DOCUMENTING TRADITIONAL ARCHITECTURE AND SETTLEMENT STRUCTURE IN EASTERN INDONESIA - A BASE FOR DETERMINING INDIGENOUS LIVELIHOOD SYSTEM SUSTAINABILITY AND DURABILITY OF TRADITIONAL HOUSING STRUCTURE IN THE CASE OF NATURAL CATASTROPHES -

F.G. Zámolyi [a], A. Zámolyi[b]
[a] Institute for Comparative Research in Architecture, Vienna, Karlsplatz 13, E251, A-1040,Austria
zamolyi.f@archimania-vision.at
[b] Department of Geological Science, University Vienna, Austria, a_zamolyi@hotmail.com

KEYWORDS: Architecture, Cultural Heritage, Anthropology, Sustainable, Disaster

ABSTRACT:
Indonesia has one of the highest diversities of different traditional building types in the world. Although the most indigenous tribes are all related to each other, they have developed architecture of highly different appearance. House types are well adapted to climate and natural hazards like hurricanes or earthquakes. The documentation of these rapidly disappearing dwellings is an important task, as "modern" architecture, which is often of inferior quality and not well adapted to local (tropical) conditions, threatens to replace traditional housing constructions.
The Indonesian region lying at the junction of the Eurasian, Indo-Australian and Philippine Sea tectonic plates poses an actively deforming area with high seismicity. This is associated with the fast motion of plates at the Sumatra subduction zone accommodating 49 mm/year of oblique convergence. Lateral displacement causes large damaging earthquakes (e.g. Mw 7.6 in 1943). Probabilistic hazard analysis shows high vulnerability across Sumatra and low to moderate hazard across the Malaysian peninsula.
As the effect of the recent tsunami has shown, selection of building site and the type and construction of houses is of enormous importance in the case of natural catastrophes .
Old village sites are often situated on hilltops or are not built directly at the coastline. Tsunamis and earthquakes are frequently remembered in folk tales and legends, and people used to be aware of these natural hazards. Traditional houses are constructed of a lightweight timber frame; the wooden elements are lashed together with the help of lianas and ropes. Therefore, the joints have a certain flexibility, and the structure is able to absorb the dynamic load during an earthquake.
During our field research in eastern Indonesia, architecture, building methods, agriculture and land use concepts will be documented. We are trying to determine specific and typical examples for each region within eastern Indonesia, as environment conditions vary to a great extent on the different islands. Typical settlements will then be selected for further case studies.

INTRODUCTION

Indonesia has a wide variety of traditional architecture, which is well adapted to climate and environment. Unfortunately there occurs a decline in traditional buildings and traditional way of life in the recent years and decades. New buildings, often made of brick walls or concrete with an inferior technology, seldom meet the requirements of the surroundings. Settlement patterns and agricultural systems of villages are often changed without considering the aftermaths of these actions.
Our project tries to document old settlement patterns and to check whether development is done on a sustainable base. Important aspects during the investigations are disaster resistance and management qualities of old systems, which should be preserved or enhanced.
The appearance of a rural settlement is always strongly connected to environmental conditions on one hand, on human needs and habits on the other hand. If the inhabitants try to adapt to requirements of nature, living in a certain place and harvesting the surplus products of the environment is possible on a long term base. Otherwise, special hazards are created through wrong lifestyle or overuse of resources. Wrong lifestyle means, especially in tropical surroundings like Indonesia, plague and illness, overuse means the danger of famine due to lack of food, but also the possibility of altering ecosystems in an irrevocably (at least on a short-term human scale) way, which may produce disasters like landslides, floods, erosion, desertification (although latter mostly not in tropical areas), loss of biodiversity, just to mention the most common ones.
These disasters in turn may endanger the very existence of the settlement, or at least lessen the quality of life for the inhabitants.
In addition to these self-generated troubles there may be disasters which are naturally part of the living environment and play often an important role in the functioning of an ecosystem. These are annual floods, and sometimes volcanic activities or earthquakes. These disasters cannot be avoided by sustainable management of an agricultural system, they have to be adapted to, or if this is not possible, the area will be sooner or later declared not suited for human habitation.
Sometimes, as in the case of volcanic activity, the disaster itself may grant good living circumstances, as volcanic soil often is very fertile. Therefore on the one hand it offers an ideal place for settlement, on the other hand it causes the permanent danger of damage through eruptions. In this case local topography and frequency of volcanic activity is a key for threat assessment.
In traditional cultures often we can notice an astonishing grade of adaptation to natural as well as human threats. As

