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Land Cover Change and Coastal Spatial Zoning in Aceh-Indonesia in the Aftermath of the Tsunami*

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Abstract: On 26 December 2004 the biggest earthquake in 40 years occured between the Australian plate and Eurasian plate in the Indian Ocean. The quake triggered a tsunami (series of large waves) that spread out to several coastal cities in Nangroe Aceh Darussalam Province, including its Capital, Banda Aceh City. In this region over 120 000 lives have lost and 1 million is homeless. Based on analysis remote sensing data (preliminary report of LAPAN), more than 120 000 hm^2 of land are damaged. In Banda Aceh City, the changes of fishponds, residential areas and conservation areas (mangrove and other forest) were dominated the land use/cover changes. These three land use/covers were decreased about 61.5%, 57.8% and 77.6% from the former respectively. The central government is preparing a new coastal spatial planning which promotes a buffer zone (about 2 km from the seashore) in the formerly most dense areas. Many groups of coastal communities and NGOs are asking for the involvement of local community in decision making process.

In order to select and adopt the best use of the land, the coastal spatial zoning in the aftermath of the tsunami should determine several basic issues. This study is focusing on Banda Aceh City as center of many socio-economic activities. This study examines the changes of land use-cover (including physical damages) due to the impact of tsunami especially for agriculture and settlement uses and analyzes the typology of affected villages based on land use/cover changes and socioeconomic aspects. Moreover, this study examines the government spatial planning in the aftermath of tsunami and the local people needs to seek some sustainable options for the future spatial arrangements.

Key words: Tsunami; Coastal; Spatial Zoning; Aceh; Land use changes

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1 Introduction

Aceh is the northernmost province on Sumatra and in Indonesia. Banda Aceh is the capital of Aceh Province, located at the North-edge of the province, facing the Indian Ocean, and also the main gateway to the province. The provincial capital of Banda Aceh is clearly the largest and most lively city in the region. About 70% of the city areas are situated on a landform system with elevation less than 10 meter above mean sea level.

On 26 December 2004 the biggest earthquake for

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40 years had occured between the Australian and Eurasian plates in the Indian Ocean. The quake triggered a tsunami and hit several coastal cities in Nangroe Aceh Darussalam and North Sumatra Provinces, including Banda Aceh City and Nias Archipelago. According to government report on 2 May 2005, in this region 126 602 were reported dead and 93 638 inhabitants are mising and over than 500 000 persons have internally displaced. Government and World Bank estimate physical loss and damage in 16 affected districts at more than Rp 41 trillions or around US $ 4.3 billions, an amount equivalent to 2.7 % of Indonesia's Gross Domestics Product and over 97% of GDP for Aceh Province.

Based on remote sensing data analysis, Indonesian Institute for Space and Aeronautics (LAPAN) has indicated that more than 120 000 hm^2 of land are damaged, which consist of settlement (21%), fishpond (17%), ricefield (28%), plantation and shrubs (28%) and open space (5%). These land use/cover changes have a significant impact on future socioeconomics activities of Aceh people. The central government has launched Master Plan for the Rehabilitation and Reconstruction of Nagroe Aceh Darussalam Province (NAD) and Nias Islands, North Sumatera.

The planning for recovery initiates three stages program for Aceh recovery, namely: rescue, rehabilitation and reconstruction programes. The Ministry of National Development Planning has developed a comprehensive plan to rebuild the lives of the people of Aceh and Nias.

This study examines the changes of land use-cover (including physical damages) due to the impact of tsunami especially for agriculture and settlement uses and analyzes the typology of affected villages based on land use/cover changes and socioeconomic aspects. Moreover, this study examines the government spatial planning in the aftermath of tsunami and the local people needs to seek some sustainable options for the future spatial arrangements.

2 Methods

Generally, areas located about 2 ~ 3 km from the seashore were severely affected by tsunami. In order to take into account several location farther this area that also affected, this study examines land use-cover changes in the areas which have distance 5 km from the seashore of Banda Aceh City.

All spatial data in this exercise are based on the base maps and remote sensing data. Base maps have been obtained from various institutes including National Agency for Survey and Mapping (Bakosurtanal) and Ministry of Public Works. The data represent latest condition before the hit of tsunami. The most important information extracted from the maps is road networks and location of bridges. All data have been digitized to allow further spatial analyses, and built into a database consists of both conventional maps and space maps from remote sensing data.

