Analysis of Soil Damage on Dry Land Based on Geographic Information System in Sawan Sub-Distric, Buleleng Regency

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Received:- 25 May 2025/ Revised:- 08 June 2025/ Accepted:- 15 June 2025/ Published: 30-06-2025

Abstract— *Sawan sub-district is one of the sub-districts in Buleleng Regency, part of which is dry land with an area of 3,144.06 ha. Dry land productivity in Sawan Sub-district is vulnerable to decline because land management is still not in accordance with conservation principles. The purpose of the study was to determine the potential for soil damage, the status of soil damage, the distribution of soil damage, and the direction of soil damage management on dry land in Sawan District. The method in this study used a comparative descriptive method. Parameters observed in the field include surface rock and soil solum depth while parameters analyzed in the laboratory are content weight, fraction composition, permeability, total porosity, pH, DHL, number of microbes and C-organic content. Based on the overlay of land use map, rainfall map, slope map, and soil type map using geographic information system, 17 SLH were obtained. The results showed two classes of potential soil damage, namely the potential for mild soil damage in Bebetin Village, Suwug Village, Sekumpul Village with a distribution percentage of 64.7% and the potential for moderate damage in Sudaji Village, Giri Emas Village, Lemukih Village, Bebetin Village and Sekumpul Village with a distribution percentage of 29.4%. Soil damage status classified as light in Bebetin Village, Giri Emas Village, Lemukih Village, Sekumpul Village and Sudaji Village with a distribution percentage of 64.7%, no factors causing soil damage status were found so that it is classified as good. Lightly damaged soil status with limiting factors of permeability is found in Sudaji Village, Suwug Village and Lemukih Village with a distribution percentage of 29.4%. Lightly damaged soil status with limiting factors of content weight, pH, and permeability is found in Bungkulan Village with a distribution percentage of 5.8%. Recommendations for improvement are the addition of organic matter and soil management can be done by planting cover crops or by crop rotation*.

Keywords— Potential For Land Damage, Status of Land Damage, Dry Land, Sawan District.

I. INTRODUCTION

Soil is the provider of all needs in supporting plant growth and production. Soil is one of the growing mediums of plants, both plants in dry and wet land farms. The soil always undergoes changes caused by materials from the soil itself or materials from outside the soil (Suripin, 2002). Drylands are lands that are never inundated with water throughout the year. It relies on rainwater as its main source of water and rarely experiences permanent inundation. Drylands are used for moorland, mixed gardens, plantations, forests and so on. Management of biomass production that does not pay attention to conservation principles, such as the selection of vegetation types on agricultural land and the use of synthetic chemicals that exceed the recommended limit, can cause soil damage. This damage is characterized by changes in soil properties that exceed the threshold of soil damage criteria, thus reducing the ability of soil to support biomass production (Government Regulation No. 150 of 2000).

Based on data from the Central Bureau of Statistics, Sawan District shows a decrease in productivity from year to year. Some dryland commodities that have decreased are cayenne pepper and shallots. Cayenne pepper productivity from 2020 to 2021 has decreased by 71 tons and shallot productivity from 2020 to 2021 has decreased by 260 tons (BPS Kecamatan Sawan, 2023). Based on data from the Directorate General of Horticultural Crops in 2015, the target production of cayenne pepper plants is 9-20 tons/ha and for shallot plants is 18-20 tons/ha. The decline is thought to be caused by soil damage and lower soil fertility levels, so an assessment of the potential and status of dryland soil damage and land management in Sawan District, Buleleng Regency is needed.

II. MATERIAL AND METHODS

The research was conducted from June to December 2024, on dry land in Sawan District, Buleleng Regency. Analysis of soil physical, chemical, and biological properties was carried out at the Soil and Environment Laboratory, Faculty of Agriculture, Udayana University, Denpasar.

