J. Jpn. Soc. Soil Phys.
土壌の物理性
No. 85, p. 19～29 (2000)

Soil Characteristics, Farming System and Conservation Strategies in the Sloping Volcanic Areas in Indonesia

MASTUR*, Hajime NARIOKA**, Makoto ANASE*** and Rokuro YASUTOMI***

* Research Center for Tobacco and Fiber Crops, Karangploso Street PO Box 199, Malang, East Java, Indonesia

** Faculty of Environmental Science and Technology, Okayama University, 3-1-1 Tsushima-naka, Okayama 700-8530, Japan

*** Tokyo University of Agriculture, 1-1-1 Sakuragaoka, Setagaya-ku 156-8502, Japan

Abstract

Volcanic soil can be easily degraded under natural conditions or when subjected to human activities. A research was conducted in Java and Bali islands in Indonesia to determine the relationship between soil characteristics, farming system and conservation strategies in highland volcanic areas. The volcanic soils in the research areas were found to have high fertility but low organic matter content. Also, soils with high clay content tend to have low erodibility. On other hand, low clay content, low cation exchange capacity (CEC), low liquid limit (LL) and low plasticity limit (PL) are associated with high soil erodibility.

The common farming systems in the research areas are growing vegetables and raising livestock. Multiple cropping is the predominant system as exemplified by relay cropping, sequential cropping and intercropping.

To control soil erosion, both agronomic and mechanical measures are practiced. Farmland agroforestry and a combination of "Taungya" and multistory agroforestry are common agronomic control strategies while vertical ridges with grass strips and bench terracing, especially on steep locations are the mechanical measures widely adopted. The attainment of effective soil erosion control and increased land productivity largely depend on the establishment of appropriate measures and conservation strategies.

Key words : farming systems, conservation, agroforestry, erodibility, Indonesia

Introduction

Volcanic soils are widely spread along the axes of Java, Bali and other islands in Indonesia. The main soil types in the volcanic areas of Indonesia are Andosol, Regosol, Brown Forest soil and Latosol (Tan, 1965 ; Soepraptohandjo, 1976 ; Subagjo, 1993). Land use types are forest plantation, agroforestry, upland and paddy fields.

The volcanic areas of Indonesia are usually considered fragile agroecosystem due to sloping topography, high precipitation, high soil erodibility, and inappropriate land use management (Carson, 1989 ; Kurnia, 1996). In the volcanic area of Citanduy watershed in West Java for example, Kalo (1989) estimated the rate of soil erosion from 7 mm to 10 mm/year due to poor management. Other reports revealed that the volcanic area close to Mt. Bromo in East Java has an annual soil erosion rate of 200 t/ha/year (Carson, 1989).

To provide a more effective erosion control measure and conserve the soil, a combination of mechanical and agronomic approaches is necessary. Terracing (mechanical) such as those constructed in a watershed in Java island (Juliardi, *et al.*, 1989 ; Sembiring, *et al.*, 1990) can be in combination with agronomic measures such as agroforestry or suitable cropping patterns. Doing these, soil physical properties and fertility can be improved.

This research aimed to study soil characteristics, farming system and conservation strategies on the highland volcanic areas in Java and Bali islands, Indonesia. Soil characteristics and other factors such as topography and climate were considered as the main factors that would influence the appropriate farming system as well as the soil conservation strategy. Sustainable farming system can be achieved by minimizing soil erosion and maintaining crop productivity.

Materials and Methods

The research was conducted in several areas in Indonesia which included Loji village, Cianjur, West Java, Bendosari and Ngadas villages, Malang, East Java and Pancasari village, Buleleng, Bali. Table 1 and Fig. 1 show the geographical position of the research sites.

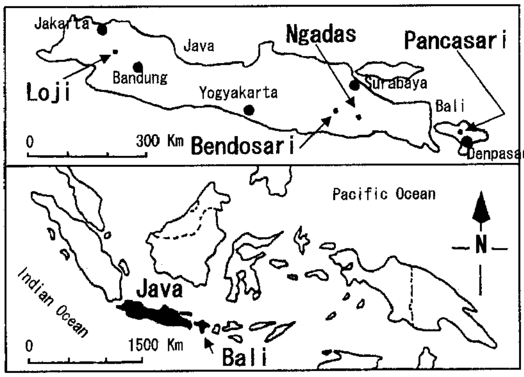

Fig. 1 Map of the study sites.

To determine the different soil characteristics in the sites, soil sampling and analysis of the physical and chemical properties were done at the Center for Soil and Agroclimate Research (CSAR) in Indonesia and at the Laboratory of Soil Environment, NODAI Research Institute (NRI) of Tokyo University of Agriculture in Japan. Also, field observation, field interview and secondary data collection helped the researchers in ascertaining and understanding the farming system and conservation strategies being practiced by the farmers in the area.