Remote sensing data are monumental for this work. The data allow fast recognition and mapping in coastal zone affected by tsunami. UNOSAT contributes much of these data through Working Group for Aceh Recovery (WGAR), Bogor Agricultural University. However, this paper presents work on QuickBird Multispectral imageries; consist of two acquisitions *i. e.* 23 June 2004 (pre/before) and 30 December 2004 (post/after tsunami). Preprocessing is required to make up the data to allow more precise information extraction. This includes geometric rectification to have best fit for both images. We achieve less than 1 pixel's shift in this work and conclude that the processing is reliable enough to have high precision. Due to Quickbird's nature as highest spatial resolution for civilian application, we rely on visual inspection for information extraction. In order to ease the inspection, we constantly used natural color scheme as primary display.

3 Land Use/Cover Changes and Villages Typology

According to Shoshany and Goldshleger [1], land use changes and their causal factors form highly complex system are composed of three main subsystems: socio-economic, bio-chemical and governmental. It is congruent to the Barlowe's concept [2] namely three folds model that have to be considered to ensure sustainable land use: biophysical suitability, socio-economical feasibility and institutional acceptability. The two concepts are highly linked each other, and the similarity that there would be no guarantee on the sustainability of land use if one of the three components were not exist.

Table 1 Land Use of pre and post Tsunami of study area (5 km from seashore)

Land Use	Pre (23-Jun-04)		Post (30-Dec-04)		Changes
	hm^2	%	hm^2	%	%
Conservation	742.5	13.40	166.6	3.01	-10.4
Industry/Commercial/Services	678.9	12.25	463.4	8.36	-3.9
Paddy Field	779.5	14.07	351.3	6.34	-7.7
Fishponds	1354.4	24.44	521.7	9.41	-15.0
Residential	1207.5	21.79	510.3	9.21	-12.6
Upland Agriculture	336.0	6.06	93.8	1.69	-4.4
Water Body	442.5	7.99	1430.6	25.82	17.8
Ruins	0.0	0.00	912.0	16.46	16.5
Open Space	0.0	0.00	1091.6	19.70	19.7
TOTAL	5541.4	100.00	5541.4	100.00	

Natural disaster in Aceh significantly changed biophysical properties of the natural resources. Land use management previously developed had dismissed and new land use planning should be rebuilt, particularly at the coastal zone such as Banda Aceh Municipal which is considered as one of the worst hit. As all economic activities are clustered in Banda Aceh Region, the tsunami highly affects both social and economic aspects. In order to plan land uses at Banda Aceh, we should comprehend land use pattern and social activities in the past.

Tsunami had caused significant impact on land use pattern in coastal areas of Banda Aceh Municipal. Table 1 describes land use changes caused by tsunami. The changes of fishponds, residential areas and conservation areas (mangrove and other forest) were dominated the land use/cover changes. These three land use/covers were decreased about 61.5%, 57.8% and 77.6% from the former respectively (Table 2). About 61.5% fishponds has changed into water bodies (open water surface or swamp). Most of fishponds are located within radius of 2 km from seashore (Table 3).

About 57.7% of residential areas are totally destroyed. The biggest destruction of residential areas were located within radius of 1 ~ 3 km from seashore which constitutes more than 540 hm^2 of residential areas. While 57.3% and 20.3% of conservation areas (forest/vegetation/mangrove) have eliminated and became open spaces and water bodies respectively. Some terrestrial areas have been lost and became sea body, meaning that there were so many changes in coastal region.

