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Full Length Article

The Impact of Implementation of the Leisa System on the Conservation and Land Restoration of Citrus Cultivation in Bali, Indonesia

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Abstract

Unmanaged agricultural land can cause erosion, reduce soil fertility and health and reduce crop production and quality. Low external input on sustainable agriculture (LEISA) technology impacted improvements in the physical, biological properties of the soil, impacted on reducing the soil erosion and soil health. The objective of this research was to improve the health of cultivated land through the application of the LEISA system. Experimental land with a planting area of 2 ha was divided into 4 experimental blocks and cultivation was carried out on these blocks. The cultivation treatments were: fertilizing using compost and bio-urine, fertilizing using compost plus NPK fertilizer and fertilizing using NPK fertilizer. Land conservation parameters include observations of infiltration rate, surface runoff, and erosion due to annual rainfall, land health parameters include changes in soil physical properties: porosity, gravity water and water holding capacity, soil chemical properties parameters: the content of macro and micronutrients, cation exchange capacity, pH, organic matter and ratio C/N. The compost and bio-urine and compost plus NPK fertilizer were able to increase porosity and water holding capacity by: 2.15–2.63, 0.86–1.58 and 1.23–1.78%/year, respectively. The compost and bio-urine and compost plus NPK fertilizer were able to increase organic matter, macronutrients, micronutrients, cation exchange, and microbial populations in the soil in the root zone namely 0.26–0.72%/year, 0.17–0.50%/year, 0.092–0.11%/year, 0.28–0.80 me/100g soil/year and 1.2–1.8 log CFU/year, respectively. The average rainfall of 222 ± 2 cm/year has an impact on surface runoff for cultivation treatment with compost and bio-urine, compost plus NPK fertilizer and NPK fertilizer systems, respectively: 48.2, 58.4 and 68.67 cm/year. Surface runoff has an impact on the erosion of 12.16–22.78 tons/ha/year, 20.83–31.24 tons/ha/year and 24.23–36.35 tons/year. The application of the LEISA system has a positive impact on the conservation and restoration of citrus cultivation areas.

Keywords: LEISA; Compost; Nutrients; Surface runoff; Erosion

Introduction

Food security, safety and sustainability are the international issue (Vågsholm *et al*. 2020), therefore areas the tourist destinations must be attention the issues. Therefore, the Bali Province to answer this issue makes a policy: (1) optimizing the cultivation of food crops including vegetables and fruit (Arifin *et al.* 2017) and (2) bringing food ingredients from other regions, including imports. One of the farmers' efforts to support government policies is to planting vegetables and fruits in the highlands. Fruits and vegetables are traditionally cultivated by following methods *i.e.,* (1) minimalist tillage, (2) use of chemical fertilizers (Kunanbayev *et al*. 2022), (3) eradication of pests and plant diseases using insecticides and fungicides (Setiyo *et al.* 2018) and (4) control weed growth using herbicides. The cultivation is carried out: (1) on land with a slope of 5–30%, (2) tillage once a year especially weed eradication and fertilization with compost, (3) areas with alluvial soil types, (4) areas with rainfall above 200 cm/year.

Cultivation with this system has the potential for erosion, because annual rain falls more than 200 cm/year and surface run off 40–60% from rain (Du *et al*. 2022). Cultivation behavior in this way was impacted on: (1) reduction of soil organic matter content as much as 0.72%/year, (2) reduction of micronutrients as much as 0.13%/year, (3) decreasing cation exchange capacity as much as 0.01 meq/100 g/year, (4) decreasing the soil

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microbe population as much as 1.6–2.3 log CFU (Reinecke and Reineke 2010), (5) decreasing in the health of cultivated land (Marais *et al.* 2012; Peter and Umweni 2020) and (6) decreasing the quality of the physical properties of the soil. Another impact of soil erosion was soil unhealthy, unhealthy land was contained Fe < 0.4 mg. kg^{-1}, Pb < 0.2 mg. kg^{-1}, Cd < 0.1 mg. kg^{-1}, Cr < 0.1 mg. kg^{-1} and Zn < 0.35 mg. kg^{-1}. These heavy metals were less than the land health standard according to WHO (Taberima 2016).

Unhealthy monoculture cultivation habits were caused soil at the root zone: (1) the soil porosity was decreased from 0.95 g/mL to 0.78 g/mL (Setiyo *et al.* 2018), (2) the infiltration rate was decreased from 3.2 cm/h to 1.2 cm/h (Ali *et al*. 2017), (3) the soil erosion was increased from 23.4 tons/ha/year to 29.87 tons/ha/year (Liaudanskiene *et al.* 2021), (4) cultivated plants were more susceptible to attack by pests and diseases and (5) plant productivity was decreases (Setiyo *et al.* 2017). Another impact that occurs was decreased the citrus productivity by 6 ton/year and the quality of citrus also was decreased.

The above problems must be resolved immediately, technology low external input on sustainable agriculture (LEISA) and intercropping method between annual citrus and chili or potato. Cultivation with the intercropping method to optimize cultivation land by optimizing the process of photosynthesis and optimizing the utilization of nutrients in the soil. In the other hand, this method can be increasing production and product quality of each cultivated plant (Morugán-Coronado *et al*. 2020).

LEISA system, this system uses basic fertilizer in the form of compost and follow-up fertilizer is bio-urine. The LEISA system by fertilizing agricultural land using compost doses of 15–25 tons/ha as basic fertilizer in food crop cultivation is able to: (1) improve soil porosity by 5–6% and soil water holding capacity by 10% w.b. (Hicklenton *et al.* 2001; Setiyo *et al*. 2018), (2) able to improve soil organic matter content and cation exchanged capacity values of 5–8 and 15–20%, respectively (Setiyo *et al.* 2017), (3) able to improve soil biological properties (Nunes *et al.* 2006; Setiyo *et al.* 2018), (4) reduced insecticide and fungicide residues, The materials for research in the demo plots are grafting citrus plant seeds, potato tuber seeds, green mustard seeds, local chili seeds, NPK fertilizer, compost, cow bio-urine fertilizer, furadan, dolomite, insecticide, and fungicide and insecticides.