nowadays the human threat has virtually ceased to exist (there are no raids of rivalling tribes or assaults of hostile powers anymore), in the last 100 years the traditional architecture and the settlement structure has transformed in Indonesia and shows now mostly the features which are important in adaptation for natural hazards. Sometimes we still encounter features like strategic placement on hilltops, the remains of walls and moats around a village, but features nowadays mainly focus on climatic and environmental adaptation.
Unfortunately these features tend to be forgotten as times and society changes, although in many ways traditional architecture would still be very suitable for living in (maybe with little alterations to respond to modern needs like running water, well equipped kitchens and bathrooms, changing family structure). Today it is not much cared about how houses are built or settlement structures are laid out.
This situation derives from an excessive growth of population and a lack of knowledge of the village people themselves alongside with ineffective planning or education strategies on this topic offered by government institutions, who are often themselves overburdened with the management of an ever growing population. Officials react on changes in Indonesia, sometimes with delay, and therefore measures are too late for preventing damage. In the Indonesian case the situation is worsened by the tectonically and volcanically highly active environment, which means frequent eruptions and earthquakes. As population growth and settlement expansion in Indonesia mainly occurred in the last 50 years, we do not know (or just now realise) the effects of wrong urban and rural planning strategies, and the damage which can be caused by earthquake impact.
In addition to these naturally and uninfluencably occurring events we have to bear in mind, that there could be disasters caused by wrong management of natural resources (e.g.: logging of rainforests, agricultural overuse of land, etc).
The aim of our project is to investigate some of these factors mentioned above. Starting from simple documentation of still existing traditional architecture and settlements with the adjoining agriculturally used area we will proceed to a detailed analysis in the next few years to make statements about the sustainability and disaster safeness of settlements investigated. In addition the local people can be given advice about how to deal with their cultural and natural resources. With the involvement of GPS data gathering we will try to develop a suitable GIS system, which can be used for regional development purposes. The central questions of our research are: “Are traditional settlement patterns and agricultural livelihood systems ecologically sustainable?”; “How well adapted are traditional house constructions to the tropical environment and especially to natural hazards?”; “How will it be possible to adapt old knowledge, agricultural systems and traditional architecture to the needs of a changing society without losing essential parts of cultural identity and useful traditional techniques?”
We had started our project about half a year before the disaster in Sumatra, which confirmed the importance of essential need for topics like these to be dealt with. Additionally, during reconstruction works on the Island of Nias, the Vienna University of Technology launched a project for documentation and research on earthquake stability of traditional housing, as a first step in a helping programme for locals to re-erect or rebuilt traditional architecture with donations from Europe. The first field research on Nias has to be conducted in June, and at the time of writing this paper it seems already for certain, that most of the traditional buildings have suffered rather slight damages only, or at least the majority of them is still standing, whereas much more “modern” style buildings have collapsed during the earthquakes. After a very brief investigational phase there will be active aid for reconstruction, during which step there will be a cooperation with members of our project on Nias too. This research will be conducted together with Gadjah Mada University in Yogjakarta, where studies on cultural landscape and culture heritage conservation form an important part of university work.