Table 2 Land use changes in the aftermath of Tsunami

Land Use: Pre	Land Use: Post	hm^2	Sub(%)	%
Conservation	Conservation	166.6	22.4	3.0
	Open Space	425.2	57.3	7.7
	Water Body	150.7	20.3	2.7
	Subtotal	742.5	100.0	
Industry/ Commercial/ Services	Industry/ Commercial/ Services	463.4	68.3	8.4
	Ruins	215.5	31.7	3.9
	Subtotal	678.9	100.0	
Paddy Field	Open Space	426.5	54.7	7.7
	Paddy Field	351.3	45.1	6.3
	Water Body	1.7	0.2	0.0
	Subtotal	779.5	100.0	
Fishponds	Fishponds	521.7	38.5	9.4
	Water Body	832.7	61.5	15.0
	Subtotal	1354.4	100.0	
Residential	Residential	510.3	42.3	9.2
	Ruins	696.6	57.7	12.6
	Water Body	0.7	0.1	0.0
	Subtotal	1207.5	100.0	
Upland Agriculture	Open Space	239.9	71.4	4.3
	Upland Agriculture	93.8	27.9	1.7
	Water Body	2.3	0.7	0.0
	Subtotal	336.0		
Water Body	Water Body	442.5	100.0	8.0
	Subtotal	442.5	100.0	
	Total	5541.4		100.0

According to Bapenas and Ministry of Public Work Working Groups, based on destruction levels the Banda Aceh Municipal could be classified into three destruction zones (BWK): most destroyed zone (BWK I), building stucture damaged zone (BWK II) and lightly damaged zone (BWK III). Areas in BWK I zone are characterized by coastal land, aluvium soil, high risk of flooding, severe drainage problem, and saline water. BWK II is characterized by lowland landform, slight slope, highly suitable irrigated ricefield, better quality of water, suitable only for earthquake-proof building. BWK III is located on upland landform system, low risk flooding problem, high quality of ground water, highly suitable for agriculture, and highly suitable soil physics for construction. Statistical clustering technique was employed in attempt to characterize the typology of 52 coastal villages in the study area. The villages were clustered into map spatial distribution of villages based on previous (pre-disaster) social activities. The clustering procedure were employed the following variables: Central Hierarchy Index, accessibility index to service center, number of households, percentage of farmers, percentage of fishermen and percentage of livestock farmers. Figure 1 describes tree diagram of the cluster analysis resulting two types of village. The characteristics of each type could be identified according to Figure 2. Village (or Desa) type 1 comprises 39 villages were characterized by periphery villages, and dominated by farmers/fishermen communities (rural area type). Village type 2 comprises 13 villages and characterized by high access to service centers and domination of non agricultural activities (urban area type). Figure 3 describes the spatial distribution of rural and urban areas based on the result of clustering analysis.

