

Full Length Research Paper

The evaluation of soil fertility status of open space in campus area and their suitability for tropical fruits production

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This study aims to determine the level of fertility and the suitability of various types of tropical fruit from open space at Universitas Pendidikan Ganesha campus area in Jineng Dalem, Singaraja. 18 soil samples with 3 depth categories (25, 50, and 75 cm) were collected, and the properties analyzed are limited to the the following parameters: soil texture, pH, base saturation, organic carbon (%), DHL (μcm^{-1}), cation exchange capacity (CEC), total nitrogen and available phosphorus and photassium. The characteristics data of the soil are used to determine their fertility status and suitability for tropical fruit plantations. The soil suitability assessment method was developed by the Indonesian Center for Research and Development of Land Resources, Agricultural Research and Development Agency, Ministry of Agriculture of the Republic of Indonesia. In addition, it was reported that the land boundary was mainly organic C content, N-total, P and available K. In addition to low fertility, this condition classifies the land suitability level in the category of marginal status for the 24 tropical fruit plants analyzed. The addition of compost is highly recommended to increase levels of C-organic in the soil. Subsequently, it is also recommended to apply manure to increase the N, available P, and K content of the soil. Availability of water sources or irrigation channels is also needed to maintain soil moisture.

Key words: Open space, tropical fruit plants, soil characteristics, land suitability.

INTRODUCTION

In Indonesia, every office area in government institution is required to have green open space. However, its usage varies; most institutions generally use it as an office park, and some are also used as fruit gardens. Furthermore, Ganesha University of Education introduced open spaces as a tropical fruit plantation. These efforts are not only part of protecting tropical fruit trees, but are also intended to be a remedial action against climate change. The use

of open space will contribute to the sequestration of urban carbon emissions. According to Wu et al. (2012), plantations contribute to the carbon cycle from storage, root respiration, and net CO_2 fluxes. Compared to other woody plants, some fruit plants have structural characteristics that allow the absorption of significant amounts of atmospheric carbon due to their long life cycle. This allows the accumulation of C in permanent

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organs such as the trunk, branches, and roots and in the soil through rhizodeposition (Wu et al., (2012). According to Sthapit et al. (2012), in a year, perennial crops can sequester between 320 to 1,100 kg of soil carbon per hectare, compared to 0 to 450 kg of annual crops.

Sthapit et al. (2012) also revealed that fruit trees provide important adaptive value, and tend to be more resilient to climate change due to their timeless nature. With increasing demand for fruits and the issue of climate change, there are opportunities for open land managers in the country to use them to produce fruit, especially around tropical fruit trees. However, land suitability must be evaluated first. According to FAO (1983), land evaluation requires physical environmental properties that are defined in land quality, where each land quality can consist of one or more land characteristics. Ritung et al. (2011) suggested the characteristics used in assessing land, which include annual average temperature, rainfall (annual or during the growth period), humidity, drainage, texture, coarse material, effective depth, maturity, and thickness of peat, CEC, alkaline base, pH, organic C, total N, P₂O₅, K₂O, salinity, alkalinity, sulfidic depth, slopes, rock on the surface, rock outcrops, landslide hazards, erosion hazards, and inundation height and length.

The suitability of the land can be determined based on the level, namely the order, class, sub-class and unit level (Ritung et al., 2011). The order is the condition for the adequacy of the land through order. In terms of soil suitability, there is a difference between land classified as suitable (S) and land classified as unsuitable (N). Class is the level of conformity in an order. At the class level, the soil of the corresponding order (S) is divided into very suitable (S1), moderately suitable (S2), and marginal (S3). While land classified as unsuitable order (N) is not differentiated. Sub-class describes the level of land suitability within the class. Land suitability classes are classified into land suitability sub-classes based on the quality and characteristics of the land, which are the limiting factors. The unit describes the level of land suitability in sub-classes based on additional properties that affect its management. All units that are in the same sub-class have the same level in the class and have the same type of barrier at the sub-class level. One unit differs from another in the nature or additional aspects of the management required and is the distinction of the limiting factors.

