AGENDA FOR URBAN CONCERN

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Detailing an impending disaster: Are we prepared?

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THAT Dhaka is vulnerable to an earthquake is well known. That a major earthquake will severely shake Dhaka or some other densely populated area in the country is also generally known.

That such an earthquake is only a matter of time about that we have been warned.

That history is against us present and that the hundred-year cycle is complete and we are floating on borrowed time.

That given the tremendous rise in urban population over the past few decades, the loss of life will be recorded as one of the all time worst hazards in the world's history, experts have informed us.

That many of our buildings have not been built to withstand even a low intensity shake has also become part of our general knowledge.

That our rescue agencies, the Fire Services, the Army and such other organisations, are not at all organised or equipped technically to tackle a compound degree of damage to many people and buildings over a wide area is evident from the salvage operation, albeit brave, in a single collapsed building.

That mindless urbanisation and rampant violation of building code and law have created for us city dwellers a precarious situation is common sense.

That in fact common sense is not working may be our peril and doom.

Despite all the seminars, roundtables, newspaper articles, television appearances and radio talks on the topic of earthquake and our lack of preparedness, we have not heeded to warnings and continue with the self destruction.

The positive aspect of the impending hazard is that our own experts, not those that come attached with strings behind a foreign aid, have been telling us to wake up and do something that will lessen loss of human lives, save animals, and damage to buildings. Perhaps because the advice is forthcoming free, our usual response is apathy.

Dr. Mehedi Ahmed Ansary, in today's piece, exhibits the level of detail that our sons of the soil are capable of. There are many others in their respective fields, engineering, architecture, planning, medicine, fire-fighting, rescue operation, housing, relief, food supply, transportation, telecommunication, international liaison, distress counselling, social management, etc., definitely not in that order.

We need to marshal all our human resources, form a task force which can draw a plan, take stock of the equipment we have and need, procure essential tools, learn lessons from recent case studies in the region, educate schoolchildren, use the media, and be prepared. This initiative has to come from the government, if necessary by an executive order.

Having been warned time and again, being unprepared would be a sin, as human lives are involved.

With regard to the earthquake that is coming, hoping for the best is not enough.

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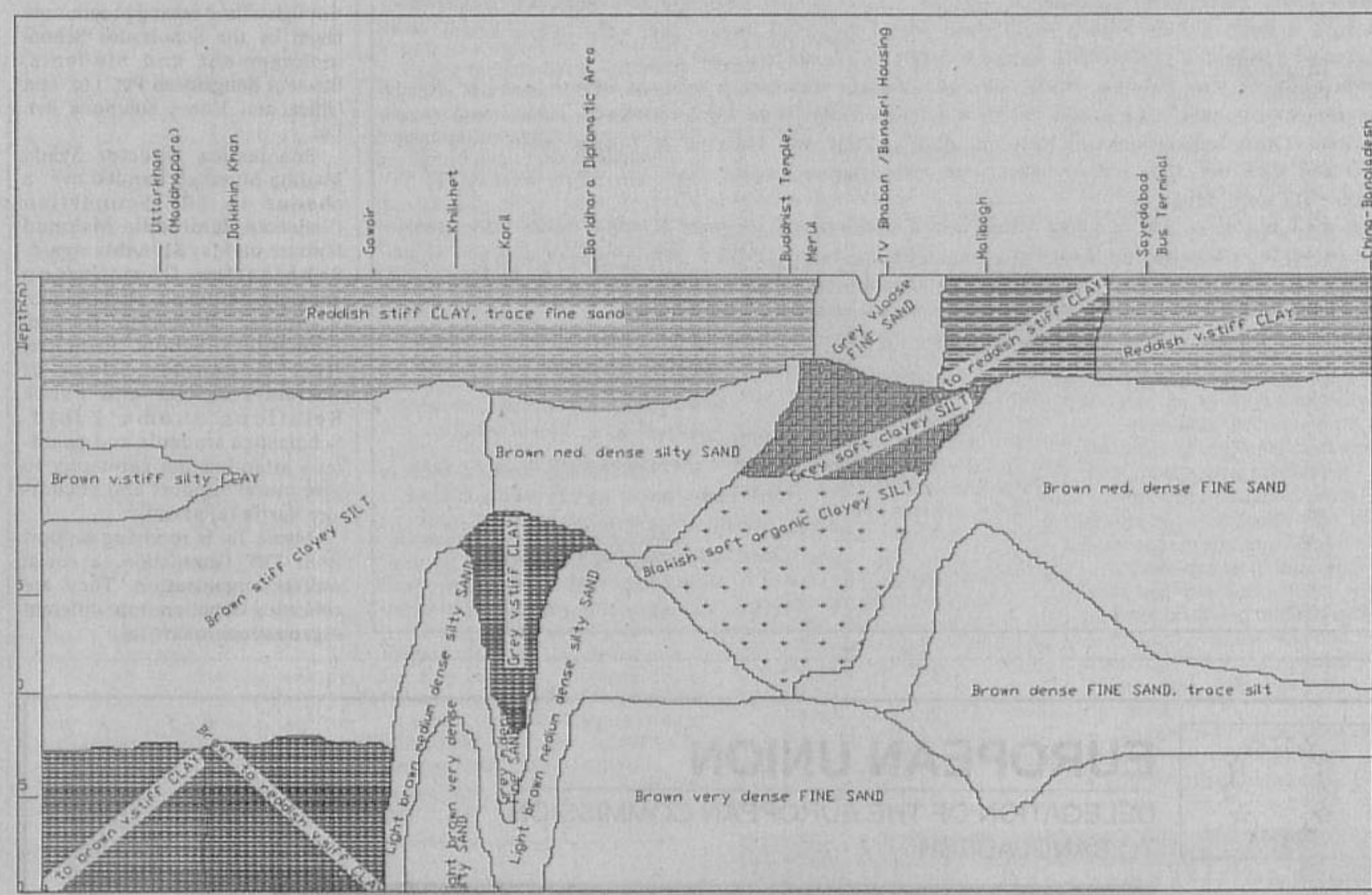