Results and Discussions

Rainfall Patterns

Based on the agro-climatic classification by Oldeman (1975) and Oldeman *et al.* (1980), the villages of Loji and Ngadas belong to the B-1 precipitation type having 7～9 wet months (over 200 mm/month) and less than 2 dry months (under 100 mm/month). On the other hand, Bendosari and Pancasari villages are under the C-2 type which is characterized by 5 or 6 wet months and 2～4 dry months.

In relation to precipitation, base saturation and pH of soils are decreased because cations are leached down the soil profile by percolating water usually brought about by high rates of precipitation.

Soil Characteristics

Generally, volcanic ash soils have higher available water, porosity, saturated hydraulic conductivity, saturated water content and water-holding capacity than non-volcanic soil with similar texture. However, the permanent wilting point of volcanic ash soil is low. Tables 2 and 3 show the chemical and physical

Table 1 Location and geographical position of the study areas.

Village	District	Province	Altitude (m)	Latitude	Longitude
Loji	Cianjur	West Java	1,100	S 6° 40′33″	E 107° 02′14″
Bendosari	Malang	East Java	910	S 7° 52′13″	E 112° 25′13″
Ngadas	Malang	East Java	2,090	S 7° 59′05″	E 112° 54′55″
Pancasari	Buleleng	Bali	255	S 8° 15′37″	E 115° 81′53″

Table 2 Chemical characteristics of the soils in the study areas.

Location (Village)	Base Saturation (BS, %)	pH		Organic Carbon (%)	Bases (cmol/kg)					CEC (cmol/kg)
		H_2O	KCl		Ca	Mg	K	Na	Total	
Loji	25	4.5	4.0	3.04	3.75	0.63	0.61	0.31	5.28	21.15
Bendosari	67	5.6	4.7	2.10	10.86	2.24	0.74	0.06	13.90	20.75
Ngadas	47	5.4	5.0	2.41	5.29	0.55	0.25	0.087	6.16	13.10
Pancasari	69	5.7	5.1	2.32	7.98	1.89	0.98	0.15	10.94	15.86

Table 3 Physical characteristics of the soils in the study areas.

Location (Village)	Water content ($\%_v$)				Hydraulic Conductivity (Ks, cm/s)	Texture	Color	Dispersion Ratio (DR, %)	Specific Gravity (Gs)	Bulk Density (ρ_d, g/cm^3)
	1 kPa	10 kPa	2 kPa	1.5 MPa						
Loji	44.6	38.9	35.0	21.4	1.75×10^{-2}	Light Clay	5YR 4/4	2.60	2.59	0.71
Bendosari	43.8	38.1	33.5	22.8	2.25×10^{-2}	Light Clay	5YR 4/3	6.63	2.65	1.01
Ngadas	45.3	34.6	30.2	13.2	3.78×10^{3}	Sandy Loam	10YR 3/3	49.62	2.58	0.79
Pancasari	45.8	40.1	35.5	14.6	3.29×10^{3}	Loam	5YR 5/4	36.29	2.66	0.89

properties, respectively, of the soils in the different study sites.

Soil type is strongly affected by volcanic ash and tuff materials. The predominant soil type in the research sites is Andosol, however, in Bendosari and Pancasari villages, some sites were found to have Regosol. Basically, Andosols have low bulk density and specific gravity (Gs) but high porosity (Narioka and Komamura, 1995). The granular structure of volcanic ash soils resulting from the interaction between organic matter and allophane is the reason for the high porosity and low bulk density of such soils. On the other hand, Regosols have higher bulk density and the effect of allophane is limited (Soepraptohardjo, 1976).

As regards soil texture, soils from Loji and Bendosari are light clay, although the Loji soil has more clay and silt and the Bendosari soil have slightly higher coarse sand particles. Ngadas has sandy loam while Pancasari is more of loam but coarse sand, very fine sand and silt particles also predominate.

Organic matter content of soils from Java and Bali is lower compared to the volcanic ash found in the Kanto loam from Japan (Tada, *et al.* 1966). This is a result of a faster organic matter decomposition in tropical areas brought about by relatively high daily air temperature.

High rates of organic matter decomposition can also be visually distinguished through the soil color. In the research areas, soil color is generally brown to dull reddish brown such as in the village of Loji. In comparison, the temperate volcanic ash soils have darker color and higher water content. Mitchell (1993) also found out that organic matter promotes high cation exchange capacity (CEC) and has a significant influence on soil plasticity. As such, soils with high CEC normally has high plasticity (Fig. 2). Organic matter and clay content contribute significantly to high water retention. Affinity of the clay to water also depends upon CEC and type of clay mineral. Smectite and allophane, for example, have higher water retention and CEC than sesquioxide and kaolinite.

