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Mapping the Distribution of Water Retention and Other Physical Properties of Soil on Intensive Agriculture Land in the Village Sumber Urip, Selupu Rejang District, Rejang Lebong Regency

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ABSTRACT

This research aims to map water availability on intensively cultivated agricultural land so that the land management method will be carried out appropriately. The method used to determine the sample points was the stratified sampling method, and 31 soil sample points were obtained. Soil samples are analyzed for their physical properties, which include soil texture, total pore space, bulk density, permeability, potential of free energy, and water content. The analysis results are presented as an overlay map of the measured variables. The research results show that agricultural land on a slope of 0-15% with a total area of 233 ha has good soil water retention in terms of the physical properties of the soil, so there is no need to improve soil management. Agricultural land on a slope of 15-25% with an area of 79 ha requires additional treatment to increase water retention by adding soil amendments to increase total soil pore space. Agricultural land on a slope of 25-45% with an area of 124 ha has excellent soil water retention supported by soil conservation practices in making terraces and installing plastic mulch. Meanwhile, agricultural land on a slope of >45% with an area of 33 ha has poor soil water retention, so soil conservation practices are needed.

Keywords : *intensive agricultural land, soil pF, water retention*

INTRODUCTION

Sumber Urip Village is one of the villages in Selupu Rejang District, Rejang Lebong Regency. This village is the center for producing good quality horticultural crops in Rejang Lebong Regency. The area of Sumber Urip village is 650 ha (Silviana *et al*., 2021). Intensive farming carried out by farmers is accompanied by high-intensity soil processing to get maximum results. In the near term, this type of processing provides significant benefits in increasing crop production. However, in the long term, intensive soil processing is detrimental because it causes a decrease in the physical, chemical, and biological quality of the soil (Jambak *et al*., 2017). The type of soil processing will determine the water retention capacity. Soil water retention is the ability of the soil to hold the water in it. This ability can be seen from the soil water characteristic curve and field water content (Wahyunie *et al*., 2012).

Too intensive tillage can cause damage to the soil structure and aggregates and cause other changes in soil properties such as volume weight, porosity, infiltration, permeability, soil moisture, erosion, and changes in the water cycle or hydrology. The soil's physical properties will determine the soil's productivity and plants (Soaloon *et al*., 2020).

The agricultural commodities cultivated in Sumber Urip Village are horticultural crops. Horticultural plants need sufficient water availability at a depth of 0-20 cm so that the plants do not wilt. Water can function as a nutrient solvent or a medium for the movement of nutrients from the soil to plant roots (Abbas *et al*., 2022). One factor that can influence the amount of water in the soil is the ability of soil pores to hold water. This ability is referred to as soil water retention. Differences in water retention capabilities in the soil will be determined by the physical properties of the soil itself (Oktarini *et al*., 2021).

The soil's ability to hold water will determine the high and low water content. Water content is the water in the soil at a certain depth (Mutmainnah *et al*., 2021). Physical properties will influence water content, namely texture, volume weight, permeability, and soil pF (Sofyan *et al*., 2017). Considering that soil water retention will be one of the limiting factors in maintaining the productivity of horticultural crops, this research needs to be carried out to determine the soil's ability to hold water so that it is available to plants. Hopefully, this research will be helpful for farmers at the research location and provide information for future research. Similar research has never been carried out in the research area. This research aims to map the distribution of groundwater retention and several soil physical properties in Sumber Urip Village, Selupu Rejang District, Rejang Lebong Regency.

MATERIALS AND METHODS

This research was conducted from October 2022 to April 2023 in Sumber Urip Village, Selupu Rejang District, Rejang Lebong Regency, Bengkulu Province, which is located at coordinates 102º37'55”-102º39'56” East Longitude and 3º27'45”- 3º29'32” . The soil samples obtained were analyzed at the Soil Science Laboratory, Faculty of Agriculture, Bengkulu University.