Table 3　Land use changes in the aftermath of Tsunami within several radius areas from seashore

Land Use		0~1 km	%	1~2 km	%	2~3 km	%	3~4 km	%	4~5 km	%	Total
Pre	Post	hm^2		hm^2		hm^2		hm^2		hm^2		
Conservation	Conservation	5.3	0.4	6.2	0.5	19.801	1.8	52.86	5.5	82.291	10.5	166.4
	Open Space	104.0	7.2	107.0	8.7	134.755	12.2	76.083	7.9	3.445	0.4	425.2
	Water Body	139.5	9.6	6.0	0.5	5.017	0.5	0	0.0	0.205	0.0	150.7
	Subtotal	248.8	17.1	119.2	9.6	159.573	14.5	128.943	13.3	85.941	11.0	742.4
Industry/	Industry/Commercial/Services	0.0	0.0	0.0	0.0	103.147	9.4	275.139	28.5	85.099	10.9	463.4
Commercial/	Ruins	24.9	1.7	63.7	5.2	99.584	9.0	24.97	2.6	2.341	0.3	215.5
Services	Subtotal	24.9	1.7	63.7	5.2	202.731	18.4	300.109	31.1	87.440	11.2	678.9
Paddy Field	Open Space	50.9	3.5	87.0	7.0	130.946	11.9	132.908	13.8	24.769	3.2	426.5
	Paddy Field	0.0	0.0	0.0	0.0	9.44	0.9	90.602	9.4	251.03	32.1	351.1
	Water Body	1.3	0.1	0.0	0.0	0.384	0.0	0	0.0	0	0.0	1.7
	Subtotal	52.2	3.6	87.0	7.0	140.77	12.8	223.51	23.1	275.799	35.2	779.3
Fishponds	Ponds	78.8	5.4	270.1	21.8	166.777	15.1	0.240	0.0	5.72	0.7	521.6
	Water Body	589.6	40.6	240.7	19.5	2.371	0.2	0	0.0	0	0.0	832.7
	Subtotal	668.4	46.1	510.7	41.3	169.148	15.3	0.24	0.0	5.72	0.7	1354.3
Residential	Residential	46.8	3.2	0.9	0.1	40.513	3.7	165.302	17.1	256.386	32.7	509.9
	Ruins	101.2	7.0	278.4	22.5	267.076	24.2	40.811	4.2	9.048	1.2	696.6
	Water Body	0.7	0.0	0.0	0.0	0	0.0	0	0.0	0	0.0	0.7
	Subtotal	148.7	10.2	279.3	22.6	307.589	27.9	206.113	21.3	265.434	33.9	1207.2
Upland	Open Space	77.8	5.4	57.0	4.6	65.468	5.9	30.187	3.1	9.483	1.2	239.9
Agriculture	Upland Agriculture	0.0	0.0	8.5	0.7	9.274	0.8	48.543	5.0	27.504	3.5	93.8
	Water Body	0.0	0.0	2.0	0.2	0.364	0.0	0	0.0	0	0.0	2.3
	Subtotal	77.8	5.4	67.4	5.4	75.106	6.8	78.73	8.1	36.987	4.7	336.0
Water Body	Water Body	230.482	15.9	109.392	8.8	47.847	4.3	28.794	3.0	25.915	3.3	25.915
	Subtotal	230.5	15.9	109.4	8.8	47.847	4.3	28.794	3.0	25.915	3.3	442.4
			0.0									
	Total	1451.3	100.0	1236.7	100.0	1102.8	100.0	966.4	100.0	783.2	100.0	5540.5