Soils with high CEC can keep the nutrients from leaching and can supply more nutrients to crops. The problem of nutrient leaching is common on coarse-textured soils and those with high percolation rates as in Ngadas and Pancasari. In these areas, the application of soluble fertilizer, such as ammonium and potassium should take into account the rate of

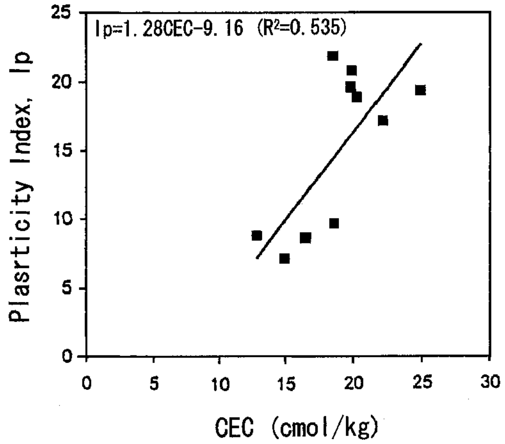

Fig. 2 Correlation between plasticity index and CEC of the soils from Loji, Bendosari and Pancasari.

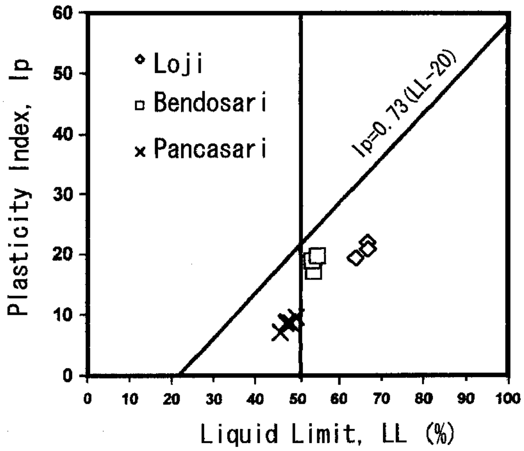

Fig. 3 Plasticity chart of the soils in Loji, Bendosari and Pancasari.

nutrient leaching. In terms of fertility, soils from Bendosari are the most fertile due to high organic matter content, high CEC and high base saturation, especially Ca and Mg. Pancasari soil is high in K. Soils from Ngadas and Loji have low to moderate base saturation.

The trend in base saturation of the soils is similar to pH. Loji and Ngadas soils have higher acidity (lower pH) than those from Bendosari and Pancasari.

Consistency of the volcanic ash soils would decrease with drying as a result of reduced affinity to water (Yamazaki and Takenaka, 1965). The consistency and water-holding capacity of the volcanic ash soils in Java and Bali islands are lower than those of the Kanto loam of Japan. Low clay content in soils is associated with low consistency. The high clay content of soils in Loji and Bendosari contributes to their having high liquid limit and plasticity index. In contrast, soils from Pancasari and Ngadas have low plasticity. Fig. 3 shows the plasticity chart of the soils from the different study sites.

Dispersion ratio is an important index of soil erodibility. Ghidey and Albert (1995) found a closer relationship between soil erosion and dispersion ratio of soil particles under 20μm (D_{20}) than those with 50μm size particles (D_{50}). Coarse soils found in Ngadas and Pancasari have higher erodibility than the finer soils from Bendosari and Loji. The rate of soil detachment by raindrop impact is also directly affected by dispersion ratio. Fig. 4 shows the correlation between soil dispersion ratio, CEC, clay content, liquid limit and plasticity index wherein a decrease in clay content, CEC, liquid limit and plasticity index will decrease the dispersion ratio of the volcanic ash soil. They exhibit a direct relationship.

In addition to the above, surface runoff will transport soil material detached through splash erosion to the lower slope. However, even under high rainfall intensity, high infiltration capacity can diminish runoff (Morgan, 1996). During high rainfall intensity, soils with high dispersion ratio are predisposed to soil erosion. Therefore, soils from Pancasari and Ngadas are more susceptible to soil erosion.

Farming Systems

Field reconnaissance and investigations conducted revealed that vegetable production and livestock raising are the main farming systems in the highland volcanic areas in Java and Bali islands. Usually, farmers construct row ridge, double ridge and bed ridge for drainage and to improve the aeration in the vegetable produc-