The materials used in the research were the map of Sawan Subdistrict, soil type map with a scale of 1:100,000, land use map with a scale of 1:100,000, slope map with a scale of 1:100,000, rainfall data, Rupa Bumi Indonesia (RBI) map, soil as a sample analysis, and chemicals for sample analysis in the laboratory.

The tools used were laptop, QGIS 3.24.1 application, GPS (Geographic Positioning System), abney level, sample ring, soil drill, field knife, plastic, pH meter, 2 mm sieve, measuring cup, volume pipette, rubber suction, detrition device, distillation device, boiling flask, titration device, petri dish, pycnometer, test tube, filter paper, scale, pipette, The research was conducted using a comparative descriptive method with field surveys, laboratory analysis and scoring of potential soil damage based on Permen LH No. 20 of 2008. The status of soil damage in this study was determined based on the standard criteria for soil damage (Permen LH No. 07, 2006). Kartini et al. (2023) have conducted research in the Baturiti District area, especially on dry land based on the same approach. Physical parameters are soil depth, surface rock, content weight, fraction composition, permeability, total porosity. Chemical parameters, namely pH and DHL, and biological parameters, namely the number of microbes, were analyzed in the laboratory. The damage status was determined based on the critical threshold set in Government Regulation No. 150 of 2000.

The research implementation consisted of several stages, namely: 1) literature study stage, 2) determination of homogeneous land units, 3) field survey and sampling, 4) laboratory analysis, 5) data analysis and evaluation of soil damage status, 6) determination of damage status and making maps of soil damage distribution. Homogeneous land units of the research area are presented in Table 1 and Figure 1.

TABLE 1
HOMOGENEOUS LAND UNITS OF THE STUDY AREA

No	SLH	Land Use	Slopes (%)	Soil Type	Extensive (ha)
1	Sudaji Village	Field	25-40	Oxisol	145.5
2	Bebetin Village	Field	8-15	Oxisol	544.57
3	Giri Emas Village	Field	0-8	Entisol	595.6
4	Lemukih Village	Field	25-40	Entisol	153.2
5	Lemukih Village	Field	8-15	Entisol	1,001.83
6	Bungkulan Village	Field	0-8	Entisol	50.52
7	Galungan Village	Field	25-40	Oxisol	164.21
8	Bebetin Village	Mixed Garden	8-15	Oxisol	88.75
9	Suwug Village	Mixed Garden	0-8	Entisol	149.47
10	Lemukih Village	Mixed Garden	25-40	Entisol	249.19
11	Suwug Village	Mixed Garden	8-15	Entisol	411.81
12	Lemukih Village	Mixed Garden	15-25	Entisol	70.63
13	Bebetin Village	Mixed Garden	8-15	Oxisol	85.11
14	Sekumpul Village	Mixed Garden	15-25	Oxisol	51.24
15	Sekumpul Village	Mixed Garden	15-25	Entisol	321.93
16	Sudaji Village	Mixed Garden	25-40	Oxisol	24.82
17	Sekumpul Village	Mixed Garden	>40	Oxisol	37.51
	Total area of the research area				**3,144.06**