Another clustering technique was also employed in attempt to describe the typology of villages based on land use/cover changes or impact of disaster. This technique was applied to following variables: acreage of village (hm^2), changes of conservation areas (%), changes of commercial/industrial/services (%), changes of paddy field areas (%), changes of fishponds (%), changes of upland agricultural areas (%), changes of water body (%), and changes of open space (%).

Figure 4 presents tree diagram of the cluster analysis and results two types of land use changes (destruction types). The characteristics of each type were identified according to Figure 5. Type-1 which comprises 16 villages were consist of villages had experienced very significant destruction due to the decreasing

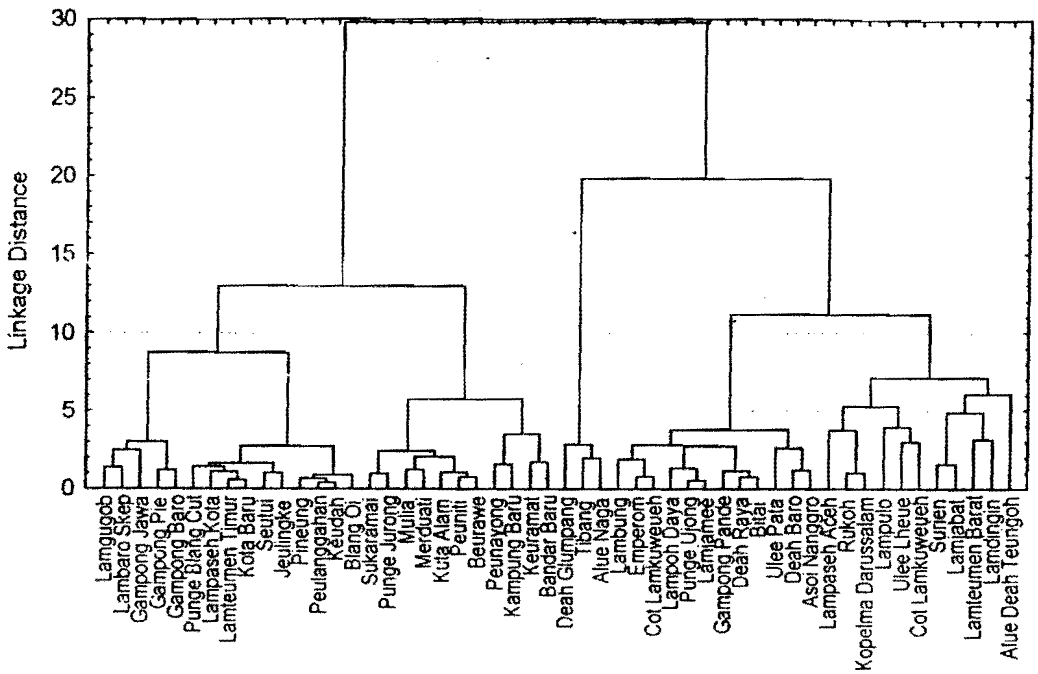

Fig. 1 Tree diagram to identify socio-activities of villages in Study Area

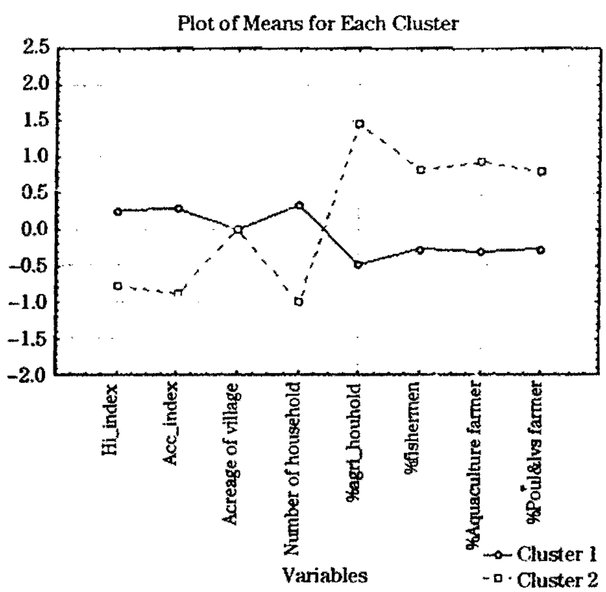

Fig. 2 Plot of standardized mean of variables for 2 types of socio-activities in 52 villages

(changing) of conservation area, services area, fishponds and residential areas. This decreasing was followed by the appearance of open space, water (sea) body and ruined area. This type of villages consist of Alue Deah Teung, Alue Naga, Blang Oi, Deah Baro, Deah glumpang, Deah Raya, Gampong Jawa, Gampong Pande, Gampong Pie, Keudah, Lambaro skep, Lambung, Lampaseh Aceh, Lampulo, Peulanggahan, and Ulee Lheue villages (Figure 6). The type 2 areas comprise of 25 villages and characterized by moderate destruction.

4 Spatial Planning in the Aftermath of the Tsunami

As the major aspect in spatial planning, land use planning is the systematic assesment of resources in order to select and adopt the best land use options that will best meet the needs of the people while safeguarding resources for the future.

Zoning is one of the most commonly tools in coastal planning and management. Basically, zoning provides a simple mechanism for urban planners to integrate complex and competing demands and land uses on to a single plan or map and zoning plans provide an effective tool for communicating implicit and often complicated management objectives to the community in an easily understood form [3].