Knowing the delimitation at the unit level facilitates detailed interpretation when planning the operation. For example, Classes S3r1 and S3r2, both have the same class and subclass with the same inhibiting factor, namely the effective depth, but different units. Unit 1 has a moderate effective depth (50 - 75 cm), and Unit 2 has a shallow effective depth (<50 cm). In land evaluation practice, suitability in this unit category is rarely used (Ritung et al., 2011).

Numerous studies have been carried out to assess the suitability of the soil. Pioh et al. (2014) carried out a land

assessment for the development of agro-tourism in the area of Lake Linow in North Sulawesi in order to manage the land and the ecosystems around the lake. The suitability of the soil for fruit plants was also carried out by Hamdan and Rahman (2015). Furthermore, Chintya (2018) analyzed the characteristics of the land as a basis for the management of sweet orange plantations. In contrast to Pioh et al. (2014) and Hamdan and Rahman (2015), Chintya (2018) analyzed the plantation land for plant management. Anwar et al (2016) analyzed the suitability of land for horticultural crops in former peat swamp forest areas in the Nagan Raya District of Aceh Province. However, all of these studies were carried out on a large scale. In these cases, it mainly depends on remote sensing data and GIS data to assess the suitability of the soil, and these methods are often unable to reflect the real conditions at the micro level. In contrast, only a few studies have considered small open spaces in built-up or domestic areas, for example, in urban open spaces, office yards, or open spaces in the campus area.

This study aims to assess fertility and suitability of small land area for tropical fruit tree species. This research is mainly due to the lack of information about the properties and quality of the soil in the area. Therefore, there is no indication of the suitability of the soil and the obstacles it might encounter. Furthermore, it aims to develop a small-scale agroforestry in the campus area as part of the campus endeavor to conserve plants and the environment.

METHOD

Research location

Soil samples were collected in an open space on the campus of Universitas Pendidikan Ganesha (Undiksha) in Jineng Dalem village, Buleleng District. Undiksha has five locations on the campus, and one is located in Jineng Dalem Village. This campus is occupied by the Faculty of Sports and Health and the Faculty of Medicine, and the land area is about 13.82 ha. The land is used for office buildings, lectures, laboratories and other supporting facilities for academic activities, which is about 6 ha. The rest are open space distributed between the campus buildings, and some are designated for orchards tropical. In addition to targeting the conservation of tropical fruit crops, these efforts support the campus carbon storage and sequestration program.

Before the land was used as a campus area, it was first used as an agricultural land. However, during the building construction process, various types of material were piled up, especially waste for the construction of buildings, and these activities have an impact on soil degradation. Therefore, before it is used for orchards, it must be evaluated for its fertility and suitability for the fruit tropical plant.

Soil sampling was carried out in the following stages: plotting, determining the sampling point, taking soil samples at the sampling point, and preparing samples for laboratory analysis. The area was divided into two plots, and each plot has a size of 10 m x 20 m (adapted to the landscape). For each plot, three sampling points were determined. At each sampling point, samples were collected in three depths: 25, 50 and 75 cm. Eighteen samples were then

