Vol. 12, No. 1 (2023) : 58 - 69
DOI : http://dx.doi.org/10.23960/jtep-l.v12i1.58-69

JURNAL TEKNIK PERTANIAN LAMPUNG

ISSN 2302-559X (print) / 2549-0818 (online)
Journal homepage : https://jurnal.fp.unila.ac.id/index.php/JTP

The Effect of Soil Preparation Methods on Rain Water Infiltration as The Basis of Irrigation Application for Dry Land Rice

Sri Widata[1]✉, Driska Arnanto[1], Maria Theresia Darini[1], Yekti Maryani[1], Djoko Heru Pamungkas[1]

[1]Faculty of Agriculture, Universitas Sarjanawiyata Tamansiswa, Yogyakarta, INDONESIA.

Article History :

Received : 15 November 2022
Received in revised form : 6 December 2022
Accepted : 29 December 2022

Keywords :

Rain,
Tillage,
Infiltration,
Dry land,
Rice

✉Corresponding Author:
sriwidata1965@gmail.com

ABSTRACT

The purpose of this study was to determine the effect of land preparation methods on the soil infiltration which can be used as a basis for designing irrigation for dryland rice cultivation. The study was arranged in a completely randomized design (CRD) with three land preparation treatments, namely T0 (no tillage), T1 (hoeing), and T2 (hoeing plus loosening). Each treatment was carried out with three replication plots. Artificial rain was given with an average intensity of 4.61 mm/h for 120 min. Observations were made on the infiltration thickness and rainwater volume. Results showed that land preparation methods resulted in very significant differences in the cumulative infiltration depth and infiltration rate, where the T2 treatment caused the highest infiltration. During 120 minutes of rain, 331.83 liters of water volume was poured out and resulted in an average infiltration thickness of 7.3 cm for T0 (no tillage), 18.09 cm for T1 (hoeing), and 21,3 cm for T2 (hoeing plus loosening). The results also showed that cumulative infiltration (y) increased with rain water volume (x) that followd a logarithmic curve with an R2 value of more 94-98% for the three land preparation methods with order T2 > T1 > T0.

1. INTRODUCTION

Indonesia is an agricultural country with rice as the staple food. Currently, Indonesia is the largest rice producing country in the Southeast Asia Region and the third largest in the world (Haryanto *et al.*, 2019). Based on data from the Directorate of Food Crops, Horticulture and Plantation Statistics, Indonesia's rice harvest area in 2021 will reach 10.41 million ha with a production of 54.42 million tonnes of dry unmilled grain (Direktorat STPHP, 2022). However, it is not easy for Indonesia to achieve self-sufficiency in rice due to the very high per capita consumption of rice. According to data from the Central

Statistics Agency (BPS) in 2018, the average consumption of rice by the Indonesian population reached 111.58 kg per capita per year, placing Indonesia as the country with the highest rice consumption in the world (Ahsani & Ardian, 2019). According to BPS (2021), the national rice productivity is still low, namely in average 52.26 quintals of dry unmilled grain per hectare. The government is only able to increase productivity by 1.9% per year. Meanwhile, the increase in the national population reached 1.64 million people (a total of 274 million people in 2022). If this condition continues, the government will experience a deficit in staple food growth against population growth (Marwanti, 2022).

Various efforts have been made to achieve self-sufficiency in rice, because the government has set a target, Indonesia must be able to be self-sufficient in rice (Hatta, 2015). There are many obstacles in rice cultivation, which causes rice to be imported to meet domestic demand. Some of the obstacles causing the difficulty of self-sufficiency in rice include the reduction in arable land due to land conversion into residential areas. The islands of Java and Bali contribute 60% to national rice production. However, since 2010 both islands have experienced a water deficit and land conversion which has implications for food supply uncertainty (Thoriq & Sampurna, 2016). The rate of land conversion, especially paddy field namely, in Indonesia has reached quite worrying levels. Paddy field conversion is estimated at 96,512 ha/year, with conversion rates varying from high (> 4%/year), medium (2-4%/year) and low (<2%/year) (Mulyani, 2016). Conversion of fertile paddy fields not only reduces rice production capacity nationally and impacted on food security, but can even affect the government's purchasing price policy on rice (Purbiyanti *et al*., 2017).