Figure 2: North-south soil profile of Dhaka city along Uttarkhan-China Bangladesh Friendship Bridge (after Sarker, 2004)

Seismic Microzonation of Dhaka City

DR. MEHEDI AHMED ANSARY

THE 2001 Gujarat earthquake in India, the 2003 Bam earthquake in Iran and the 2005 Muzafarrabad earthquake in Pakistan and India revealed the vulnerability of "non-earthquake-proof" cities and villages in Asia. In 1897, an earthquake of magnitude 8.1 caused serious damages to buildings in the north-eastern part of India (including Bangladesh) and 1542 people were killed. Recently, Bilham et al. (2001) pointed out that there is high possibility that a large earthquake will occur around the Himalayan region. The current population around this region is at least 50 times greater than the population of 1897 and cities like Chittagong, Dhaka, Kathmandu and Guwahati have populations exceeding several millions. It is a cause for great concern that the next great earthquake may occur in this region at any time.

The findings of this study would benefit engineers, city planners, developers, emergency personnel, government officials, and anyone who may be concerned with the potential consequences of earthquakes in Dhaka. This may provide useful information regarding earthquake hazards for a given site, and should be an integral part of the whole process of economic and social development for the city.

Methodology

Seismic hazards due to local site effects such as soil amplification and liquefaction can be estimated by combining the available soil parameters with the current hazard models. Due to recent improvement in the availability and quality of GIS (Geographical Information System) technology the current research utilised GIS technology for seismic microzonation of Dhaka city. A soil database of 253 boreholes is developed in MS EXCELL. The soil data are used to develop site amplification and soil liquefaction potential assessment. Both of these site effects are integrated in GIS platform for combined hazard assessment. Three past historical earthquakes are used as scenario events namely the 1885 Bengal earthquake, the 1897 Great Indian earthquake and the 1918 Srimangal earthquake. Intensity values obtained for these events are calibrated against attenuation laws to check the applicability of the laws for this study. Using these laws, bedrock Peak Ground Acceleration (PGA) values are obtained. Finally, a bedrock PGA value for the scenario events is selected. PGA values are also converted into intensity values to integrate the effect of site amplification as well as liquefaction.

Geology of the study area

Quaternary sediments consisting of deltaic and alluvial deposits of the Ganges, Brahmaputra and Meghna rivers and their numerous tributaries underlie more than 80% of Bangladesh. According to the study of Morgan and McIntire (1959), there are two major areas of Pleistocene sediments, commonly known as Madhupur tract and Barind tract. The Madhupur block lies between the Jamuna and Old Brahmaputra rivers and 6 to 30m above the mean sea level.