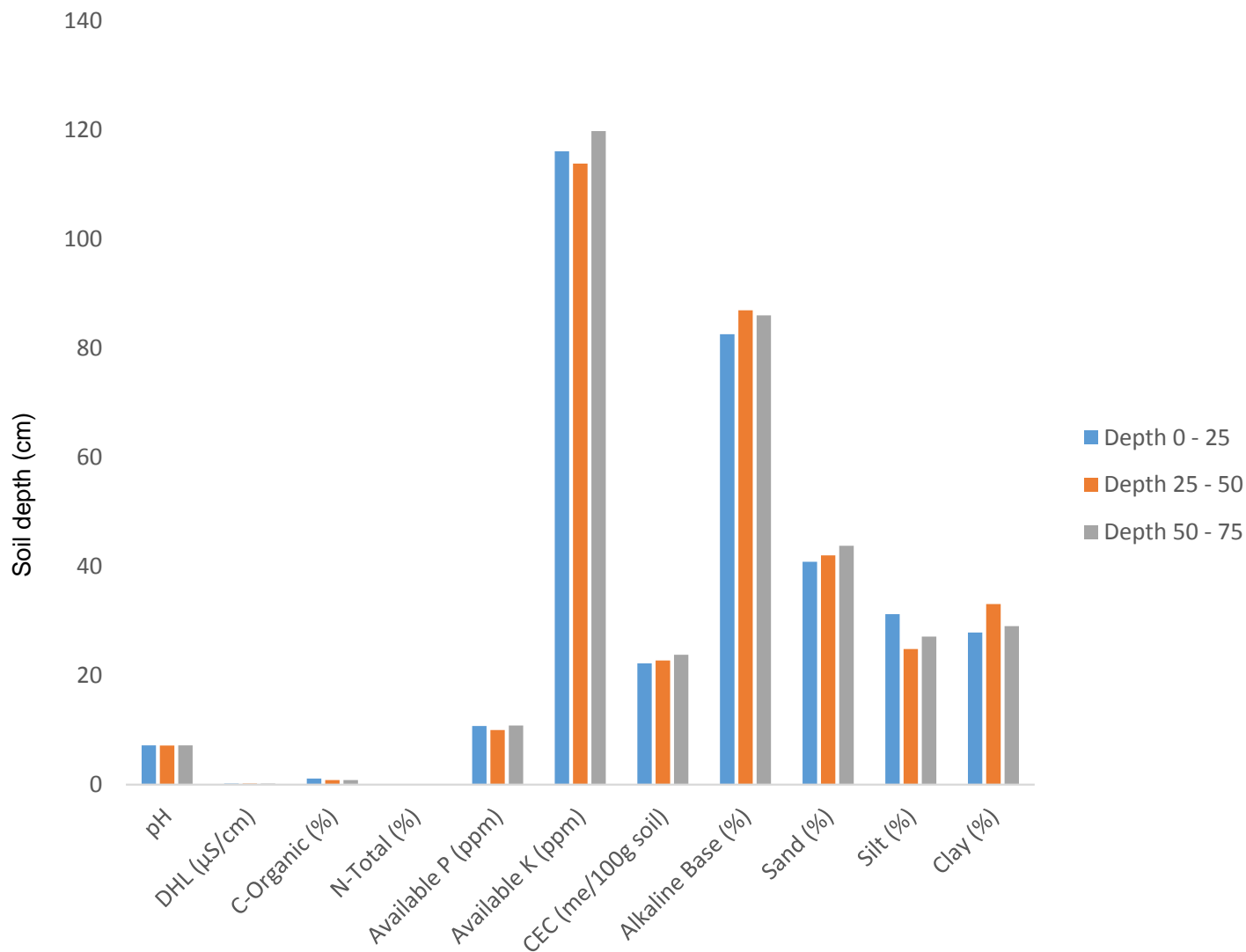


Figure 1. Sample characteristics from Plot I.

collected and analyzed for their properties in the laboratory.

The soil properties examined include texture (Hydrometer method), pH (potentiometric method), organic carbon (Walkely and Black method), Total Nitrogen (Kjeldahl), available Phosphorus (Bray I), and Potassium (flamefotometre), electrical conductivity (conductimetry using NaCl). Base saturation was calculated as the percentage of CEC occupied by base cations, and cation exchange capacity (using NH_4OAc). All of these soil analysis methods referenced the Technical Guidelines for Chemical Analysis of Soil, Plants, Water and Fertilizers issued by the Soil Research Center Soil Research Center, Agricultural Research and Development Agency, Agriculture department Republic of Indonesia (Sulaiman et al., 2005). The laboratory analysis was carried out at the Undiksha Chemical Analysis Laboratory and the Soil Science Laboratory, Faculty of Agriculture, Udayana University, Denpasar.

The soil suitability was evaluated using appropriate data on soil properties; the land suitability rating tables were compiled based on land use requirements including the growth/survival requirements for fruit farming commodities according to Technical Guidelines for Land Evaluation for Agricultural Commodities (Djaenudin et al., 2011).

