tin, ban khlong Muang, Ban khlonghin, Ban Ao Nam Hua, Ban ko Kuang, Ban Khlong in, Ban Nong Thale, Ban Nai Rai, Ban Lem seom, Ban thung, Tup kaek beach, Phulay Beach, Ban Tup kaek, Khlong Muang Beach, Siew Beach, Siew Bay, The princess residence, Railay beach, Aonanag beach, Phranang Bay,Noppharat Bay, Nammao Bay, Ban suan pak, ban nong koh, Ban Khlong Huang and Ban khlong chilai **(as shown in Fig.2).** It has three main villages such as Nong Thale, Aonang and Sai Thai which consist of area about more than 900 km^2 with plenty of trees and forests.

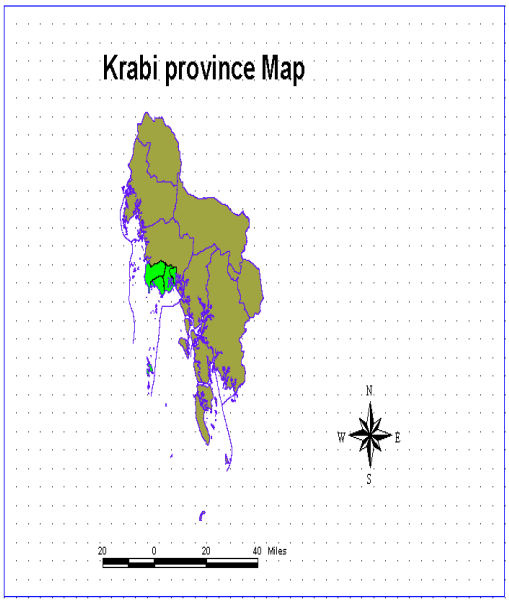


Fig.1. Map Of Krabi Province

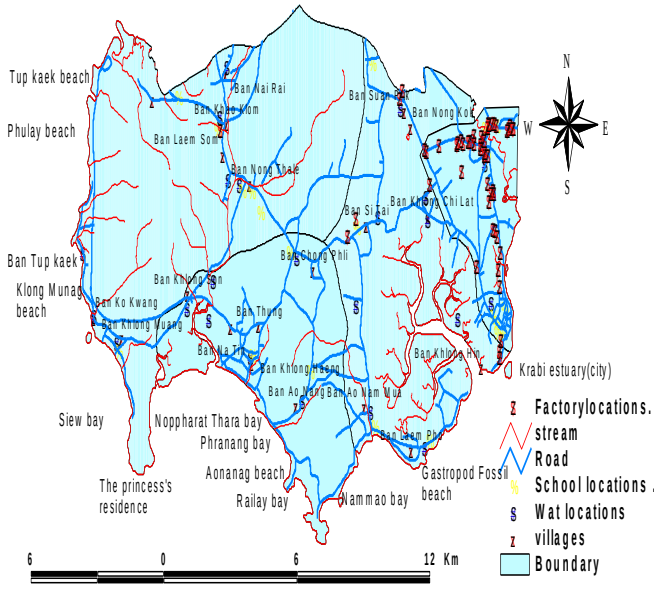


Fig.2. Map Of Krabi Coastline

2.1 Krabi estuary

It occupies in Munag Krabi, one of the city of Krabi provinces in south Thailand. It is full of mangroves, forests, mudflats, canals, large sea grass bed, a good example of urban and natural environments. It opens to the sea with bank of 2 meter below the road. In December 26, 2004, during inundation of tsunami in Thailand, the tidal waves reached to Krabi city, 50 m near to the road causing floods to the roads and other infrastructures. As estuaries are always tsunami prone as natural water rushes from narrow drains to vast drains. This estuary affected Phulay beach more than krabi city comparatively as it has very narrow escape from phulay beach while from Karbi city, it has very vast mouth for inundation.

2.2 Klong Muang Beach

It is 15 km far from Muang Krabi. There are mostly two villages in front of the beach: 1.Ko kwang 2 Khlong Muang, with slight population of 500 people/village. This beach was slightly affected by tsunami with minimum height of less than 1 m because this beach was not opposite to tsunami waves. This beach is far from krabi estuary with elevation of 13-25 m height which protects it from coastal waves inundation. .

2.3 Phulay beach:

This beach is at the distance of 10 km from krabi city and 5 km from khlong Muang (city) beach. Krabi estuary affected this beach during inundation of tsunami with maximum 5 m height, as first wave height was about 2-3 m, while second and third wave height was of 5 m. The distance of higher elevation grounds is about 1.5 km far from coastline. It has two villages; one is Tubkek, located on higher elevation was safe from tsunami inundations while another village Lom Pong was affected by tsunami waves. The distance of tsunami inundation was of 0.5m. The total population of these two villages is about 1000 people/ village. Krabi estuary

is near to Lom pong village that's why it has been affected a lot. The debris impact of 5 m tsunami inundation is so high that it moved more than 20 tons crane to higher grounds which were lying on the beach before tsunami. This beach is very sensitive and the villages are also at very risk of tsunami due to proximity of krabi estuary which is at the distance of 30 m.

