LAND MANAGEMENT FOR SUSTAINABLE AGRICULTURE IN NORTH COASTAL PLAIN OF BALI [1]

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ABSTRAK

Sistem pertanaman intensif bisa mengarah pada *trade-off* antara manfaat ekonomi dalam jangka pendek dan kerusakan lingkungan seperti degradasi kesuburan tanah dalam jangka panjang. Oleh karena itu, pengelolaan lahan sebagai salah satu komponen pengelolaan teknologi pertanian diperlukan dalam sistem pertanian berkelanjutan.

Penelitian di TMB-59, Desa Tembok, daerah pesisir Bali bagian utara dilakukan secara purposif dengan pertimbangan bahwa petani di TMB-59 menyelenggarakan sistem usahatani campuran berbasiskan irigasi air tanah. Analisis difokuskan pada kesesuaian lahan, kesuburan tanah, pendugaan erosi dan pengelolaan nutrisi tanah.

Temuan penelitian ini adalah: (1) status kesuburan lahan usahatani di TMB-59 tergolong rendah sehingga hanya memiliki kesesuaian marginal untuk tanaman jagung, ubi kayu, kacang tanah, ubi jalar, melon, cabai, pisang, jambu mete, kelapa, dan lontar, serta cukup sesuai untuk tanaman mangga, pepaya, dan rumput sebagai pakan ternak; (2) Tingkat erosi tanah di TMB-59 tergolong sangat ringan dan jauh lebih kecil daripada tingkat erosi yang diperbolehkan sehingga tidak diperlukan tindakan konservasi di daerah tersebut; dan (3) kebutuhan pupuk kandang untuk berbagai tanaman di TMB-59 sekitar 342 ton per tahun tetapi baru tersedia sekitar 202,74 ton dari populasi sapi, babi, kambing dan ayam di daerah tersebut. Berdasarkan temuan tersebut, direkomendasikan bahwa (1) perlu penambahan bahan organik yang cukup untuk meningkatkan status kesuburan tanah dan produktivitas lahan, (2) walaupun tidak perlu tindakan konservasi, pemeliharaan tanah diperlukan untuk mengantisipasi erosi tanah yang lebih tinggi, dan (3) petani di TMB-59 disarankan tetap melaksanakan usahatani campuran dengan meningkatkan jumlah ternak untuk memenuhi kebutuhan pupuk kandang yang lebih tinggi dari berbagai jenis tanaman yang diusahakan.

Kata Kunci: Kesesuaian Lahan, Kesuburan Tanah, Erosi, dan Pertanian Berkelanjutan

ABSTRACT

Intensive cropping system with their technology such as the one in the project area will lead to trade-off between economic benefits in the short run and environmental damages, especially soil fertility degradation in the long run. As environmental degradation increases, agriculture will eventually become unsustainable; therefore, land management as a component of agricultural technology management is required in sustainable agricultural system.

A research in TMB-59, Tembok village, north coastal plain of Bali, is conducted purposively with a reason that farmers in which have done groundwater irrigation-based mixed farming system. The analysis is focused on the land suitability, soil fertility, soil loss prediction, soil nutrient management.

The research finding is: (1) the farmland in TMB-59 is actually classifiable as poor fertile soil, its only marginal suitable for for maize, cassava, groundnuts, sweet potato, melon, chili, banana, cashew, cacao, coconut, and Palmyra palm and suitable enough for mango, papaya, and fodder grasses; (2) the soil erosion level in TMB-59 is categorized as very light and less than soil loss tolerance in the area; (3) crops animal-manure requirement is approximately 342 tons per year but the available stock is only 202.74 tons generated by cattle, pig, goat and chicken. Therefore, it can be recommended that: (1) it needs organic matter application in middle to high levels to improve the soil fertility status and land productivity; (2) it needs land maintaining such as addition of organic matter to protect soil against erosion to some extent; and (3) the farmers in TMB-59 should continuously carry out mixed-farming practices and increase livestock population based on the crop manure requirement and greenery and crops by-product availability.

Key words: Land Suitability, Soil Fertility, Erosion, and Sustainable Agriculture.

