ISSN 0024-9521
Indo.J.Geog. Vol. 38, No. 1, June 2006 (53-68)

INDONESIAN JOURNAL OF GEOGRAPHY

GEOMORPHOLOGICAL APPROACH FOR REGIONAL ZONING IN THE MERAPI VOLCANIC AREA

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ABSTRACT

Geomorphologial approach can be used as the basic for identifying and analyzing the natural resources potentials, especially in volcanic landscape. Based on its geomorphology, Merapi volcanic landscape can be divided into 5 morphological units, i.e.: volcanic cone, volcanic slope, volcanic foot, volcanic foot plain, and fluvio-volcanic plain. Each of these morphological units has specific characteristic and natural resources potential. Based on the condition of geomorphology, the regional zoning can be compiled to support the land use planning and to maintain the conservation of environmental function in the Merapi Volcanic area.

Key words: geomorphological approach, natural resources, regional zoning, Merapi volcano

INTRODUCTION

Merapi Volcano is known as the most active unique volcano in the world, because the period of repeated eruption is relatively short and frequently causes many disasters with many deaths and the loss of treasure. The study area of the Merapi Volcano is from the volcanic cone to fluvio-volcanic plain. The study on Merapi Volcano so far always emphasizes on the hazard, mitigation, and its eruption prediction. The study on the potential of natural resources of Merapi Volcano as a whole has never been done before.

To have the base for developmental planning, it needs to find out the potentials of natural resources in the area. The potential of natural resources containing in this area to support the society around it need to find out. The management of natural resources of Merapi Volcano is an example in active strato volcano, and has various ecosystems with all natural treasure in it.

The existence of natural resources potentials in Merapi Volcano affects the pattern and the intensity of the natural resources using. The use of the natural resources will affect to continuity of existing ecosystem, in which composed of related component and affecting each other as a unity in continuity. Therefore, in the use of natural resources, it needs neither to pay attention to various considerations in order nor to reveal negative effect toward the physical, biotic, or socio-cultural environments in the society. These considerations are subsequently poured in the meaning of land use planning in the Merapi Volcano area.

The land use planning should be carried out in sustainable and integrated manner. Therefore, this can't be carried out in disciplinary, although certain district has high potentials, while other sectors have medium or low potentials, but it has to be directed to support the ecosystem stability. As an illustration, the forest yield in the area is relatively low wood compared to the yield of sand and rock as mined. But, the function of forest is very important in maintaining the stability of ecosystem in Merapi Volcano area, especially to support the hydrological function. Firmly, it can be stated that sand and rock mining will give sufficient benefit, compared to forest products, but it will give negative effect toward the water resource availability for the society and flood danger or lava.

Based on above conception and fact, it can be formulated the main problem of this study, emphasizing on the identification of natural resources potential to the formulation of region zoning as the base for the land use planning in the area. The study on the potential of natural resources can be identified and analyzed based on geomorphologic unit. Each geomorphologic unit in volcanic area will give a view on the characteristic and potential of its nature. Therefore, the direction of zoning formulation for region zoning is to maintain its environmental function conservation, and can be based on its geomorphologic unit.

Problem Formulation

So far, the society know Merapi Volcano because of natural disaster it causes, either by hot lava, hot cloud (*wedus gembel*), or lava flow. Most of the scientific study on Merapi Volcano emphasizes on geological aspect of volcano, and the hazard or disaster it cause. Meanwhile, the study on the natural resources potential of Merapi Volcano based on the geomorphologic aspects has small number.

Based on its geomorphologic condition, Merapi Volcano landscape, starting from the peak to the down, can be categorized into 5 morphological units [*Pannekoek*, 1949], i.e.: volcanic cone, volcanic slope, volcanic foot, volcanic foot plain, and fluvio-volcanic plain (Fig.1). Each of these morphological units has different characteristic, affecting its characteristic and natural resources. Therefore, it needs to study about the characteristic and the potential of natural resources to make region zoning and the formulation of environment strategy in Merapi Volcano area. Geomorphology can be used as an approach to study and analyze in this research.

Research Objective

The aims of this research are: (1) to analyze the characteristic and potential of natural resources in each geomorphologic unit in the Merapi Volcano area; and (2) compose the regional zoning as the bases for land use planning in the Merapi Volcanic area.