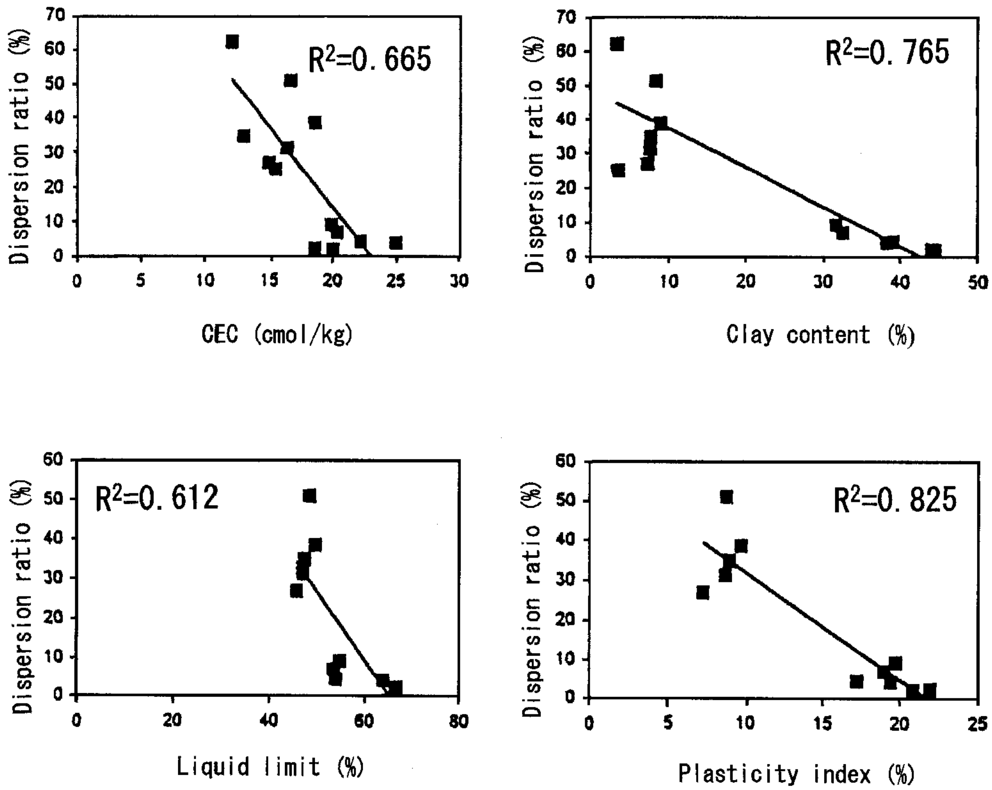

Fig. 4 Correlation between soil dispersion ratio and CEC, clay content, liquid limit and plasticity index.

tion areas. Notwithstanding, livestock is the main source of farmer's income as well as organic manure for crop production.

The farming system in the area is highly dependent on rainfall, although there is irrigation in some areas. Where the ground water is not so deep, shallow wells are constructed as irrigation source such as in farms close to Lake Bunyan located in the northwest of Pancasari. In areas with deep ground water table, small ponds are being constructed and lined with plastic material for storing irrigation water to be used later for the vegetables being grown. Farmers in Pancasari, for example, construct modified ridge-furrow system for water harvesting.

With crop production, either monoculture or multiple cropping maybe found in the study areas. In most cases, though, multiple cropping is better than monoculture cropping when considering stability of production (Mastur, *et al.* 1995) or biological pest control (Ranert, 1996). These viewpoints were observed in the area since the vegetables are usually grown in multiple cropping system. Intercropping which is the planting of two or several crops together is the most preferred system.

Relay cropping, where there is overlap in the growing period of the crops planted, is practiced in Bendosari. Planting starts early in the rainy season to efficiently utilize soil moisture. The main vegetables grown there are shallot, cabbage, maize and carrot. Fig. 5 shows the monthly precipitation in relation to the relay cropping system in Bendosari.

In Loji, farmers grow French beans at the onset of rainy season. This is followed by cabbage and then carrot which is already towards dry season. This system is called sequential cropping system.

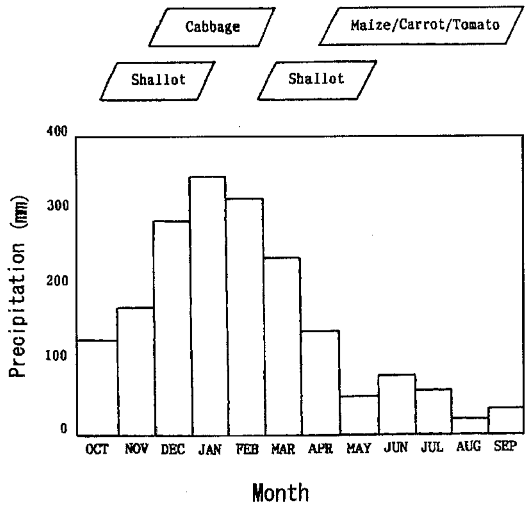

Fig. 5 Monthly precipitation and relay cropping system in Bendosari.

Ngadas farmers grow vegetables that are suitable to their soil which include garlic, potatoes, leek, cabbage and maize. Farmers in Pancasari grow almost similar kinds of vegetables.

Aside from crop production, livestock play an important role in the farming system in the study villages. Dairy farming is the main enterprise in Bendosari. The sub-district of Pujon where Bendosari village is located, is one of the important milk producers in Malang. Dairy farming is also important to the farmers in Ngadas while beef production is the major livestock enterprise in Pancasari.

To supply fodder to the livestock, farmers plant grass in the terrace embankments. They also use small areas in their farmlands for fodder production.