Source: Spatial data Analysis

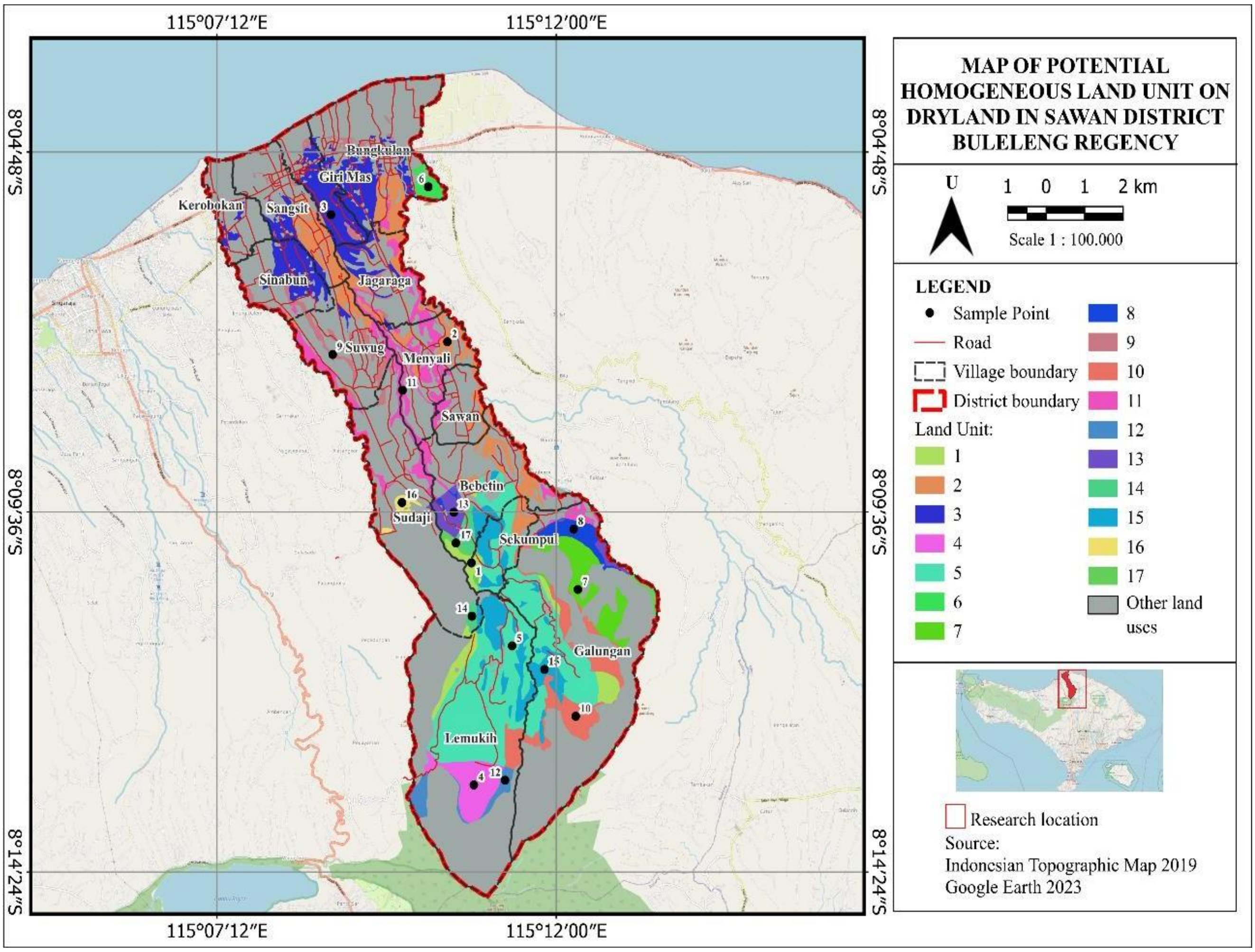

FIGURE 1: Map of dry land homogeneous land units in Sawan District

2.1 Determination of Potential Soil Damage:

The score of potential soil damage on dry land is determined based on the results of the analysis with the scoring method on each parameter. The score and potential for dryland soil damage in Sawan Subdistrict are determined based on the results of multiplying the rating values of land use, slope, soil type, and rainfall by the weight value. The distribution map of potential soil damage is obtained based on the value of the results of the overlay map of slope, soil type, land use and rainfall. Classes of potential soil damage are presented in Table 2.

TABLE 2
POTENTIAL SOIL DAMAGE CLASS

Symbol	Potensi Kerusakan Tanah	Weighting Score
PR.I	Very Light	<15
PR.II	Light	15-24
PR.III	Medium	25-34
PR.IV	High	35-44
PR.V	Very High	45-50

Source: Regulation of the Minister of Environment Number 20 of 2008

2.2 Soil Damage Status Analysis:

Physical, chemical, and biological properties of soil based on soil damage parameters based on the standard criteria for soil damage (PP No. 150/2000) were analyzed by means of field observations and laboratory analysis. The analyzed parameters are presented in Table 3.