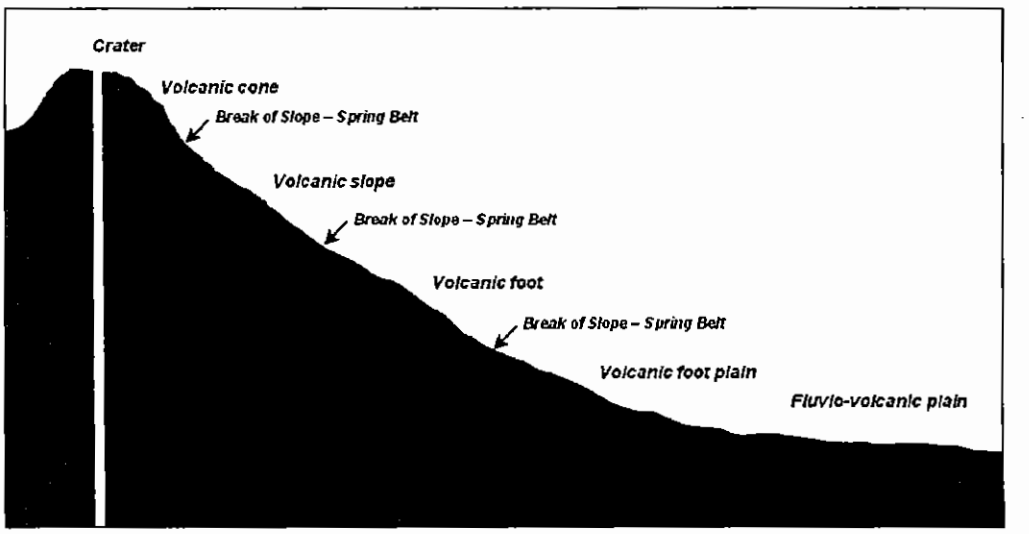

Figure 1. The Sketch of Morphological Unit of the Strato Volcano [*Pannekoek*, 1949]

Theoretical Framework

Natural resources is a basic capital for the development, so that in using the natural resources has to know about its characteristic first, such as its unequal distribution, interrelated and interdependent. The complex interaction among the natural resources component cannot be assumed separately, but form a comprehensive and through system [*Katili*, 1983; *Dietz*, 2000]. The study of the relation between the community and natural resources and its environment has an important meaning, because the use of natural resources and environment by the community if not considering their characteristic will result in the reduction of natural resources quality and environment it self.

The components of natural resources analyzed in this study are: land resource (the land capability and land use), water resources (rainfall, groundwater, river, and spring), and mineral resources. Natural resources and environment are in dynamic, changing from time to time either in the number or quality, and the change of natural resources and environment experience transitional, which previously dominated by the nature, then dominated by human [*Messerli, et al.*, 2000].

The data on natural resources can be presented temporal and spatially. The spatial and temporary data of natural resources can be obtained through the interpretation of the remote sensing data, satellite image, or other remote sensing

image [*Lillesand* and *Kiefer*, 1979; *Verstappen*, 1983; *Zuidam*, 1985]. Each type of remote sensing data has different ability to obtain data on natural resources. Remote sensing can be use to obtain data on natural resources in quite detail to detail, such as: geology, geomorphology, hydrology, soil, and land use [*Mekel*, 1974; *Vertappen*, 1977, 1983; *Lillesand* and *Keifer*, 1979; *Zuidam*, 1985]. Satellite image (Landsat) has ability to obtain data on natural resources in quite detail to review, but the ability of Landsat image to obtain data on natural resources depends on the band used [*Lillesand* and *Kiefer*, 1979].

The potential of natural resources in Merapi Volcano area is related with the genesis and its geomorphology condition. The variation of types and age of rock from Merapi Volcano located in various heights and limited by the notch of the slope will affect to the landform condition, soil, and its drainage pattern. Landform is the reflection of interaction between the type of the materials and the geomorphic process [*Thornbury*, 1949; *Summerfield*, 1991], and landform affects the distribution of soil type [*Gerrad*, 1995]. Besides, landform can be used as an approach to study groundwater, different landform unit having different groundwater characteristic [*Walton*, 1970; *Verstappen*, 1983; *Brown*, 1995].

The activity of volcano is able to yield materials enriching and renewing the soil for agriculture. Volcano gives other economic benefits, such as: plantation, mineral industry, and tourism asset [*Tjia*, 1987]. The activity of Merapi Volcano can yield pyroclastic material (sand and stone), so that on the volcanic cone and volcanic slope (upper slope) can be function as recharge area, and the groundwater in the volcanic foot and fluvio-volcanic plain, relatively large number and good quality, the occurrence of spring generally exists in break of slope and/or composing materials.

Large amount of natural resources availability in Merapi Volcano area, in fact, has appeal for the people, so that Merapi Volcano becomes the society concentration point shown by the high density. Therefore, it needs a study on the potential of natural resources related to the hazard it causes, so that it allows the region zoning and recommendation of natural resources and land use planning in the Merapi Volcano area.

Geomorphology is a science studying the form of earth surface, genesis and its development process, and its effect to the surrounding environment. The geomorphologic characteristic reflects the characteristic of natural resources containing in it, so that geomorphology can be used as an approach to study the potential of natural resources in a region.

Based on its morphology, Merapi Volcano landscape has specific geomorphologic condition, starting from cone to fluvio-volcanic plain. The different of geomorphologic condition is certainly will affect the potential of natural resources containing in it, either water resource, land capability, land use, or mineral resource. The overlay between various potential of natural resources, related to the zoning of hazard zone, allow the formation of region zoning as the

basic framework of recommendation for its land use planning, as presented in Fig. 2.