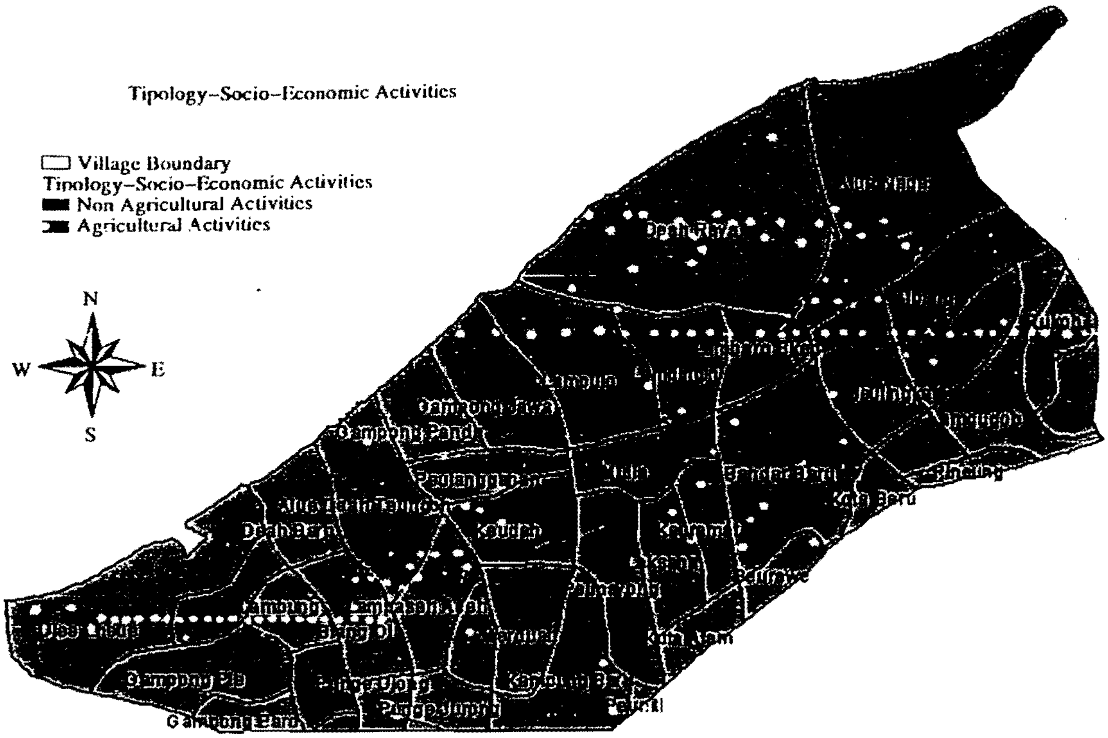

Fig. 3　Spatial pattern of urban and rural villages (Desa) based on Clustering technique