The current study area is situated on the southern tip of the Madhupur tract. Two characteristic units cover the city and its surroundings, i.e., the Madhupur clay of Pleistocene age and alluvial deposits of recent age. The Madhupur clay is the oldest sediment exposed in and around the city area. The alluvial deposits are characterised by flood plains, depression and abandoned channels. The geological map of Dhaka metropolitan area is presented in Figure 1.

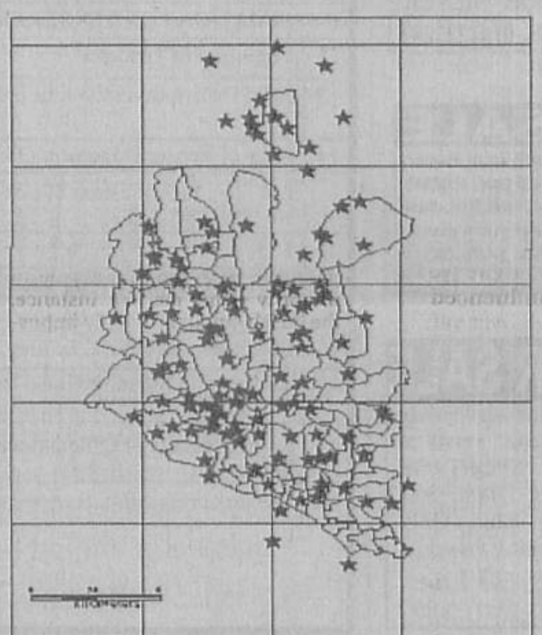

Figure 3: Borehole locations

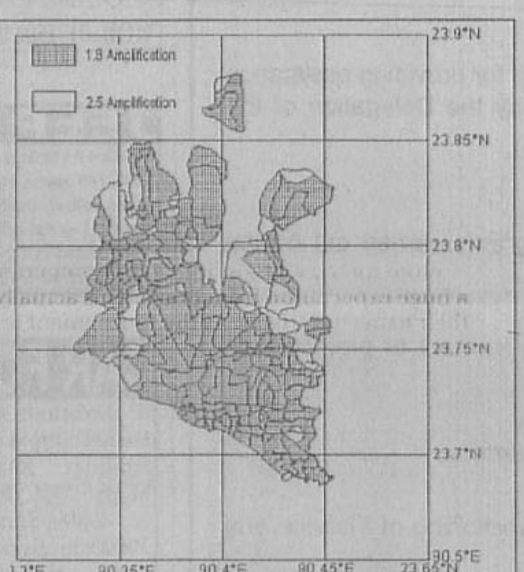

Figure 4: Map of 1.8 and 2.5 times amplified areas

The subsurface sedimentary sequence, up to the explored depth of 300m, shows three distinct entities; one is the Madhupur clay formation of Pleistocene age and is characterized by reddish plastic clay with silt and very fine sand particles. This Madhupur clay formation uncomfortably overlies the Dupi Tila formation of Pleistocene age composed of medium to coarse yellowish brown sand and occasional gravel. The incised channels and depression within the city are floored by recent alluvial flood plain deposits and is further subdivided into lowland Alluvium and high land Alluvium (WASA 1991). Figure 2 shows North-south soil profile of Dhaka city along Uttarkhan-China Bangladesh Friendship Bridge (Sarker, 2004)

Regional seismicity

The major earthquakes that have affected Bangladesh since the middle of the last century are presented in Table 1.

Table 1: Magnitude, EMS Intensities and distances of some major historical earthquakes around Dhaka (after Ansary, 2001)

Name of Earthquake	Magnitude	Intensity at Dhaka	Distance (km)
1869 Cachar Earthquake	7.5	V	250
1885 Bengal Earthquake	7.0	VII	170
1897 Great Indian Earthquake	8.7	VIII+	230
1918 Srimangal Earthquake	7.6	VI	150
1930 Dhubri Earthquake	7.1	V+	250

Soil data

Necessary soil data was collected from different relevant sources of Dhaka City and compiled in a database using Microsoft Excel. A total of 253 boreholes with SPT data were collected from different organizations and used to study site amplification and soil liquefaction potential characteristics of municipality area. Generally for building construction, boring is done up to a depth of 50 ft only. Among the compiled database, 20 boreholes with SPT-N data up to a depth of 100 ft (30 m) were directly carried out by BUET for checking the authenticity of other collected data. Figure 3 shows borehole locations.