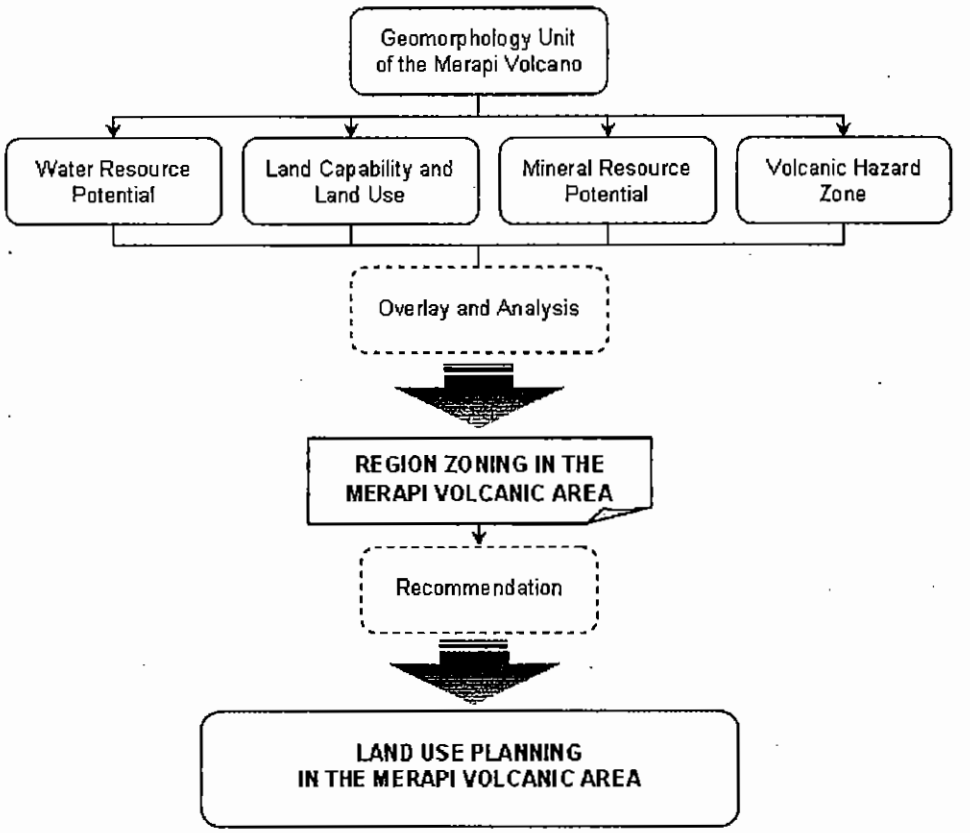

Figure 2. Theoretical Framework: Geomorphological Approach for Region Zoning as based on the Land Use Planning in the Merapi Volcanic Area

THE METHODS

The method used in this study was survey method, either institutionally, interpretation of image and map, or field survey. The smallest analysis unit for the potential of natural resources is geomorphologic unit of Merapi Volcano, interpreted of the Landsat TM image. The potential of natural resources was analyzed based on secondary data of the result of institutionally survey in various related institutions in Merapi Volcano area. Besides, the potential of natural resources was also formulated from the result of interpretation and analysis of related thematic maps, such as: geological map, soil, hydrogeology, and the data of climatology. Furthermore, it was carried out a field test and measurement to fit the result of the interpretation, whose determination was using purposive sampling.

Based on the result of the analysis on the potential of natural resources with geomorphologic analysis unit, subsequently it was carried out integration and

overlay of thematic maps: water resource potency, land capability and land use, mineral, and hazard zone, to zoning map on region function. Based on this zoning, thus the land use planning in the area can be formulated.

RESULTS AND DISCUSSION

Geomorphologic Unit of the Merapi Volcano Area

Merapi Volcano is one of the landscapes having typicality, either its formulation genesis (process), composing materials, and its structure; so that to identify the boundary on geomorphologic unit can be identified easily based on its morphology.

Viewed from the geomorphologic process in Merapi Volcano landscape, it can be differentiated into endogenous process because of magma activity, and exogenous process because of the media activity or other geomorphologic activities. The endogenous process, taking the form of magma activity, strongly determines the formation of volcano body in general. The exogenous process affecting the development or the dynamic of Merapi Volcano landscape, such as the storm water flowing into surface stream, strongly determines the development of fluvio-volcanic landscape. In detail, the morphological units reflecting the geomorphologic condition of Merapi Volcano are presented in Table 1 and Fig. 3.

Table 1. Morphological Units and its Characteristic at the Merapi Volcano Area

Morphology Unit	Relief	Rocks and Structure	Process	Characteristic
Volcanic Cone	Moun-tainous	Pyroclastic and lava flow	Deposition of pyroclastic and gravity	The top of volcano, very steep slope. The landforms included in this morphology unit are crater, lava dome, lava field, lahar field, and parasiter cone.
Volcanic Slope	Hilly	Pyroclastic	Deposition of pyroclastic and gravity	Morphology after the volcanic cone, moderate slope.
Volcanic Foot	Undulating	Pyroclastic and alluvium deposit	Deposition of pyroclastic, fluvial, and gravity	Morphology after the volcanic slope, gentle to moderate slope.
Volcanic Foot Plain	Flat up to gentle	Pyroclastic and alluvium deposit	Deposition of pyroclastic, and fluvial	Morphology after the volcanic foot, flat to gentle slope.
Fluvio-volcanic Plain	Flat	Alluvium deposit	Deposition of fluvio-volcanic material	Lowest morphology of the volcanic landscape, flat slope, formed by fluvial process.