The Sumber Urip Village administrative map is a map used as a base map to determine the administrative boundaries of Sumber Urip Village. Information on the slope of Sumber Urip Village was made from the Digital Elevation Model (DEM) obtained from the DEMNAS website which was then processed using ArcGIS 10.3. Based on the 1986 Guidelines for Preparing Land Rehabilitation and Soil Conservation Patterns in Manabung et al. (2021), the slope is classified into 5 classes, namely 0-8% flat, 8-15% sloping, 15-25% rather steep, 25-45% steep, and > 45% very steep.

The Sumber Urip Village Land Use Map was created based on Google satellite imagery downloaded from the SAS Planet application which was then digitized manually with three land cover components, namely horticultural agricultural land, residential land, and shrub land. Land use for agricultural activities in Sumber Urip Village is + 469 ha.

The map components obtained are superimposed (overlaid) to become a working map. Determining the location for taking soil sample points using the stratified sampling method with slope class as the differentiator. The slope class that has the largest area has the most sampling points and vice versa.

This research began by collecting the necessary tools and materials, arranging permits to carry out field surveys, and creating a 1:15,000 scale work map using the stratified sampling method with slope as the differentiator. The number of samples taken at the research location is presented in Table 1.

Table 1. Number of samples based on slope class

Slope class (%)		Agricultural area (ha)	Number of samples
0 – 8	Flat to gentle undulat-	130	9
8 – 15	Undulating	103	7
15 – 25	Moderately steep	79	5
25 – 45	Steep	124	8
>45	Very steep	33	2
	Total	469	31

The initial survey is the first step to directly inspect the research area to obtain an overview of field conditions and determine the location for observations and soil sampling. This observation is carried out to determine the geographic position of sample points in the field by matching the points determined on the map with actual conditions in the field.

The primary survey is carried out by taking soil samples at locations corresponding to the work map's observation points. The selected sample points are points that fall in agricultural areas. At each selected sample point, 3 whole soil samples will be taken at a 0-5 cm depth using a sample ring. Disturbed soil samples were taken using a mineral soil drill to a 0-20 cm depth. Researchers also compiled a questionnaire to obtain additional information. The questionnaire contained questions about intensive agricultural land management carried out by farmers in the research area with 20 informants.

The variables observed in this research include soil texture, which is determined based on the hydrometer method (Musdalipa *et al*., 2018), total pore space determined based on the gravimetric method (Priatna, 2019), soil bulk density (Nurhartanto *et al*., 2022), soil permeability based on the constant head permeameter method (Putri *et al*., 2020), soil pF (potential of free energy) based on the pressure plate apparatus (Rusman *et al*., 2015), and soil water content based on the gravimetric method which measures differences weight (Yusnaini *et al*., 2022). The data analysis stages were carried out to interpret laboratory analysis data in a qualitative descriptive manner. The data that has been obtained is analyzed using a GIS or Geographic Information System application. GIS can summarize survey data information more simply. This makes it easier to carry out data analysis (Sutarto *et al*., 2017).

RESULTS AND DISCUSSION

Sumber Urip Village's relief ranges from flat to gentle undulating to very steep, and some have highlands. This village's widest distribution of soil types is soil in the order Inceptisols. 70% of the Sumber Urip Village area is used as agricultural land with horticultural crops as a superior commodity, and the other 30% of the area is residential and bushland. Most residents in Sumber Urip Village rely on the agricultural sector as their main livelihood.

The clay fraction will form micropores so that water retention is solid. The soil in this condition is not porous, so water and air circulation is difficult, but the water in the soil only disappears slowly. The sand fraction will form macro pores, which will cause very weak water retention. Soil with this condition has straightforward circulation between water and air, but only a little water is retained in the soil (Jayanti & Mowidu, 2015). The results of soil texture analysis are presented in Table 2.