2.4 Hat Noppharat Thara Beach

It is located about eighteen kilometers northwest of Krabi in the boundary of Hat Noppharat Thara. Tsunami hit this beach on 10:05 am with inundation height about 2m. The ground level is 2 m above the sea level. The distance of main road proceeding to sea shell beach and Ao Nang beach is 50 m far from this coastline. It is totally flat beach but after tsunami inundation, dyke has been built about 2 m on the road level to protect from inundation. It is in Tambon Ao Nang administration. It has flat land, scattered vegetation and trees in front of beach and total shore line is 1.5 km .The building storey's are 99% one storey and 1 % only two storeys in front of this beach. The tsunami inundation distance **was** 0.5 km. Noppharat Thara village has about 1000 people population including male and female. There is flowing one river behind this beach about 2 km far from village with dense mangroves. This beach is highest risky than other beaches.

2.5 Shell cemetery Beach or Susan Hoi (Fossil Shell Beach)

The elevation of this beach is about 60 m higher than sea level that's why tsunami could not inundate this beach. But near this beach there is one tambon Sai thai which ground level is less than 20 m which was affected little bit by tsunami from Nammao bay with slight damage of boats. Tambon Sai thai is 200m far from sea shell beach. Tambon sai thai has 7 villages which are 3 km far from higher grounds. The mangroves are back of these villages Especially sea shell beach is safe but the villages lying in Thai sai near to Nammao bay are risky from tsunami hazards**..**

A Nang Beach

It is hardly 18 km away from Muang Krabi. This bay has 83 islands. This is the most developed beach in the area. This is most popular and attractive beach for tourists and business men. The tidal amplitude at Ao Nang varies from 1 m to 3 m at highest spring tide. Road distance from this beach is about 50 m only but this beach has 3 m water embankment dyke that's why previous tsunami even 5 m height could not be inundate and water was bounced back by protection of dyke. There was slight flood on road. The distance of higher grounds is about 500 m from coastline. The shops and restaurants are in front of this beach while road is between beach and shops The building ratio in front of the beaches is about 60% three storey's and 40% less than three storey's building. There is lot of vegetation, forests and mangroves on the higher grounds but not on this beach. The famous islands 2 km inside this bay e.g. phi phi Don and phi phi ley were badly affected by tsunami inundation with 5 meter height. These islands are lying in this tambon. Ao nang has about 83 islands. The cause of these famous islands destruction is that these islands are circular shaped islands, which are always tsunami prone islands. However this beach is always less damaging beach due to in front of Phi Phi Don and Phi Phi Ley of it which can first absorb the damage then transfer its remaining destruction to Ao Nang.

3. DATA AND METHODS

The flow chart methodology has been presented in **(Fig. 3)** for identifying the different hazard zones of tsunami.

This methodology processes the different steps as ; first of all, tsunami hazard criteria was developed based on the literature review, experts opinions, adopting participatory approach with the local people living there or with the tourist and collecting various record of previous tsunami occurred locations. After that, the tsunami hazard parameters were developed using such comprehensive detailed information. These parameters were incorporated by using geographical Information Systems (GIS) techniques. Those techniques comprise the different sub techniques as sub setting the data layers, converting the data layers into vector to raster format, reclassification of the different data layers into required classes and map calculation technique for developing final out put model entitled as tsunami hazard model using GIS software with datum WGS- 84, UTM projection and zone 47.

3.1 Tsunami Hazard criteria

Tsunami hazard criteria and parameter has been developed as shown in **Table 1.**