INTRODUCTION

Vision of Indonesian agricultural development in 2020 is to form modern and efficient agriculture. Some characteristics of which are optimal and sustainable use of agricultural resources and sustainable development of comprehensive diverse agriculture (Kasryno *et al*, 1997).

Sustainable agriculture conserves land, water, plant and animal genetic resources, which are environmentally non-degrading, technically appropriate, economically viable and socially acceptable (FAO Council *in* Kwaschik *et al*, 1996). Sustainability involves constrained optimization to maximize benefit subject to natural resource-based maintenance (Dixon & de Los Reyes *in* Widodo, 1993:15). In describing sustainable agriculture, Widodo (1998) stated that agricultural sustainability requires three in farming systems, i.e. animal and crop productivities, socioeconomic viability, and the long-term natural resouce-based maintenace.

Feature of sustainable agricultural system embraces some components of agricultural technology management, i.e. soil nutrient management, pest management, cultivation, livestock production or animal integration (Benbrook, 1990:7-12; Edwards, 1990:253-6) and watershed (land and water) management (Saragih, 1989:40; Logan, 1990:585-9).

Coastal plain such as the Sustainable Development of Irrigated Agriculture in Buleleng and Karangasem (SDIABKA) project area is generally region with poor fertile soil, high water losses through percolation and evapotranspiration, and groundwater as being the primary water source. The project, which was carried out in 5,300 hectares, covered 39 schemes of irrigated agriculture in 12 villages in Buleleng and Karangasem regencies (Project Management Unit, 1995; 2003). The project introduced profitable mixed-farming practices and procedures in order for the farmers to be able to realize the optimal and sustainable use of agricultural resources in approximately 703 hectares effective area in SDIABKA project (Leckie and Budi Susrusa, 2003; 2005).

Intensive cropping system with their technology such as the one in the project area will lead to trade-off between economic benefits in the short run and environmental damages, especially soil fertility degradation in the long run (Herianto, 2002). The expansion of cultivated land produced severe erosion problems (Barbier *in* Small, 2003:3), whereas the unregulated farming practices have caused critical soil erosion (Saragih, 1989:38). In general, deep, medium textured, moderately permeable soils that have sub-soil characteristics favorable for plant growth were assigned tolerable soil erosion of 1.1 kg/m^2/year (Mitchell and Bubenzer, 1980:45). The excessive erosion has reduced soil quality, then caused rapid reduction in land productivity or even made the land unsuitable for agriculture (Saragih, 1989:38; Lal *et al*, 1990:210). These phenomena have adversely jeopardized agricultural production in the long run. This means that as environmental degradation increases, agriculture will eventually become unsustainable (Sugino and Hutagaol, 2004), therefore, farming system requires best management practices for on-farm production.

Based on the background above, this paper aims to assess land suitability, soil fertility, soil erosion and conservation, and soil nutrient management for irrigated mixed farming system in TMB-59, the north coastal plain of Bali.

METHODOLOGY

Research Location

The research, which was carried out in TMB-59 (one of the 39 schemes under the SDIABKA project), lies in Tembok Village, Tejakula District, Buleleng Regency. It was chosen purposively for the following reasons (1) new scheme, (2) supply quantity is 23.34 l/s, (3) effective area 23.02 ha, and (4) mixed farming system operated by 41 farmers.

Material and Equipment

Soil observation in TMB-59 needed a lot of material and equipment. The equipment is (1) augerlcore (Belgi type bore), (2) hoe and shovel, (3) gauge, (4) stiletto knife, (5) munsell soil color chart book, (6) pH electrode, (7) loupe, (8) handboard, (9) abney level, (10) binoculars, (11) compass, (12) altimeter, and (13) topographic map of TMB-59. Then, the material is (1) clean water in bottle, (2) plastic bag for soil samples, (3) label paper for coding on the soil samples, (4) questionnaire in database format to record the soil characteristics and morphology systematically, from soil profile and around the land, and (5) key book of soil taxonomy.