GEOLOGICAL CHARACTERISTICS OF THE AREA

Besides from climate, soil, flora and fauna, geology and tectonic activities bear special significance, as they are the cause for a permanent threat, which is posed by earthquakes and volcanism. It is no coincidence, that Indonesia is very often called the “ring of fire”, as a chain of volcanoes stretches across most of the islands. This is caused by the Indian Ocean crust being subducted northwest of the west Australian continental margin beneath the Sunda volcanic arc, which stretches from Sumatra eastwards. The effects in geological terms are:

- Continent – continent collision (begins in Sumba – Timor region and continues around the curve of the Banda arc as far as Seram. (The seismics show a very uniformly structured subduction zone). There is therefore subduction related seismicity (Milsom 2000, Tectonophysics), which causes earthquakes.
- These earthquakes are concentrated in three zones (one south of Seram, a second coinciding roughly with the active southern segment of the Banda volcanic arc and a third associated with the eastern end of the Sunda arc). The gap between Sunda and Banda arc seismicity coincides with a break and offset between the Seram and southern Banda seismic zones (Milsom 2000, Tectonophysics)
- There are: subduction zone interface earthquakes, subduction zone deep intraslab earthquakes, strike-slip transform earthquakes, and intraplate earthquakes (Petersen 2002, Tectonophysics). These different types of earthquake have different effects on buildings: depending on whether they cause mainly vertical and/or transversal movement of the earth, stress and dynamic loads affect buildings differently. This is a topic which has to be investigated thoroughly for the case of traditional Indonesian buildings, where we suppose a kind of adaptation to these conditions.
- Two major faults that are contributing to earthquake generation: The Sumatran subduction zone and the Sumatran transform fault (Petersen 2002, Tectonophysics).
- There is also volcanic activity related to the back arc region of the subduction. This caused the chain of volcanoes, which stretch from Sumatra to the eastern part of the Flores area. The activity in the fore arc region subsided very rapidly, although there is evidence of submarine volcanism (Khan 2004, Earth and planetary science letters EPSL)
- Problems to be investigated are: ash fall (putting a heavy load on roof constructions; not only hot but also physically heavy) and volcano induced landslides. It is not clear, whether such disasters happened in the investigation area, although it is very possible, as in the east Flores region there are settlements high up on the slopes of different volcanoes (e.g. Ile Ape on Lembata).

- Monitoring the volcanic activity would be possible with MODIS images, which show heat flares on the earth's surface.

PROJECT STRUCTURE AND METHODS APPLIED

The project focuses on eastern Indonesia, namely the island of Sulawesi and the area of the province of Nusa Tenggara Timur, which comprises the islands of Sumba, Sumbawa, Flores and Timor. This is a very large area with lots of different ethnics involved, and with different environmental conditions. From this area of interest, which ranges roughly from 115° E to 125° E and from 2°N to 11° S a few villages for case studies will be selected. Depending on their special cultural heritage and environmental setting. These settlements will be examined and classified due to their agricultural systems, their settlement pattern and their special architecture, which will be supposedly in each example a different one, as Indonesia has one of the most diverse architectonical and cultural landscapes of the world.

Project Structure:

1.The area will be scanned during field trips for suitable villages, which can be investigated in detail
2. Documentation of architecture, settlement structure, field and garden plots on site. Apart from these features exploitation of additional natural resources will be recorded (logging, fishing, animal husbandry).
Documentations are performed with a GPS mapping device and conventional surveying methods.
These features will be entered into a GIS system, where the collected data will be analysed and stored for further use
3.To assess special qualities of a settlement e.g. the earthquake resistance of traditional buildings of the settlements, additional investigations have to be performed, in this case an external modelling of house types (for calculations based on finite element computer programmes – like NASTRAN) , and material qualities have to be determined from samples during tests (load bearing capacity of materials, joints and structure).