Sources: Interpretation of the: Landsat 457 (2002), Topography Map (2001), Geology Map (1992), Hydrogeology Map (1988); [*Sutikno, et al.*, 2004]

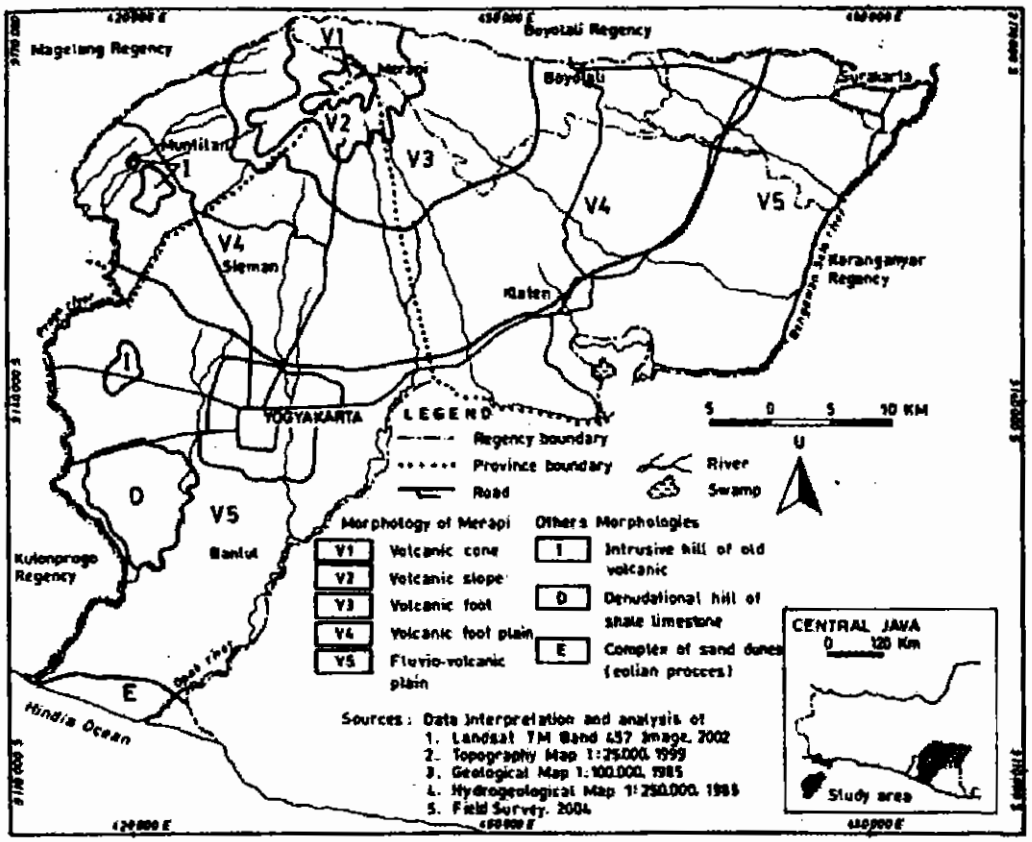

Figure 3. The Geomorphological Units in the Merapi Volcanic Area

Water Resources Potency

Based on the distribution of annual rainfall average, its relation with geomorphologic unit, starting from volcanic cone to fluvio-volcanic plain, thus the potential of rainfall in Merapi Volcano area is presented in Table 2. Based on the result of rainfall data analysis, in Merapi Volcano area has medium potential of rainfall (800-1800 mm/year), distributed in all area. The rainfall potential is moderate, so that appropriate to develop agricultural plants or similar type of plants. But, related to its morphological condition, it is better for the development of agricultural plants is carried out in lower land, i.e.: volcanic foot plain and fluvio-volcanic plain. The upper land can be developed as annual plant field, such as plantation. In volcanic slope unit, it is used as recharge area, and volcanic cone as a catchments area, in the protecting forest form.

Based on its character and discharge flow, there are two high potential rivers, i.e.: Progo and Opak River, and upper of the Bengawan Solo River (Dengkeng and Pepe River). The branches of Progo River potentially to supply water to its main stream are: Pabelan, Blongkeng, Batang, Krasak, and Bedog Rivers, in which each of them has discharge average of 700-1000 litre/second. Such a condition gives

many contributions to the character of Progo River, which always flowing all over the year, called by perennial stream, with discharge average of 150,000 litre/second. Winongo, Boyong-Code, Gajahwong, Sembung, Kuning, Tepus, and Gendol Rivers are the branches of Opak River, which has upper parts in Merapi Volcano. Discharge average in each tributary is between 500 - 1,000 litre/second, able to give contribution to the discharge of Opak River up to 50 m^3/second. Dengkeng and Pepe River supply the Bengawan Solo River up to >1500 m^3/second.