In general, some criteria has to be considered when determining suitable farming or cropping system that could give good benefits. These include the following :

a) Suitable Climatic Condition : The type of crops to be planted should be adapted to rainfall distribution, air temperature or photoperiodicity.

b) Prevention of Soil Erosion : Crop canopy characteristics has significant effect in protecting soil surface against raindrop impact. A dense canopy is usually preferred over thin canopy. The crop factor value (C) in the Universal Soil Loss Equation (USLE) can be a useful tool to assess the effect of cropping.

c) Increasing Soil Fertility : Various crops provide different residual effects. Incorporating leguminous crops will increase soil nitrogen content (Mastur and Suhartatik, 1993 ; Sunarlim, *et al.*, 1994). Planting of cassava without adequate fertilizer supplement to the soil may deplete soil nutrient content (Pearson, *et al.*, 1995).

d) Appropriate Crop Combination : Similar plant groups or monoculture cropping may increase the population of certain pests. Therefore, incorporation of other crops can break pest cycles. In some crop combinations though, allelopathy may take place (Stoney, *et al.*, 1992).

Soil Conservation Strategies

The main soil conservation approaches in the research areas are agronomic and mechanical methods. Agronomic approach is mainly the establishment of agroforestry systems where the most widely practiced are multistory agroforestry system, trees on farmland agroforestry and Taungya agroforestry. Agroforestry is a land use system where annual crops are planted in special pattern with trees to achieve mutual benefit. For mechanical methods, contour ridge, bench terrace and intermittent terrace are usually adopted.

Multistorey Agroforestry System

This is a system where different crops with different heights (perennial and annual) are planted on the same land. In Bendosari, for instance, a forest tree (*Agathis loranthifolia*) occupies the top canopy, followed by a fruit tree, coffee, Calliandra and grass, respectively. Fig. 6 shows the multistory agroforestry system in Bendosari. There are two types in this system namely, home garden (Pekarangan) which is a system associated with houses and mixed garden (Kebun campuran).

The system provides a good canopy cover to the soil. Without plant canopy, raindrops will

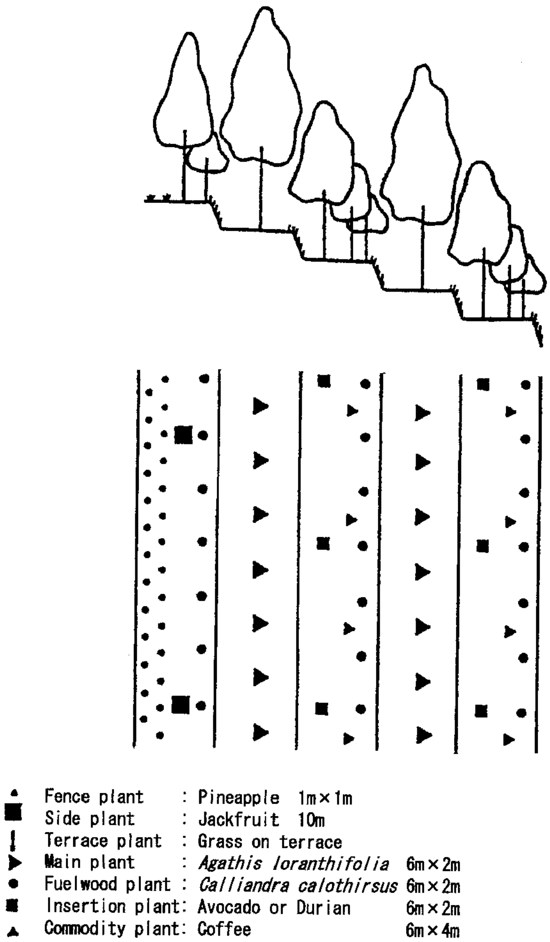

Fig. 6 Multistorey agroforestry in Bendosari (Basic data from Perum Perhutani, 1995).

easily detach soil particles (Berliner, *et al.*, 1995). *Agathis loranthifolia*, when young, is shade-tolerant (Stoney, *et al.*, 1992). Therefore, it can combine well with other trees. Coffee, which usually occupies a middle stratum in the canopy order is also shade-tolerant (Lasco and Furoc, 1996). The grass on the riser bank of the bench terrace can be pruned for fodder.

Trees on Farmland Agroforestry

This involves planting of trees on farmland either in spots or boundaries, arranged in rows or planted along contours. The trees are good to prevent erosion, supply food and firewood and for slope stabilization.

Coniferous trees in Ngadas are planted in rows along the slope particularly at the edge of the slope ditch. These trees are well adapted to extreme high elevation up to 2,000 meters. Also, the trees have deep roots that can penetrate even up to the depth of the parent material and these can very well protect the soil from landslide (Gray and Sortir, 1996).

Taungya Agroforestry

Taunya system is the planting of annual and perennial crops together but the proportion of annual crops is reduced with time while the perennial crops gradually develop their canopy. Once the canopy of the perennials closes in, planting of annuals is gradually stopped, although shade-tolerant crops maybe planted. Without the planting of annual crops, the Taungya system will mainly be a source of fodder and fuelwood. This is also a common system in Bendosari and after about four to five years as can be seen in Fig. 7, crop production shifted from annuals to perennials such that the perennial crops or the trees become dominant in the system.

