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## Soil Fertility Evaluation and Land Management of Dryland Farming at Tegallalang Sub-District, Gianyar Regency, Bali, Indonesia

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# Soil Fertility Evaluation and Land Management of Dryland Farming at Tegallalang Sub-District, Gianyar Regency, Bali, Indonesia

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**Abstract.** The land use of Tegallalang Subdistrict is dominated by dryland farming. The practice of cultivation on agricultural dryland that ignores the carrying capacity of the environment can lead to land degradation that makes the land vulnerable to the deterioration of soil fertility. Soil fertility evaluation and land management of dryland farming in Tegallalang Sub-district, Gianyar Regency were aimed at (1) identifying the soil fertility and its respective limiting factors, (2) mapping the soil fertility using Geographic Information Systems (GIS) and (3) developing land management for dryland farming in Tegallalang Sub-district. This research implementing exploratory method which followed by laboratory analysis. Soil samples were taken on each homogeneous land units which developed by overlay of slope, soil type, and land use maps. The following soil fertility were measured, such as CEC, base saturation,  $P_2O_5$ , K- Total and C-Organic. The values of soil fertility were mapping using QGIS 2.18.7 and refer to land management evaluation. The results showed that the soil fertility in the research area considered high, and low level. The High soil fertility presents on land units at the flat to undulating slope with different land management systems (fertilizer, without fertilizer, soil tillage and without soil tillage). The low soil fertility includes land units that present on steep slope, and without land managements. The limiting factors of soil fertility were texture, C-Organic, CEC,  $P_2O_5$ , and K- total. It was recommended to applying organic fertilizer, Phonska, and dolomite on the farming area.

**Keywords:** Soil fertility, Land Units, Management Directives, Geography Information System

## 1. Introduction

Tegallalang Sub-District has most of its territory in the form of dry land. Commodities that often planted by farmers in dry land, among others, are oranges, coconut, banana, cocoa, coffee, ginger, and cassava. The main obstacles in the utilization of dry land for agriculture is low levels of soil fertility caused by chemical barriers that limit plant growth, such as, nutrient availability problems. Dry land has a low-level of soil fertility, and low levels of organic material. This condition is exacerbating by the limited use of organic fertilizers, especially during the annual food crop. In addition, naturally the levels of soil organic matter in tropical areas are fastly declining, reaching 30-60% within 10 years [1]. On the other hand, an intensive tillage is the cause of the decline in productivity of the dry land. The results



showed that tillage overload can damage the soil structure [2]. Then good land management efforts (based parameter of chemical soil fertility) are needed in accordance with the requirements for the types of plants that are cultivated. There are five soil parameters used in this study to assess the status of the soil fertility.

Evaluation of soil fertility was done with the analysis of the soil and the plant in total or partial, as fertility recommendations and increase the fertility of a land [3]. Assessment of the status of soil fertility based on the content of Nitrogen, phosphorus and Potassium. This macro nutrients needed in large quantities [4]. Some common ways that is done to determine the status of soil fertility according to Tisdale et al. (1990) is to (1) see symptoms of nutrient deficiency, (2) analysis of plant tissue, (3) analysis of soil biology and (4) a chemical analysis of the soil. The approach was conducted to find out the status of soil fertility in this study i.e. using chemical analysis of soils. In order to establish the status of soil fertility is required parameters such as soil chemical properties; Cation exchange capacity, Base Saturation, organic-C, P and K levels of total land. To formulate appropriate action, then I need to know what the status of soil fertility. So, known chemical properties of soils which become the limiting factor in each land unit, this can be done by evaluating the fertility of the soil [5].

One of the ways that are commonly used in assessing the fertility of the soil is a soil analysis or test with soil samples. Soil test is a chemical in the laboratory analysis activities that are simple, fast, cheap, right, and may be repeated for a presumes the availability of nutrient elements. Soil test in the broad sense i.e. concerning aspects of the interpretation, evaluation and preparation of the fertilizer recommendations from soil test results as well as the taking of soil samples [6]. The spread of soil fertility status can be determined by means of a survey for mapping soils. In addition to this survey aims to determine the land unit also evaluating the potential of soil nutrient elements in providing for the plant through the soil analysis in the laboratory [7]. Given the importance of soil fertility, the necessary evaluation of the status of soil fertility in dry land at Tegallalang Sub-district to establish land management that can be applied to farmers in order to support the production and food security in Tegallalang.