Research Implementation

Soil observation was conducted by (1) drilling, and (2) minipit. Drilling was needed to obtain the data of part of soil morphology. Soil characteristics, which can be perceived by drilling, are texture, color, consistency, gravel, and rustiness. Minipit that has a measurement of 0.5 m x 0.5 m x 0.5 m, is used to get the data of soil morphology and know the spreading of various soil characteristics in TMB-59. To make description of soil depth more than 0.5 m, drilling could be continued until the desired depth is obtained. Minipit is needed because the land such as TMB-59, which is sandy land, would not be possible to be dug more deeply.

Soil classification and land evaluation based on soil samples were taken representatively at three-observation point in TMB-59. Soil samples were collected from two layers of each observation point at the amount of 0.5 – 1.0 kg. Besides that, it was taken as soil samples for special purposes i.e. (1) undisturbed soil samples by ring from some layers (0 – 0.27 m, 0.27 - 0.44 m, and 0.44 – 1.05 m) to obtain bulk density, permeability, electric conductivity; (2) composite soil samples for fertility soil analysis which were collected from some observation point by drilling were then mixed to become homogeneous soil samples.

Method of Analysis

Data analyses consisted of: (1) land suitability and soil fertility assessment, (2) erosion prediction, (3) conservation planning, and (4) soil nutrient management.

Land suitability and soil fertility assessment were based on observation and analysis result from Soil Laboratory of Udayana University, Denpasar. The analysis result was then fitted in well with the specific parameters for crop requirements by Sys *et al*, 1993 and the criteria of land suitability for agricultural commodities by Djaenudin *et al*, 2000.

The most widely used method of soil loss prediction by conservationists in the United States is the Universal Soil Loss Equation (USLE) (Mitchell and Bubenzer, 1980: 21): A = (0.224)RKLSCP where A = the soil loss (kg/m^2/year); R = the rainfall erosivity factor; K = the soil erodibility factor; L = the slope length factor (m); S = the slope gradient factor (%); C = the cropping management factor; and P = the erosion control practice factor. The rainfall erosivity factor (R) is calculated by Bollinne formulae, R = 159.56 + 0.27 P where P = rainfall in mm/year (Darmawan, 2001:111). The soil erodibility factor (K) is calculated by Wischmeier and Smith equation (Nuarsa, 1991: 27), $100\ K = 1.292\ [2.1M^{1.14}(10^{-4})(12 - a) + 3.25(b-2) + 2.51]$ where M is particle size of erodible soil = (% silt + % powder sand) (100- % clay), a = organic matter content of soil (%), b = the texture class, and c = permeability class (cm/hour). The slope length and slope gradient are represented as L and S, respectively, however, they are often evaluated as a single topographic factor $(LS) = \sqrt{}\ L(0.00138S^2 + 0.00965S + 0.0138)$. Estimation of the cropping management factor (C) and the erosion control practice factor (P) were based on field observation and the CP value table was assesed in Pusat Penelitian Tanah Bogor *in* Nuarsa (1991:40).

Conservation planning needs the recommended value for maximum soil loss tolerance (Edp) in mm/year or ton/ha/year. In accordance with Hammer (*in* Nuarsa, 1991: 29), soil loss tolerance is calculated by equation:

Edp = (soil depth x depth factor) ÷ useful life of soil.

The result of erosion prediction was compared to the recommended value for maximum soil loss tolerance. If the erosion level is more than Edp, the conservation planning and implementation will be needed by determining C and/or P value to generate the expected erosion less or equal to the Edp. However, if the erosion level is less than or equal to Edp, the action will be soil maintaining so that this would not make new damage possible.

Nutrient cycling is the key to nutrient management in sustainable agricultural system. An agricultural system on farm level, one loss from the cycle is the harvested crop. This loss is minimized by means of mixed-farming practices, where a large fraction of nutrients consumed by animal do not leave the cycle because they are returned to the soil in manure (King, 1990:89:105). On mixed-farming system nutrient loss from the system are replenished with commercial fertilizers and purchased feed (King, 1990: 89). If a goal of sustainable agriculture is to reduce off-farm inputs (commercial fertilizer), N, P, K inputs must be obviously increased from manure, biological N fixation and other sources, such as wastes (Miller and Larson, 1990:560). Animal manuring is an important process for the cycling of nutrients to maintain or improve soil fertility, especially in those intensively cropped location where chemical fertilizer are limited (Parker, 1990:242-3). Animal manure contains 0.51, 0.73, and

0.71 percent of N, P, and K, respectively (Follett *et al* in Miller and Larson, 1990: 557). Application of organic matter to soil surface especially in sloping farmland will protect soil against erosion to some extent (Foth and Turk *in* Sukartaatmadja *et al*, 2003:85).