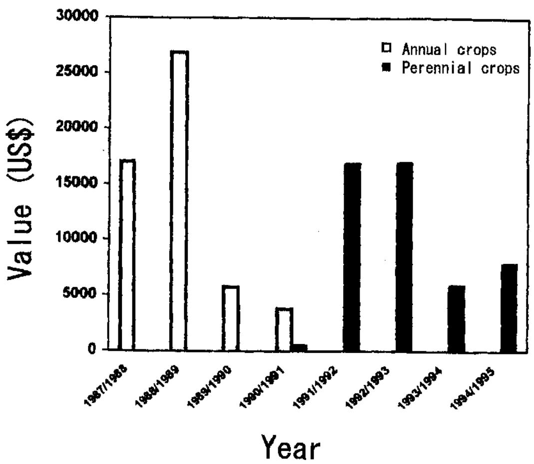

Fig. 7 Production of annual and perennial crops in Taungya agroforestry in Bendosari. (Basic data from Perum Perhutani, 1995) Note : Annual crops were maize, cabbage, shallot, carrot, chili, peanut and bean ; perennial were coffee, avocado and grass ; conversion rate for 1 US× was Rp. 2,000).

There are three important points to consider on the benefits of the Taungya system. First, in the initial year, the annual crops mainly protect the soil against raindrops. Secondly, the drying of the volcanic ash soil is prevented by the annual crop canopy, although water absorption by the crops also occur and in some instances may cause some soil drying. Third, the combination of annual and perennial crop increases cropping intensity which increases land productivity.

The Taungya agroforestry system in Bendosari is established under the Social Forestry Program of the Ministry of Forestry.

Bench Terracing

Soil erosion control on deep and stable soils such as in Bendosari and Pancasari can be effectively done by the construction of bench terraces. However, since the soil in Bendosari is shallower compared to that in Pancasari, the bench terraces are narrower. It is noted here that bench terrace is suitable in areas with gentle slopes. However, bench terraces are highly recommended in steep places. Based on these cases, soil characteristics and ground slope are important to consider in terrace construction.

Contour Ridge

Under conditions where bench terracing is not suitable, contour ridge is recommended to reduce runoff velocity and control soil erosion. This is simpler to construct and also suitable for steep and unstable soils such as in Ngadas. However, according to Rosland and Hosoyamada (1992), this may not be suitable if the soil is highly erodible. On gentle slopes, Komamura and Nakamura (1996) reported that erosion from the vertical ridge and contour ridge are not significantly different. Fig. 8 illustrates the effect of runoff on vertical and horizontal (contour) ridge. Destruction of ridge may take place during excess runoff concentration on low strength soil such as in Ngadas. To control high runoff velocity, addi-

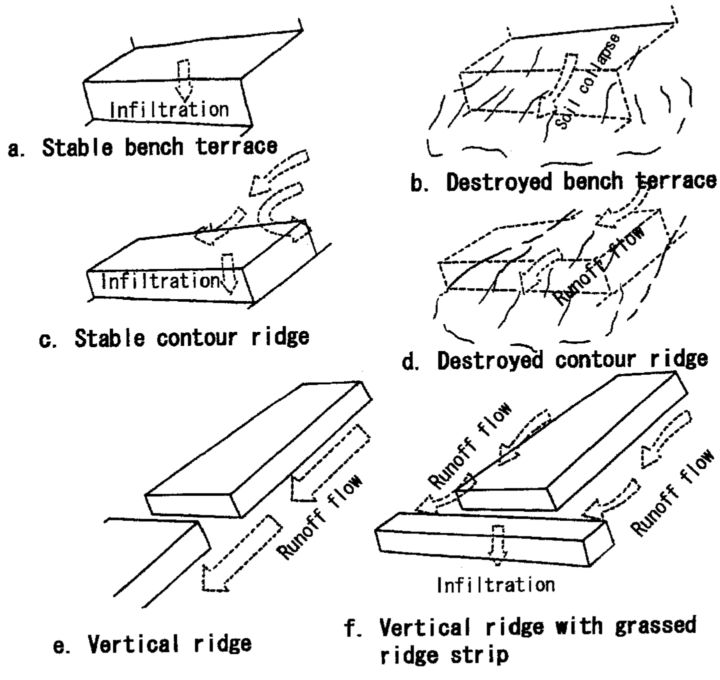

Fig. 8 Mechanical conservation strategy in relation to soil characteristics. (a and b are bench terrace on stable soil ; b and d are bench terrace on unstable soil ; e is vertical ridge only).

tional measures like grass strip planting may be established to slow down water velocity.

Conclusions

Volcanic soils in Loji and Ngadas have low base saturation, pH, Ca, Mg, K and bulk density than Bendosari and Pancasari soils. Generally, fertility of the volcanic soils is moderate to high, and the soil in Bendosari was the most fertile. Soils in Loji and Bendosari, having higher clay content, had higher CEC, plasticity and water content at 1.5 MPa (pF 4.2), but low in dispersion ratio (DR). Therefore, erodibility tends to be higher on soils with low clay content, CEC, liquid limit and plasticity.