Methods applied:

Documentation: Architectural documentation is conducted with the help of conventional methods of building survey, by making sketches and assessing lengths by laser distometer and measuring tape. Material samples are taken and a comprehensive photographical documentation is made, alongside with interviews on building processes and habits and customs regarding this topic.
After that a rough sketch of settlement pattern should be made, with housing areas, garden plots and on the wider scale with field areas included. The expression of a rough sketch is applied here, because absolutely precise measurements would be too expensive (equipment) and too time intensive. For the kind of settlement structure studies we are conducting, an accuracy at best conditions at around +-1m should be provided.

Agricultural features have to be recorded on one hand at with the help of mapping at the spot – here the soil type, slope, and position of the fields are relevant, but also the crops grown during the year. As the survey is limited to one certain time of the year (or two times at best) there have to be interviews and polls about frequency of planting and crop change. The surveys will be made in the rainy season (although in some areas this is not relevant, as there is humidity and rainfall all the year round) in some areas, especially in eastern Nusa Tenggara Timur, the only time crops are grown is the rainy season, due to low rainfall rates. In some areas, where there is no wet rice cultivation with watered fields, a kind of shifting cultivation with prior logging of primary or secondary forest vegetation may occur. In this case the assessment of data about fallow periods and duration of use for one plot should be conducted with special care, as this may prove ecologically very significant.
Soil types will be sampled and classified.

Data processing: All field work data has to be processed and inserted in an appropriate GIS system together with map material (1:25 000 or 1:50 000), which may not be available in all cases, due to government restriction. The same case may apply to areal photographs. The possibility to use satellite imagery is limited as well, as most of the time conditions are very cloudy.
However, some features, like probabilistic and deterministic earthquake hazard maps already exist on Malaysia, Sumatra and parts of eastern Indonesia (Milsom 2002), but a GIS based approach to gather also landslide and volcanic hazards would be of great interest; for instance morphometric classification based on curvature and surface derivatives with the aim of preliminary mapping of geomorphologic features based on free SRTM (= shuttle radar topography mission) DEMs. Tsunami hazard can be estimated from the position of the settlement and the shape and distance of the coastline and the surrounding topography.
After creating a basic map with classified hazard areas; e.g.: steep slopes and high density of faults, which indicate a metastable area likely to be damaged by landslides, existing settlement and land use structures can be overlaid and this data could be used for forecasting possible damage areas or conflict situations, where wrongly practised agriculture could lead to soil erosion and thus to soil destabilisation.
Vegetation layers with basic floral data (forest types, grassland, etc) may also give data on degradation.
Difficulties may arise due to different datasets in different countries also using different map projections, where homogenization is necessary (DEM is already homogenized with the SRTM approach).

Special research on detail topics: The detailed research on architecture comprises of the drawing of plans and virtual 3d models of houses, which can be used for further investigation by importing them into a FEM (finite element) calculation computer-programme, where dynamic loads occurring during earthquakes can be simulated. Special care is given to determine the properties of building materials, as tropical woods and bamboo are used for building Indonesian houses, where load bearing capacities and other parameters have not been well tested in Europe, and therefore exact values are not always known.
As the joints in most cases of Indonesian traditional architecture are not rigid, but the beams and posts are lashed together with liana (rattan) strings, the building gains some extra flexibility, which helps to absorb dynamic earthquake forces.

Project implementation

Task	Time frame	Area of investigation	Comments
Selecting appropriate sites	2004 May 2005 February - Mai	Timor Sulawesi, Flores	Architectural survey conducted, no GPS surveys so far
Processing of architectural data (plans, 3d models)	2005 Nov –Dec (Timor) 2005 October		
start special investigations of earthquake stability of architecture	2005 October - Nov		
Data collection from existing sources (geological maps, geographical, climate, and soil maps), Satellite Imagery ,etc	2005 October - Nov		
Development of GPS mapping method suited for data gathering on the spot	2005 Dec		
Field trip to selected sites	2006 February - May	Main Focus Flores and Timor, short visit to some sites in Sulawesi	Main topic: GPS surveys
Implementing Data into GIS	2006 June -October		
Analysing data with GIS	2006 October - Dec		