The government has made various laws and regulations in order to maintain and maintain fertile land, but there are no regional regulations that specifically regulate the protection of fertile agricultural land (Barkatullah *et al*., 2016). Another obstacle to rice cultivation is the demand for too much water, both during land preparation, during the growth period and just before flowering. Various attempts have been made to increase rice production in Indonesia, including expanding rice planting in wetlands and expanding rice planting in dry land. BPS data states that the total area of dry land in Indonesia is 63.4 million ha or around 33.7% of Indonesia's total area. Meanwhile, the area of dry land in the form of upland is around 1,244,906 ha which has the potential to become paddy fields (Yulianto, 2020). Thus dry land in Indonesia has enormous potential to be developed in supporting food security, especially to achieve rice self sufficiency. For example, Production of upland rice in Lampung Province in 2014 reached 149,873 ton from a harvested area of 47,981 ha (Hafif, 2016). This means a productivity of 3.12 ton/ha, indicating a very large potential for upland rice cultivation. Production of upland rice can be important contributor for some areas such as Morotai Island, which in 2016 produced 2,853 ton of upland rice and contributed 41.34% of the total rice production on Morotai Island (Saleh *et al*., 2021).

Dry land is suitable for growing upland rice because the life cycle of this type of rice does not require abundant water. Upland rice has the potential to support increased national rice production (Mulyaningsih & Indrayani, 2014). Its existence can be a solution for optimizing dry land as a substitute for converted paddy fields, and can further support the rice self-sufficiency program that has been proclaimed by the Government. Several regions in Indonesia have specific conditions that are not served by irrigation systems and instead have the potential to develop upland rice commodities as a reliable main food source to meet consumption needs (Saleh *et al*., 2021).

Cultivating rice in dry land requires further thinking, especially regarding the effectiveness and efficiency of providing water. An irrigation technique using artificial rain is suitable for activities in the field of agricultural cultivation, especially upland rice plants, which require effective and efficient use of water when planted on dry land. The key to effective and efficient use of water is how water with a limited and controlled volume can quickly reach the root zone of rice plants. Therefore, it is important to carry out research with this tool, so that the volume of water and time it takes for it to penetrate to the root zone of rice can be known. Widata *et al*. (2011) said the success of this artificial rain is determined by the volume of rainwater needed to reach the plant root zone. Method of soil preparation will affect the ability of the soil to absorb water. The purpose of this study was to determine the effect of land preparation methods on the soil's ability to absorb water into the soil up to the rice root zone. This can be used as a benchmark for providing irrigation water for dryland rice plants.

2. MATERIALS AND METHODS

2.1. Research Location

The research was conducted in the screen house of the Faculty of Agriculture, Universitas Sarjanawiyata Tamansiswa (UST), Yogyakarta. The soil used is a type of regosol soil with a very dominant sandy soil texture. The research was carried out during the dry season (June to August), so that the soil water content was not saturated and the dynamics of water absorption was clearly visible.