RESULTS AND DISCUSSION

The research area is located at an altitude of 75 m above sea level with an average temperature of 27.05°C and an average rainfall of 51-100 mm. It is located in an area of approximately 400 m^2 which is divided into two plots according to its terraced topographic profile. In each plot, three viewing points were assigned with sampling at each point at a depth of 0 – 25 cm, 25 - 50 cm, and 50 – 75 cm. The properties of the soil are shown in Figure 1 for characteristics of soil in plot I and Figure 2 for plot II.

The observations show that the soil in plot I tends to be neutral with a pH value ranging between 6.8 to 7.4 (Figure 1) and in plot 2 the study area tends to be alkaline with a pH value ranging from 7.3 to 7.9 (Figure 2). Soils at all depths have low or very low available K-organic, N-total, available P, and K. CEC was medium and ranges from 17.77-28.18 Cmol^+/kg and the base

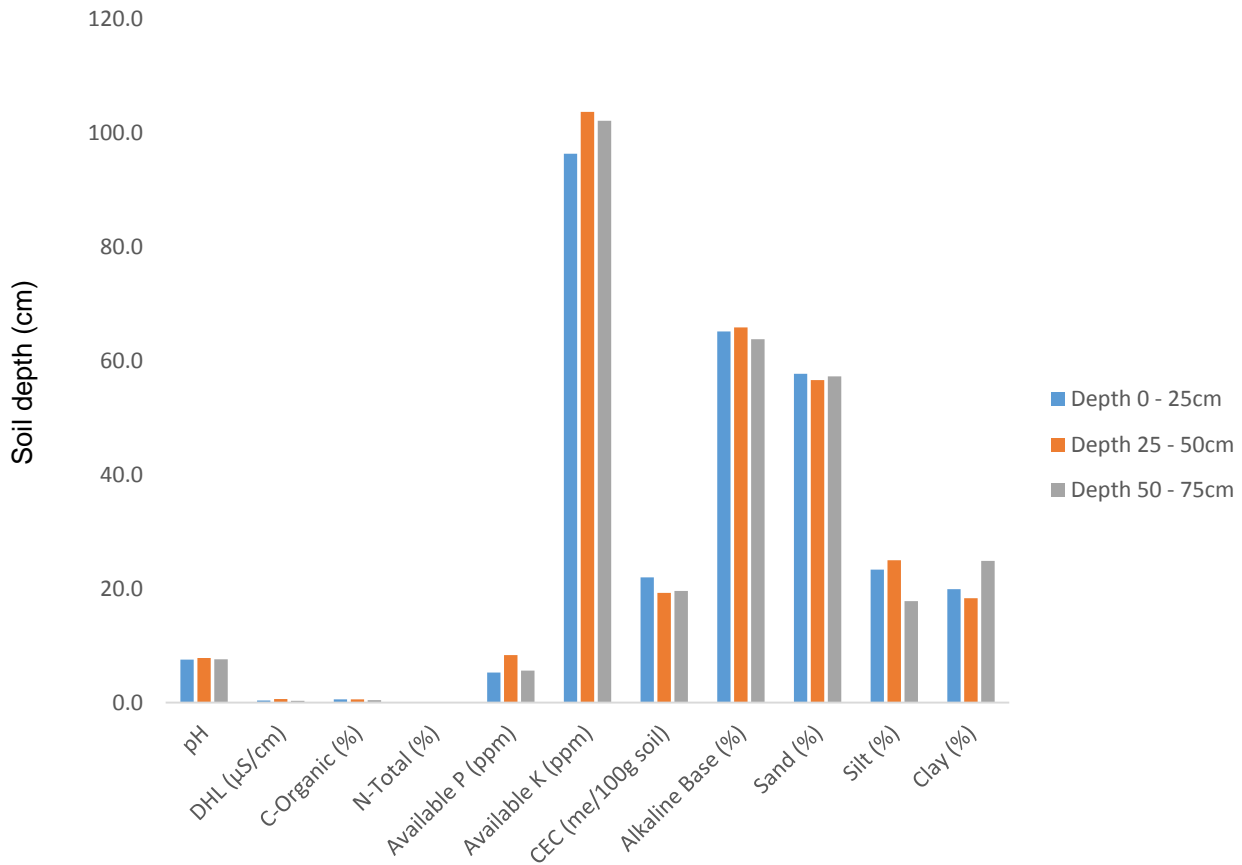


Figure 2. Sample characteristics from Plot II.