The balance of nutrients in soil ecosystem can be predicted by the following equation (Follett *et al* in Miller and Larson, 1990:555):

$$RN_{tn} = \sum(AP_{t}+AR_{\Delta t}-RM_{\Delta t} -L_{\Delta t})$$

where RN is the soil inorganic and organic nutrients remaining at time *tn*, AP is the soil inorganic and organic nutrients present at time *t*, AR is the soil inorganic and organic nutrients added or returned to the soil during the time interval Δt, RM is the plant nutrients with the harvested product during the time interval Δt, L is the soil inorganic and organic nutrients loss during the time interval Δt, *t* is the beginning time, *tn* is the ending time, and Δt is the time interval between *t* and *tn*.

RESULT AND DISCUSSION

Genesis and Soil Classification

All factors of soil maker, main materials, relief, organism, and time have great influence in soil formation and development processes. But, the main materials and organism have dominant share compared to the other factors.

The main material has considerable influence to the soil characteristics. TMB-59 has soil texture looking like sediment of volcanic sand, sandy loam. The reason for the phenomenon is a slowly decaying process of soil due to little annual rainfall (1477 mm/year) and distribution of monthly rainfall, which is not steady in a year (minimum 0 mm/month and maximum 397 mm/month) (BMG Wilayah III Denpasar, 2006). Besides that, the existence of organism, i.e. (1) a few of vegetation have a little organic matter share to the soil, and (2) human share is not optimal, this is shown by unintensive land management and a few livestock/animal population sharing organic matter to the soil.

By the climate influence being rather dry (climate type E because the amount of dry month mean is equal to the amount of wet month mean in a year) (Schmidt and Ferguson *in* Balai Penelitian Tanah, 2004:51-2), and land preparation being unintensively done, then the process of soil formation and development are very slow, so that the soil in TMB-59 is categorized as low developing soil (Inceptisol order). In suborder category, Inceptisol soil is categorized as Usteps because it is assumed to have the Ustik regime according to Badan Penelitian Tanah (2004: 108). Ustik regime is a regime with limited soil water content but available at its condition suitable for plant growing. Furthermore, in great group, soil in TMB-59 is classifiable into Plagepts based on soil classification and characteristics (Djaenudin *et al*, 2000: 40), because it actually has soil depth more than 50 cm, texture class of rather hard (ak), C-organic more than or equal to 0.6 percent, pH more than 0.5, and saturation base more than 50 percent. Data of soil profile description is presented in appendix 1.

Land Suitability

According to Djaenudin *et al* (2000: 3), land evaluation is estimation process of class of land suitability and potential land for special land use (agriculture or non agriculture). Potential land for agricultural development is basically determined by appropriateness between the physical characteristic (climate, soil, terrain that consists of topography, rock on the surface of and in soil profile and also rock outcrop, hydrology) and crops requirement. Suitability between physical characteristic of the land and the commodities that are evaluated give information that commodities are potentially developed in the land. These mean that special land use with some consideration including needed inputs can generate expected outputs.

Land suitability is appropriateness of a land for special use such as irrigated agriculture, fishpond, seasonal or perennial crops (Djaenudin *et al*, 2000: 10). The result of land suitability assessment for food crops, horticulture, and agro forestry is presented in table 1.