TABLE 3
SOIL DAMAGE EVALUATION PARAMETER

No.	Parameters	Symbol	Ambang Kritis (PP 150/2000)
1	Soil Thickness	s	<20 cm
2	Surface Rock	b	>40%
3	Fraction Composition	f	<18% koloid; >80% pasir kuarsitik
4	Content Weight	d	>1,4 g/cm^3
5	Total Porosity	v	<30 %; >70 %
6	Degree of Water Smoothness	p	<0,7 cm/jam >8,0 cm/jam
7	pH (H2O) 1:2,5	a	<4,0;>7,0
8	Electrical Conductivity/DHL	c	>4,0 mS/cm
9	Microbial Count	m	$<10^2$ cfu/g soil

Source: Government Regulation Number 150 of 2000

2.3 Determination of Soil Damage Status:

Determination of soil damage status is done by scoring based on the relative frequency (%) of each parameter used. The relative frequency of soil damage is the percentage value of soil damage based on the comparison of the number of soil samples classified as damaged to the total number of samples observed and analyzed in each parameter (Permen LH No. 20, 2008). The score value of all parameters is used to determine the category of soil damage status. Soil damage status is categorized into five, namely not damaged (N), lightly damaged (R.I), moderately damaged (R.II), severely damaged (R.III), and very severely damaged (R.IV).

III. RESULTS AND DISCUSSION

3.1 Potential Land Damage In Sawan Sub-District:

Soil Damage Potential on dry land in the research area based on the results of the analysis with the scoring method, there are two classes of potential damage to dry land soils, namely the class of light and medium damage potential. The potential for light damage to dry land in Sawan Sub-district with the symbol PR.II is scattered in SLH 2, 8, 9, 11, 13 and 14 located in Bebetin Village, Suwug Village and Sekumpul Village spread over an area of 1,330.95 ha with a percentage of 35.3%. The potential for moderate damage with the symbol PR.III is scattered in SLH 1, 3, 4, 5, 6, 7, 10, 12, 15 16 and 17 located in Sudaji Village, Giri Emas Village, Galungan Village, Lemukih Village, Bungkulan Village, Bebetin Village and Sekumpul Village spread over an area of 1,813.11 ha with a percentage of 64.7%. Scores and classes of potential dryland soil damage in Sawan Sub-district are presented in Table 4.

TABLE 4
SCORE AND POTENTIAL SOIL DAMAGE

No	Score	Potential Land Damage	Symbol	Area (ha)
1	15-24	Light	PR.II	1,330,95
2	25-34	Medium	PR.III	1,813,11

Source: Regulation of the Minister of Environment Number 20 of 2008

The class of light soil damage potential in the study area is influenced by land use and slope. This potential for minor damage is different on each dry land in all SLH, 17 sample points have 2 types of land use, namely mixed gardens and fields, rainfall of 1000-2000 mm/year, soil types yellowish brown Latosol, gray brown Regosol, brown Regosol. However, there are differences in the slope class of each SLH.

Uncontrolled land management and utilization can cause soil damage which has an impact on the decline in soil function and quality (Dela Rosa, 2005). Soil damage will result in damage to the basic properties of the soil, both physical, chemical, and biological properties of the soil, so that it can interfere with the process of plant growth. The inhibition of plant growth will result in reduced biomass production (Arisandi et al., 2015).