Vegetable production on upland fields in combination with livestock farming are the main farming system in the highland volcanic areas of Java and Bali islands. Multiple cropping is preferred than monoculture. There are two main approaches to soil erosion control namely agronomic and mechanical measures. Agroforestry is practiced for soil conservation as well as improving soil environment. Boundary planting is a typical agroforestry system for Ngadas. Agroforestry types in Bendosari are a combination of Taungya and multistory with *Agathis loranthifolia* as the main tree species.

Ridges are made on the highland volcanic areas to improve soil environment and prevent soil erosion. Vertical ridge is constructed for better aeration and drainage. It is suitable on soils with extremely low clay content. The ridge should be complemented by grass strip in controlling runoff and erosion. On more stable soils such as in Loji, Bendosari and Pancasari, soil erosion can be controlled by constructing bench terraces and contour ridges. The effective cropping area when adopting bench terracing may be affected by soil depth or slope steepness. When the soil is shallow and the slope is steep, bench terraces are narrower and more frequent thus, could cause a reduction in the effective cropping area. On steeper slope, though, intermittent terrace, platform and ditching may be incorporated with bench terraces to compensate for the limited width of the cropping area.

Acknowledgment

The authors wish to express their gratitude to Dr. Tineke Mandang, Ir. I W. Sandi Adnyana, MS, and Ir. Rully Hadianto for their cooperation during the survey. Dr. Simplicio Mendoza Medina, UPLB, Philippines, cooperated with English proofreading. Also, deep appreciation to PERHUTANI and Puslittanak (CSAR) for providing facilities in the conduct of the research.

References

Berliner, P.R., I. Rapp, F.M. Ndaraya, and E. Imbogo (1995) : The effect of intercropping and planting density on the biomass production of a runoff agroforestry system. In : Soil Moisture Control in Arid to Semi-Arid Region for Agro-Forestry. M. Anase and R. Yasutomi, (eds). Tokyo University of Agriculture Press, Japan. pp. 269-274.

Carson, B. (1989) : Soil conservation strategies for upland areas of Indonesia. East-West Environment and Policy Institute. Occasion paper 9 : 120 p.

Ghidey, F. and E.E. Alberts (1995) : Plant root effects on soil erodibility, splash detachment, soil strength, and aggregate stability. Trans. ASAE. 40, 129-135.

Gray, D.H. and R.B. Sortir (1996) : Biotechnical and and soil bioengineering slope stabilization : A practical guide for erosion control. John Wiley and sons, New York.

Juliardi, I., H.M. Toha and A.M. Fagi (1989) : Change of soil nutrient composition caused credit terrace in Citanduy watershed. In : Proceeding of workshop on research and development of conservation farming system in Citanduy watershed, Liggarjati 9-1 August 1988 The Upland Agriculture and Conservation Project. AARD, Salatiga. pp. 263-274. (in Indonesian with English abstract).

Kalo, H.T. (1989) : Evaluation of model farming system in upper Citanduy watershed area. In : Proceeding of workshop on research and development of conservation farmng system in Citanduy watershed, Luggarjati 9-1 August 1988. The Upland Agriculture and Conserva-