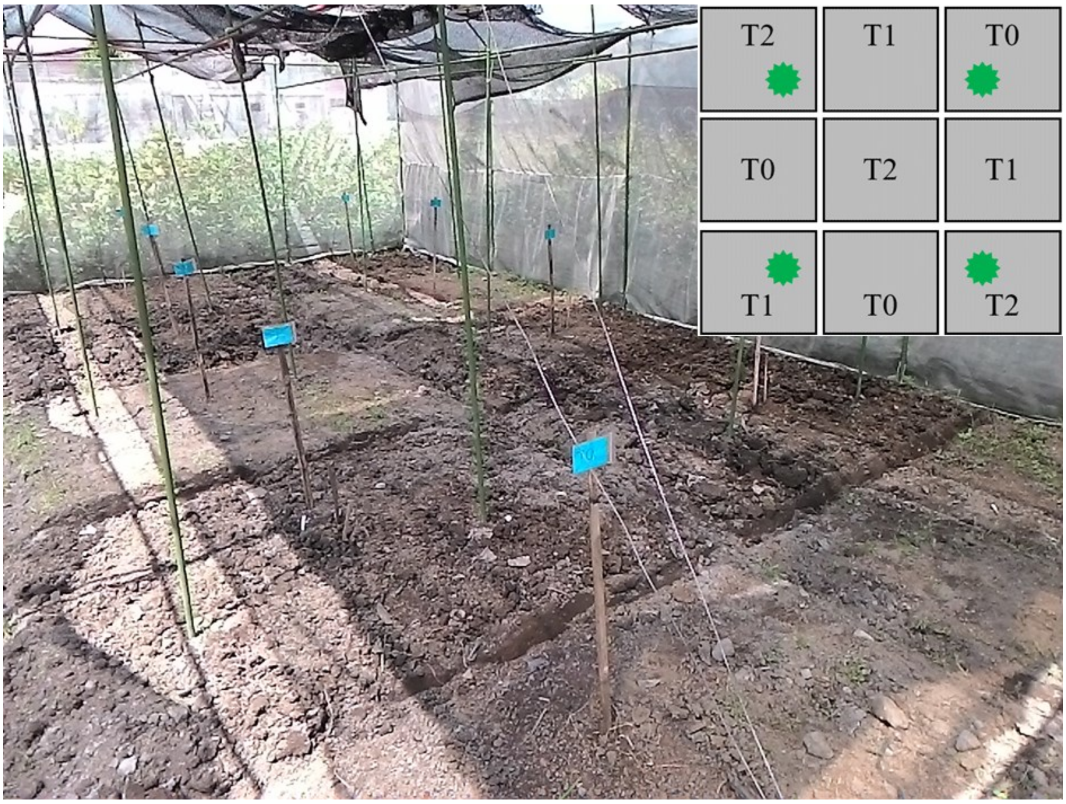

Figure 1. Experimental plot for infiltration experiment. (Inzeted: Plot layout and rain discs position represented by green stars)

2.3. Artificial Rain System

Artificial rain was carried out using an artificial rain system which consists of 4 rain discs. The components of a rain maker involve direct current motor, disc, water regulator, frame, water pump, adapter, water reservoir and hose components. Figure 2 showed a sketch of the artificial rain system. Artificial rain sources were placed at four points. The way the artificial rain system works is as follows: the switch was activated so that the electric current will reach the adapter which will then reach the motor which functions to rotate the disc at a speed of 2500 rpm. At the same time, the electric current also reached the pump in the reservoir or water reservoir. The pump automatically activated to circulate water through the pipe to the disc which has been rotating at 2500 rpm. The flowing water fell right on the rotating disk so that the water will splash in all directions and it will rain. This rain wetted the soil layer used for the experiment.

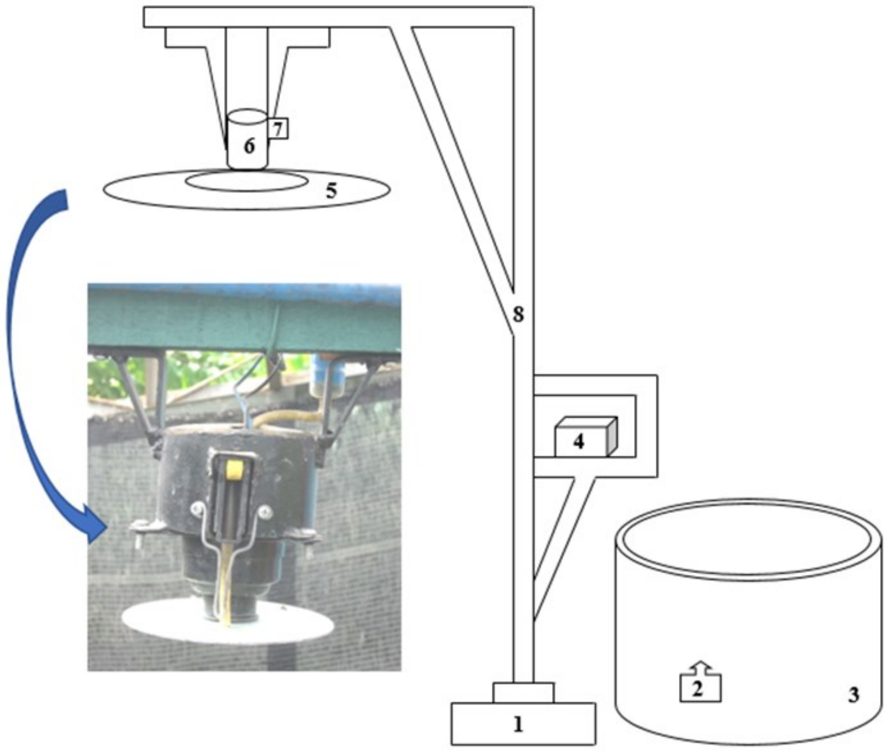

Figure 2. Sketch of artificial rain gear: 1. Foundation, 2. Water pump, 3. Water reservoir, 4. Current rectifier (Adapter), 5. Disc, 6. Disc rotating motor, 7. Motor drive, 8. Frame.