The rainfall situation in the dryland is 1000-2000 mm/year. Rainfall intensity and slope slope produce an influence that is directly proportional to soil erosion which has an impact on the potential for soil damage to be higher (Sitepu et al., 2017). Soil erosion has a major negative impact on changes in soil physical properties including soil structure, soil texture, soil moisture content, and soil content density over a long period of time (Trigunasih and Saifulloh, 2023). Other studies have found that the potential for soil damage is closely related to unproductive land areas due to the impact of eruptions and landslides (Trigunasih et al., 2023; Diara et al., 2023). In land management, it is important to pay attention to this factor to optimize soil conservation and prevent land degradation. High slope can cause a decrease in soil pH due to erosion which increases the loss of soil nutrients and bases (Septiaji et al., 2024). The first step in overcoming soil damage is to inventory the potential for soil damage in an area. Inventory can be done by spatial mapping, especially of potential soil damage factors (Lias, 2021).

3.2 Status of Soil Damage in Sawan Sub-District:

The results of the analysis of soil physical, chemical and biological properties were matched with the standard criteria for soil damage in Government Regulation No. 150 of 2000, there were three parameters that exceeded the critical threshold of soil damage, namely content weight, pH and permeability in several SLH. Based on the relative frequency, the content weight parameter obtained a damage of 6%, the pH parameter obtained a damage of 6% and the permeability parameter obtained a damage of 35%. The total score obtained from the relative frequency of damaged soil on dry land in Sawan Subdistrict is 2 which indicates that the area has a lightly damaged soil damage status. The determination of the results of the relative frequency of damaged soil and soil damage status is presented in Table 5.

TABLE 5
RESULT OF ACCUMULATIVE SCORE OF SOIL DAMAGE

No.	Parameter	Relative Frequency of Damaged Tanah	Skor	Status
1	Soil Thickness	0	0	Not Damaged
2	Surface Rock	0	0	Not Damaged
3	Fraction Composition	0	0	Not Damaged
4	Weight Content	6	0	Not Damaged
5	Total Porosity	0	0	Not Damaged
6	Permeability	35	2	Not Damaged
7	pH (H2O) 1:2,5	6	0	Not Damaged
8	Electrial Conductivity	0	0	Not Damaged
9	Microbial Count	0	0	Not Damaged
Total Score			2	Mildly Damaged

Source: Government Regulation Number 150 year 2000

The results of the analysis show that dryland in Sawan Subdistrict has a lightly damaged status with the factors causing damage are content weight, pH and permeability. Weight content becomes a damage factor when it is higher than the critical threshold of soil damage $(1{,}4\ g/\mathrm{cm}^3)$. High weight contents indicate soil compaction, which can inhibit plant root growth, reduce water infiltration, and limit soil aeration (Brady & Weil, 2016).

Compacted soil has fewer and smaller pores, making it difficult for plant roots to penetrate, roots tend to grow shallowly and spread laterally rather than penetrating deeper in search of water and nutrients. As a result, plants are more susceptible to drought and nutrient deficiencies as they cannot access resources in deeper soil layers.

Based on the data from the analysis of soil damage status, permeability in some SLH is classified as damaged with a percentage of 17.6%. Soil permeability affects the ability of soil to pass water, which is important to ensure water availability for plants (Hura, 2024). Low permeability can be caused by soil compaction, high clay content, or lack of organic matter. As mentioned earlier, the addition of organic matter can increase soil permeability by improving soil structure and increasing pore space (Lal, 2004). According to Andyana, el al (2023) the wetter (moister) a soil is, the lower its permeability value. In drier soils, high permeability will result in a reduced ability of the soil to hold water and nutrients.

Based on the data from the analysis of soil damage status, the pH in one SLH is classified as damaged with a percentage of 5.8%. Soil pH indicates the acidity or basicity of the soil, and the ideal pH for most plants is between 6.0 and 7.0 (Havlin et al., 2016). pH that is too low (acidic) or too high (basic) can affect the availability of nutrients for plants. In terms of soil type, laboratory test results show that the permeability value of Entisol soil is the highest compared to Ultisol and Inceptisol soils, this is due to the high sand composition of Entisol soil, which is 50.05%, so that the soil easily passes water and reduces the occurrence of surface flow (Surono at al., 2013). Hardjowigeno (2003) stated that the first factor affecting the formation process of Entisol is a very dry climate, so weathering and chemical reactions run very slowly. Oxisol is a mineral soil that has undergone advanced weathering. This soil is commonly called old soil. The specific feature of Oxisol soils is the presence of oxic horizons whose upper limit is at a depth of 150 cm or less from the surface of the mineral soil and there are no kandic horizons at that depth (Hardjowigeno, 2003; Soil survey staff, 2014). In addition, Oxisol soils are characterized by low natural fertility, low organic matter content, and relatively acid pH (Carducci et al., 2017).