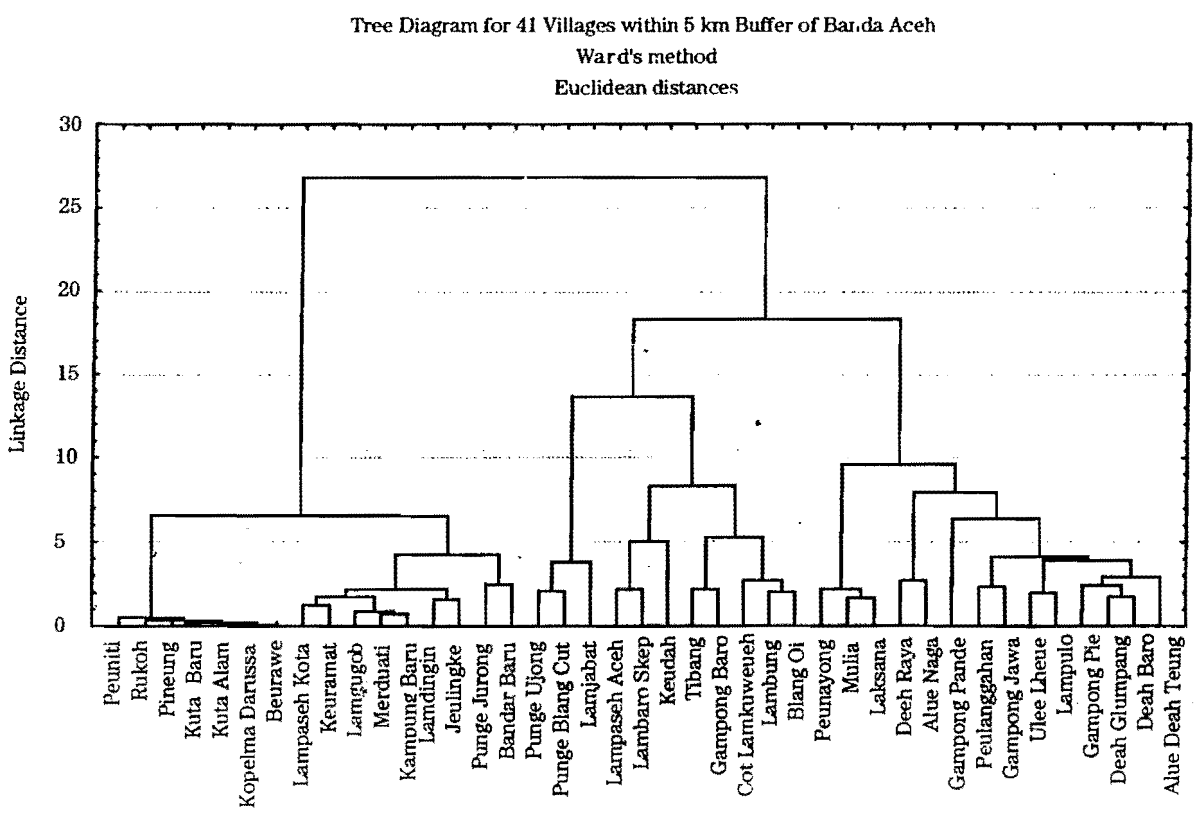

Fig. 4　Tree diagram of villages based on land use change characteristics

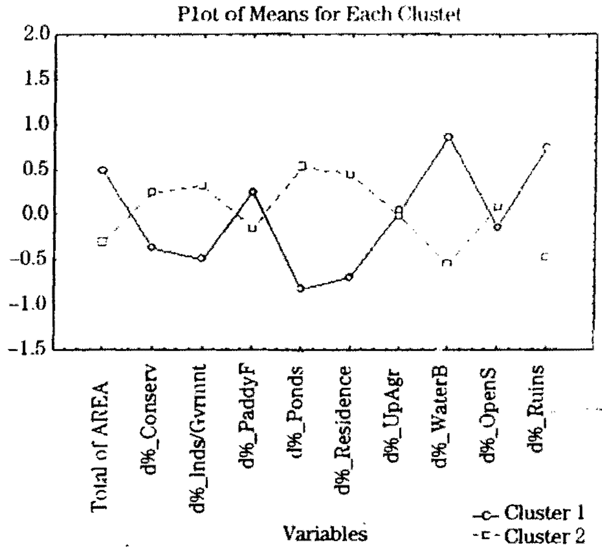

Fig. 5 Plot of standardized mean of variables for 2 type of land use changes (destruction type) of 52 villages in the study area

The effectiveness of a zoning plan will ulitimately rely on the community's acceptance and government's commitment to provide the resources to implement. There are two conditions must be met if planning is considered usefull: (1) the need for changes, must be accepted by the people involved. (2) the political will and ability to put the plan into affect [4]. Studies have shown that where the public has been actively and meaningfully involved in the planning process there is a greater acceptance of the plan, its regulation and their implementation [5-8].

Therefore, Disaster Risk Reduction and Recovery Activities (including spatial planning) should be based of the involvement of local institutions. The Panglima Laot (The Sea Admiral) or Chieftains of the coastal and fishing communities is one of some lesser-known traditional institutions because of decades of uniformity of government structure. Their togetherness has reflected through their organization Lembaga Adat Panglima Laot Provinsi Nanggroe Aceh Darussalam which made easier for outside organization to assist and work with them. Facilitated by Yayasan Laut Lestari and Bogor Agricultural University, on 19-20 February 2005 they were able to gather remaining resources they had to assist survivors. The meeting launched several points of recommendation on Aceh Recovery and the ongoing Government's planning process [9].