2.4. Research Variables

Water absorption from artificial rain was measured according to the specified time period. Data collection was carried out in three different places with a time interval of 5 minutes, 15 minutes, 30 minutes, 50 minutes, 75 minutes, 105 minutes, 120 minutes. Each time interval was carried out at 3 data sampling points with 3 repetitions. The variables studied were as follows:

a. Soil water content and soil texture

Determination of the initial moisture content of the soil is done by weighing the soil sample before it is put in the oven, the weight is recorded as the wet weight. then the soil sample is baked in the oven until the weight is constant (minimum 4 h at 105 °C). After that, put it in the desiccator. After cooling, the soil samples were weighed and recorded as dry weight. The initial moisture content was calculated by subtracting the wet weight of the sample from the dry weight after baking.

b. Volume of rain water

The volume of water is calculated from the reservoir by means of the volume of water in the initial reservoir minus the volume of water in the final storage after artificial rain.

c. Depth of water infiltration (cm)

The depth or thickness of infiltration was calculated by measuring the thickness of the infiltration of water according to the specified rainy season using a measuring instrument to a depth of approximately 20 cm (rice plant roots).

d. Infiltration rate (cm/menit)

Infiltration rate (Ir) was calculated from the difference in infiltration (dI) over the time interval (dt) through Equation 1 (Amami *et al*., 2021):

$$Ir(t) = \frac{dI}{dt} \quad (1)$$

2.5. Data Analysis

The data obtained was analyzed using the regression method to determine the relationship between the volume of water and the thickness of the infiltration that occurred up to the root zone. Furthermore, to determine the differences in the three treatments, analysis of variance was used with a level of 5% and 1%. Then proceed with the Duncan Multiple Range Test (DMRT) analysis at the level of α = 5%.

3. RESULTS AND DISCUSSION

3.1. Moisture Content and Soil Texture

The results of soil texture analysis showed that the soil was dominated by the sand fraction of 87.71%, followed by the clay fraction of 9.71% and the dust fraction of 2.67% (Table 1). Based on the soil texture triangle, the soil in this study belongs to the soil type of loamy sand. The results of the analysis of initial soil moisture content and soil fractions are presented in Table 2. The initial soil moisture content showed that the initial soil moisture content ranged from 13.64% to 16.98% (wet basis) with an average value of (15.17±1.69)%. Agustin et al. (2015) stated the results of his research that soil texture has the lowest efficiency in storing water found in sandy textures. This texture is able to store water in small amounts. Loam soil texture has the highest storage efficiency. This is reinforced by a statement from Hanafiah (2012), that the smaller the particle size, the greater the number and the greater the surface area per unit weight of soil, which indicates the denser the particles per unit volume of soil. Ardiansyah et al. (2019) in his research the effect of sand content on the infiltration rate is 52.1%, with a positive direction of influence, where every increase in the value of the sand content, the infiltration rate will increase, so that the ability to store water is less.

Table 1. Texture of soil used in the experiment

Soil component	Fraction (%)
Sand	87.71
Silt	2.67
Clay	9,71

Table 2. Initial soil water content (wet basis)

Sample	Water content (%)
1	14.89
2	16.98
3	13.64
Average	15.17
Standard deviation	1.69

3.2. Rain Intensity

In this study, the total volume of rain produced from 4 units of rain disks for 120 minutes was an average of 331.83 L. This amount of rain was poured in the study area with a total area of 36 m2 for 9 research plots. It can be calculated that artificial rain in this study is equivalent to a rain intensity of 4.61 mm/h. According to the BMKG classification, the artificial rain intensity is in the range of light rain (<5 mm/h) (Endarwin et al., 2014). Likewise, according to Wang et al. (2021), rainfall in the range of <5 mm/h is classified as light rain. However, according to Thies *et al*. (2008), rain in the intensity range of 1.9 to 8.0 mm/h is classified as moderate rain. According to Wischmeier & Smith (1958) rain that falls to the earth will give a blow to the ground with energy (Y) which increases with rain intensity (X) and follows the equation Y = 916 + 331 log X. Therefore, rain with an intensity of 4.61 mm/h (0.18 in/h) will have an energy of 669 (ft.ton/acre.in) which is equivalent to 17.57 MJ/m3. Rain intensity greatly affects the depth of water infiltration into the soil because the higher the rain intensity, the thicker (deeper) infiltration will result. A positive correlation between rainfall intensity and infiltration of water into the soil has been reported by Nadal-Romero *et al*. (2011) and Hao *et al*. (2008).