3.3 Distribution of Potential and Status of Soil Damage in Sawan Sub- District:

The distribution of potential soil damage on dry land varies in Sawan Sub-district, Buleleng Regency. The potential for light damage is spread in SLH 2, 3, 4, 5, 7, 8, 10, 13, 14, 15 and 16 with a percentage of 64.7%. Medium damage potential is spread in SLH 1, 9, 11, 12 and 17 with a percentage of 29.4% and potential for light damage in SLH 6 with a percentage of 5.8%. The distribution map of potential soil damage is presented in Figure 2.

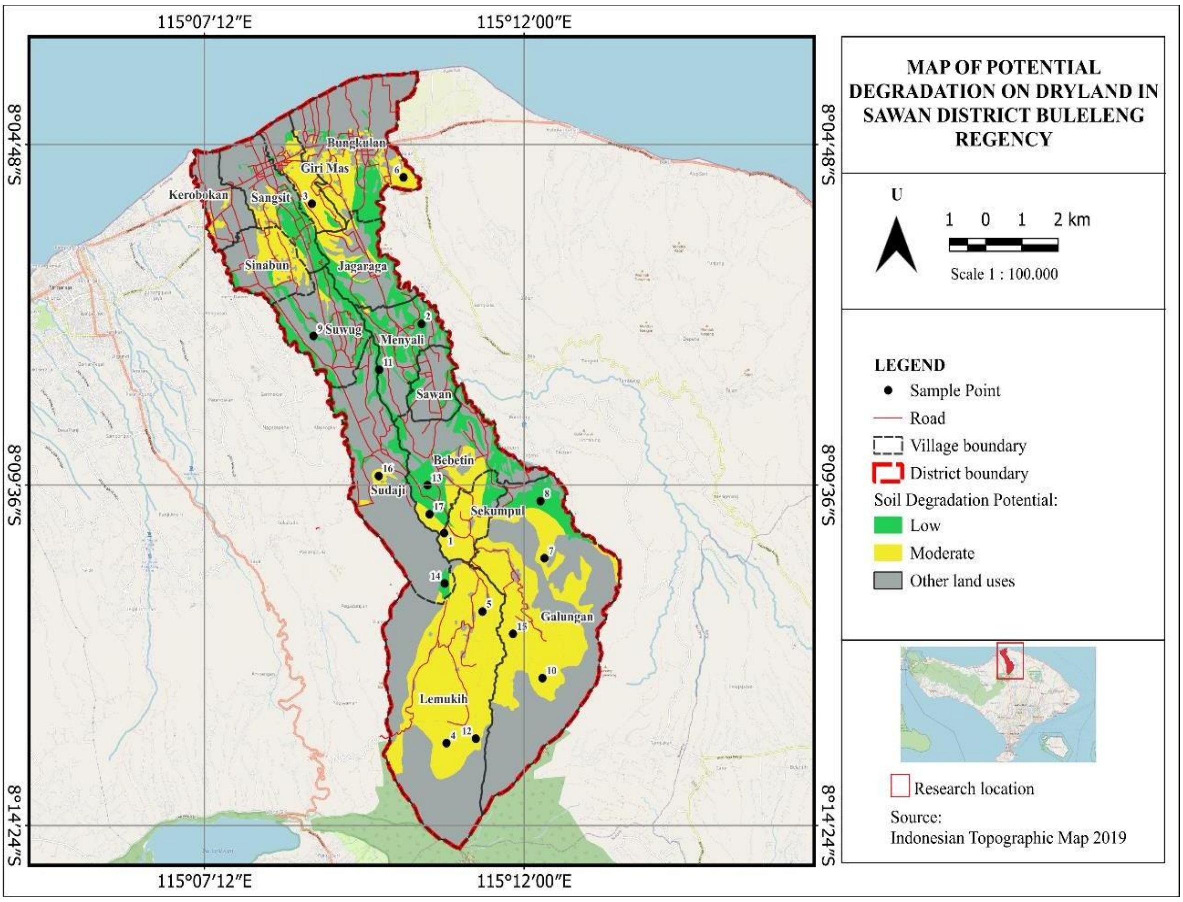

FIGURE 2: Map of Potential Damage to Dry Land in Sawan Sub-District

The actual conditions in the field only show land with mild soil damage status which is divided into three classes based on the limiting factors in it. In SLH 2, 3, 4, 5, 7, 8, 10, 13, 14, 15 and 16 which are located in Bebetin Village, Giri Emas Village, Lemukih Village, Sekumpul Village and Sudaji Village covering an area of 2,278.62 ha with a percentage of 64.7% no factors causing soil damage status were found so that it is classified as good (N). In SLH 1, 9, 11, 12 and 17 located in Sudaji Village, Suwug Village and Lemukih Village covering an area of 814.92 ha with a percentage of 29.4% potential for light damage factor of mild soil damage status on dry land is permeability (R.I.p). In SLH 6 in Bungkulan Village spread over an area of 50.52 ha with a percentage of 5.8% the factors causing the status of heavy soil damage on dry land are content weight, pH, and permeability (R.I.d.p.a). Field conditions that have undergone various changes such as land management by farmers and conservation measures applied are factors that differentiate the results of the analysis between the potential and status of soil damage. A map of the actual distribution of the soil damage status is presented in figure 3.