Table 2. Distribustion of the Annual Rainfall Average at the Merapi Volcano Area

Morphology Unit	Annual Rainfall Average (mm)	Rainfall Type	Storm Water Resource Potency
Volcanic cone	1734	B2	Moderate, tropical rain forest
Volcanic slope	1406	B2, C2	Moderate, annual plantations
Volcanic foot	1550	B2, C3	Moderate, seasonal plantations: paddy (twice per year)
Volcanic foot plain	1186	B2, C2	Moderate, seasonal plantations: paddy (twice per year)
Fluvio-volcanic plain	1328	B2, C2	Moderate, seasonal plantations: paddy (twice per year)

Sources: Rainfall Data Analysis (1987-1996) according to Oldeman method [in *Sutikno et al.*, 2004]

Based on the result of the water chemical analysis, in general it showed that the river water quality is included in class C, for husbandry or fishery, and class D for irrigation. The forbidding factor is used for the need of drinking water, Class A and B in general in the form of high content BOD, COD, and coli bacterial, showing that these rivers have been contaminated by waste, especially domestic waste. It is very possible because in generally people throw waste into the river, especially living in urban area. Therefore, if one wants to use it as drinking water, one has to carry out filtration and good processing. The result of data analysis, the value of electric conductivity of the river water generally far beyond the class C or D, generally under 1000 µmhos/cm, measured between 500-700 µmhos/cm. Therefore, it can be concluded that the rivers existing under the Merapi Volcano area, generally, have potential as water resource for fishery, husbandry, and irrigation.

Beside river water, spring is also a potential surface water resource in Merapi Volcano area. It is noted that 212 spring locations, distributed starting from volcanic slope to fluvio-volcanic plain, with the pattern following the same height. The pattern of spring occurrence existing in young strato volcano like Merapi Volcano is still real as a spring belt. The main concentration of the distribution of this spring is in volcanic slope to volcanic foot unit. This shows that infiltration of storm water in the upper parts, in volcanic slope and volcanic foot units, is

relatively intensive, and as a result of the existence of slope change in the break of the slope, thus many springs occur in the lower land.

Generally the discharge average of spring is <10 litre/second, but there are also springs with higher discharge, such as: Umbul Ingas, Sungsang, and Ponggok Spring di Boyolali Rengency with discharge of >1000 litre/second; Doyo, Nilo, Nepen, Kapilaler, Kayan, Sigedang, Pengging, and Kendat Spring in Boyolali Regency with discharge between 118 -710 litre/second; Pluneng, Kapilaler, and Nolo Cokrotulung Spring in Klaten Regency with discharge between 350-1200 litre/second; Kali Kuning in Sleman with discharge of 1220 litre/second; and many more springs with discharge between 5 -10 litre/second. Besides it is used as drinking water resource, especially in springs with high discharge, recently, the spring use is more developed for tourism objects of fishing with floating kiosk, pool, and bathing. Even, in several big springs, such as in Klaten and Boyolali Regencies, they have been used as raw materials of packed drinking water, such as Aqua in Cokrotulung, Umbul Ingas, and Sungsang Spring.

The potential of groundwater resource was analyzed based on the result of interpretation of Hydrogeological map, field measurement, or institutional data. The potential of groundwater in Merapi Volcano area can be classified into 3 (three) zones, as follow:

(a) High potential groundwater zone. Groundwater is stored in aquifer with wide distribution, shallow water table (<7 meter), good quality, and discharge of >10 litre per second, even in several places >50 litre/second. This aquifer exists in volcanic foot plain unit in Yogyakarta city and around Klaten Regency.

(b) Medium potential groundwater zone. Groundwater is stored in aquifer with wide distribution, relatively shallow water table (<7 meter), good quality, discharge of 5-10 litre per second. This aquifer is generally located in volcanic foot and volcanic foot plain unit.

(c) Low potential groundwater zone. Groundwater is stored in aquifer with limited distribution, water table relatively shallow to medium (7-15 meter), discharge of <5 litre/second. This aquifer located the slope to volcanic foot unit, fluvio-volcanic plain along Bengawan Solo River; fluvio-volcanic plain in the north of Baturagung Hill in Klaten Regency, and in the south Bantul Regency closing the Parangtritis coastal area.

One group is not included as aquifer because it has low productivity so that lack of groundwater. Water table is relatively deep so that it is impossible to fetch the water. It exists in volcanic cone unit, isolated small hills in Salam, Moyudan, and Sedayu of Sleman Regency, Pajangan Municipal of Bantul Regency, and Bayat Municipal of Klaten Regency.

Land Capability and Land Use

Natural resources potential in this study is reflected by land capability class and land use so far. Based on its land capability class, in Merapi Volcano, it can be classified into 8 classes, as presented in Table 3.