Table 1. The result of land suitability assessment for some commodities

		Location (in TMB-59)		
Type of Commodity		Upland	Middle	Lowland
1. Maize	A	S3 rc	S3 rc	S3 rc
	P	S3 rc	S3 rc	S3 rc
2. Cassava	A	S3 rc	S3 rc	S3 rc
	P	S3 rc	S3 rc	S3 rc
3. Groundnuts	A	S3 rc	S3 rc	S3 rc
	P	S3 rc	S3 rc	S3 rc
4. Sweet potato	A	S3 rc	S3 rc	S3 rc
	P	S3 rc	S3 rc	S3 rc
5. Melon	A	S3 rc	S3 rc	S3 rc
	P	S3 rc	S3 rc	S3 rc
6. Chili	A	S3 rc	S3 rc	S3 rc
	P	S3 rc	S3 rc	S3 rc
7. Mango	A	S2 rc nr eh	S2 rc nr	S2 rc nr
	P	S2 rc	S2 rc	S2 rc
8. Papaya	A	S2 rc nr eh	S2 rc nr	S2 rc nr
	P	S2 rc	S2 rc	S2 rc
9. Banana	A	S3 rc	S3 rc	S3 rc

	P	S3 rc	S3 rc	S3 rc
10. Cashew	A	S3 rc	S3 rc	S3 rc
	P	S3 rc	S3 rc	S3 rc
11. Coconut	A	S3 rc	S3 rc	S3 rc
	P	S3 rc	S3 rc	S3 rc
12. Palmyra palm	A	S3 rc	S3 rc	S3 rc
	P	S3 rc	S3 rc	S3 rc
13. Fodder grass	A	S2 wa nr eh	S2 wa nr	S2 wa nr
	P	S2 wa	S2 wa	S2 wa

Based on land suitability assessment for maize, cassava, groundnuts, sweet potato, melon, chili, banana, cashew, cacao, coconut, and palmyra palm, the farmland in TMB-59 is actually classifiable into S3 (marginal suitable) with root condition (rc) as a major constraint. For mango and papaya, the farmland in TMB-59 is categorizable into S2 (suitable enough) with root condition (rc), nutrient retention (nr), and erosion hazard (eh) as major constraints, while for fodder grass, the farmland is categorized as S2 (suitable enough) with water available (wa), nutrient retention (nr) and erosion hazard (eh) as major constraints.

Root condition component that affects land suitability is soil texture (sandy loam). The effective nutrient retention is low level of cation exchangeable capacity (CEC) (between 5 and 16 me/100 g of soil) while the influencing erosion hazard factor is slope gradient rather than the slope length (Baver; Schwab *et al* in Nuarsa, 1991: 36). Utomo (*in* Nuarsa, 1991: 38) claims that the dominant influence of slope gradient to soil erosion is possible due to the fact that slope gradient affects the speed and volume of surface movement. The bigger percentage of slope gradient the fewer the available time for infiltration. Then, the faster the runoff the bigger the stream volume and erosion are. The slope length only influences volume of runoff so that it also influences the possibility of erosion.

Based on the soil evaluation, some type of commodities can be developed in farmland of TMB-59 with major constraints consideration. The soil texture cannot improve hence the land suitability class is still potentially categorized into S3 for maize, cassava, groundnuts, sweet potato, melon, chili, banana, cashew, coconut, and palmyra palm, and S2 for mango, papaya, and fodder grass. Even though the soil texture cannot improve in relatively short time, some soil characteristics that are interconnected with soil texture can be improved such as soil water content and its ability to hold nutrient. To increase land productivity can be done by addition of organic matter that will improve the soil ability to hold water and nutrients. The addition of organic matter can also increase CEC of soil so that the effort will also anticipate the nutrient retention factor. Intensive cropping system such as utilization of seed with best quality, land preparation, cropping pattern, irrigation, fertilization, and pest management must be done to increase land productivity also to maintain of land fertility. Furthermore, erosion hazard especially slope gradient can be anticipated by terraces and increasing the closeness of plants.

Land Fertility

The result of land fertility assessment, which will be presented in Table 2, shows that farmland in TMB-59 is actually categorizable as poor fertile soil. Some components that generates it is the low level of CEC and organic matter content. Improving the fertility status can be done by addition of organic fertilizer up to the middle or high level. Application of organic matter will better utilize animal manure or other source such as compost.