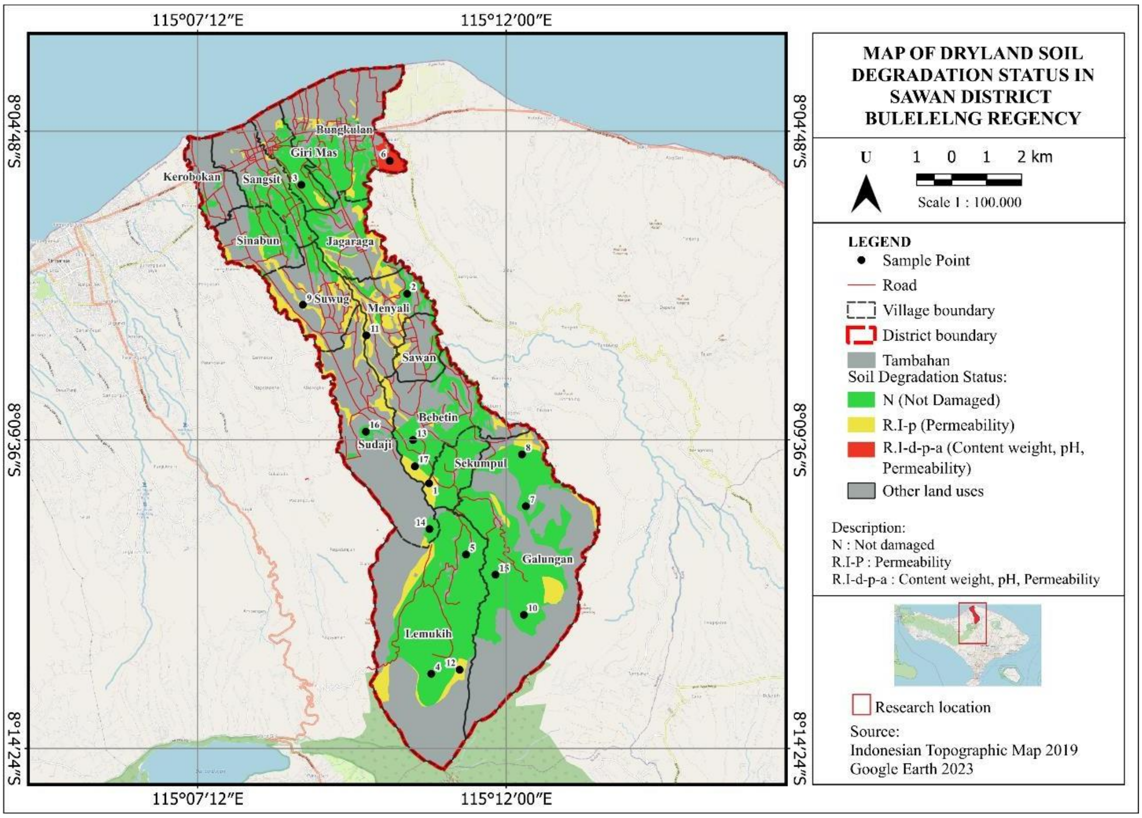

FIGURE 3: Map of Dry Land Soil Damage Status in Sawan Sub-District

3.4 Improvement Efforts:

Soil improvement efforts can be done by adding organic materials and tillage. The application of organic matter in the form of compost or manure into the soil causes an increase in soil C-organic levels (Syukur and Indah, 2006). Barzegar et al. (2002) reported that the application of organic matter in the form of manure plays a role in improving the weight of soil content in the tillage layer (0-20 cm). Organic matter also provides nutrients for microbial activity in decomposition activities, improves soil stability, and increases soil recoverability (Limbong, 2017). Therefore, the addition of organic matter is a comprehensive strategy to improve soil quality and increase agricultural productivity. The positive impact of this improvement is that it can increase soil looseness, improve soil aeration and drainage, and facilitate tillage.

Soil management can affect soil physical properties, including texture, soil permeability, volume weight, total pore space, moisture content, and aggregate stability. In addition, the use of crop residues will be embedded into the soil, increasing soil looseness and further increasing soil permeability. The process of soil loosening is also beneficial in helping to restore the condition of the growing medium to be fertile, making it easier for plant roots to penetrate the soil, reducing the leaching of nutrients that support plant growth. In addition, crop rotation is one way of soil management that must be applied, effective rotation will increase soil microbiological activity and improve soil structure (Sutanto, 2002).