Table 3. Land Capability, Characteristic, and Its Distribution at the Area

Land Capability	Land Characteristic	Land Use	Distribution
I	This land capability doesn't have limitation to using, and suitable for land agriculture. Land characteristics are: flat to gentle of relief, no erosion, thick in soil dept, well drainage, easy to be cultivated, high potential of water resources, fertile, no flood, and the climate is suitable to growing of plant.	Irrigation land to paddy field and settlement.	Most of Merapi fluvio-volcanic plain in Klaten, Sleman dan Bantul Regency.
II	This land has little limitation to using, and need a conservation activity in a low to moderate level. Be careful in cultivation, including in conservation activity to defend land degradation, so that the land can be used as agriculture cultivation. The limited factors generally are water potential and soil deepness.	Dominantly are paddy field and settlement.	Part of Merapi fluvio-volcanic plain and volcanic foot plain in Sleman, Bantul, Klaten, Boyolali, and Magelang Regency.
III and IV	This land has moderate limitation, and need specific conservation activity. The limited factors are more weight than class II, that decreasing the time period if the land will be used for seasonal plantation cultivation.	Paddy field, dry land, and part of mix garden.	Merapi volcanic foot plain in Klaten, Sleman, and Magelang Regency.
V and VI	The land is limited by thin in soil dept, moderate to steep in relief, and weight erosion, so difficult to be done land cultivation.	Mix garden, brush, and limited cultivation forest.	Merapi volcanic foot, Turgo, Plawangan, Gono, and Gendol hill slope.
VII	The limited factors are more weight than class VI, the limited factors area thin in soil dept, steep in relief, and very weight erosion, so difficult to be done land cultivation, and not suitable for agriculture. Has to be make terraces to defend erosion and land slide, and to be done vegetative conservation.	Mix garden and conservation forest.	Merapi volcanic slope, parasiter cone, and small hills its around.
VIII	The land in this class is the hazard area from lava and lahar flow, and impossible to be done cultivation activities.	Bare land: lava or lahar field (lava and lahar flow).	Merapi volcanic cone, lava dome, Turgo, Plawangan, and Gono parasiter cone.

Sources: Data Analysis [in *Sutikno et al.*, 2004]

Mineral Resource Potency

The potency of mineral resource existing in Merapi Volcano is in the form of C mining material, especially sand and rock. Sand, gravel, and pebble materials as the result of Merapi Volcano eruption are distributed through the existing stream flow, such as Pabelan, Putih (upper parts of Krasak River), along Progo River, Blongkeng, Code Rivers to Gendol and Opak Rivers. Besides, in Yogyakarta Special Province, the mining of C materials can be met in many Merapi Volcano slope units, such as in Cangkringan Municipal, Sleman Regency, and the surrounding.

In Klaten Regency, the mining of C materials is in the form of sand material, which has been carried out long time ago, so that recently this site is only ex mining location, like along the Simping, Woro, Dengkeng Rivers, and others. This needs to be considered because of its relation to the field conservation actions ex mining.

In Boyolali Regency, the mining of C materials in the form of sand and rock and still ongoing in relatively steep valley river body, like in Cepogo and Selo Municipal. Meanwhile, in Magelang Regency, besides sand material distributed through Progo River and its branches, the mining of C materials is also in the form of andesite rock, used as the raw material of sculpture. Similarly is with Surakarta and Sukoharjo Regency, and mining is carried out in along Bengawan Solo River.

Based on the data obtained from the institution in all district, the production value of C materials mining reaches 400 million rupiahs. The location of mining activity mainly is in Tempel, Turi, and Pakem Municipals of Sleman Regency; Sawangan, Dukun, and Srumbung Municipals of Magelang Regency; Wedi Municipal in Klaten Regency; and Ampel and Selo Municipals in Boyolali Regency.

Hazard Zone of the Merapi Volcano

Based on the type of analysis and the distribution of volcanic activity results, and its geomorphologic characteristic, thus the hazard of Merapi Volcano can be classified into three hazard zones as follow:

(1) Hazard zone I is the restricted area for all kind of activities, because it is an area in which active lava always passes through. This zone comprises of area surrounding crater and cone of Merapi Volcano.

(2) Hazard Zone II is the area which is better to be avoided from the use of settlement, because in an occasion it is still affected by lava stream activities, or dust and gas flow (*nuess ardente*). This zone comprises of area around the cone and upper slope of Merapi Volcano.

(3) Hazard Zone III is the area that has to be monitored because it is the route of lava flow if the intensity of the volcano is high. This zone comprises of river valleys in the upper side with certain velocity comply with the intensity of lava flow.

Regional Zoning and Land Use Planning

The regional zoning meant here is the classification of regions based on certain criteria to give main function picture of the area, so that in the use of natural resources can be optimum to increase the surrounding societies welfare, with keep paying attention on the sustainability of environmental function. Based on the criteria used as the guidance of region zoning arrangement of Merapi Volcano is the geomorphologic condition (landform), water resource potential, land resource potential (land capability and land use), and hazard zone. Based on this concept, thus Merapi Volcano area can be classified into 6 (six) types of region zone, as presented in Table 4, and spatially in Fig. 4.