## **2. Methodology**

### *2.1. Area of Study*

Tegallalang sub-district is geographically located between the coordinates 8°19'40" to 8°29'38" South Latitude and 115°15'18" - 115°49'8" East Longitude. Tegallalang Sub-district administratively bordering with Bangli Regency in the north, Tampaksiring Sub-district in the East, Ubud sub-district in the south, and Payangan sub-district in the west. Tegallalang sub-district has 7 villages namely Keliki Village, Kenderan village, Tegallalang Village, Sebatu Village, Kedisan Village, Pupuan Village and Taro Village. Tegallalang Sub-district area is 61.80 km<sup>2</sup> with an altitude ranging between 225-975 meters above sea level. Rainfall in Tegallalang is 1,558.5 mm per year with temperature of 21°C – 24°C [8]. Soil type at Kecamatan Tegallalang have Sub groups of Typic hapludands, with the slope of 3-8% (flat), 8-15% (undulating), 15-25% (rather steep), 25-40% (steep) and >40% (very steep). Soil analysis was done in the laboratory of soil science of Udayana University. Geographic Information Systems (GIS) analysis done on Evaluation of Land Resources Lab of the Faculty of Agriculture of Udayana University.

### *2.2. Tools and Material*

The materials used in this research includes:

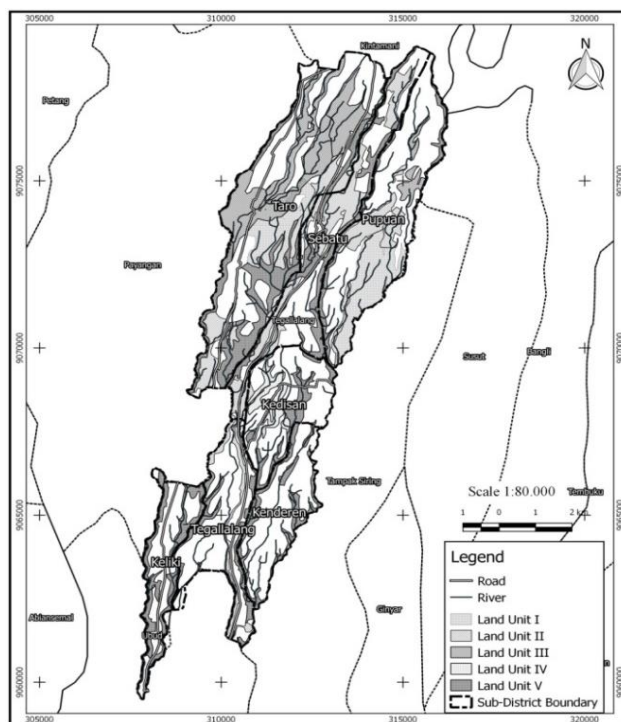
- Digital Topographical Map, scale 1:25,000
- Soil semi detailed map of Gianyar Regency 1:50,000 scale
- Soil samples
- Aquades 0.5 N HCl,
- Solution of peroxide (H<sub>2</sub>O<sub>2</sub>) 10% and 30%
- The chemicals for soil analysis in the laboratory.

The tools used in this research include:

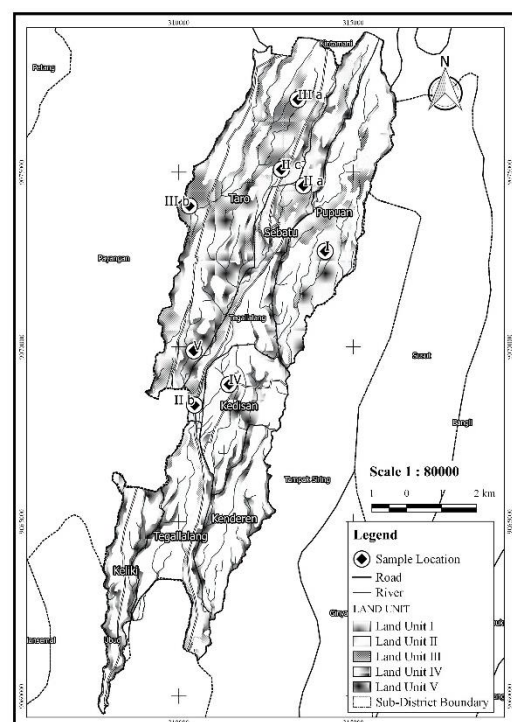
- Equipment for the survey include daggers, hoes, meter, drill bhelgy, camera, label, plastic, ring samples
- GPS (Global Positioning System)
- Equipment for the analysis of soil samples includes: sieve diameter 2 mm and 0.5 mm, weigh the bottle, pH meters, measuring cup, test tubes, scales, as well as Erlemeyer.

### 2.3. Methodology

This research using field survey and soil test in the laboratory. Field survey begins with the creation of a map unit of the research area with intersecting thematic maps, namely soil type map, slope map and landuse map. Field survey conducted to re-check set the tentative map units to become permanent land units. The tentative land units is presented in Figure 1 and location sample can be seen on Figure 2. Retrieved five land unit, that unit I, II, III, IV and V. Each unit land soil in composite samples taken at a depth of 0-20 cm. Soil samples have been taken, further analysed in the laboratory. The chemical properties of the soils analysed in laboratory among other things the C-organic (Walkley and Black method); CEC (method 1 N  $\text{NH}_4\text{OAC}$  pH 7); Saturation of the base (Base Saturation/CEC \*100%);  $\text{P}_2\text{O}_5$  HCl Extraction method of total (25%);  $\text{K}_2\text{O}$  HCl extraction methods (25%). Analysis of the soil properties with certain specified criteria based on Technical evaluation of soil fertility [5] are presented in Table 1. Primary data obtained from soil analysis results in the laboratory, then conducted the analysis based on the criteria of the status of soil fertility [5]. Combination of soil fertility of low, medium and high can be seen in Table 2. Meanwhile existing condition of the vegetation, fertilizer and land management practice are obtained from interviews with local farmers at the sample location.



**Figure 1.** Tentative Land Unit Dry Land Farming at Tegallalang Sub-District



**Figure 2.** Sample Location

**Table 1.** Criteria for Assessment of Chemical Properties of Soil

Soil Parameter	VL	L	M	H	VH
C organik (%)	< 1,00	1,00 -2,00	2,01-3,00	3,01 - 5,00	> 5,00
Base Saturation (%)	< 20	20-35	36-50	51 - 70	> 70
P <sub>2</sub> O <sub>5</sub> HCl 25 %	< 10	10-20	21-40	41 - 60	> 60
K <sub>2</sub> O HCl 25 %	< 10	10-20	21-40	41 - 60	> 60
CEC (me/100 g)	< 5	5-15	17-24	25 - 40	> 40

Description: VL/L/M/H/VH; Very Low/Low/Medium/High/Very High

**Table 2.** Combination of Soil Fertility

CEC	Base Saturation	P <sub>2</sub> O <sub>5</sub> , K <sub>2</sub> O, C-organic	Fertility Status
H	H	≥2 H without R	High
H	H	≥2 H without R	Medium
H	H	≥2 M Without R	High
H	H	≥2 M dengan R	Medium
H	H	H > S > R	Medium
H	H	≥2 L dengan H	Medium
H	H	≥2 L dengan S	Low
H	M	≥2 H Without R	High
H	M	≥2 H dengan R	Medium
H	M	≥2 S	Medium
H	M	Other Combination	Low
H	L	≥2 H Without R	Medium
H	L	≥2 H dengan R	Low
H	L	Other Combination	Low
M	H	≥2 H Without R	Medium
M	H	≥2 S Without R	Medium
M	H	Other Combination	Low
M	M	≥2 H Without R	Medium
M	M	≥2 S Without R	Medium
M	M	Other Combination	Low
M	L	3 H	Medium
M	L	Other Combination	Low
L	H	≥2 H Without R	Medium
L	H	≥2 H dengan R	Low
L	H	≥2 S Without R	Medium
L	H	Other Combination	Low
L	M	≥2H Without R	Medium
L	M	Other Combination	Low
L	L	All Combination	Low
VL	H, M, L	All Combination	Very Low