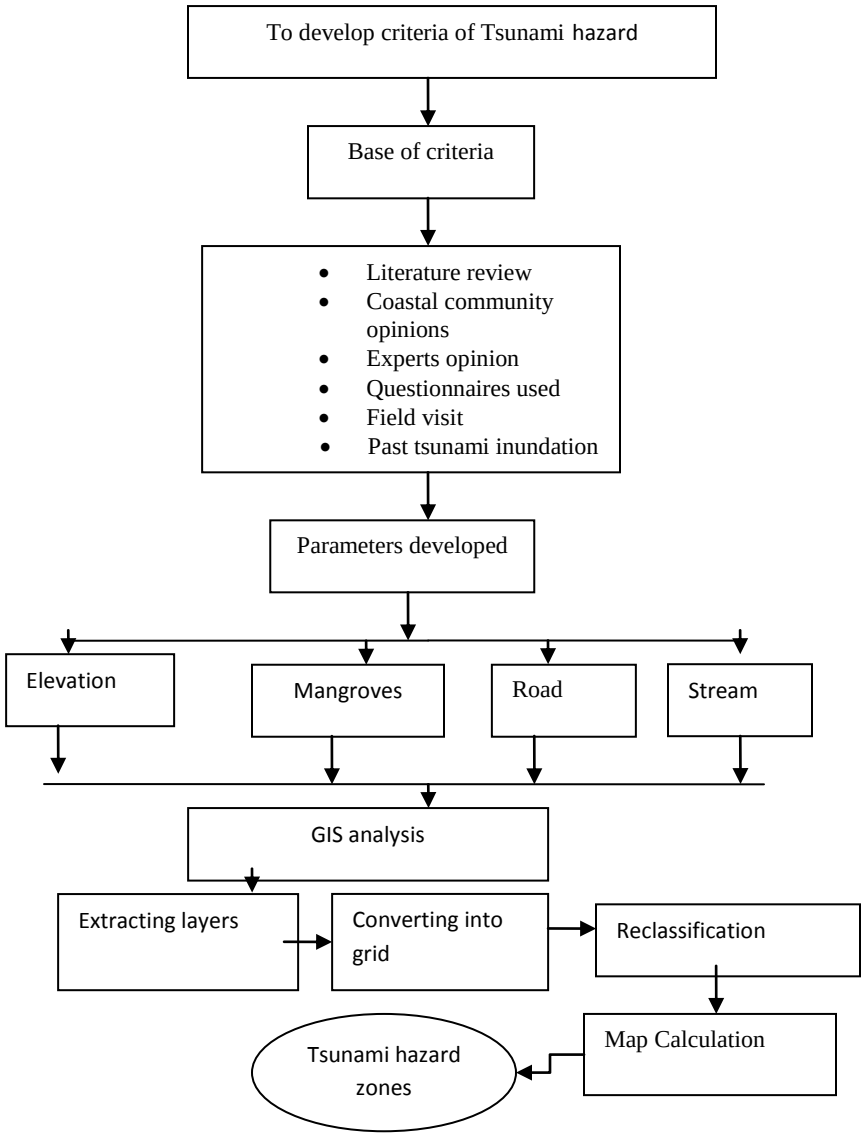


Fig.3. Tsunami Hazard Methodology

Table 1. Tsunami Hazard Criteria, Parameters With Justification

No	Criteria	Parameters	Justification of Criteria
	Landover	Mangroves/Forest	Protects from Erosion, storm damage and wave action
	Land use	Road	Proximity to a possible hazardous event and Feasible to evacuate after disaster
3	Topography	Elevations	Tidal inundation risk and Hazard area boundaries
5	Hydrology	River/stream/estuary /canal	Might be planned in different areas

The different levels of tsunami hazard were categorized into five classes which have been mentioned in **table 2.**

Table2. Tsunami Hazard Classes

No	Parameters	Very High hazard	High hazard	Moderate Hazard	Low hazard	Very low Hazard
1	Elevation	0-5m	5-8m	8-15m	15-35	>35m
2	Road		5-50m	50-100m	100-500m	.>500m
3	River	0-50m	50-100m	100-300m	300-500m	>500m
4	Mangroves	Nill in areas	Moderate density	Low density	High density	Very High density

3.3 Comparison of Weight Matrix method

It is a ratio method developed by Saaty which has been used to justify the developed criteria and its assigned weight in GIS analysis for identifying tsunami hazard zones with five different classes. The assigned weight of the parameters has been shown in **Table 3.**

Table 3. Matrix of Importance for tsunami hazard mapping.

	Elevation	mangrove	Forest	Stream	λ=Average /weight
Elevation	1	3	4	7	4.011
mangrove	0.334	1	1.334	2.334	4
Forest	0.25	0.75	1	1.75	4.014
Stream	0.143	0.429	0.572	1	4.013
Sum of column	1.727	5.179	6.906	12.084	4.009

The value for the lambda (λ) is simply the average value of the consistency vector

λ = wi +wi +wi +wi +wi…wn /wn

λ= 4.011+4+4.014+4.013 / 4 = 4.0095

To find out the consistency ratio, we know first consistency index as below;

CI = ((λ-n) / (n-1) = (4.0095-4) /4-1=0.0095 /3=0.0031

So we now easily the consistency ratio as below;

CR = CI / RI = 0.0031 /0.90 = **0.003 (** As value of RI is constant depending on the number of the used parameters, so in our this research, the used parameters are four, the constant value of consistency Index(RI) for four parameters is 0.90. So our criterion is reasonable as our tsunami hazard mapping criteria consistency ratio is below the value of CR < 0.10 for the reasonable consistency.