The stable productivity of citrus plants still depends on external resources that must be purchased, such as chemical fertilizers, compost, insecticides, and fungicides. The efforts made include: (1) more intensive use of insecticides and fungicides, (2) pruning of diseased plants, (3) the use of other citrus varieties, (4) cultivation of annual crops under citrus plants, (5) fertilization with compost and (6) land clearing after each harvest. In addition, citrus cultivation carried out on slope of 5–30%, tillage once a year, and alluvial soil type has the potential for erosion due to surface runoff of 40–65% of annual rainfall. The LEISA system results in an increase in the infiltration rate causing the spread of nutrients in the root zone due to the washing process.

LEISA technology was impacted on improvements in the physical and biological properties of the soil and also was impacted on reducing the soil erosion and soil health. Cultivation by intercropping on citrus trees with vegetable crops (Chen and Chen 2003) can reduce the risk of crop failure losses in citrus crops and benefits from vegetable cultivation. The aim of this research is: (1) reducing soil erosion, (2) improving soil health, (3) increasing soil fertility, (4) increasing plant production and (5) increasing quality plant.

Materials and Methods

Time and location of research

The research was conducted in Kintamani District, Bangli Regency, Bali Province, Indonesia, April 2019 – November 2021. The research location has an altitude of ±1300 a.s.l., slope 10–30%, average rainfall of ± 220 cm/year, temperature 24–31°C and relative humidity 75–85%.

Research materials

The materials for research in the demo plots are potato tuber seeds, green mustard seeds, local chili seeds, NPK fertilizer, compost, cow bio-urine fertilizer, furadan, dolomite, insecticide and fungicide. Chemicals used for C-organic analysis, K_2O, N-organic, P_2O_5, and cation exchange capacity were $K_2Cr_2O_7$, Fe_2SO_4, H_2SO_4, $CuSO_4$, Na_2SO_4, NaOH, HCl, NH_4OH, Na_2SO_5, $BaCl_2$, alcohol 80%, distilled water and NH_4-acetate.

Research stages

The experimental design of this study used a completely randomized design (Table 1). Each experimental unit was carried out on 0.8 ha consisting of 4 blocks as replicates. Cultivating citrus was done with a 3 m spacing and between the citrus plants chilies or potatoes were planted with an intercropping system. The experiments were carried out in 2019, 2020 and 2021, thus there were 6 chili and potato cultivations and 1 citrus cultivation.

Local chilli cultivation

Land preparation was carried out with a depth of 30 cm until the soil structure was crumbly and had a porosity of more than 50%. Application basic fertilizer was carried out according to the treatment and followed by making beds and drainage channels. The dimensions of bed were: width 0.9 m, length 10 m, height 0.3 m and drainage channel width 0.4 m with a depth of 0.3 m. Chili cultivation was carried

Table 1: Cultivation treatment

Cultivation treatment	Annually plants	Seasonal crops	Blok	Kind of basic fertilizer	Type of follow-up fertilizer
LEISAKU	Citrus	Chili	I, II, III, IV	Compost	Compost and bio-urine
	Citrus	Potato	I, II, III, IV	Compost	Compost and bio-urine
LEISANPK	Citrus	Chili	I, II, III, IV	Compost	NPK
	Citrus	Potato	I, II, III, IV	Compost	NPK
NONLEISA	Citrus	Chili	I, II, III, IV	NPK	NPK
	Citrus	Potato	I, II, III, IV	NPK	NPK

LEISAKU: fertilizing using compost and bio-urine, LEISANPK: fertilizing using compost plus NPK fertilizer, and NONLEISA: fertilizing using NPK fertilizer

out in beds with a spacing between furrows of 60 cm and a spacing of 35 cm in furrows. The seeds used were certified which have specifications: 5 cm high, 5 leaves, 3–4 cm long root (Setiyo *et al*. 2018).

Fertilization was done according to treatment. The compost used has the following specifications: C/N is 10–12, cation exchange capacity was 27–29 meq/100 g, pH 6.5–6.8, and organic matter content was 30–32%. NPK fertilizer 15:15:15 specification N content 15%, P_2O_5 15% content, K_2O content was 15%, MgO content is 2%, CaO content was 0.5%, B content is 0.1% and Zn content is 0.05%. Cow bio-urine fertilizer specifications: electrical conductivity value was 1200 ± 12 μS. m^{-1}, pH is 6.8 ± 0.2 and cation exchange capacity was 29.2 ± 1.5 meq/100 g). Cultivation by controlling pests and plant diseases by spraying using fungicides: Daconil, Acrobat, Atracol and Dithane M45, while the insecticide group used wais Curacron and Detacron once a week.

Potato cultivation

Land preparation, making mounds and basic fertilization were carried out in the same way as chili cultivation. Cultivation of potato seeds of the G2 granola variety on beds with a spacing between furrows of 60 cm and a spacing of 35 cm in furrows. The seeds used were certified as spreading seeds which have the following specifications: (1) weight size was 40 ± 1.2 g, (2) growth power was 98.3 ± 1.2%, (3) shoot height was 0.8 ± 0.22 cm and (4) the number of shoots was 2–3 shoots/tuber. Fertilization was done according to the fertilization treatment on chili plants. Potato tubers were harvested after the plants were 12 weeks or 3 months old.

Citrus cultivation

Cultivation with a spacing of 3.0 m from avocado trees and 3.0 m from citrus trees. The planting hole measuring 80 cm x 80 cm x 80 cm was filled with compost and after 1 month the grafting citrus plant seeds, were planted in the hole. The grafting citrus plant seeds, had the following specifications: certified from grafting on the branches, 70 cm high, 6 months old. Plant maintenance by spraying bio-urine at a dose of 25 L/month/plant and NPK fertilizer every month. The control of pests and plant diseases was carried out every month with insecticides and fungicides. Harvesting was done after 0.5 kg/plant bears fruit and the fruit was about 6 months old.