Table 4. Regional Zoning, Characteristic, and Land Use Planning in the Merapi Volcano Area

Region Zoning	Characteristic	Morphology Unit	Land Use Planning
Retricted Area	▪ The area of lava flow, lahar flow, and nuess ardente. ▪ Land capability of VIII class, bare land, and pyroclastic area. ▪ High rainfall, but very low potential of groundwater (rare).	▪ Volcanic cone ▪ Lava field ▪ Lahar filed ▪ Volcanic slope	▪ Continuously of monitoring. ▪ Restricted for all kind of activities, except protected or conservative forest.
Conservative Area	▪ The area which still influence of lava flow, lahar flow, and nuess ardente. ▪ Land capability of VII class, most of area as conservative forest. ▪ High rainfall, but very low potential of groundwater (rare).	▪ Part of volcanic cone ▪ Parasiter cone ▪ Volcanic slope ▪ Upper river valley ▪ Intrusively small hilly	▪ Forbidden for all kind of activities related with land cultivation. ▪ Conservative forest or natural tourism area of mountain. ▪ Plan of natural tourism infrastructures.
Recharge Area	▪ Primary recharge area and infiltration of rainfall to the aquifer, as a supply of groundwater. ▪ Land capability of V and VI class, land use of mix garden, brush, dan limited cultivation forest. ▪ High rainfall, pyroclastic material (good aquifer), many spring, soil develop and thick in solum.	▪ Part of volcanic slope ▪ Volcanic foot ▪ Slope of parasiter cone	▪ Management of land cover and building, artificial recharge well. ▪ Conservation of spring, and green belt in the side of river. ▪ Arrange to settlement area. ▪ Better to annual plantation cultivation and mix garden.

....continue

Table 4.Regional .. ..

Region Zoning	Characteristic	Morphology Unit	Land Use Planning
Annual Plantation Cultivation Area	▪ Save area from the influence of lava flow, lahar flow, and nuess ardente. ▪ Land capability of III and IV class, most of area as a mix garden, dry field, brush, and there is simple irrigation of paddy field. ▪ High to moderate rainfall, high to moderate of groundwater potential, and high potential of surface water resource.	▪ Volcanic foot plain	▪ Annual plantation cultivation, mix with paddy field, fishery, and husbandry. ▪ Land use planning (spatial planning) need to arranged well. ▪ Arrange to people growth.
Seasonal Plantation Cultivation Area	▪ Save area from and so far of Merapi volcanic hazard. ▪ Land capability of I class, most of area as a simple to technical irrigation of paddy field. ▪ Moderate rainfall, high to moderate of groundwater potential, and high potential of surface water resource.	▪ Fluvio-volcanic plain	▪ Suitable for seasonal plantation cultivation (paddy field) mix using with fishery and settlement. ▪ Well in land use planning.
Non Agriculture Cultivation Area	▪ Save area and so far from Merapi volcanic hazard. ▪ Land capability of II class, most of settlement and citizen. ▪ Moderate rainfall, high potential of groundwater resource, and as a groundwater basin.	▪ Volcanic foot plain ▪ Fluvio-volcanic plain	▪ Developing to non agriculture activities (settlement and citizen). ▪ Detail spatial planning (urban planning). ▪ Arrange to the center of service facilities, and well in region infrastructures. ▪ Arrange to density and people growth.

Sources: Data Analysis [in *Sutikno et al.*, 2004]