tion Project. AARD, Salatiga. pp. 45-63. (in Indonesian with English abstract).
Komamura, M. and T. Nakamura (1996) : Soil erosion and soil conservation in the upland field reclaimed from slopes at the foot of a volcano : A research on the actual conditions in Tsumagoi District, Gunma Prefecture, Japan. In : Rehabilitation and Development of Upland and Highland Ecosystem. M. Anase, T. Mandang and R.Lasco (eds). Tokyo University of Agriculture Press, Japan. pp. 265-280.
Kurnia, U. (1996) : Land rehabilitation and soil conservation practices on upland agriculture : A case study at Upper Citanduy watershed, Indonesia. In : Rehabilitation and Development of Upland and Highland Ecosystem. M. Anase, T. Mandang and R. Lasco (eds). Tokyo University of Agriculture Press, Japan. pp. 88-102.
Lasco, R.D. and R.P. Furoc (1996) : Sustainable upland agriculture in the Philippines : A Multilateral Project. Proceeding of International Seminar on Development of Agribusiness and Its Impact on Agricultural Production in Southeast Asia (DABIA). Sponsored by JSPS, TUA, SAEDA and ISSAAS. pp. 73-81.
Mastur and E. Suhartatik (1993) : Effect of N fertilizer, straw incorporation and green manure on physical and chemical characteristics of Grey Hidromorphic soil. Bull. Food Crops Res. 4, 73-81. (in Indonesian with English abstract).
Mastur, Darmijati S., and N. Sunarlim (1995) : P and K uptake competition on soybean-maize intercropping. Unpublished BORIF Report (in Indonesian with English summary).
Mitchell, James K. (1993) : Fundamentals of Soil Behavior, 2nd John Wiley and Sons, Inc., NY. pp. 172-189.
Morgan R.P.C. (1996) : Soil Erosion and Conservation. Longman Group Ltd. London. pp. 9-11.
Narioka, H. and M. Komamura (1995) : Structure properties and macropore drainage in andosol. In : Soil Moisture Control in Arid to Semi Arid Region for Agro-Forestry. M. Anase and R. Yasutomi (eds). Tokyo University of Agriculture Press, Japan. pp. 59-64.
Oldeman, L.R. (1975) : An agro-climatic map of Java. Contr., Centr. Res. Inst. Agric. Bogor. 17. 22 p.
Oldeman, L.R., I. Las and Muladi (1980) : The agroclimatic maps of Kalimantan, Maluku, Irian Jaya and Bali, West and East Nusatenggara. Contr. Centr. Res. Inst. Agric. Bogor. 60, 32 p.
Pearson, C.J., D.W. Norman and J. Dixon (1995) : Sustainable dryland cropping in relation to soil productivity. FAO Soils Bulletin 72. pp. 38-89.
Perum PERHUTANI (1995) : Social Forestry, Plot 5 C BKPH Pujon, KPH Malang. Perum PERHUTANI UNIT II Jatim. Malang.
Ranert, B. (1996) : Intercropping as a strategy for reducing damage to carrots caused the carrot fly Psita rosae (F). Bio. Agric. Hort. 13, pp. 359-369.
Rosland Z.A. and K. Hosoyamada (1992) : Effects of soil grading and ridging with regards to soil erosion. Trans. JSIDRE. 157, pp. 17-26.
Sembiring, H., M. Thamrin, A. Syam, A. Abdurrachman and S. Sukmana (1990) : The role of conservation farming in controlling erosion in Srimulyo, Malang, Brantas watershed. In : Proceeding of Seminar on Upland Agriculture and Soil Conservation. A. Adimihardja *et al.*, (eds). Tugu-Bogor, 11-13 January 1990. The Upland Agriculture and Conservation Project. AARD, Salatiga. pp. 27-40.
Soepraptohardjo, M. (1976) : Soils of Indonesia. Soil Research Institute. Bogor. 20 p. (in Indonesian with English abstract).
Stoney, C., M.Y. Mile and T. Sukandi (1992) : The role of multipurpose trees species in agroforestry system. Proceeding Seminar Agroforestry Regional Sulawesi I, 14 November 1991. Forestry Research Institute. Ujung Pandang. 33 p.
Subagjo, H. (1993) : Characterization of Brown Forest Soils, East Java, Soil Fert. Res. J. 11, pp. 53-69. (in Indonesian with English abstract).
Suganda, H., S. Abu Jamin, A. Dariah, and S. Sukmana (1994) : Evaluation of soil conservation techniques in vegetable farming system on Andisol in Batulawang, Pacet. Soil Fert. Res. J. 12, pp. 47-57 (in Indonesian with English abstract).
Sunarlim, N., S. Hutami and Y. Supriati (1994) : The effect of organic matter and N residue of some legumes on corn. Agric. Res. 14, pp. 66-71. (in Indonesia with English abstract).
Tada, A. (1965) : On the compaction curve of the Kanto Loam and its permeability 1. Trans. AESJ 13, pp. 36-40. (in Japanese with English abstract).
Tan, K.H. (1965) : The Andosol in Indonesia. Soil Sci. 99, pp. 375-378.
Yamazaki, F. and H. Takenaka (1965) : On the influence of air-drying on Atterberg's limit. Trans. AESJ 14, pp. 46-48 (in Japanese with English abstract).

インドネシアの火山灰傾斜地における土壌特性，農法および保全対策

マストゥル*・成岡　市**・穴瀬　眞***・安富六郎***
* インドネシア国タバコ研究所
** 岡山大学環境理工学部
*** 東京農業大学

要　　旨

火山灰土壌は，自然条件下もしくは人間活動によって容易に劣化する。また，土壌保全の方策は地域性が高く，各々の現地ですでに確立していることが多い。そこで本論では，インドネシア国ジャワ島およびバリ島の火山灰傾斜地における土壌特性，農法および保全方策の実態について検討した。

調査地域の火山灰土壌は，高い肥沃性を持つ反面，低い有機物含有量であることが明らかにされた。この場合，粘土含有量，陽イオン交換能（CEC），液性限界（LL）および塑性限界（PL）などが低い火山灰土壌では高い受食性を持つ特徴があった。

調査地域では野菜生産や小規模の畜産が共通に見られた。このような地域では主として間作および混作が行われ，土壌侵食を制御するための農法的および工法的手段が適切に組み合わされ実践されていた。現地には多層的アグロフォレストリー方式があった。そこでは，たとえば急傾斜地のベンチテラス上に縦畝が作られ，さらに等高線に沿って草帯が取り入れられるというような工法的・農法的制御方法が組み合わされていた。この例のように効果的かつ適切な土壌侵食制御が実践され，その結果土地生産性が高められるような保全方策が確立されていることが明らかとなった。

キーワード：土壌保全，受食性，農法，アグロフォレストリー，インドネシア

受稿年月日：1998 年 10 月 2 日
受理年月日：2000 年 7 月 1 日