The procedure for observing soil physical and chemical properties and microbe population

1. Physical properties of the husk charcoal media. Parameters of porosity, field capacity moisture content, permanent wilting point moisture content and specific gravity of the planting medium were observed using the gravimetric method. This data from each treatment was 5 replications and soil samples were taken and observed every month.
2. Chemical properties of the planting medium. Cation exchange capacity parameters were observed using the washing method. Analysis of soil pH content using electrometric methods (H_2O and 1 *M* KCl), analysis of N-total by the Kjedahl method, C-organic by the Walkley and Black method, P-available soil by the Bray II method and by alkaline cations (K, Ca, Mg) by the Ammonium acetate 1 *M* (NH_4Oac) saturation extraction method pH 7.0 (Setiyo *et al*. 2018). This data from each treatment was 5 replications and soil samples were taken and observed every month.
3. The microbes that were analyzed were the bacteria group, because in previous studies the mold population was smaller than the bacteria population. Soil sampling in each demonstration plot was carried out at 5 sample points after 3 days from the time of pesticide spraying, the depth of collection was 0–10 cm. Sampling with soil range sample with the position of the sampling points crossed and the distance between points was 1 m. Bacterial populations were observed using the total plate count method.

Plant productivity and diseased plants

1 Productivity of potatoes was measured by observing the total tuber weight and the number of tubers produced each tree. The number of samples for observing the total number of tubers was 50 plants for each treatment. Parameters of production quality were (1) percentage of tubers that were rotten or damaged during storage, and (2) weight distribution of tubers based on weight per tuber (class consumption potato with weight more than 60 g and seed potato with weight less than 60 g. Observation of tuber weight distribution by class was carried out by taking a sample of 50 trees and then weighing the tubers.

2 Chili productivity was measured from the total chili harvested from 50 plant samples per experimental unit in one growing season.

3 Citrus productivity was measured from the total citrus harvested from 50 plant samples per experimental unit in one year.
4 The number of diseased plants for potato and chili plants from each experimental unit was observed in one growing season. As for citrus plants observed within a period of one year.

Soil erosion parameters

1 The rain erosion index (R) was a function of the annual rainfall in an area (R, inch/year) and the R value was calculated by the equation: R = 0.01Σi (916 + 331 log i) (Wischmeier and Smith 1978), with was rain fall intensity each year. Annual rainfall data for the last three years were taken from the nearest meteorological station.
2 The soil erosion index (K) was sought by approaching the physical properties of the soil, especially soil structure and texture in the root zone.
3 The length and slope index (LS), the LS factor can be obtained from the map of the percentage of land slope (S) generated using the Digital Elevation Models (DEM) elevation map, with the equation: LS = 0.2*s*1.33 + 0.1 (Wischmeier and Smith 1978).
4 Vegetation cover index (C) was influenced by factors in the stages of cultivation (soil tillage, young plants, mature plants), types of cultivated plants and cropping patterns.
5 Conservation action (P) was a factor of plant cultivation and land conservation which affects the level of erosion.
6 Analysis of the amount of erosion quantitatively using the universal soil loss equation (USLE) (Wischmeier and Smith 1978). Value E = R x K x LS x C x P.

Data analyses

The data collected were analyzed by SPSS to obtain the mean and standard deviation as well as the ANOVA test for soil fertility parameters and erosion parameters, if there were significant differences between the data, the test was continued with the smallest difference test or Duncan's test. Soil physical properties data graphed the relationship between year and research treatment with parameter values (%). The microbial population and soil organic matter content related to rooting depth were graphed and the relationship equation was sought. The relationship between observation time and data on rainfall, infiltration and surface runoff was graphed.

Results

LEISA system and land sanitation

Base on Table 2, the LEISA (LEISAKU and LEISANPK) system was combined with the intercropping method with chili and potatoes in citrus cultivation was able to improve soil physical properties: porosity, field capacity, water holding capacity and gravity water so as to support the three parameters of land health in terms of soil physical properties (Setiyo *et al*. 2018). But an increase in soil physical properties due to the application of the LEISA system was inversely proportional to the NONLEISA system.

Soil porosity due to the application of the LEISAKU and LEISANPK systems increased by 2.63 and 2.15%/year, while the amount of gravity water increased by 1.58 and 0.86%/year, respectively. An increase also occurred in field capacity and water holding capacity, for the LEISAKU and LEISANPK treatments, the increase in field capacity was 1.58 and 1.26%/year, while the increase in water holding capacity was 1.78 and 1.23%/year, respectively.

ANOVA test on the parameters of soil physical properties showed that there were significant differences between the LEISAKU, LEISANPK and NONLEISA treatments. Duncan's test results showed that the parameter values for soil physical properties were different for each year of experiment, so this indicated that the LEISA treatment and intercropping patterns gave positive results on soil physical properties (Table 2).

The improvement of soil physical properties in the root zone of potato and chilli seasonal crops intercropped with annual arrange in the LEISAKU and LEISANPK cultivation system is illustrated in Fig. 1. Based on changes in the parameters of the physical properties of the soil and the results of statistical analysis, the LEISAKU system treatment is the best cultivation treatment.

Parameters of soil health and fertility were soil organic matter content, cation exchange capacity, macro and micro nutrient content, fungicide and insecticide residues and C/N (Table 3). Decomposition of minerals from compost, bio-urine and NPK fertilizer in this experiment improves soil fertility or characterizes soil chemical properties in the root zone of annual crops and annual crops cultivation.

Base on, ANOVA test showed significant differences from each treatment. The results of the Duncan test, the values of these parameters were also different for each trial year, so this shows that the LEISA treatment and intercropping patterns give positive results on soil fertility and health and LEISAKU was the best treatment cultivation.

The relationship between root depth and soil organic matter content for cultivation with the LEISAKU system using compost and bio-urine and cultivation with the LEISANPK system using compost plus NPK is exponential, while in cultivation with the NONLEISA system the relationship is linear (Zinati *et al*. 2001; Magdoff and Weil 2004). Cultivated annual plants absorb nutrients from the 0–60 cm root zone, while cultivated annual plants absorb nutrients from 0–150 cm depth. Profile of the amount of soil organic matter in 2021 for the three cultivation models as shown in Fig. 2.