Table 2. The results of soil texture analysis

Slope class (%)		Textur (%)			Criteria
		Sand	Clay	Silt	
0 - 8	Flat to gentle undulating	80	6.68	13.31	Loamy sand
8 – 15	Undulating	81.96	7.05	10.99	Loamy sand
15 - 25	Moderately steep	81.02	6.91	12.07	Loamy sand
25 - 45	Steep	79.21	6.28	14.51	Loamy sand
>45	Very steep	78.21	6.9	14.88	Loamy sand

Soil texture data shows that soil samples from 5 slope classes covering an area of 469 ha only have one soil texture class, namely clayey sand with a dominant sand fraction of 70% to 90%. This aligns with the distribution of soil types in Sumber Urip Village based on sheet 0912, namely the Inceptisols soil order, which is identical to young, newly developing soil with sand particles that dominate. According to Zainab *et al*. (2019), clayey sandy soil has a high percentage of sand, so macro pores dominate the soil. Soil with this texture has low aggregation, so its ability to hold water and nutrients is also low. This type of soil texture is generally unsuitable for plants with shallow roots, such as horticultural plants developed by farmers in Sumber Urip Village, because the soil cannot hold plant bodies firmly. However, adding organic material can overcome the problem of soil aggregate formation. In the interview results, 95% of informants used organic materials as soil amendments to improve soil aggregation. This remedial action will improve soil aggregation while increasing soil water retention.

Soil porosity is formed based on the fractions that make up the soil. Soil with a sand texture will make macro pores more dominant, allowing water to infiltrate quickly. Clay textured soil has more dominant micropores, so water will be retained longer but causes large amounts of surface runoff if the water received exceeds its holding capacity. A soil texture good at holding groundwater is a clay texture with meso pores in a more dominant number than macro pores and micropores. Mesopores can hold water well to meet plants' water needs (Fadel *et al*., 2021). The results of the total pore space analysis are presented in Table 3.

Table 3. The results of the total pore space analysis

Slope class (%)		Total Pore Space (%)	Criteria
0 – 8	Flat to gentle undulating	55.5	Moderate
8 – 15	Undulating	54.03	Moderate
15 – 25	Moderately steep	47.16	Low
25 - 45	Steep	59.02	High
>45	Very steep	57.76	Moderate

The higher the amount of organic matter in the soil results in the lower the bulk density of the soil and the higher the total pore space. Soil pores are divided into macro, meso, and micropores, which determine the capacity of the soil to hold water (Margolang *et al*., 2015). The total pore space data analyzed shows that slopes of 0-8%, 8-15%, and 45% with an area of 239 ha have moderate total pore space. The 15-25% slope class with an area of 79 ha has low total pore space, while for the 25-45% slope class with an area of 124 ha the total pore space is high. This is related to the intensity of land processing on the land. From the results of the interviews, information was obtained that 10% of the informants cultivated the land once a year, 30% of the informants cultivated the land twice a year, 30% of the informants cultivated the land 3x a year, 20% of the informants cultivated the land 4x a year. The other 10% of the informants cultivated the land 5x a year. However, this questionnaire has not tracked the level of land cultivation with slope. According to Suburika *et al*. (2018), processing the soil in making beds makes the soil pores open correctly, and the soil becomes loose for a while. However, over a long period, this will cause a decrease in soil porosity because the broken particles will close the soil pores. The total pore space of the soil will significantly influence soil water retention. To maintain total porosity, Actions need to be taken, such as adding organic material or carrying out minimum tillage.

The size of the soil bulk density value is influenced by the specific gravity and arrangement of particles and the organic material content (Faridlah *et al*., 2016). The results of the soil bulk density analysis are presented in Table 4.