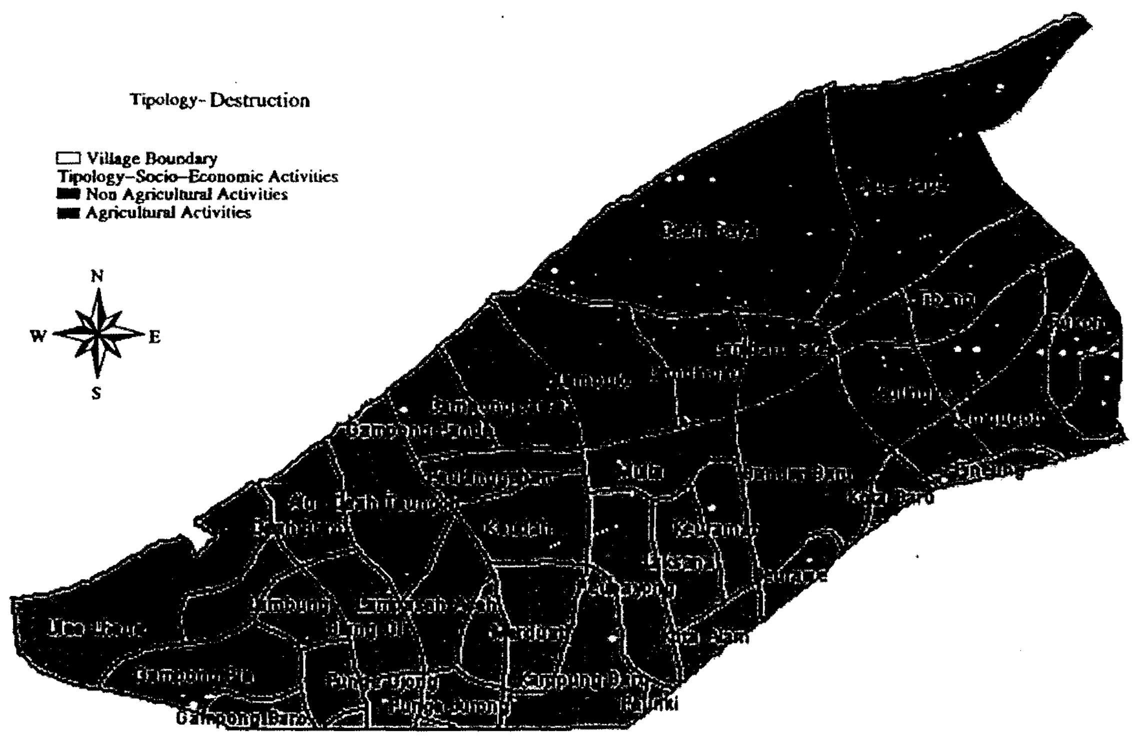

Fig. 6 Spatial pattern of destruction level based on Clustering technique

The Master Plan proposed by Central Government (Bapenas) gives special attention to spatial arrangement issues and offers draft plans on how to use space in affected districts or municipals. Local governments are invited to build on the drafts as they develop detailed spatial plans in close consultation with communities. The primary aims of the process are to ensure that as areas, cities, regions, and settlements are rebuilt, living conditions are improved and property are safeguarded in the event of future disasters. Business centers, social services, and densely populated urban settlements are best located in tsunami-proof zones, for example. With the emergency relief efforts concluded, the Master Plan will guide efforts or activities over the next five years. Master Plan is a policy and strategy document that will guide ongoing dialogue, planning, and action it is not designed to be a finished blueprint. In short, the Plan promotes: locally and cultural appropriate solution, community participation and broad stakeholder input, holistics and integrated approaches, transparency, accountability and effectiveness.

5 Land Use Planning and Zoning

Spatial zoning considered as a tool often used to manage region in an efficient and effective way. The master plan promotes 9 zones, namely: (1) coastal zone, (2) fishery culture zone, (3) city garden, (4) settlement, (5) city center/landmark, (6) new settlements areas, (7) new bussines and offices center, (8) education areas, and (9) agriculture. The coastal zone functions mainly as buffer zone (wave/wind breaker), and located within 300 ~ 400 meters from coastal line. The aquaculture areas mainly serves as fishery (ponds) activities and as the second wave breaker and fisherman housing. This area located in the range about 1300 m from the first zone line. City Garden/Public Greenery areas are the third buffer area, and utilized as public space and city garden. Settlement areas function as a limited settlement and public facilities centers. The City Landmark is the location of main city landmarks (Baiturrahman Mosque, Museum of Tsunami and other city landmarks), local govenment offices, and Cultural Centers. New settlement areas function as new housing complex of the relocated inhabitants (formerly were living closed area to the seashore), new settlements areas. New bussines and offices centers are promoted as the city and province service centers (CBD and government offices). Education Center areas function as location og high education campus and its supporting facilities. Agricultural areas function as agriculture production areas, rural settlements and their supporting facilities.

The three buffer zones (about 2 km from the seashore) are located in the formerly most dense areas. Many groups of coastal community and NGOs are asking for the involvement of local community in decision making process. According to National Land Agency (BPN) assesment, within the promoted buffer areas, amount of 8 795 houses were located (Table 4) which some of them have been ruined. During the planning process, many of inhabitants have started to claim and build their own new houses.

6 Conclusion Remarks

Tsunami has significant impact on land use pattern in coastal areas of Banda Aceh City. The changes of fishponds, residential areas and conservation areas (mangrove and other forest) were dominated the land use/cover changes. These three land use/covers were decreased about 61.5%, 57.8% and 77.6% from the former respectively. Most of destructed villages in coastal areas of the city formerly were developed as urban and very dense areas.

The effectiveness of government spatial planning will ultimately rely on the community's acceptance and government's commitment to provide resources to implement. The government promoted buffer zones (about 2 km from seashore) are located in the formerly most urbanized dense areas. To implement this planning, community based participatory planning process is needed.

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