Table 2: Value of soils parameters

	Soil porosity (% w.b.)			Field capacity moisture content (% w.b.)		
	LEISANPK	LEISAKU	NONLEISA	LEISANPK	LEISAKU	NONLEISA
2019	40.9 ± 1.1b	45.6 ± 1.3b	40.9 ± 0.7a	24.4 ± 1.4b	27.3 ± 1.1b	24.5 ± 1.2a
2020	45.6 ± 1.2b	53.1 ± 0.9c	41.0 ± 1.2a	27.3 ± 1.2b	31.8 ± 1.2c	24.6 ± 1.1a
2021	47.4 ± 1.5b	53.5 ± 1.2c	41.1 ± 1.1a	28.4 ± 1.1b	32.1 ± 0.9c	24.6 ± 1.4a
	Soil water gravitation, % w.b.			Spoil water holding capacity, % w.b.		
2019	18.9 ± 0.3b	18.2 ± 0.5b	16.3 ± 0.2a	15.3 ± 0.5b	18.2 ± 0.8b	15.3 ± 0.6a
2020	18.2 ± 0.1b	22.6 ± 0.7c	16.4 ± 0.1a	18.2 ± 0.4b	22.7 ± 0.4c	15.4 ± 0.5a
2021	18.9 ± 0.6b	22.9 ± 0.4c	16.4 ± 0.5a	19.3 ± 0.6b	22.9 ± 0.2c	15.4 ± 0.4a

LEISAKU: fertilizing using compost and bio-urine, LEISANPK: fertilizing using compost plus NPK fertilizer, and NONLEISA: fertilizing using NPK fertilizer

Table 3: Soil chemical properties

Years	Macronutrient (%)			Micronutrient (%)		
	LEISAKU	LEISANPK	NONLEISA	LEISAKU	LEISANPK	NONLEISA
2019	4.7 ± 0.1b	4.7 ± 0.2b	3.4 ± 0.1a	1.1 ± 0.1b	1.1 ± 0.3b	0.51 ± 0.3a
2020	5.8 ± 0.2c	4.8 ± 0.2b	3.7 ± 0.2a	1.3 ± 0.2c	1.3 ± 0.4c	0.43 ± 0.1a
2021	6.2 ± 0.1c	5.2 ± 0.2c	2.8 ± 0.1a	1.4 ± 0.3c	1.4 ± 0.1c	0.38 ± 0.1a
	Fungicide and insecticide residues, mg. kg^{-1}			Organic Material, %		
2019	0.01 ± 0,002a	0.02 ± 0,003b	0.05 ± 0,002c	6.3 ± 0.1b	5.8 ± 0.3b	3.9 ± 0.2a
2020	0.008 ± 0,001a	0.02 ± 0,002b	0.051 ± 0,002c	7.9 ± 0.3c	6.2 ± 0.1b	3.5 ± 0.2a
2021	0.002 ± 0,002a	0.02 ± 0,003 b	0.05 ± 0,002c	8.5 ± 0.1c	6.6 ± 0.1b	3.2 ± 0.2a
	Cations exchanged capacity, meq/100 g			C/N		
2019	27.0 ± 0.1b	25.9 ± 0.2a	25.45 ± 0.3a	13.4 ± 0.2b	10.4 ± 0.2a	9.4 ± 0.1a
2020	28.3 ± 0.3c	26.2 ± 0.1b	25.4 ± 0.2a	12.7 ± 0.1b	10.3 ± 0.1a	9.0 ± 0.2a
2021	29.4 ± 0.2c	26.7 ± 0.3b	25.3 ± 0.1a	11.7 ± 0.1b	9.6 ± 0.2a	8.0 ± 0.2a

LEISAKU: fertilizing using compost and bio-urine, LEISANPK: fertilizing using compost plus NPK fertilizer, and NONLEISA: fertilizing using NPK fertilizer