Table 4. The results of the soil bulk density analysis

	Slope class (%)	BV (g cm^{-3})	Criteria
0 - 8	Flat to gentle undulat-	0.91	Moderate
8 – 15	Undulating	0.92	Moderate
15 - 25	Moderately steep	0.91	Moderate
25 - 45	Steep	0.86	Moderate
>45	Very steep	0.88	Moderate

Soil with high organic matter results in low soil bulk density, so the soil becomes very loose. Providing organic material affects the amount of water available in the soil. Organic matter contained in soil can absorb water, namely 2 to 4 times its weight (Intara *et al*., 2011). The analyzed soil bulk density data shows that soil samples from 5 slope classes with an area of 469 ha have the same soil bulk density class, namely medium with an interval of 0.86-0.92 g cm^{-3}. The bulk density of soil at this interval is quite suitable for plant root growth because the soil can hold the plant upright, and the plant roots can easily penetrate. According to Haryati (2014), the soil in dry land horticultural crop cultivation in the highlands with a wet climate usually has low to moderate soil bulk density. This soil has characteristics including loose particles that are easily penetrated by plant roots. However, the soil will pass water more quickly to the lower layers of the soil, so proper management is needed to overcome this problem. One way that can be done to overcome this problem is by providing organic materials.

Soil permeability shows the ability of the soil to pass water through it. Soil permeability can be influenced by physical conditions, namely soil texture and soil chemistry, namely the amount of soil organic matter (Penhen *et al*., 2022). The results of the soil permeability analysis are presented in Table 5.

Soil dominated by the sand fraction will leak water very quickly because its macropores cannot hold water (Soputan *et al*., 2022). The analyzed soil permeability data shows that soil samples from 5 slope classes covering an area of 469 ha have the same soil permeability class, namely very fast. This can happen because the soil texture in the research area is uniform, namely clayey sand. According to Siahaan & Kusuma (2021), the number and size of soil pores determine whether soil permeability is low or high. The considerable permeability value is caused by large porosity, so the permeability and porosity values are directly proportional. A permeability value that is too large means that more water received by the soil will move underground (infiltration). At the same time, if the permeability value is too small, more water received by the soil will become surface flow (runoff). According to Kias *et al*. (2016), organic materials can increase the soil's ability to store water, increase soil infiltration, and slow surface flow .

Table 5. The results of the soil permeability analysis

Slope class (%)		Soil permeability (cm $hour^{-1)}$	Criteria
0 - 8	Flat to gentle undulating	102.79	Very fast
8 – 15	Undulating	63.05	Very fast
15 - 25	Moderately steep	107.38	Very fast
25 - 45	Steep	143.22	Very fast
>45	Very steep	88.89	Very fast

The potential of free energy (pF) of soil is the ability of the soil to bind the water in it. The measurement can be done using a pressure membrane apparatus, hanging water column, or pressure plate apparatus. The pressure used in the pressure plate apparatus is 0 atm (pF 0), 0.1 atm (pF 2), 0.33 atm (pF 2.54), and 15 atm (pF 4.2). The fast drainage pore is obtained from the difference between pF 0 and pF 2.0. A pF value of 0 without pressure is a condition where the soil is saturated; pF 2.0 with a pressure of 0.1 atm is when the drainage flow stops quickly. Slow drainage pores are obtained from the difference between pF 2.00 and pF 2.54. Total drainage pores are the sum of fast and slow drainage pores. A pF value of 2.54 with a pressure of 0.33 atm is a condition when the slow drainage pore flow stops. Water available to plants can be determined from the difference between pF 2.54 and pF 4.2. A pF value of 4.2 with pressure means the soil is at a permanent wilting point. Plants cannot grow in soil with a permanent wilting point because water cannot be available. Soil pF values can also represent the distribution of soil pore sizes (Tutkey *et al*., 2017). The results of calculating this variable are presented in Table 6.