DATA GATHERED DURING FIELD TRIP 2005

Field research data obtained in:
Kadidiri, Sulawesi

This Bajo („Sea Gypsies“) camp comprising roughly a dozen stilt houses is built over a reef flat between the Island of Kadidiri and a little rock island in front of the shoreline. The water is shallow, at low tide maybe not more than 0,5-0,75m. The Bajo people are fishermen, travelling about large distances in their tiny boats. The settlement is of temporary character, as the Bajo never used to live in houses, but their only home being their boat. In recent times they gave up this habit and became sedentary, although they might shift the position of the village after some decades, if the resources are exhausted. The buildings are rather of improvised quality, but the location of the settlement is a favourable one. Bajo focus rather on boatbuilding, than on housebuilding. On the nearby shore they have some sheds where boats are permanently built or repaired. Problems can arise, as the Bajo regard the fishing areas as a boundless resource, and practice no selective fishing of whatever kind. In this way overfishing in general and overuse of threatened species can occur. This pattern of fishing is due to the nomadic tradition of the Bajo, as it is no problem if a nomadic group uses the resources of one area to full extent, because if there are depleted, the people will change location and the ecosystem has time to recover. But due to the new sedentary lifestyle and more effective (and often more destructive) fishing methods like dynamite fishing ecosystems are in danger. Conflict between Bajo and Indonesian fishermen, who are sedentary on a long term base arise due to the facts mentioned above. The Bajo do not practise agriculture in any form.

Bira, Sulawesi

Bira lies in the district of Bulukumba, approx. 200km to the east from Ujung Padang. The villages in this area have a distinct ship building tradition (especially Tanah Beru). However villages facing the eastern coastline are situated not right on the shore, but on hilltops in some distance to the sea. Exceptions are fishermen's villages and Tanah Beru,

Fig. 1. Bajo settlement on Kadidiri Island, Central Sulawesi

where the area is very flat. These settlements have distinct Bugis-style architecture, where often the same techniques for joints are used as in shipbuilding practise. Inside the settlement behind the houses there are usually gardens, where a variety of vegetables, herbs and fruits are grown. Outside the village boundaries there are field plots, usually fenced with coral rocks, where crops are grown on the quite scarce soil. The ground is very rocky, the humus layer is thin.

Fig. 2. Traditional Bugis House in Tanah Beru, Southern Sulawesi

Fig. 3. Garden plot surrounded with coral blocks near Bira, Southern Sulawesi

Usually there are huts erected on these fields. Agar-Agar (Rumput laut or Seaweed) is grown in front of the shoreline for export and dried in the villages. Tanah Beru has a big shipbuilding industry; there are dozens of ships being built with very archaic techniques along the shoreline. The need for construction wood is big, it is unclear where these materials come from: From nearby logging, from legal trade or from illegally logged resources in Kalimantan and Sulawesi.

Lowobunga, Adonara

Adonara is one of the Islands east of Flores (district: Flores Timur), which is inhabited by the Lamaholot people, a tribe where ancient tradition still live on strongly. However most of the population is Christian due to strong missionary activities of the catholic SVD order. But still, traces of ancestor worship are practised alongside with catholic religion. There are still new ancestor or clanhouses constructed, which are entered only with great respect. For the documentation works, which I conducted here, I had to ask for permission to take photographs and make drawings, which where not granted in each village on the Island. On some places even the visit to clan houses was not possible due to spiritual reasons.
In Adonara houses are not built on stilts, like in nearly all other regions of Indonesia. This might be due to drier conditions, which allow to build on earthen platforms. In Adonara there is no wet rice cultivation, most of the crops are grown during