saturation was very high. The texture varies from sandy loam to clay.

pH

Soil pH is an important chemical parameter because it helps to ensure the availability of essential plant nutrients (Deshmukh, 2012). Soil pH ranges from 6.8 to 7.9, with a mean value of 7.41 (Table 1). This shows the neutral and slightly alkaline soil properties. 33.33% of the soil samples had a pH of 33.33% slightly alkaline and 66.67% neutral. The soil is slightly alkaline possibly as a result of the filling performed using limestone. Dropping takes place around the site during the campus building construction. Soil dryness implies that nutrients are likely not available for plant uptake. Therefore, organic fertilizers can be added to lower soil pH with slightly alkaline locations.

Soil organic matter

Organic matter has a vital role in agricultural soil; it supplies plant nutrients, improves soil structure,

infiltration, and water retention, feeds soil micro-flora and fauna, and the retention and fertilizer cycle is applied (Johnston, 1986). The organic matter content expressed as C-organic ranges from 0.41 to 1.27% with an average value of 0.72% (Table 1), and this indicates a very low organic matter media status. The distribution of soil samples to the organic matter content shows that about 77.77% of the samples have a very low organic matter, while 33.33% of the other samples have a low organic matter. The presence of organic matter shows low variability (0.10) among soil samples. Due to the low organic matter content, the type of land improvement effort required is to add organic fertilizers, for example by applying compost.

Total nitrogen

Nitrogen is one of the most important plant nutrients and is the most frequently deficient of all nutrients. Likewise in the observed area, the total nitrogen content ranges from 0.01 to 0.06% with a mean value of 0.04% (Table 1). This indicates a very low land total nitrogen status. The N-total data for all samples shows that all samples have a very low nitrogen content. There was almost no variation in

Table 1. Parameters for soil chemical properties.

Statistical parameter	pH	DHL ($\mu\text{s}/\text{cm}$)	C-Organic (%)	N-Total (%)	P-Available (ppm)	K-Available (ppm)	KTK (me/100 g soil)	KB (%)
Mean	7.41	0.31	0.72	0.04	8.59	108.63	21.75	89.33
Standard Error	0.07	0.05	0.07	0.00	1.66	7.59	0.52	1.65
Median	7.40	0.21	0.84	0.04	5.59	99.52	22.14	87.67
Mode	7.10	0.21	0.42	0.05	#N/A	#N/A	#N/A	#N/A
Standard Deviation	0.30	0.21	0.32	0.02	7.04	32.22	2.19	7.01
Sample Variance	0.09	0.04	0.10	0.00	49.63	1038.04	4.80	49.15
Kurtosis	-0.64	10.11	-0.91	-1.20	1.22	1.55	-0.33	-0.76
Skewness	-0.09	2.95	0.54	-0.22	1.48	1.69	-0.48	-0.29
Range	1.10	0.90	0.86	0.05	23.07	98.14	7.41	23.01
Minimum	6.80	0.15	0.41	0.01	1.92	81.99	17.77	75.86
Maximum	7.90	1.05	1.27	0.06	24.99	180.13	25.18	98.87
Sum	133.30	5.52	13.01	0.63	154.70	1955.34	391.49	1607.95
Count	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
Confidence level(95.0%)	0.15	0.10	0.16	0.01	3.50	16.02	1.09	3.49

total nitrogen between samples. The unfavorable conditions in organic matter may be the reason for the very low status in total nitrogen. Therefore, according to Khadka et al. (2019) management should be applied with the full dose (100%) of the recommended nitrogen dose.

Available phosphorus

Phosphorus plays an important role in energy transformation and metabolic processes in plants (Rai et al., 2014). The available phosphorus ranges from 1.92 to 24.99 ppm with an average value of 8.59 ppm (Table 1). Furthermore, it shows a moderate to very low available phosphorus status. The results showed that about 16.67% of samples were moderate and 5.55% low, while 77.78% of the samples were very low in phosphorus content. Generally, the phosphorus content can be categorized as very low. The variability of phosphorus content among soil samples is 49.63. The presence of available phosphorus content in the soil may be caused by the application of land clearing practices, especially the side of the land closest to the university building. Fertilizer management is therefore necessary in order to cultivate the soil. Khadka et al. (2019) recommend using areas with very little available phosphorus and fertilizer levels of 100 and 60% phosphorus.