Description: H/M/L/VL: High/ Medium/ Low/ Vey Low

### 3. Result and Discussion

Intersection processes of soil map, landuse map and slope map resulting land unit map. There are five land unit, namely, land unit I, II, III, IV and V. Each land unit in composite samples taken at a depth of



0-20 cm. Soil samples have been taken, further analyzed in the laboratory. Each soil sample taken at different land unit which indicates different slopes, landuse and vegetation. The slopes, namely, 3-8% slope, 8-15 slope, 15-25% slope, 25-40% slope and more than 40% slope. The soil subgroup at research area indicates the same type which is Typic hapludands and the landuse is dryland farming. The vegetation, fertilizer and land management are obtained from interviews with local farmers. Recent vegetations in dryland farm in Tegallalang are Orange, Papaya, Peanut, Coffee, Snake fruits, Chili, Cassava, Ginger, Chocolate, Coconut, Big Grass, Banana, Sweet potato and Mangosteen. Fertilizer in each land units are different. No fertilizer occupied in land unit I, IV and V. Meanwhile Organic fertilizer, Phonska, dolomite are the most common fertilizer for other land unit. Land management system is still traditional with Soil tillage with hoe or without soil tillage at all. Table 3 shows the description of each soil samples.

**Table 3.** Land Unit Description

Land Unit	Sample	Slope	Sub Group	Land Use	Vegetation	Kind of Fertilizer	Land Management
I	I	3-8 %	Typic hapludands	Dry Land Farming	Orange, Papaya, Peanut	Without fertilizer	Without Soil Tillage
II	Ila	8-15 %	Typic hapludands	Dry Land Farming	Coffee, Orange, Snake fruits	Organic Fertilizer,	Soil tillage with hoe
	Ilb	8-15 %	Typic hapludands	Dry Land Farming	Orange, Chili, cassava	Organic fertilizer, Phonska, dolomite	Soil tillage with hoe
	Ilc	8-15%	Typic hapludands	Dry Land Farming	Banana, sweet potato, mangosteen	Without fertilizer	Soil tillage with hoe
III	III a	15-25 %	Typic hapludands	Dry Land Farming	Orange, Ginger, Chocolate	Organic fertilizer, Phonska	Soil tillage with hoe
	III b	15-25 %	Typic hapludands	Dry Land Farming	Ginger, Orange, Turmeric	Organic fertilizer	Soil tillage with hoe
IV	IV	25-40 %	Typic hapludands	Dry Land Farming	Chocolate, Coffee, Banana	Without fertilizer	Soil tillage with hoe
V	V	40-60 %	Typic hapludands	Dry Land Farming	Coconut, Big Grass, Mango	Without fertilizer	Soil tillage with hoe

### 3.1. The Measurements of Parameters of Soil Fertility

**3.1.1 Cation Exchange Capacity.** Cation Exchange Capacity (CEC) is an indicator of soil fertility. The research at Tegallalang Sub-district has indicates a value of cation exchange capacity varies from low to high with the highest average value of 27.92 me/100 g until 15.08 me/100 g. The high value of the CEC allegedly is influenced by dominant of clay fraction content. High value of CEC also influenced by levels of clay, because the land dominated by the fraction of clay that has capacity of ion exchange and holds water, therefore the high aggregate stability is due to soil particles in the bond. The value and criteria of CEC at dry land mixed farming presented in Table 4.

**Table 4.** Values and criteria of Cation Exchange Capacity

No	Land Unit	Sample	CEC	Criteria
I	I	I	15,93	Low
IIa	II	IIa	21,14	Medium
IIb		IIb	27,92	High
IIc		IIc	17,87	Medium
IIIa	III	IIIa	22,45	Medium
IIIb	IV	IIIb	17,47	Medium
IV		IV	15,08	Low
V	V	V	19,67	Medium

**3.1.2. Base Saturation.** Base saturation is a comparison between the numbers of base cation exchanged with the cation exchange capacity (CEC) of soils that are expressed in percent. Tegallalang Sub-district has value from a high base saturation to very low with the highest median value 95.24% to 29.23%. The value soil CEC is usually directly proportional to the ground, because the saturation KB base is the description of the high number of cation in complex soil colloids [9]. This statement is contrary to the results of this research. This is due to the soil at research area experience a lot of leaching of base cations in the soil. The value and criteria of Base Saturation at dry land mixed farming presented in Table 5.