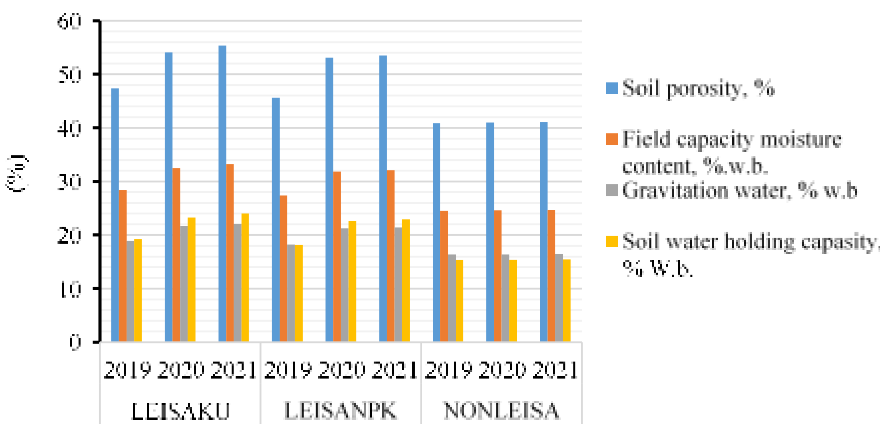

Fig. 1: Physical properties of soil in the root zone

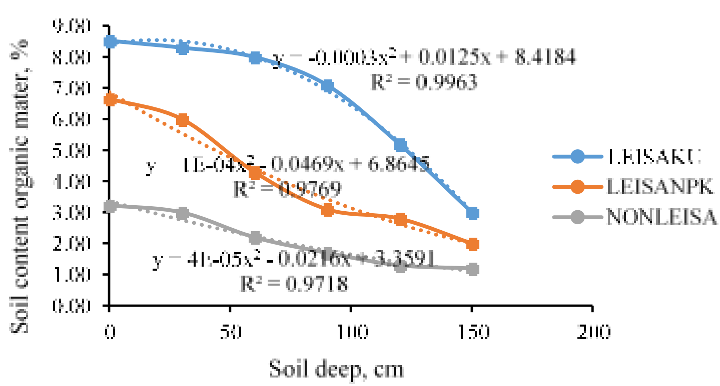

Fig. 2: Soil organic matter content at a root depth of 0–150 cm

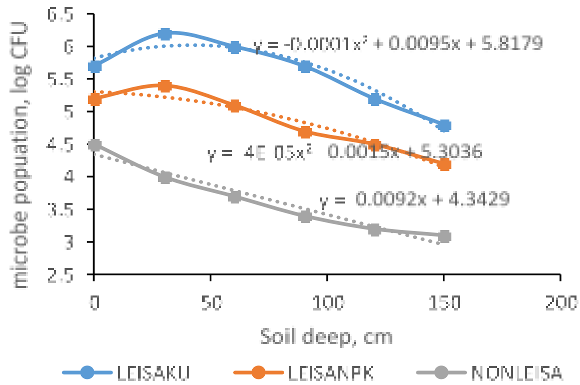

Fig. 3: Microbial population in the root zone of plants

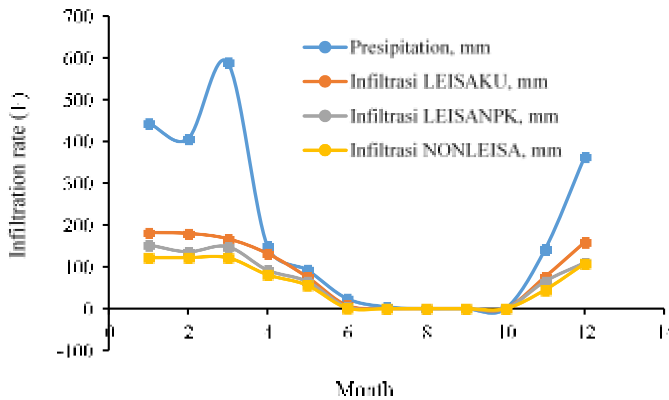

Fig. 4: Infiltration pattern in citrus cultivation

The relationship between soil organic matter content and root depth for cultivation treatment with the LEISAKU, LEISANPK and NONLEISA systems is quadratic with the equation y = -0.0003x^2 + 0.0125x + 8.4184, y = 1E-04x^2 - 0.0469x + 6.8645 and y = 4E-05x^2 - 0.0216x + 3.3591 (Zinati *et al.* 2001; Magdoff and Weil 2004). The average difference in organic matter content between the LEISAKU treatment and the LEISANPK treatment was 3.66 ± 0.3% while the average difference in organic matter content between the LEISANK treatment and the NONLEISA treatment was 7.23 ± 1.1%.

In the LEISAKU system the soil organic matter content began to decrease in the root zone of more than 60 cm, while in the LEISANPK and NONLEISA systems the soil organic matter content began to decrease at a depth of 30 cm. The organic matter content in each soil depth is strongly influenced by the absorption of organic matter by roots and the leaching process by soil infiltration.

Soil physical properties, soil organic matter content, soil pH, C/N value and soil cation exchange capacity value are closely related to the microbial population in the soil. Fig. 3, illustrates the profile of microbial populations in the root zone of seasonal crops intercropped on perennial plants using the LEISAKU, LEISANPK, and NONLEISA cultivation systems. In cultivation using the LEISAKU and LEISANPK systems, the relationship between the microbial population and root depth was quadratic (y = -0.0001x^2 + 0.0095x + 5.8179 and y = -4E-05x^2 -0.0015x + 5.3036). Peak the microbial populations for each treatment is 6.2 log CFU and 5.4 log CFU, respectively, peak of population at a root depth of 30 cm. Meanwhile, in the NONLEISA treatment, the relationship between root depth and microbial population was linear (y = -0.0092x + 4.3429).

The application of the LEISA system in citrus cultivation which was intercropped with potato or chili plants was able to increase the microbial population at a depth of 0–150 cm by 1.2–1.95 log CFU. This is strongly influenced by soil organic matter content and soil physical properties. Therefore, the microbial population remains high at a soil depth of 0–60 cm.

Impact of the LEISA system on water holding capacity,infiltration, surface runoff and soil erosion

From Fig. 4, research location from 3 years' rainfall data has 7 wet months and 5 dry months. Based on the concept of mass balance, rainfall that falls to the ground surface will infiltrate into the soil and flow through the soil surface to become surface runoff. Infiltrated rainwater increases the soil water content according to the water holding capacity

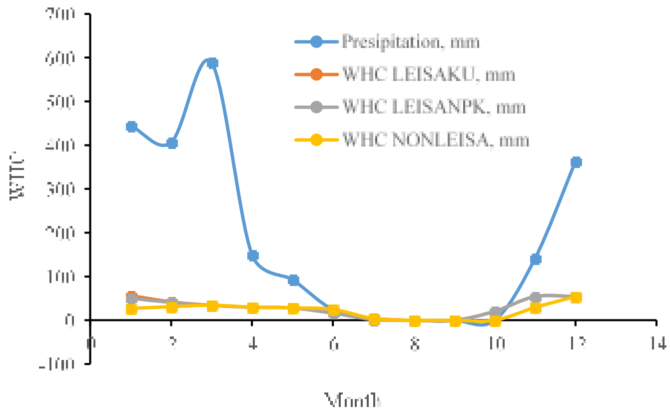

Fig. 5: Precipitation and WHC value due to rain at Kintamani Region

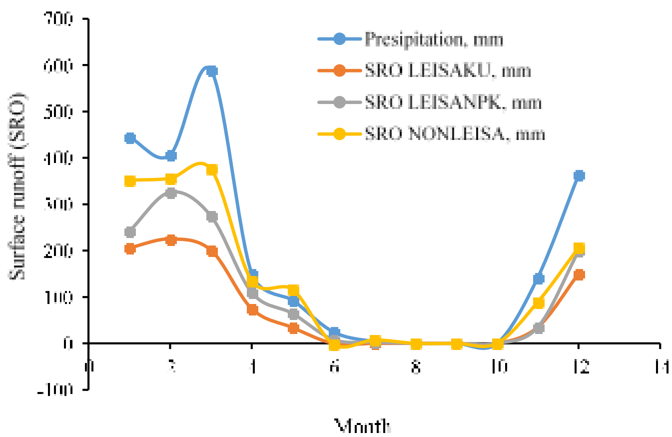

Fig. 6: Precipitation and surface runoff at Kintamani Region

value and enters the soil through the infiltration process into groundwater. The average annual rainfall in the study area is 221.8 cm, the amount of rainwater infiltrated into the soil in the LEISAKU, LEISANPK and NONLEISA cultivation treatments is 12.25, 9.65 and 8.20 cm/month. The amount of rainfall that infiltrated into the soil was 44.42, 34.79 and 29.91%, respectively. In accordance with Table 2, the soil porosity in the root zone with the LEISAKU treatment is better than the other treatments, so that the infiltration rate of rainwater is also greater.