Available potassium

Potassium is not an integral part of the main plant component, but it plays an important role in a variety of physiological processes that are important for plant

growth from protein synthesis to maintaining the plant water balance (Sumithra et al., 2013). The available potassium content varies from 81.99 to 180.13 ppm with an average value of 108.63 ppm (Table 1). This indicates a low to moderate status for available potassium. The data showed that 16.67% of the soil samples tested had moderate extractable potassium content, while the remaining 83.33% of the samples were in low status. A very high variability (1038.04) in extractable potassium among soil samples was reported. The unfavorable condition of the potassium that can be extracted on the land is because the area has not been managed. Since most of the study area is low in calcium, the recommended fertilizer application method is the same as the phosphorus mentioned in the phosphorus section for very low, low, and moderate status.

Cation exchange capacity

The CEC is the total land capacity to accommodate exchangeable cations. CEC is an inherent characteristic of the soil and is difficult to change significantly. It influences the ability of the soil to retain essential nutrients and provide a buffer against soil acidification (Sumithra et al., 2013). The CEC reported varies from 17.77 to 25.18 ppm with an average value of 21.75 ppm (Table 1). This indicates that the land is in moderate status for CEC. The data show that 11.11% of the soil samples tested have a high CEC, while the remaining 89.89% of the samples are in moderate status. Low variability (4.80) was reported in the CEC among the soil samples. The unfavorable condition of CEC on land is caused by the unmanaged area. Since most of the study area is in moderate condition, processing by liming or

Table 2. Soil particle size distribution.

Statistical parameter	Sand (%)	Silt (%)	Clay (%)
Mean	49.89	24.81	25.47
Standard Error	2.56	2.44	1.58
Median	49.46	26.94	26.10
Mode	#N/A	#N/A	#N/A
Standard Deviation	10.87	10.35	6.72
Sample Variance	118.19	107.13	45.19
Kurtosis	-0.67	-1.26	1.25
Skewness	0.22	0.09	0.60
Range	36.04	31.64	28.56
Minimum	32.87	8.19	14.14
Maximum	68.91	39.83	42.70
Sum	897.99	446.56	458.39
Count	18.00	18.00	18.00
Confidence Level(95.0%)	5.41	5.15	3.34

applying organic fertilizers is recommended.

Base saturation

Base saturation is the percentage of the total cation exchange capacity (CEC) occupied by base cations such as potassium, calcium, magnesium, and sodium. The value of family planning is closely related to the pH and level of soil fertility (Bawman and Lannan, 1995). KB was reported to vary from 75.86 to 98.87% with a mean value of 89.33% (Table 1), and this indicates a very high status for KB. It was also reported that all (100%) soil samples tested had very high FP. High family planning variability (49.15) was also reported among the soil samples. Basic cations are generally nutrients needed by plants (Sudaryono, 2009). Soils with high base saturation release base cations and can be exchanged more easily than soils with lower base saturation.

Soil texture

Soil texture is one of the most important physical properties of soil because it affects water retention, nutrient availability, pore space, aeration, slope stability, and erosion vulnerability (Brady and Weil, 2008). The percentage of sand ranges from 32.87-68.91% with a mean of 49.89% and a silt percentage of 8.19 -39.83% with a mean of 24.81%; while the range of clay percentages was 14.14 - 42.70% with a mean of 25.47% (Table 2). Five texture classes such as loam, clayey loam, sandy loam, sandy loam, and sandy loam were observed (16.67, 27.77, 16.67, 33.33 and 5.56%) of the samples studied, respectively (Table 2). Soil sample variations were 118.19, 107.13 and 45.19% for the content of sand, silt, and clay. The overall texture of the

soil is sandy loam. Based on the texture, it can be concluded that the land tends to have sandy clay properties.