Table 3. Rainfall duration, rainwater volume, and infiltration thickness

Rain duration	**Volume**	**Infiltration depth (cm)**		
(min)	**(L)**	**T0**	**T1**	**T2**
5	17.36	0.98d	2.79g	4.31g
15	43.73	2.41c	7.29f	8.51f
30	82.31	4.68b	9.92e	11.39e
50	140.83	6.12a	11.44d	14.61d
75	214.79	6.52a	13.13c	16.32c
105	291.95	7.13a	16.73b	18.98b
120	331.83	7.30a	18.09a	21.30a

Note: Different letters indicate significantly different based on 5% DMRT. T0 = no tillage, T1 = hoeing, T2 = hoeing plus loosening.

3.3. Water Infiltration

Table 3 presents data on rainfall duration, rainwater volume, and infiltration thickness for the three land preparation methods. The results showed that the longer the rainy period, the deeper the water absorption rate in the top soil layer. The results also show that land preparation methods also affect the depth of water absorption. Without tillage, the rainfall intensity of 4.61 mm/hour for two hours was only able to seep into the soil as thick as 7.30 cm. This is still lacking for rice plant root depth which reaches 20 cm. If the soil is hoed, the thickness of the water infiltration increases significantly to 18.09 cm after two hours. To reach an infiltration depth of 20 cm, it takes even longer time, which means more volume of rainwater. Land preparation by hoeing plus loosening produces the best soil absorption. Within two hours, soil absorption has reached 21.30 cm. Rusdiansyah (2001) said that of the 26 cultivars of upland rice in East Kalimantan, they had a maximum root length of 16.74 cm. Therefore, preparing the land by hoeing alone is enough to absorb water into the root zone of the upland rice. Thus what is recommended for further research on upland rice cultivation is the T1 or T2 treatment.

The results of our study are in line with the results of the study by Destra *et al.* (2014), where the intensive tillage system produced the highest infiltration and cumulative infiltration rates (293.7 mm and 585 mm/hour), compared to minimum tillage (158.8 mm and 320 mm/hour) or no tillage (106, 7 mm and 205 mm/hour). Similar results were also conveyed by many other studies (Auchaogu *et al.*, 2015; Kroulík *et al.*, 2007; Akinbile *et al.*, 2016) where more intensive tillage resulted in a greater infiltration rate than minimum tillage or no tillage. Hoeing or ploughing causes the soil structure in the top soil layer to crack and break so that it becomes crumbly and is more easily penetrated by water. In addition, hoeing will also enlarge the pores of the soil, both macro and micro, which will make it easier for water to seep into the soil. Loosening after hoeing will result in the soil structure becoming crumbly and high porosity thereby accelerating water infiltration so that in the same rain period it will have a deeper infiltration thickness, compared to soil with no tillage. In addition, cultivated soil has the effect of better circulation of water, air and organic matter. However, overly intensive tillage involving plowing, harrowing, and filling can reduce the infiltration rate due to the fact that the soil particles become so fine that they close the active macro-pores (Atta-Darkwa *et al.*, 2022). The results of this study can be applied to planting upland rice in dry land, especially in providing moisture content in the root zone of upland rice.