The LEISAKU and LEISANPK systems in intercropping citrus cultivation with seasonal crops increased the amount of rainwater converted to infiltration water by 14.51 and 4.82%, respectively. In addition, in the LEISAKU and LEISANPK systems there was an increase in infiltration capacity of 20.04 and 10.92%, respectively. Seasonal plants in intercropping pattern with annual plants were very effective in increasing water holding capacity and infiltration values by 8.8 and 13.37%, respectively.

Based on Fig. 5, monthly rainfall of less than 45 cm can only increase the soil water content to the field capacity water content limit. However, if the monthly rainfall is more than 45 cm, then the rainwater will be converted into groundwater and runoff. Therefore, from June to October there will be no additional groundwater and surface runoff. The LEISAKU and LEISA NPK systems were able to increase the average monthly groundwater holding capacity by 9.5 and 6.8 cm of total monthly rainfall, respectively or the LEISAKU and LEISANPK systems, there was an increase in water holding capacity by 29.4 and 23.9%, respectively.

Improvements in soil porosity of 2.63 and 2.15%/year for the LEISAKU and LEISANPK treatments had an impact on increasing the water holding capacity of the soil by 4.52 and 3.22%, respectively. However, because the rainfall from June to October is less than 45 cm, all of the rainfall is converted to soil water content, because all the rainfall is infiltrate into the ground.

The average rainwater converted to surface runoff from November to May for cultivation treatments using the LEISAKU, LEISANPK and NONLEISA systems are 13.22, 18.20 and 23.28 cm/month, respectively (Fig. 6). Based on Table 2, the porosity of the NONLEISA treated soil is the smallest, so the surface runoff due to rainwater is the highest and the infiltration is the lowest.

The amount of rainwater that becomes surface runoff for the LEISAKU, LEISANPK, and NONLEISA systems are 48.28, 58.46 and 68.67%, respectively. The

LEISAKU and LEISANPK systems for intercropping citrus cultivation with seasonal crops reduced the amount of rainwater converted to surface runoff by 10.76 and 10.71%, respectively. The surface runoff value has an impact on the amount of soil particles carried by rainwater or erosion (Du *et al*. 2022). The categories of land erosion due to the application of the LEISA system and intercropping in citrus cultivation areas that have a land slope of 20% are presented in Table 4. Based on the erosion index equation, Table 1, the LS index equation, Table 5–7 the data for R index, K index, LS index, C index, and P index are obtained: 3670–3753, 0.18, 0.4–0.54, 0.11 and 0.9, respectively.

In the cultivation of citrus or avocados intercropped with chili, potato or other horticultural seasonal crops using the LEISA or NONLEISA system, the C index is 0.40–0.54 depending on the stage of cultivation. Compost fertilizer applied to plants has an impact on different soil processing patterns from the application of NPK fertilizer. The value of the P index in this case is 0.9, so that the erosion in citrus cultivation using the LEISAKU, LEISANPK and NONLEISA systems are 26.78–27.47 tons/ha (light), 27.47–29.46 tons/ha (light) and 35.32–36.15 tons/ha (light). The LEISA system was able to reduce erosion by 6.69–9.37% and the erosion category remained in the light category. Organic matter and enzymes due to microbial activity along with the clay fraction of the soil will unite soil particles into soil aggregates that are difficult to break down by the presence of surface runoff, so that erosion can be controlled slightly (Purba *et al.* 2020).

Discussion

Results on the impact of LEISA system and intercropping on land conservation were interesting. Based on changes in soil physical properties (Table 2), changes in soil chemical properties (Table 3) and change of microbial population (Fig. 3), cultivation using the LEISAKU system is better than cultivation treatment with the LEISANPK system and cultivation using the NONLEISA system (Ibeawuchi *et al.* 2015; Al-Hamed *et al.* 2017; Niu *et al.* 2021). Compost decomposition by microbes produces minerals such as K^+, Ca^+, Fe^{+2}, Al^+ and other cations, the results of compost decomposition are solid particles. The result of urine decomposition is in the form of simple compounds that are bound or dissolved in water.

The addition of compost and bio-urine as organic fertilizers in the LEISAKU system can increase soil porosity better than the LEISANPK and NONLEISA treatments. Soil porosity due to the application of the LEISAKU and LEISANPK, NONLEISA systems increased by 2.63, 2.15 and 1.58%/year. The use of compost fertilizer improved soil porosity by 1.58 ± 0.2%/year for each fertilization dose of 15–25 tons/ha, while bio-urine was only able to increase porosity by 0.03 ± 0.004%/year. Soil porosity due to the application of the LEISAKU and LEISANPK, NONLEISA systems increased by 2.63, 2.15 and 1.58%/year. Particles result from compost and bio-urine decomposition can increase the porosity of the soil, increasing the number of micro pores and macro pores. This is because compost decomposes into particles with a diameter of 200–2000 m (fine sand), dust with a diameter of 2–200 m and clay with a diameter of < 2 m. The increase in soil porosity is also supported by an increase in the binding capacity of soil particles due to an increase in the amount of soil organic matter and soil organic acids.

Soil porosity increased due to the addition of compost and bio-urine, but soil porosity decreased due to soil compaction during the cultivation process. Soil porosity increased due to the addition of compost and bio-urine, but soil porosity decreased due to soil compaction during the cultivation process. In addition to the amount of soil porosity, the soil in the root zone treated with LEISAKU, LEISANPK and NONLEISA has an average micropores of 57.6, 50.7 and 44.8% from total soil porosity. While the number of macropores of the three treatments respectively is of 42.3, 49.3 and 55.2%.

The increase in the number of micro pores in the LEISA system is 0.3–2%/year. The LEISAKU system with fertilization using compost and bio-urine further strengthens the bonds of soil particles, so that the number of micro pores is greater than the LEISANPK treatment. Number of macro and micro pores in the root zone is closely related to the water holding capacity of the soil and the infiltration rate of rainwater.