Land suitability

The results of the soil suitability assessment for 24 (twenty-four) types of tropical fruit plants are presented in Table 3, and the assessment was carried out in actual or potential land suitability. The actual land suitability is the type generated by the assessment based on the current land condition (actual land suitability), without improvement input. Meanwhile, potential land suitability is the suitability of land produced when the land has been given improvement inputs, such as fertilization, irrigation, or terracing, depending on the type of limiting factor (Ritung et al., 2011). The results of the analysis showed that the actual land suitability for the twenty-four types of fruit plants indicated a marginal suitability class (S3). With input for improvement, it can be upgraded to a fairly appropriate class (S2). Based on the data on land characteristics, the conditions that need to be improved are mainly the content of C-organic, N-total, P and K-available or the availability of harvests. This can be carried out through fertilization. In addition, rainfall is also a limitation of suitability. Considering that the annual average rainfall in Buleleng is very low, ranging from 50-100 mm, the recommended improvement is the provision of water sources or drains.

Based on the data of land characteristics, the available nutrient content (N, P, K) of land is very low. Therefore, the results of land suitability evaluation for tropical fruit crop commodities as in Table 3 provide a marginal land suitability class (S3). Therefore, the results of the evaluation and the summary presented in Table 3 show that improvement efforts can be made because the

Table 3. Actual land suitability class for some tropical fruit plants on the open space at Jineng Dalem Campus.

Kind of Plant	Class of Suitability	
	A	P
Banana (<i>Musa acuminata</i> COLLA)	S3	S2
Papaya (<i>Carica papaya</i> L.)	S3	S2
Citrus (<i>Citrus aurantium</i>)	S3	S2
Apple (<i>Malus silvestris</i> MILL)	S3	S2
Avocado (<i>Persea americana</i>)	S3	S2
Mango (<i>Mangifera indica</i>)	S3	S2
Jackfruit (<i>Artocarpus integra</i> MERR)	S3	S2
Sugar Apple (<i>Annona squamosa</i>)	S3	S2
Salak (<i>Salacca edulis</i>)	S3	S2
Klengkeng (<i>Euphoria longan</i> LAMK)	S3	S2
Grapes (<i>Vitis sp.</i>)	S3	S2
Coconut (<i>Cocos nicifera</i> L.)	S3	S2
Melingo (<i>Gnetum gnemon</i> LINN)	S3	S2
Rambutan (<i>Nephelium lappaceun</i> LINN)	S3	S2
Guava (<i>Psidium guajava</i> LINN)	S3	S2
Durian (<i>Durio zibethinus</i> MURR)	S3	S2
Starfruit (<i>Averrhoa bilimbi</i>)	S3	S2
Duku (<i>Lansium domesticum</i> CORR)	S3	S2
Cempedak (<i>Artocarpus champeden</i> SPRENG)	S3	S2
Soursop (<i>Annona muricata</i> LINN)	S3	S2
Breadfruit (<i>Artocarpus communis</i> FORST)	S3	S2
Sawo (<i>Marchas zapota</i>)	S3	S2
Mangosteen (<i>Garcinia mangostana</i> LINN)	S3	S2
Passion Fruit (<i>Passiflora edulis</i> SIMS.)	S3	S2
Cashew (<i>Anacardium occidentale</i> L.)	S3	S2
Oil Palm (<i>Elaeis guinensis</i> JACK.)	S3	S2

minimum limiting factor is the nutrients available (N, P, K from moderate to high). The results of the final land evaluation are 1). The actual land suitability is included in S3na class, and 2) improvement efforts can be applied to the available nutrients/soil fertility, from S3 to S2 in such a way that the potential land suitability becomes S2na class.

Conclusion

It was reported that the limiting factors of soil were mainly organic C content, N-total, P, and K-available. This condition classified the land suitability level in the category of marginal status for the tropical fruit plants analyzed. Therefore, the identified limiting factors of soil should be managed to suit the fruit plants. In this case, efforts are needed to improve the nutritional quality. The addition of compost is highly recommended to increase the levels of C-organic in the soil. Moreover, it is also recommended to apply manure to increase the N, P, and K content of the soil. Availability of water sources or

irrigation channels is also needed to maintain soil moisture.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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