Table 2. The result analysis of soil fertility status

Soil Sample	CEC	Saturation-based (SB)	P_2O_5	K_2O	C-organic	Soil Fertility Status
1	11.23 (R)	177.78 (T)	43.87 (T)	634.42 (T)	1.22 (R)	R
2	10.58 (R)	188.23 (T)	21.73 (S)	633.25 (T)	1.62 (R)	R
3	7.78 (R)	178.95 (T)	233.74 (T)	367.51 (T)	1.60 (R)	R
4	7.21 (R)	160.01 (T)	8.44 (R)	197.55 (T)	1.20 (R)	R
5	8.99 (R)	172.72 (T)	131.22 (T)	195.81 (T)	1.99 (R)	R
6	8.29 (R)	189.99 (T)	27.31 (S)	458.89 (T)	0.81 (R)	R

Notes: T=high, S=middle, R = poor

Land Conservation

Erosion Prediction

Solution of the USLE (Mitchell and Bubenzer, 1980: 21) provided soil loss in the amount of 3.57, 1.53, and 0.88 tons/ha/year in the up-land, middle, and lowland of TMB-59, respectively (table 3).

Table 3. Erosion prediction and erosion level

Location in TMB-59	Erosivity (R) [a]	Erodibility (K) [b]	LS Factor [c]	CP Factor	Soil Loss (ton/ha/year)	Erosion Level [d]
Up-land	558.35	0.2209	1.6147 L=7; S=13	0.08 [e]	3.57	Very light
Middle	558.35	0.1571	0.9744 L=8; S=6	0.08	1.53	Very light
Low-land	558.35	0.1661	1.0608 L=12; S=4	0.04 [f]	0.88	Very light

Notes: a. The rainfall erosivity factor based on Bollinne formulae, R = 159.56 + 0.27P (Darmawan, 2001:111) where P=rainfall 1477 mm/year (BMG Wilayah III Denpasar, 2006);

b. Soil erodibility factor based on Wischmeier & Smith equation (Nuarsa, 1991: 27) (t**able 4**)
c. LS factor based on Wischmeier and Smith equation (Nuarsa, 1991: 28); L < 50 m is very short (FAO *in* Balai Penelitian Tanah Deptan, 2004:29); 0% <S< 8% is flat, 8% <S< 15% is sloping
d. Erosion level classification according to Greenland and Lal (*in* Nuarsa, 1991: 62)
e. Multiple cropping, middle vegetation and traditional terraces (Nuarsa, 1991: 40)
f. Multiple cropping, high vegetation, and traditional terraces (Nuarsa, 1991: 40)

Estimation of the cropping management factor (C) and the erosion control practice factor (P) based on field observation, and then it was compared the CP value table by Pusat Penelitian Tanah Bogor (*in* Nuarsa, 1991:40).

Table 4. Soil erodibility factor, K

Location in TMB-59	Particle size of soil (M)	Organic matter content (a)	Soil structure class (b)	Perme-ability class (c)	100 K	K	Erodibility Class *)
Up-land	2684.99	3.43	2 (sg)	4 (rt)	22.0863	0.2209	Middle
Middle	2520.65	2.75	2 (sg)	2 (rq)	15.7085	0.1571	Low
Low-land	2824.02	2.10	2 (sg)	1 (q)	16.6131	0.1661	Low

Notes: *) Soil erodibility class by Dangler and El-Swaify (*in* Nuarsa, 1991: 61);
sg = smooth granular, rt = rather tardy, rq = rather quickly, and q = quickly
(Utomo *in* Nuarsa, 1991: 60).

Soil Loss Tolerance (Edp)

Soil loss tolerance is the maximum rate of soil erosion that permits a high level of productivity to be sustained (Mitchell and Bubenzer, 1980: 45). In TMB-59, the soil loss is less than the soil loss tolerance (table 5). This means that no action for land conservation is made, but it needs land maintaining so that land productivity can be sustained.

Table 5. Soil loss tolerance in TMB-59

Location	Soil depth (mm)	Depth factor	Useful life of soil (year)	Edp (mm/year)	Bulk Density (gr/cm^3)	Edp (ton/ha/year)
Up-land	1080	1.00	300	3.60	1.104	39.74
Middle	800	1.00	300	2.67	1.098	29.32
Low-land	1100	1.00	300	3.67	1.187	43.56

Soil Nutrient Management

Nutrient cycling is theoretically based on the balance of nutrient in soil ecosystem, but in this research, soil nutrient management is only based on crop manure requirement in SDIABKA project area. The manure requirement for perenial, semi perenial and seasonal crops in TMB-59 is presented in table 6.