The increase in the number of micro pores in the LEISA system of 0.3–2%/year also has an impact on increasing soil water content and the soil's ability to hold water by 1.26–1.58%/year and 1.23–1.78%/year. Improvement of soil porosity in the root zone supports the process of land health and soil conservation, because improving soil porosity can: (1) increase the availability of water for plants, (2) increasing the availability of oxygen for microbial in the soil, and (3) controlling soil water content at the field capacity value with a good infiltration process (Nunes *et al.* 2006; Brown and Cotton 2011; Setiyo *et al.* 2017, 2018, 2020).

In addition, the impact of increasing the number of macro pores due to the addition of the sand fraction in the soil resulted in an increase in the value of gravity water from 18.24% w.b. (2019) to 22.14% w.b. (2021). The impact of increasing the amount of water gravity on potato cultivation is better in the root zone. The infiltration rate of rainwater from the root zone (0–80 cm) was 2.2 cm/hour (Khater 2015).

Based on Fig. 6, the rainfall from June to October is less than 180 mm/month, so this month rainwater infiltrates into the soil and increases the soil water level and only a small part becomes to ground water. The surface runoff at the wet month is 5–518 cm/month or 1.8–72.8% of the total monthly rain.

Based on the amount of rainwater that has the

Table 4: Erosion parameters

Soil erosion parameters	LEISAKU			LEISANPK			NONLEISA		
	2019	2020	2021	2019	2020	2021	2019	2020	2021
Rain falls cm/year	201 ± 2	221 ± 3	222 ± 1	201 ± 2	222 ± 3	222 ± 1	201 ± 2	222 ± 3	222 ± 1
Soil Erosion, tons/ha	27.5 ± 5	27.4 ± 4	26.8 ± 2	27.5 ± 3	28.8 ± 2	29.4 ± 3	35.2 ± 3	36.1 ± 2	36.1 ± 3

LEISAKU: fertilizing using compost and bio-urine, LEISANPK: fertilizing using compost plus NPK fertilizer, and NONLEISA: fertilizing using NPK fertilizer

Table 5: Soil erosion index (K) (Abdurachman *et al.* 1985)

Soil kind	K Value
Alluvial Hidromorf	0.156
Alluvial	0.193
Litosol	0.273
Grumusol	0.187
Regosol	0.188

Table 6: Vegetation cover index (Abdurachman *et al.* 1985)

Land use	Cover index (C)
Weeds	0.1
Field	0.4
Settlement	0.6
Rice field	0.15
Building	0.5
Bush	0.3
Garden	0.4

Table 7: Conservation action index (Abdurachman *et al.* 1985)

Land slope, %	Value of P
0–8	0.50
8–15	0.75
15–25	0.90
25–40	0.90
40–90	0.90

potential to increase the value of field capacity and ground water flow, rainwater above 180 cm/month has the potential to cause surface runoff. The average number of surfaces runoff is 1082–1835 cm/year. The surface runoff value was 36.59 ± 1.1% of the total annual rainfall in cultivation with the LEISAKU system, 45.3 ± 2.3% in cultivation with the LEISANPK system and 62.0±1.7% in cultivation with the NONLEISA system. The LEISA system in citrus cultivation intercropped with chili or potato cultivation was able to improve: soil porosity, field capacity value, water holding capacity, amount of gravity water. These parameters of soil physical properties support increasing the infiltration value of the soil and decreasing the surface runoff value (Grant 1985; Purastru and Neida 2013; Du *et al*. 2022).

Based on Table 2, the annual rainfall is 221.8 cm/year has an impact on the number of surfaces runoff for cultivation treatment with LEISAKU, LEISANPK and NONLEISA systems respectively: 48.2, 58.4 and 68.67 cm/year. Surface runoff has an impact on erosion of 12.16–22.78 tons/ha/year, 20.83–31.24 tons/ha/year and 24.23–36.35 tons/year. The LEISA system supports the following parameters: (1) the P index, (2) the index C, (3) the index K, so that with the application of the LEISA system these parameters are decreased. As a result of the decrease in these parameters, land erosion that applies the LEISA system is smaller than land that does not apply the LISA system in cultivation, although erosion is still in the mild category (Suwandi *et al*. 2003; Flavel and Murphy 2006; Kateb *et al*. 2013; Ibeawuchi *et al.* 2015; Restitiasih *et al*. 2015; Falcã *et al.* 2020).

The LEISAKU and LEISANPK cultivation treatments had an impact on the value of runoff, and the binding capacity of the particles. Both of these have an impact on the amount of erosion. The amount of surface runoff is influenced by the physical properties of the soil, especially soil porosity, soil infiltration rate, and rainfall. The binding capacity of soil particles is influenced by the content of soil organic matter, the content of humid acids, the population of soil biota and soil structure (Grant 1985).

The impact of the LEISA system and intercropping on land health and fertility were of great importance. Increases in soil porosity, soil water content, and oxygen concentration in the soil have an impact on increasing the process of decomposition of compost and bio-urine into minerals that can increase soil fertility or improve soil chemical properties. Base on Table 3, LEISAKU and LEISANPK treatments were able to (1) increase organic matter by 0.72 and 0.26%/year (Lambert *et al*. 2005), (2) increase micronutrient content by 0.11 and 0.092%/year, (3) increase the macronutrient content by 0.50 and 0.17%/year and (4) increase the cation exchanged capacity values by 0.8 meq/100 g soil/year and 0.28 meq/100 g, respectively (Lambert *et al*. 2005).

Compost and bio-urine contain macronutrients, micronutrients and microbes, while NPK fertilizers only contain micronutrients. Compost fertilizer was able to increase the content of macro nutrients in the soil by 1.10 ± 0.04% and micro-nutrients in the soil by 0.15 ± 0.002%. Cow bio-urine was able to increase the macro-nutrient content in the soil by 0.56 ± 0.03% and micro-nutrients in the soil by 0.343 ± 0.02%. In addition, the improvement in soil fertility from the LEISAKU and LEISANPK treatments was supported by a decrease in the values of: (1) C/N of 0.57/year and 0.27/year, respectively, (2) content fungicide and insecticide residues of each of 0.0026 mg. kg^{-1}/year and 0 mg. kg^{-1}/year and (3) soil pH 0.003/year (Niu *et al*. 2021).