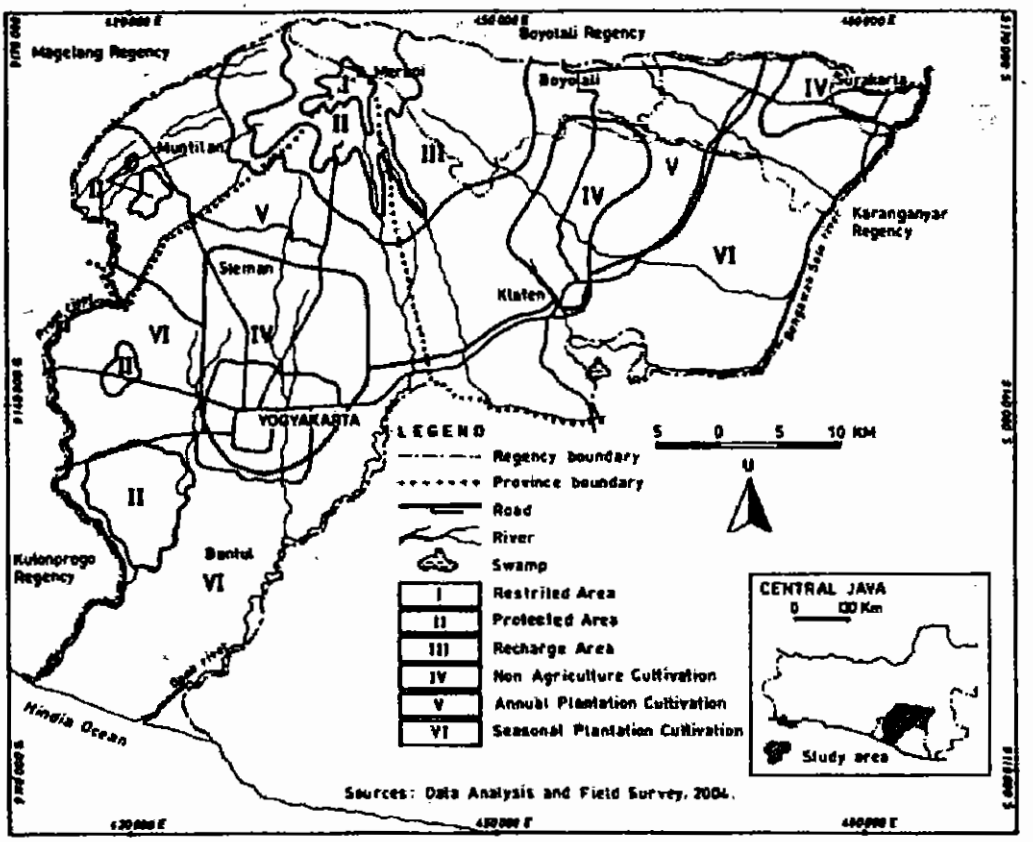

Figure 4. Regional Zoning in the Merapi Volcanic Area

CONCLUSION

(1) Related to the morphological condition, the areas having high natural resources potential can be met in volcanic foot, volcanic foot plain, and fluvio-volcanic plain. In these morphological units, it is very potential to develop plantation, fishery, and wet land agriculture. The high use and economic value of the production of natural resources in those morphological units are supported by the potential of water resource, land capability and high environmental capacity to encourage the sustainable use, and avoid from Merapi Volcano hazard.

(2) Based on its geomorphologic characteristic, the water resource potential, the land capability and land use, and hazard zone, thus the area in Merapi Volcano can be classified into 6 region or zone, as below:

(a) Restricted Area, located in Merapi volcanic slope, lava dome, lava field, lahar field, and Merapi volcanic cone;

(b) Protected or Conservation Area, located in Merapi volcanic slope and deep river valleys having upper around Merapi volcanic cone, parasiter cone, and Sentolo Formation hills in Sedayu and Pajangan (Bantul);
(c) Recharge Area, located in lower part of Merapi volcanic slope and Merapi volcanic foot;
(d) Annual Plantation Cultivation Area, located in small part of Merapi volcanic foot and almost all units of Merapi volcanic foot plain;
(e) Seasonal Plantation Cultivation Area, located in small part of Merapi volcanic foot plain and most part of Merapi fluvio-volcanic plain; and
(f) Non Agricultural Cultivation Area, located partly in Merapi Volcano Foot Plain unit and all Merapi Fluvio-volcanic Plain, especially in hydrogeological is called as groundwater basin, including the urban area of Yogyakarta, Klaten, Sukoharjo, Surakarta, and the surrounding.

ACKNOWLEDGEMENTS

Thank you very much for Directorate General of Higher Education Republic of Indonesia that had funded the research of Hibah Bersaing X within 3 years for 2002-2004 periods, through UGM Research Institution that has facilitated the implementation of this research. We also thank to research team: Widiyanto, Andri Kurniawan, and Taufik Hery Purwanto for all the time, thought, and energy to complete the result of Hibah Bersaing X research. Thanks are also due to an anonymous reviewer for improving on the article.

REFERENCES

Brown, A.G. (1995), *Geomorphology and Groundwater*, John Wiley & Sons, New York.

Dietz, T. (2000), *Entitlements to Natural Resources Countours of Political Enviromental Geography*, diterjemahkan oleh Roem Topatimasang, Isist Press & REMDEC, Jakarta.

Gerrard J. (1995), *Soil Geomorphology*, Chapman & Hall, London.

Katili, J.A. (1983), *Sumberdaya Alam untuk Pembangunan Nasional*, Ghalia Indonesia, Jakarta.

Lillesand, T.M. and R.W. Kiefer (1995), *Remote Sensing and Image Interpretation*, Prentice Hall Inc., New York.

Mekel, J.F.M. (1974), *The Use of Aerial Photographs in Geological Mapping*, ITC, Delf.

Messerli, B., G. Martin and H. Thomas (2000), From nature-dominated to human-dominated environment changes, *International Geographical Union Bulletin, 50* (1).

Pannekoek, A.J. (1949), *Outline of the Geomorphology of Java*, E.J. Bn'll, Leiden.

Summerfield, M.A. (1991), *Global Geomorphology*, Longman Scientific & Technical, New York.

Sutikno, Widiyanto, L.W. Santosa, A. Kurniawan, and T.H. Purwanto (2004), Potensi Sumberdaya Alam Gunungapi Merapi dan Pengelolaannya Untuk Mendukung Kehidupan Masyarakat Sekitar, Laporan Penelitian, Hibah Bersaing X, Lembaga Penelitian UGM, Yogyakarta

Thornbury, H.D. (1949), *Principles of Geomorphology*, John Wiley & Sons, New York.

Tjia, H.D. (1987), *Geomorfologi*, Dewan Bahasa dan Pustaka Kementerian Pendidikan, Universiti Kebangsaan Malaysia, Kuala Lumpur

Verstappen, H.Th. (1977), *Remote Sensing in Geomorphology*, Elsevier, Amsterdam.

Verstappen, H.Th. (1983), *Applied Geomorphology for Environmental Management*, Elsevier, Amsterdam.

Walton, W.C. (1970), *Groundwater Resources Evaluation*, McGraw Hill, Hogakusha-Tokyo.

Zuidam, R.A.van (1985), *Aerial Photo-interpretation in Terrain Analysis and Geomorphologic Mapping*, ITC, Enschede.