IV. CONCLUSION

Potential soil damage on dry land in Sawan Subdistrict, Buleleng Regency obtained two classes of potential damage, namely lightly damaged (PR.II) and moderately damaged (PR.III) and there are soil damage status, namely not damaged (N), lightly damaged (R.I.p) with limiting factors of permeability and light damage (R.I-d-p-a) with limiting factors of content weight, pH and permeability. The potential distribution of lightly damaged soil damage is scattered in SLH 2, 8, 9, 11, 13 and 14 located in Bebetin Village, Suwug Village and Sekumpul Village spread over 1,330.95 ha with a percentage of 35.3% and the potential for moderate damage is scattered in SLH 1, 3, 4, 5, 6, 7, 10, 12, 15, 16 and 17 located in Sudaji Village, Giri Emas Village, Lemukih Village, Bungkulan Village, Bebetin Village and Sekumpul Village spread over 1,813.11 ha with a percentage of 64.7%. The actual distribution of damage status in the field includes: Undamaged status (N) in SLH 2, 3, 4, 5, 7, 8, 10, 13, 14, 15 and 16 with a distribution percentage of 64.7% light soil damage status (R.I.P) spread in SLH 1, 9, 11, 12 and 17 with a distribution percentage of 29.4% and light soil damage status (R.I.d.p.a) spread in SLH 6 with a distribution percentage of

5.8%. Management directions recommended for improvement are the addition of organic materials and tillage and can be done by rotating crops or crop rotation.

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