The soil pF data analyzed did not meet the criteria for calculation, as explained in the first paragraph, due to the limited capabilities of the equipment available at the Soil Science Laboratory, Faculty of Agriculture, Bengkulu University. Hence, the researchers only presented the difference between the saturated weight of the soil and the weight of the soil after being pressurized at 0.1 atm using a pressure plate apparatus. Data obtained on slopes of 0-8%, 8-15%, and 8-25% with an area of 312 ha are in the medium class; on slopes of 25-45% with an area of 124 ha, the difference is high, and on slopes >45% with an area of 33 ha the difference in weight is low. The difference between saturated pF and pF after applying a pressure of 0.1 atm shows the amount of water the soil can hold. This difference in pF class occurs because of the difference in soil volume weight in the 25-45% slope class; the lowest is 0.86 g cm^{-3}, and the highest total pore space is 59.02%. It can be concluded that in this slope class, meso and micropores are dominant and can hold water well. Land with a slope >45% has a soil volume weight of only 0.88 g cm^{-3} and a total pore space of 57.76%. It can be concluded that the soil in this slope class is dominated by macro pores, which cannot hold water well, so that the difference between saturated pF and pF after giving a low pressure of 0.1 atm.

Table 6. Calculation results of the difference between saturated soil and pF pressure of 0.1 atm

Slope class (%)		pF - 0.1 atm (g)	Criteria
0 - 8	Flat to gentle undulat-	14.3	Moderate
8 – 15	Undulating	15.53	Moderate
15 - 25	Moderately steep	12.5	Moderate
25 - 45	Steep	19.59	High
>45	Very steep	8.05	Low

Soil water content can be determined using two methods, namely directly measuring differences in soil weight using the gravimetric method or indirectly through measuring other physical soil variables that are related to soil water availability (Ahmad *et al*., 2022). The results of soil water content analysis are presented in Table 7.

Soil water content will decrease as the slope becomes steeper, but at the research location conservation methods have been implemented, namely making terraces, so that soil water content is more influenced by elevation than slope. This is in line with the concept of water movement where water will move from high places to lower places (Zauhairah *et al*., 2022). Soil water content data analyzed in the research area shows that the slope is 0-8%; 8-15% and 25-45% with an area of 357 ha have moderate soil water content. This moderate or sufficient water content is very good for plants because it is able to supply water needs well. Slope class 15-25% with an area of 79 ha has high ground water content. This high water content can occur because the organic material content is quite high in the observation area. Meanwhile, for the slope class >45% with an area of 33 ha, the soil water content is low, this will inhibit plant activity because the soil is unable to supply water so that many chemical processes in plants do not run smoothly

Table 7. The results of soil water content analysis

Slope class (%)		Soil water content (%)	Criteria
0 - 8	Flat to gentle undu-	7.51	Moderate
8 – 15	Undulating	7.52	Moderate
15 - 25	Moderately steep	14.15	High
25 - 45	Steep	9.64	Moderate
>45	Very steep	4.21	Low

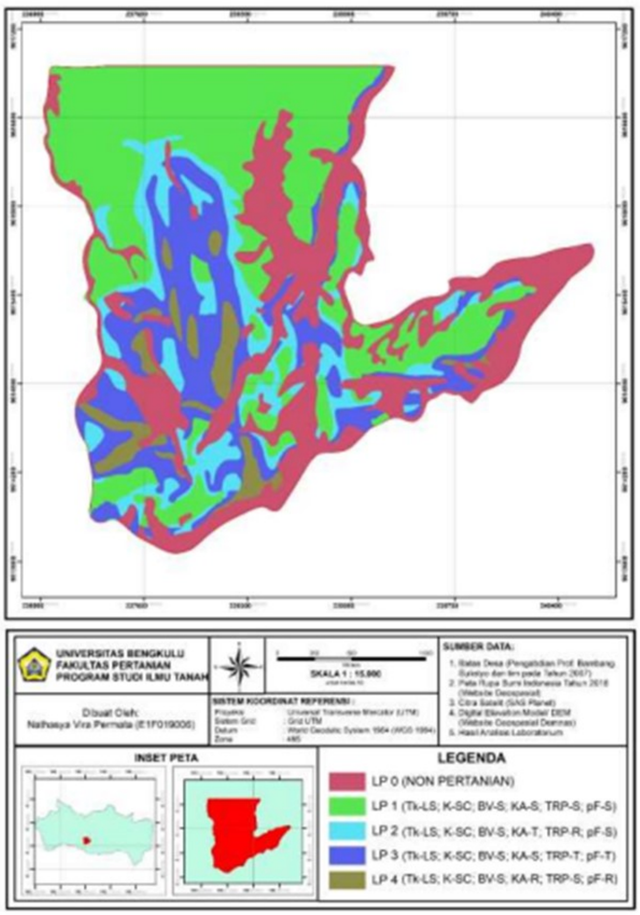
Soil water retention can be determined from the relationship between observed variables. Agricultural land in all slope classes with a total area of 469 ha has the same texture, namely clayey sand and very fast permeability and medium class volume weight. Soil with a clayey sand texture has very low water retention because soil with a sand-dominated texture has high macropores, so adding organic material to improve soil aggregates is necessary. Apart from that, organic matter can maintain the stability of soil volume and will slow down soil permeability so that water will be retained for a longer time and can be utilized by plants.