**Table 5.** Value and criteria of Base Saturation

No	Land Unit	Sample	Base Saturation	Criteria
1	I	I	95,24	Very High
2	II	IIa	38,00	Medium
3		IIb	59,37	High
4		IIc	68,84	High
5	III	IIIa	56,08	High
6	IV	IIIb	54,76	High
7		IV	66,67	High
8	V	V	29,23	Low

**3.1.3. Content of C-Organic.** The results of the determination of the levels of C-Organic in dry land research at the Tegallalang Sub-district varies from very low to high with a percentage of the average value of 4.20% to the lowest is 0.93%. If the C-Organic content on any type of soil in dry land location at Tegallalang Sub-district shows an average 2% still considered low. This is allegedly due to differences of the climatic conditions, rainfall and vegetation of the area so that it can affect the availability of organic matter in the soil. Low content of C-Organic indirectly shows the low production of organic matter in soil, because soil organic matter is one of the parameters that determine the fertility of the soil. The increase of organic matter also means action against conservation of carbon in the soil, so when the carbon trapped in the ground, then the CO<sub>2</sub> emissions into the air [11]. The value and criteria of C-Organic at dry land mixed farming presented in Table 6.

**Table 6.** The value and criteria of C-Organic

No	Land Unit	Sample	C-Organic	Criteria
1	I	I	0,98	Very Low
2		IIa	6,39	Very High
3	II	IIb	5,56	Very High
4		IIc	3,17	Medium
5	III	IIIa	8,46	Very High
6		IIIb	6,44	Very High
7	IV	IV	0,93	Very Low
8	V	V	4,20	High

**3.1.4. Content of Phosphate ( $P_2O_5$  total).** The results of the measurement of the content of phosphor soil from each land unit, that the content of  $P_2O_5$  varies from moderate to high with the highest median value range from 40.43 mg/100 g to the lowest i.e., 12, 21 mg/100 g. The value of P in the research indicates the existence of a low content of Phosphate especially in the IIa, IIc and V that causes a limiting factor or constraint of soil fertility in dryland locations so that it necessary to add reserves of phosphorus into the soil. Land units that containing the element P are high derived from organic matter (manure and the remains of plants), chemical fertilizers (TSP) and the minerals in the soil (apatite). The value and criteria of Phosphate content farming presented in Table 7.

**Table 7.** The Value and criteria Content of Phosphate

No	Land Unit	Sample	$P_2O_5$ total	Criteria
I	I	I	25,49	Medium
IIa		IIa	12,21	Low
IIb	II	IIb	40,43	High
IIc		IIc	11,01	Low
IIIa	III	IIIa	28,49	Medium
IIIb		IIIb	33,74	Medium
IV	IV	IV	41,03	High
V	V	V	10,52	Low