The dynamics of the microbial population is closely related to changes in the C/N of organic matter. The microbial population in the cultivation of seasonal crops intercropped with NONLEISA annual plants is inversely proportional to the depth of the root zone, this is due to the amount of organic matter in the soil decreasing if the depth of the root zone increases. Microbes in the root zone using the LEISA system are able to actively decompose: compost, bio-urine, NPK fertilizer, insecticide residues and fungicide residues. At the beginning of cultivation with this LEISA system, the microbial population in the root zone (0–30 cm) was 5.2–5.3 log CFU and at the end of 2021 the microbial population was 5.6–5.7 log CFU. The pattern of microbial dynamics in the root zone of cultivated (Qian *et al*. 2003; Santillán *et al*. 2014; Setiyo *et al.* 2016).

Therefore, the process of decomposition of nutrients from fertilizers given by microbes needs to be considered in the process: (1) providing nutrients for plants in the root zone, (2) land health and (3) land conservation. In the decomposition process of organic fertilizers (compost and bio-urine) the following processes will occur: (1) changes in the physical properties of nutrients and soil aggregates, (2) changes in chemical properties, and (3) changes in microbial populations which then have an impact on changes in physical properties.

The next impact, the improvement of the parameters of the physical properties of the soil supports the in-situ bioremediation process of insecticide and fungicide residues by ± 92%, because microbes in the soil are able to grow with the availability of water and air in the root zone of plants (Setiyo *et al*. 2018). In addition, the nutrients in the root zone are more easily absorbed by plant roots. The real result of improving the physical properties of the soil is the improvement of the quality and productivity of annual crops and annual crops that are cultivated in an intercropping manner (Morugán-Coronado *et al*. 2020).

Cultivation of seasonal and annual horticultural crops with the application of the LEISAKU system using compost plus bio-urine is better than the cultivation with the LEISANPK system using compost plus NPK or cultivation without the NONLEISA system. Micro-nutrients are present in compost and bio-urine, so that these two components increase the content of soil organic matter, while NPK fertilizers do not have micro-nutrients, so that the content of micro-nutrients in horticultural cultivation in soil each year actually decreases (Flavel and Murphy 2006). In addition, compost decomposition also produces macronutrients, thereby contributing to an increase in soil organic matter content.

Fertilization with compost helps increase the concentration of C-organic, K_2O, N, K_2O, Al, P_2O_5, Mg, Fe, Ca and cation exchanged capacity the soil. The increase in minerals was very significant with increasing compost dose, but the compost dose did not significantly increase soil pH (Eghball *et al*. 2004; Brown and Cotton 2011). The role using the LEISAKU system is very high for the process of adding soil organic matter and has an impact on land health. In addition, increase in the parameters of important soil physical properties, the composition of the number of micro pores and macro pores in the soil is able to provide water and oxygen for the development of microbial decomposers and the process of absorption of nutrients by plant roots.

Both of these causes the consumption of nutrients by plants cultivated in the 0–60 cm zone is higher than the nutrient consumption in the 50–150 cm zone. In addition, fertilizer application is only carried out at a depth of 0–30 cm, while nutrients at a depth of 30–150 are only due to the process of leaching nutrients by rainwater. Therefore, the relationship between the depth of the root zone and the organic matter content of the three seasonal crop cultivation models intercropped with different annual plants, the LEISA system with compost and bio-urine provides better nutrients, at a depth of 0–60 cm the amount of organic matter are 19.2–24.5 and 13.2–16.2% for depths of 60–150 cm.

The average soil pH in the root zone of citrus was 6.6 to 6.8. Soil pH lower than 7 because the compost in the soil is acidic so there is an excess of H^+ and the release of Ca^{2+} and $Mg^{2+,}$ metal cations from mineral and organic matter due to microbial activity. Some organic acids at neutral pH accelerate the compost demineralization process (Eghball *et al.* 2004; Joa *et al*. 2011; Santillán *et al*. 2014).

At a pH of 6.5–7.2 nutrients are easily absorbed by plants so that the cation exchange capacity of land with the NONLEISA system is 25.5 meq/100 g, the LEISANPK system is 26.048 meq/100 g and the LEISAKU system is 27.24 meq/100 g (Eghball *et al*. 2004). The amount of micronutrients, the C/N value and the enzymes produced by the microbial decomposers support the increase in the cation exchanged capacity value of the soil, so that the absorption of nutrients by the roots of cultivated plants is easier.

It was important to notice the impact of the LEISA system and intercropping on the number of plants affected by disease and productivity. The impact of the LEISA system and intercropping was very real on the conservation, health and fertility of the land cultivated for citrus, potatoes, and chilies. These impacts were followed by a decrease in the number of plants affected by the disease. Citrus, chili and potato plants affected by the disease was decreased as much as 10.9–17.0, 5.5–10.1 and 2.4–5,6%. The decrease in plant disease attacks is due to an increase in plant immunity due to the health of the soil and the availability of nutrients in the root zone. The decrease in plant disease attacks also resulted in an increase in the production of citrus, chilies, and potatoes each by 6.6–33.0 tons/ha/year, 2.8–7.0 tons/ha/year and 1.7–6.7 tons/ha/year.

Conclusion

The LEISA system applied to the cultivation of citrus intercropped with local chili and potato was able to: (1) reduce the rate of land erosion by 6.69–9.37%/year and erosion was categorized as light, (2) reduce the concentration of insecticide and fungicide residues to 0.008–0.02 mg. kg^{-1}, (3) to increase in cation exchange capacity was 1.029–1.82 meq/100 g/year, (4) to increase production of: (a) citrus from 73.2 tons/ha/year to 106.2 ton/ha/year, (b) chilies from 5.3 tons/ha to 11.9 tons/ha and (c) potatoes from 25.5 tons/ha to 32.1 tons/ha, and (5) reduce the number of diseased plants from 18.2 to 1.9%.

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Author Contributions

Y Setiyo, IBP Gunadnya and IBW Gunam planned and designed the research. Y Setiyo, IBP Gunadnya, P Budisanjaya and NL Yulianti performed the experiments, data collection, analysis and compiling. Y Setiyo, IBW Gunam and IGAL Triani edited the manuscript. All authors reviewed the manuscript.

Conflict of Interest

All authors declare no conflict of interest.

Data Availability

Data presented in this study will be available on a fair request to the corresponding author.

Ethics Approval

Not applicable to this paper.

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