Assessment of seismic hazard

In the regional seismic loss estimation analysis it is considered necessary to determine the bedrock motion in the region. The most common method involves the use of an empirical attenuation relationship. These relationships communicate a given ground motion parameter in a region as function of the size and location of an earthquake event. To pick the most appropriate attenuation law for predicting rock motions, 1885 Bengal earthquake, 1897 Great Indian earthquake and 1918 Srimangal earthquake are considered.

Distance versus PGA values for earthquakes is plotted on log-log paper. From isoseismal maps, the epicentral distances of different locations and their intensities are found. These intensities are converted into PGA by Trifunac and Brady (1975) equation and were plotted on preceding figures. It is found that McGuire (1978) equations follow the PGA trend of the study area. 1897 Great Indian Earthquake is selected as the scenario event which has a PGA value 0.12g (g=981 cm/s2) at bedrock level.

Microtremor observations

Microtremor observation was carried out at Dhaka city during 2002 by the author using equipment supplied by the University of Tokyo, Japan. All the measurement points are shown on the map in Figure 3. The equipment used was Tokyo Buttan Services GEODAS-10-24DS system connected to a triaxial accelerometer with a natural period of 1 second. In this experiment, the recording system operated continuously for about 6 minutes, with a sampling rate of 100 Hz. For the analysis of microtremors, base line corrections were done and then a Butterworth band pass filter (0.40 to 25 Hz) was applied to the data. From the processed data sixteen 2048 point windows were selected and Fourier Spectra for NS, EW and UD components were computed with a Parzen window. Then the mean curve for sixteen spectra both for NS and EW components were calculated. Finally, the Nakamura spectral ratio was obtained as follows:

$$HV = \frac{\sqrt{NS}\sqrt{EW}}{UD}$$

Microtremor H/V ratios versus numerical transfer functions

To validate the results obtained from microtremor observations, H/V spectral ratios were compared with the transfer functions obtained from a one-dimensional numerical simulation using the computer program SHAKE, which consists of the response analysis of horizontally layered soils under seismic excitation, with linear equivalent soil behaviour. Similar transfer functions from soil column using SHAKE were also estimated for areas where no microtremor observations were made.

Use of geotechnical data for each of the sites and a synthesis of drilling data extracted from the existing subsurface database of Dhaka enabled to determine soil columns representative of each site. In most of the soil columns, a dense sand layer was encountered at a depth of 30 m and in some cases, silty clay later was found.

Using the soil configurations a transfer function was calculated for each site using the SHAKE numerical code. In addition, recordings of background noise by microtremor observations for each site were used to calculate average H/V spectral ratios. Good overall concordance between the transfer functions obtained by the two methods is observed.

The amplification and the fundamental frequency obtained by the two methods are almost similar for all the sites studied. From the frequency map, ward areas of 1.8 times of amplification and 2.5 times amplification are separated. Figure 4 shows map of amplification at fundamental frequencies of Dhaka City. From this map, it was found that all the 90 wards are fully/partially affected by the 1.8 times amplification and only 36 wards was partially affected by the 2.5 times amplification.

Liquefaction analysis

Liquefaction phenomena (process of turning to liquid) have been recorded and developed in many parts of the world where ground shaking is frequent and soils consist of loose fine sand under water table. Bangladesh including Dhaka is largely an alluvial plain consisting of loose fine sand and silt deposits. Although the older alluvium consisting of mainly silty clay with deeper ground water table is less susceptible to liquefaction, the recent deposits consisting of loose fine sand with shallower water table along the river flood plains may liquefy during a severe earthquake. The ground water table is quite deep (20 to 25 m) in most places except the areas near the rivers. Clearly liquefaction is a serious component of the earthquake hazard in certain parts of Dhaka as indicated by Ansary and Rashid (2000) and needs to be considered.

A simple method suggested by Seed et al. (1983) was used here to evaluate a liquefaction resistance factor, FL. In this method required parameters are SPT N-values, grain-size distribution curves of soils, overburden pressure, and estimated peak surface acceleration.