Table 6. Crop manure requirement for some commodities in TMB-59

	Crop Number	Manure Requirement (ton/year) *)
Mango	1082 trees	43.28
Coconut	739 trees	29.20
Cashew	336 trees	13.44
Banana	6,393 trees (41,850 m^2)	127.86
Papaya	562 trees (5,600 m^2)	33.72
Melon	2,180 m^2	6.54
Sweet potato	22,700 m^2	45.40
Chili	800 m^2	1.60
Fodder grasses	4,647 m^2	16.26
Maize	17,600 m^2	17.60
Maize + Groundnuts	3,000 m^2	3.00
Maize + Cassava	4,100 m^2	4.10
Total	230,200 m^2	342.00

*) Based on the result of trial plot in SDIABKA project area.

The manure requirement for some commodities in 23.02 ha effective area in TMB-59 is approximately 342 ton per year (table 6), but animal manure available produced annually is approximately 202.74 ton (table 7). It means that animal manure available is defisite 139.30 ton per year. The number can be obtained by addition of cattle number is approximately 76 units.

Table 7. Existing animal population and potential manure produced annually in TMB-59

	Livestock Number (unit)	Potential Manure Production (ton/year) *)
Cattle	94	171.55
Pig	120	25.23
Goat	17	3.09
Chicken	358	2.87
Total		202.74

*) Based on USDA data (*in* Logan, 1990: 589)

CONCLUTION AND RECOMMENDATION

Based on the analysis and discussion above, the research finding is:

(1) Farmland in TMB-59 is actually classifiable into poor fertile soil due to the low lwvwl of CEC and organic matter content so that it is potentially categorize as marginal suitable (S3) for maize, cassava, groundnuts, sweet potato, melon, chili, banana, cashew, coconut, and palmyra palm, and suitable enough (S2) for mango, papaya and fodder grasses.

(2) The soil erosion level in TMB-59 is categorized as very light with soil loss is approximately 3.57, 1.53, and 0.88 tons/ha/year in the up-land, middle and low-land of TMB-59 respectively. The soil loss is less than the soil loss tolerance in amount of 39.74, 29.32, and 43.56 tons/ha/year for the respective area.

(3) The crop fertilizer requirement from organic matter such as composted animal manure for cropping system in 23.02 ha effective area in TMB-59 is approximately 342 tons per year. But, availability of animal manure produced annually is only 202.74 tons, so that animal manure defisit is aproximately 139.3 tons per year.

Furthermore, it can be recommended that:

(1) To increase the soil fertility status and land productivity can be done by addition of organic matter up to middle or high level so that it will improve the soil ability to hold water and nutrients. The other components of best management practices in cropping system such as utilization and pest management must be done to rise land productivity.

(2) It is no action for land coservation due to the fact that soil erosion in TMB-59 is less than the soil loss tolerance, but it needs land maintaining such as addition of organic matter to protect soil against erosion to some extent, also land productivity can be sustained.

(3) To minimize organic matter loss, farmers in TMB-59 should continuously carry out mixed-farming practices and increase livestock population based on the crop manure requirement and availability of animal feed (dry-matter from agricultural by-product). The addition livestock number is better considered based on the optimal condition as the result ot linear programming analysis that is carry out, separately.

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APPENDICES

Appendix 1
Soil Description from minipit (0.5 m x 0.5 m x 0.5 m) and drilling (> 0.5 m) in TMB-59

Soil type : Regosol
Location : TMB-59, Tembok Village, Tejakula District, Buleleng Regency
Relief : Wavying
Slope : 6 %
Slope direction : South – North
Elevation : 35 m above sea level
Land use : Irrigated mixed-farming
Vegetation : Banana, mango, cashew, papaya, cassava, maize, fodder grass
Mains substance : Sediment of volcanic sand
Soil classification : Inceptisol (order), Plagepts (great group)
Date of observation : 22 May 2006
Researcher : Budiasa, I Wayan and Made Mega

Description :