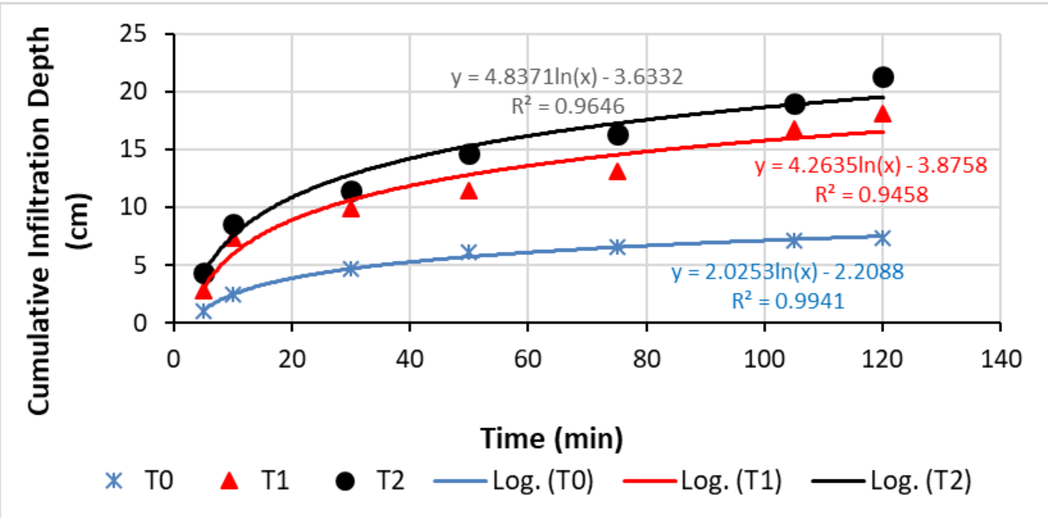

Figure 2. The effect of rain duration on the cumulative infiltration depth in the T0, T1, and T2 treatments with a rain intensity of 4.61 mm/h.

Figure 2 shows the relationship between rain duration and cumulative infiltration depth. It can be seen that infiltration thickness increases with rainfall duration and follows a logarithmic function for all land preparation methods. The relationship between rain duration (x) and cumulative infiltration depth (y) for the three of land preparation methods are presented as the following:

$y = 2.0253 \ln(x) – 2.2088$	$R^2 = 0.9941$	(No till)
$y = 4.2635 \ln(x) – 3.8758$	$R^2 = 0.9458$	(Hoeing)
$y = 4.8371 \ln(x) – 3.6332$	$R^2 = 0.9646$	(Hoeing + loosening)

A very close relationship between rainfall duration and infiltration depth is shown by the high R2 value of all land preparation methods (R2 = 95% to 99%). Jian et al. (2018) also found a positive relationship between the depth of infiltration and the amount of rain in the form of a logarithmic function.

3.4. Infiltration Rate

Figure 3 shows the relationship between infiltration rate and time. We can see that the infiltration rate is high at first and then slows down as time goes on. This can be understood as a result of the high degree of saturation in the soil (Akinbile et al., 2016). The relationship between rainfall duration and infiltration rate follows the power function with a negative power. This pattern applies to all land preparation methods.

$y = 1.7715\ x–0.969$	$R^2 = 0.8320$	(No till)
$y = 2.3362\ x–0.738$	$R^2 = 0.7664$	(Hoeing)
$y = 3.1061\ x–0.76$	$R^2 = 0.8184$	(Hoeing + loosening)