The FL method defines that ground water level to be considered as less than 10m from the ground surface. The liquefaction resistance factor, FL, for the top 20m of soil, and the resulting liquefaction potential, PL for the 253 sites were estimated. The total area of Dhaka city are classed into two categories, one is liquefiable area whose IL ³ 5.0 and another is non-liquefiable area exhibiting IL < 5.0. From the liquefaction map, areas of liquefied and areas not liquefied have been separated using GIS program. Figure 5 shows the map of liquefied areas and not liquefied areas.

Integration of site effects in the GIS environment

Every analysis region is different; therefore the quantification of the secondary site effects and the weighting scheme for combining the various seismic hazards is heuristic, based on judgment and expert opinion about the influence of local site conditions in the region and the exactness of the available geologic and geotechnical information. However that is not the circumstances in Bangladesh. Heuristic rules for quantification and combination were used which were developed by Stephanie and Kiremidjian (1994).

The bedrock-level ground shaking in the region was ascertained. The shaking was depicted in terms of peak ground motion values. The regional distribution of bedrock-level shaking was estimated as 0.12g. Bedrock level PGA was measured as constant since the study area is small. It is decided that the final combined seismic hazard would be quantified in terms of Modified Marcelli Intensity (MMI). There are several relationships for converting PGA to MMI. The equation used here is developed by Trifunac and Brady (1975). The following heuristic rules are used to quantify the seismic hazard attributable to liquefaction:

For regions with liquefiable soils with high liquefaction potential

MMILIQ= MMIGS+2

For regions with liquefiable soils with moderate liquefaction potential

MMILIQ= MMIGS+1 and otherwise:

MMILIQ= 0

The rules for combining the assorted hazards are based on expert opinion (after Stephanie and Kiremidjian, 1994) about the comparative precision of the hazard information and the behaviour of the local geology. By over-laying the regional maps for each hazard as shown in Figures 4 and Figure 5 in GIS environment, the Dhaka City had been separated into four groups as areas of 1.8 times amplification, areas of 2.5 times amplification, areas of 1.8 times amplification plus liquefaction and areas of 2.5 times amplification plus liquefaction. Finally, Figure 6, the regional distribution of the final combined seismic hazard (MMIF) was produced.

Conclusions

The purpose of this study is to develop a methodology for using GIS technology to integrate the various components of a regional multi-hazard seismic risk analysis. The seismic risk analysis presented here includes local site effects such as soil amplification and liquefaction. A soil database of 253 boreholes has also been developed in MS EXCELL. The soil data were used to develop site amplification and soil liquefaction potential maps of the city. Both of these site effects are integrated in Geographical Information System (GIS) platform for combined hazard assessment. The GIS-based analysis is useful to engineers, planners, emergency personnel, government officials, and anyone else who may be concerned with the potential consequences of seismic activity in a given region. The results are presented in the form of microzone maps which will serve as an effective means of transferring information from the scientific community to the professional community of decision makers involved in hazard and risk mitigation.

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Notes:

**Magnitude is directly related to energy release due to plate movement. It has a unique value for an earthquake. It varies from 1 to 10.*

***Intensity is related to human feelings, behaviour of secondary structures and structural behaviour. It has different values at different locations for a particular earthquake. It varies from I to XII.*