LP code 1 on a slope of 0-15% with a total area of 233 ha has a medium total pore space, which can retain sufficient water for plants. The difference between the weight of saturated soil and the weight after being subjected to moderate pressure of 0.1 atm and moderate water content shows that this soil holds water well. Land with code LP 1 does not require improvements in soil management because its physical properties are good enough to support plant growth. After all, the soil management implemented has been proven to maintain soil water retention quite well.

Code LP 2 on a slope of 15-25% with an area of 79 ha has a low total pore space which can occur due to quite intensive tillage practices, as in the interview results, 60% of informants tilled the land 3-5x in one year. This shows that in the long term intensive tillage practices do not have a good impact on the soil because it will destroy soil aggregates. The difference between the weight of saturated soil and the weight after being pressurized at 0.1 atm indicates that water is available in sufficient quantities. High water content can occur due to high organic material content. Land with code LP 2 requires an additional volume of organic material to overcome the low total soil pore space in order to maintain the stability of the soil's ability to hold water.

LP code 3 on a slope of 25-45% with an area of 124 ha has high total pore space, and the difference between the weight of saturated soil and the weight after pressure of 0.1 atm is high, and the water content is moderate. This shows that the physical properties of the soil on land with the LP code 3 are very good at supporting the growth of horticultural plants. Interview results showed that 65% of informants implemented terrace construction and installation of plastic mulch, while 35% of other informants only implemented terrace construction. Conservation practices have been proven to help maintain the quality of soil physical properties to increase soil water retention.

Figure 1. Overlapping results of observation variables



LP code 4 on slopes > 45% with an area of 33 ha has a medium total pore space because at least one organic material is applied in one planting period. The difference between the saturated weight of the soil and the weight after being subjected to low pressure of 0.1 atm and low water content is caused by a very steep slope, so the rate of surface flow and erosion is very high. The impact of rainwater directly on the soil will destroy soil aggregates. Soil particles released due to the impact of rainwater, including organic material, will be transported by surface flows to the lower slopes and then settle—the loss of soil organic matter through the erosion process results in a decrease in soil water retention. Land with an LP 4 code requires conservation practices such as building terraces and installing plastic mulch.

CONCLUSION

Agricultural land on a slope of 0-15% with a total area of 233 ha has good soil water retention seen from the physical properties of the soil, so there is no need to improve soil management. Agricultural land on a slope of 15-25% with an area of 79 ha requires additional treatment to increase water retention by adding soil amendments to increase total soil pore space. Agricultural land on a slope of 25-45% with an area of 124 ha has excellent soil water retention supported by soil conservation practices in making terraces and installing plastic mulch. Agricultural land on a slope >45% with an area of 33 ha has poor soil water retention, so soil conservation practices are needed.

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