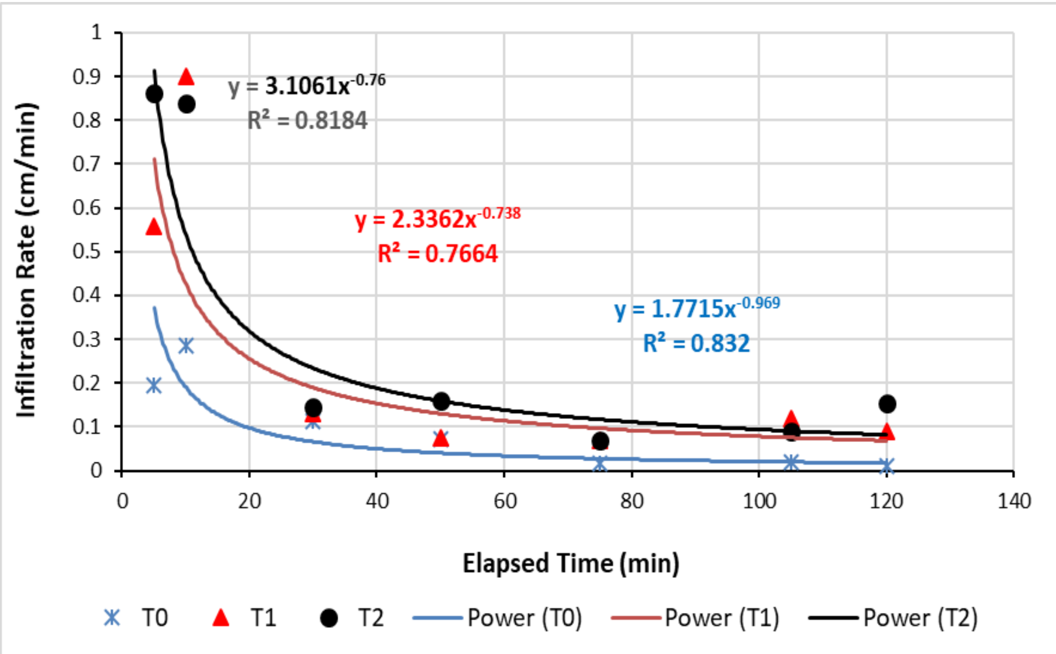

Figure 3. Infiltration rate of loamy sand (regosol) soil with different soil preparation

A close relationship is indicated by a high R^2 value in the range of 0.77-0.83. According to Sugiono (2014), with a range of R^2 values, the power function model is strong to very strong. A similar pattern was also reported by Wei *et al.* (2022) where the infiltration rate is practically unchanged after 12 minutes. Similar patterns regarding the relationship between infiltration rate and land preparation intensity was also reported by Kroulik et al. (2007) where land preparation by plowing resulted in an infiltration intensity of 1.00 L/min, greater than the infiltration intensity on land without tillage (0.53 L/min). Other studies also reported similar findings where soil tillage methods resulted in different soil infiltration rates. After 45 minutes, the infiltration rate is about 40 L/min with harrowing, 30 L/min with plowing, and only 25 L/min without tillage (Osanyinpeju & Dada, 2018).

3.4. Water Volume vs. Infiltration Depth

Figure 4 shows the relationship between infiltration depth and rainwater volume for the three land preparation methods. We can observe that the depth of infiltration (y) increases with the volume of rain (x) and follows a logarithmic function, namely:

$y = 2.2520 \ln(x) - 5.5452$	$R^2 = 0.9797$	(No till)
$y = 4.8221 \ln(x) - 11.282$	$R^2 = 0.9644$	(Hoeing)
$y = 5.4546 \ln(x) - 11.959$	$R^2 = 0.9777$	(Hoeing + loosening)

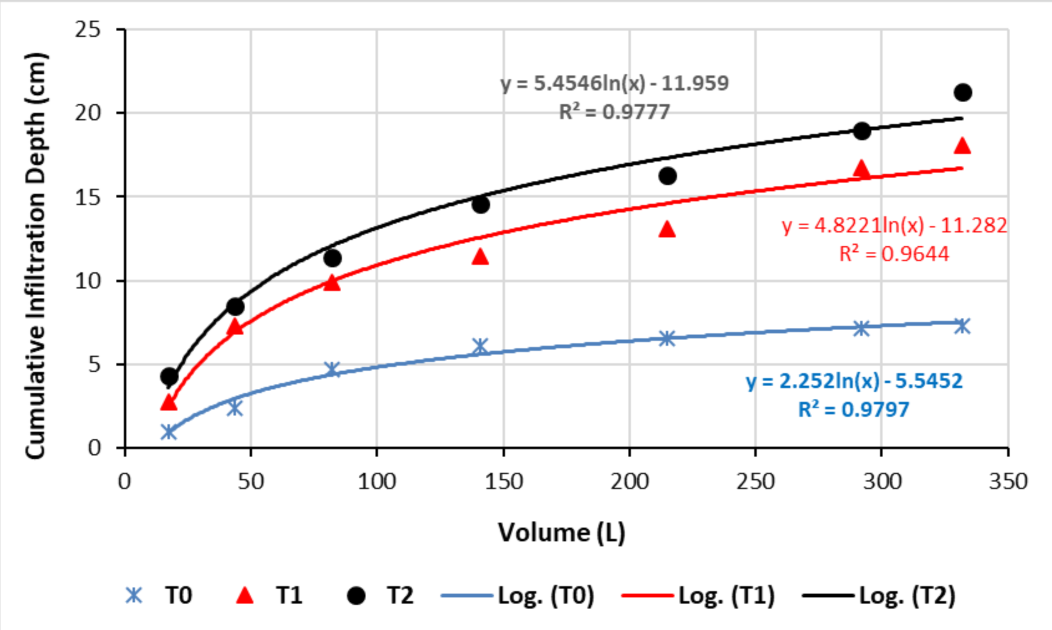

Figure 3. Interaction of water volume with infiltration depth for treatment T2 (hoeing + loosening)