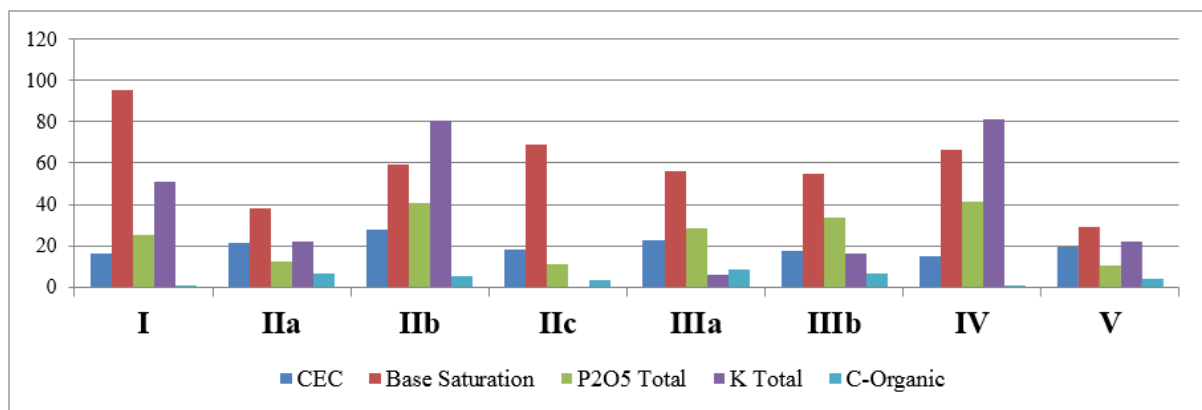
**3.1.5. Content of Kalium ( $K_2O$ ).** The results of measurements of soil potassium content location research showed a total  $K_2O$  content of soil at each land unit is low to very high. The average value of 100 mg/80.71 up 15.91 mg/100 g. Low potassium relates to lauder that occur due to the high rainfall [11]. The high Potassium value due to the high value of the CEC on a land unit IV and II b. Cation Exchange Capacity of the soil capability increases K holing at the soil, thus the soil solution was slow to take off lowering the potential leaching, thereby Potassium buildup occurs [12]. The value and criteria of Kalium content at dry land mixed farming presented in Table 8.



**Table 8.** Value and Criteria of Kalium ( $K_2O$ )

No	Land Unit	Sample	$K_2O$	Criteria
I	I	I	50,75	High
IIa	II	IIa	21,72	Medium
IIb		IIb	80,71	Very High
IIc		IIc	27, 24	Medium
IIIa	III	IIIa	15,91	Low
IIIb		IIIb	16,22	Medium
IV	IV	IV	81,41	High
V	V	V	21,89	Low

The graph of parameter of soil fertility in dry land farming at Tegallalang Sub-district presented by Figure 3.

**Figure 3.** Value of Parameter of Soil fertility in Tegallalang Sub-District.

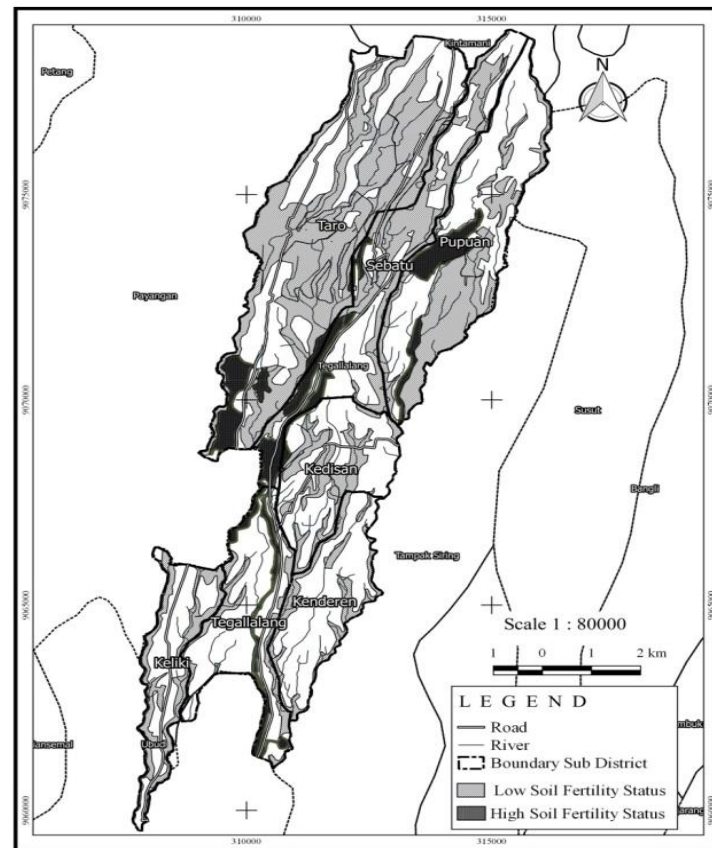
### 3.2. Evaluation of Soil Fertility

Soil fertility is the ability of a soil to provide nutrient elements, in a certain measure and balance on an ongoing basis, to support the growth of a type of plant on the environment with other growth factors in the profitable circumstances. Availability of excellent fertile soil nutrients available to plant will not limiting for plant to growth. The status of soil fertility is the condition of soil fertility in a certain place and time that are judged by the criteria of raw soil fertility parameters according to the instructions of the technical evaluation of the fertility of the soil [5]. The Result of the soil fertility status presented by Table 9. The map of soil fertility in dry land farming at Tegallalang sub-district can be seen in Figure 4.