No	Horizon	Soil Depth (cm)	Detail
I	Ap	0 – 27	Grey chocolate and very dark (10 YR 3/2); sandy loam; crumb structure, smooth, weak, rather coherent and rather plastic; a little smooth root; a little rock fragment; soil reaction is rather acid, mixed boundary and flatten
II	Bw	27 – 44	Grey chocolate and dark (10 YR 3/1); sandy loam; crumb structure, smooth, weak, rather coherent and rather plastic; a little smooth root; soil reaction is rather acid, mixed boundary and flatten
III	Bc	44 – 105	Dark chocolate and rather yellow (10 YR 3/4); loamy sand; crumb structure, smooth, weak, rather coherent and rather plastic, a little harsh root, enough rock, soil reaction is rather acid

Appendix 2
Soil characteristic in TMB-59

Characteristic	Location					
	Upland		Middle		Lowland	
	I	II	I	II	I	II
Temperature (^oC)	27.7	27.7	27.7	27.7	27.7	27.7
Water available						
Annual precipitation (mm)	1477		1477		1477	
Amount of dry month [a]	6		6		6	
Root media						
Drainage	Good	Good	Good	Good	Good	Good
Texture [b]	SL (ak)	SL (ak)	SL (ak)	SL (ak)	SL (ak)	SL (ak)
Sand (%)	63.04	53.86	74.89	55.17	71.08	67.55
Hard sand	55.826	45.988	68.632	48.395	64.885	57.229
Powder sand	7.213	7.871	6.257	6.774	6.195	10.213
Silt (%)	24.90	36.81	20.24	37.13	22.50	28.70
Clay (%)	12.06	9.33	4.87	7.70	6.43	3.76
Hard substance (%)	5	10	2	2	2	2
Soil depth (cm) [c]	108		80		110	
Nutrition retention (nr)						
Apparent CEC (me/100 g soil) [d]	11.23	10.58	7.78	7.21	8.99	8.29
Saturation Based (%) [e]	177.78	188.23	178.95	160.01	172.72	189.99
pH H_2O [f]	6.69	6.90	6.89	7.12	6.83	7.06
C-organic (%)	1.22	1.62	1.60	1.20	1.99	0.81
Salinity/EC (Mmhos/cm) [g]	0.06	0.12	0.13	0.08	0.08	0.12
Sodicity/alkalinity/ESP (%) [h]	0.0029	0.0052	0.0039	0.0051	0.0027	0.0025
Erosion hazar						
Slope gradient (%) [i]	13		6		4	
Erosion level (ton/ha/year) [j]	3.57		1.53		0.88	
Land preparation						
Rock on the surface (%)	1		2		2	
Pull back rock (%)	3		2		1	
Permeability (cm/hour) [k]	14.000		7.000		0.846	
Bulk Density (g/cm^3)	1.104		1.098		1.187	

Notes:

a. Climate type E (rather dry) based on Q ratio value (Schmidt and Ferguson *in* Balai Penelitian Tanah Deptan, 2004: 52)
b. SL (ak): sandy loam rather hard (Sand 43 – 85 %, Silt 0-50%, Clay 0-20%) (Balai Penelitian Tanah Deptan 2004:78)
c. Middle (50 -100 cm) and Deep (100 – 150 cm) (Balai Penelitian Tanah Deptan, 2004: 45-6)
d. Low: 5 – 16 me/100 g soil (?)
e. High: > 50 % (?)
f. Neutral: pH 6.6-7.3 (Balai Penelitian Tanah Deptan, 2004 : 102)
g. Non saline: 0-2 Mmhos/cm (Balai Penelitian Tanah Deptan, 2004:103)
h. Suitable for any crops if Exchangeable Sodium Percentage < 15 % (Djaenudin *et al*, 2000 : 18)
i. Rather wavying: 4-8 % (under boundary) and 8 – 16 % (upper boundary) (NSH *in* Balai Penelitian Tanah Deptan, 2004:29)
j. Very light: 0 – 14.4 ton/ha/year (Greenland and Lal *in* Nuarsa, 1991: 62)
k. Quickly: > 12.50 cm/hour, rather quickly: 6.25 – 12.50 cm/hour, and rather slowly: 0.50 – 2.00 cm/hour (Utomo *in* Nuarsa, 1991: 60)