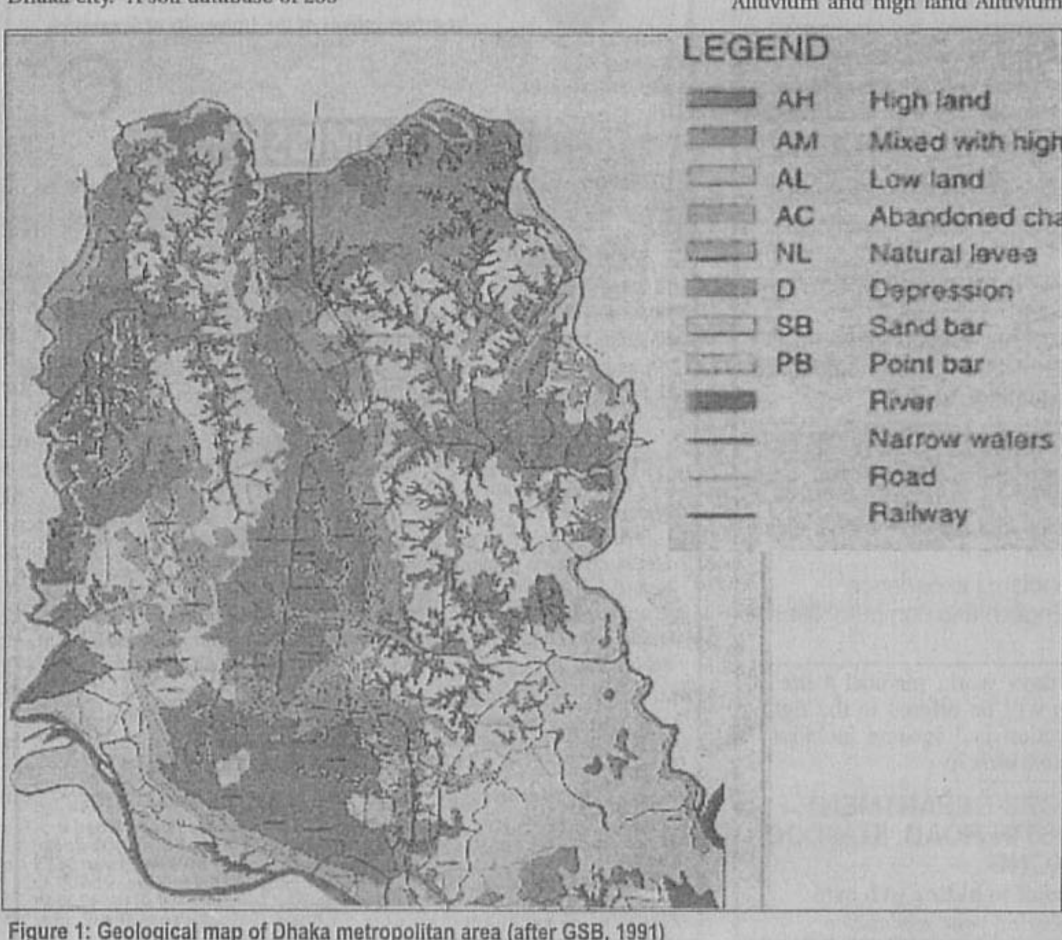

Figure 1: Geological map of Dhaka metropolitan area (after GSB, 1991)

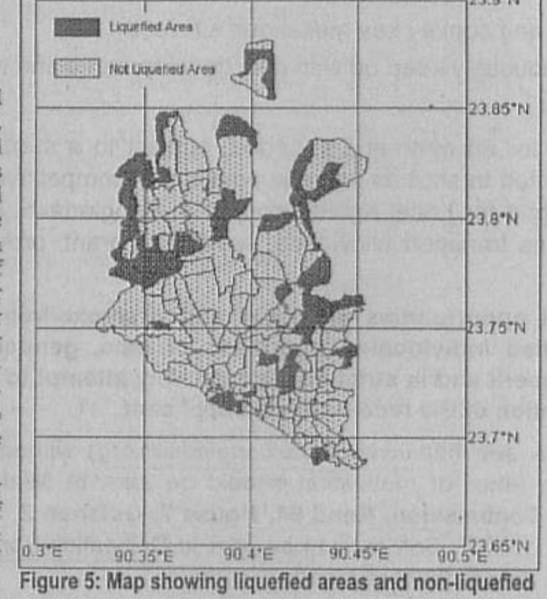

Figure 5: Map showing liquefied areas and non-liquefied areas

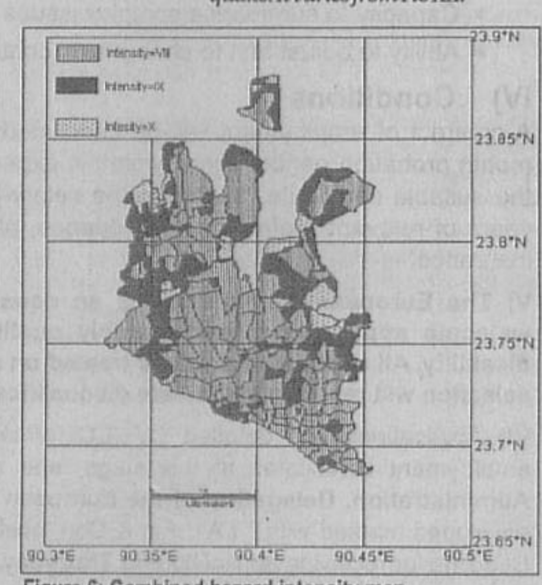

Figure 6: Combined hazard intensity map