4. RESULTS

The tsunami hazard has been developed based on developed parameters, criteria and classes **(as described Table 1 and Table 2)**. The various hazard classes were split into five classes **(Table 3)** to generate the model. The five categories were prepared as very high tsunami hazard zone (maroon), high tsunami hazard zone (red), moderate tsunami hazard zone(orange), low tsunami hazard zone (light yellow) and very low tsunami hazard (yellow) as shown below in **Figure 4.** The predicted tsunami hazard zones have been mentioned with the names of the areas as shown in **Table 4**.

Table 4.Names of Predicted tsunami Hazard areas

No.	Tsunami Hazard Zones	Names of Predicted Tsunami Hazard Zones
1	Very High Tsunami Hazard Zones	Ban khlong Hin, ban na tin,ban khlong Muang
2	High Tsunami Hazard Zones	Ban khlong hin, Ban Ao Nam Hua, Ban ko Kuang, Ban Khlong in , Ban Nong Thale, Ban Nai Rai, Ban Lem seom , Ban thung , Tup kaek beach, Phulay Beach, Ban Tup kaek, Khlong Muang Beach, Siew Beach, Siew Bay, The princess residence, Railay beach, Aonanag beach, Phranang Bay,Noppharat Bay, Nammao Bay
3	Moderate tsunami Hazard Zones	Ban suan pak, ban nong koh,
4	Low Tsunami Hazard Zones	Ban Khlong Huang
5	Very low Tsunami Hazard zones	Ban khlong chilai,

5. DISCUSSIONS

This research is hybrid approach based using geoinformation technology in the areas of coastal zone management for resolving the remedial solution of one of the natural disasters as tsunami for preventing human lives and infrastructure in future. The tsunami hazard predicted zones have been classified based on the suitable, reasonable, and practical criteria. Though the criteria is always criticized to be subjective in its essence, so weight of comparison matrix method was used to justify the reasonability of the developed criteria with the assigned weight of the different parameters.

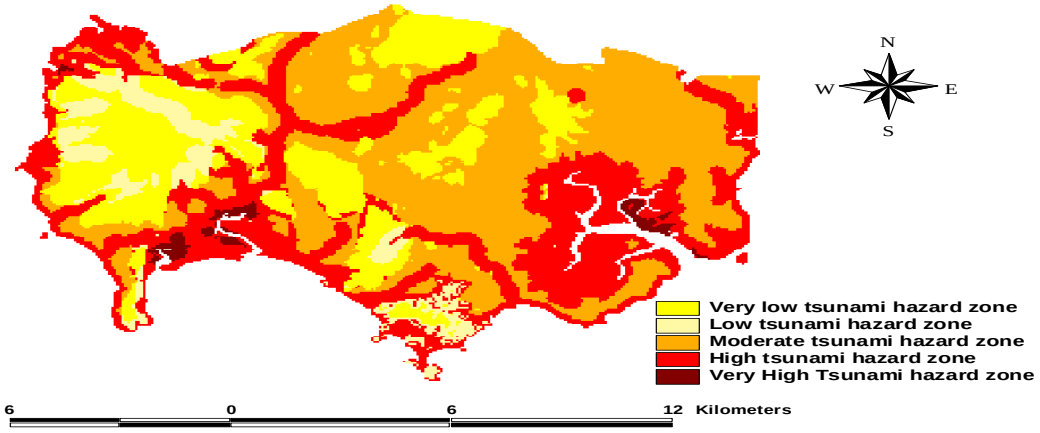


Fig. 4. Tsunami hazard Model

6. CONCLUSIONS

In this GIS-based tsunami hazard identification research, the predicted various zones of tsunami hazard can be fruitful for the decision makers to redevelop the region. The very high tsunami hazard areas such as Ban khlong Hin, ban na tin,ban khlong Muangshould be thought suitable for the adventurism, boating etc. While the high tsunami hazard zones such as Ban khlong hin, Ban Ao Nam Hua, Ban ko Kuang, Ban Khlong in , Ban Nong Thale, Ban Nai Rai, Ban Lem seom , Ban thung , Tup kaek beach, Phulay Beach, Ban Tup kaek, Khlong Muang Beach, Siew Beach, Siew Bay, The princess residence, Railay beach, Aonanag beach, Phranang Bay,Noppharat Bay, Nammao Bay are suggested to accommodate for ecotourism only. The moderate tsunami hazard areas such as Ban suan pak, ban nong koh might be suggested for the commercial purposes while low and very low tsunami zones such as Ban Khlong Huang and Ban khlong chilai can be can be suitable for the commercial, residential, official, sports and other positive purposes in this region.

It is believed that this research can save human lives and infrastructure in this region again if it may be implemented by the decision makers in the region.

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