Fig. 4. Lamaholot ancestor-house in Lowabunga, Adonara, East-Flores

Fig. 5. “Kebang” (storage hut) in a “Kebun” (field plot) near Waiwerang, Adonara

the wet season. Near the field plots there are storage huts, called “Kebang”, mainly for maize and other crops, they are used as shelter after or during work on the field. The name of the rice storage building is “Lewat” a type is often situated in the village area. Gardens within the village boundaries are not really significant (differing from the systems in southern Sulawesi)

Lamalera, Lembata

Lamalera belongs as well to the Lamaholot area, it is a fisherman’s village on the southern slopes of the island of Lembata. The speciality of the inhabitants is to catch whales (sperm whale, killer whale, dolphins, etc) and big fish (swordfish, manta rays, sharks) from tiny boats with the help of harpoons. The sheds for the boats and the whaling boats themselves are constructed in traditional ways. They have sails and go out for the hunt with them, as modern means are not suitable for catching sperm whales or other big species. However, for catching dolphins and fish there are boats equipped with motor engines, which go faster than the traditional ones. But even with this enhancements no big amounts of whale or fish are caught by harpooning, the hunt being still dangerous and hard work, where often the whale turns over boats and manages to escape (Usually the number of sperm whales caught ranges between 10-15/year, the number of dolphins is around 10 / week at maximum). The catch of manta rays depends on the season, as this species

Fig. 6. Lamalera village, Southern Lembata

Fig. 7. Fishermen from Lamalera on the hunt

Fig. 8. Volcanoes tower over the horizon in the eastern Flores region

has extensive migrations. The houses of the settlement are unfortunately not of traditional type anymore, although many other aspects of lifestyle still are kept traditional. There is no real agriculture, just gardens around the houses, where cotton and indigo for weaving and some herbs and fruits are cultivated. Agricultural produce is acquired every week on a barter market, where locals change dried fish for vegetables, rice and staple crops, which is brought by people from the villages on the nearby hills (orang gunung).

FURTHER STEPS

Apart from the sites mentioned above, further sites have to be selected. We are thinking of approximately 3 additional settlements, from Timor , Alor or other areas of Nusa Tenggara Timur. Until the start of the next field trip, which will start in February 2006, a simple, but effective GPS based mapping method has to be developed, which is well adapted to tropical fieldwork circumstances. The processing of architectural documentations has to be started and a computer simulated earthquake-stability investigation on typical buildings from the areas mentioned above has to be performed. Data from interviews conducted so far has to be compiled and archived. Data assessment from published resources (maps, satellite images, etc.) for the future GIS system will start this October.

CONCLUSION

Our project hasto perform two big tasks: One is the documentation of traditional architecture and settlement structures, the other is to get a better understanding for the interaction between human settlement and the surrounding ecosystem. The results of the analysis can be used to give advice to local people, which aspects of their traditional lifestyle they should keep, which ones they could alter, to deal with their land in a sustainable way. This in turn would give a better possibility to manage disasters, for which there is a big natural potential in Indonesia, but the effects of which will be worsened through a lack of settlement planning and extensive population growth. Our project should create a basis for a management tool and a better understanding on these topics, where cultural heritage and natural heritage are woven together within a delicate web.

REFERENCES

Hafkenscheid E., Buiker S., Wortel M., Spakman W., Bijwaard H., 2000. Modelling the seismic velocity structure beneath Indonesia: a comparison with tomography, Tectonophysics, 333, pp. 35-46.

Hall R., Ali J., Anderson C., Baker S., 1995. Origin and motion history of the Philippine Sea Plate, Tectonophysics, 251, pp. 229-250.

Petersen M., Dewey J., Hartzell S., Mueller C., Harmsen S., Frankel A., Rukstales K., 2004. Probabilistic seismic hazard analysis for Sumatra, Indonesia and across the Southern Malaysian Peninsula, Tectonophysics, 390, pp. 141-158.

Milsom, J., 2000. Subduction in eastern Indonesia: How many slabs?, Tectonophysics, 338, 161 -178.