**Tabel 9.** Evaluation of Soil Fertility

Land Unit	Sample	CEC (me/100)	Base Saturation (%)	P <sub>2</sub> O <sub>5</sub> total (mg/100g)	K Total (mg/100g)	C-Organic (%)	Soil Fertility Status
I	I	15,93 (L)	95,24 (VH)	25,49 (M)	50,75 (H)	0,98 (VL)	L
II	IIa	21,14 (M)	38,00 (M)	12,21 (L)	21,72 (M)	6,39 (VH)	L
	IIb	27,92 (H)	59,37 (H)	40,43 (H)	80,71 (VH)	5,56 (VH)	H
	IIc	17,87 (M)	68,84 (H)	11,01 (L)	27, 24 (M)	3,17 (M)	L
III	IIIa	22,45 (M)	56,08 (H)	28,49 (M)	15,91 (L)	8,46 (VH)	L
	IIIb	17,47 (M)	54,76 (H)	33,74 (M)	16,22 (L)	6,44 (VH)	L
IV	IV	15,08 (L)	66,67 (H)	41,03 (H)	81,41 (VH)	0,93 (VL)	L
V	V	19,67 (M)	29,23 (L)	10,52 (L)	21,89 (M)	4,20 (H)	L

Description: H/M/L/VL: High/ Medium/ Low/ Vey Low



**Figure 4.** Soil Fertility Map at Tegallalang Sub-District

The status of the assessment of the overall fertility of dry land at Tegallalang Sub-district is low except at land unit II which shows high soil fertility status. Low fertility status due to a limiting factor that is the low C content of organic soil and soil CEC. C- organic content (organic material) very influential towards the ability of soils in sustaining soil fertility and productivity through the activity of soil organisms, many soil properties at the land units are good affecting the physical, chemical and biological conditions directly but not affected the organic material.

Absolute organic additions should be given because soil organic matter is very instrumental in creating soil fertility. Base saturation is always connected as a clue about the fertility of the soil. Capability in releasing ions to plants depending on the degree of base saturation. The soil is very fertile when having more than 80% base saturation, and if base saturation is less than 50% then the soil is infertile. This is based on the nature of the ground with 80% base saturation will free alkaline cations that can be exchanged more easily from the ground with 50% base saturation.

### 3.3 Land Management Directives

Dryland farm management in Tegallalang Sub-district is based on evaluation results of the status of soil fertility and the limiting factor. Land management needed to improve soil fertility in order to increase agricultural production, as well as to achieve a sustainable agricultural system. An important component to note is the use of fertilizers, as well as tillage. The direction of the recommended fertilizer use is manure and fertilizer with phosphate content. Especially on a land unit I, II a, II, c III a, III b, IV and V. The addition of manure and fertilizer must comply with the conditions of the soil and plant needs.

Soil conservation is part of the preparation of the land to make land productivity remains high [13][14]. Conservation tillage is characterized by reduced demolition or reversal of land,

intensifying the use of the remaining plants or other materials as mulch. On a land unit with a slope of more than 40% is recommended for making the patio bench. This technique has been developed extensively since 1975 through presidential intrusion [15].

#### 4. Conclusions

The status of soil fertility in dry land in the High to low i.e. Tegallang. High soil fertility status shown on the land unit II (II b soil samples). The status of soil fertility low in the show on land units I, II (a sample of IIa, IIb, IIc), III, IV and V. The parameters of the soil fertility which becomes the obstacle of the status of soil fertility in the location of the research on each unit land is CEC soil, C-organic. P and K are low. The recommended management to improve the status of soil fertility is by the addition of organic fertilizer and Phonska Fertilizer in accordance with the needs of the plant. On the other hand need to be done as well as the manufacture of tillage terrace to the efficiency of fertilizer.

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