A very high R^2 value (0.96-0.98) indicates a very strong relationship between cumulative infiltration depth and rainfall volume. Infiltration rises high at first, then slopes down. This is because the soil is getting saturated, thereby reducing its ability to absorb water. Jian *et al.* (2018) also showed a similar pattern of logarithmic relationship (function) between the depth of infiltration and the amount of rain in the soil around shrub with an R^2 value 0.77 and 0.89 in positions around the shrub stems and an R^2 of 0.81 in the soil outside the shrub. From Figure 4 we can observe that in tillage with hoeing plus loosening (T2), a volume of 350 L of rain (equivalent to a rain thickness of 9.7 mm) can produce water infiltration up to a rooting depth of 20 cm.

4. CONCLUSION

Based on the results of the research and discussion above, several conclusions can be drawn. Land preparation methods have a significant impact on the soil's ability to absorb water. Infiltration depth and infiltration rate sequentially from the highest to the lowest are indicated by the land preparation method hoeing + loosening > hoeing > no till. With a rainfall intensity of 4.61 mm/hour and approx. time, water has seeped into the depth of plant roots, namely 18.09 cm for land preparation by hoeing and 21.30 cm for hoeing plus loosening soil. The infiltration depth has not yet reached the roots (7.30 cm) on land with no tillage. The relationship between rainfall duration as well as rainfall volume on cumulative infiltration depth follows a logarithmic function with a very high R2 value (≥ 95%) indicating a very strong relationship. The relationship between rain duration and infiltration rate follows a power function with a negative power with an R2 value between 0.77-0.83 (strong to very strong). The effect of land preparation methods on infiltration will be determined by the type of soil. Therefore, the results of this study need to be replicated in other soil types to obtain a more complete relationship.

Acknowledgement

Thanks and appreciation are delivered to the Rector of Universitas Sarjanawiyata Tamansiswa (UST) Yogyakarta, the head of the LP2M, and the dean of the Agriculture Faculty, UST Yogyakarta, who have provided equipment and facility for this research to be completed.

REFERENCES

Ahuchaogu, I.I., Etim, I., & Etuk, A.I. (2015). Effects of tillage methods on soil infiltration rate in Uyo, Nigeria. *Continental J. Engineering Sciences*, ***10***(2), 10 – 20. DOI: 10.5707/cjengsci.2015.10.2.10.20

Agustin, Z.A., Novita, E., & Widodo, S. (2015). Kajian efisiensi penyimpanan air dari berbagai tekstur tanah. *Berkala Ilmiah Teknologi Pertanian*, ***1***(1), 1-4.

Ahsani, F.T., & Ardian, D. (2019). Analisis faktor yang memengaruhi swasembada beras di Indonesia tahun 2018. *Prosiding Seminar Nasional Official Statistics 2019: Pengembangan Official Statistics dalam Mendukung Implementasi SDG's*, 196-201.

Akinbile, C.O., Famuyiwa, O.A., Ajibade, F.O., & Babalola, T.E. (2016). Impacts of varying tillage operations on infiltration capacity of agricultural soils. *International Journal of Soil Science*, ***11***(2), 29-35. DOI: 10.3923/ijss.2016.29.35

Amami, R., Ibrahimi, K., Sher, F., Milham, P., Ghazouani, H., Chehaibi, S., Hussain, Z., & Iqbal, H.M.N. (2021). Impacts of different tillage practices on soil water infiltration for sustainable agriculture. *Sustainability*, ***13***, 3155. https://doi.org/10.3390/su13063155

Atta-Darkwa, T., Asare, A., Amponsah, W., Oppong, E.D., Agbeshie, A.A., Budu, M., Larbi, I., Akolgo, G.A., & Qua, D.N.D. (2022). Performance evaluation of infiltration models under different tillage operations in a tropical climate. *Scientific African*, ***17***, e01318. https://doi.org/10.1016/j.sciaf.2022.e01318

Ardiansyah, E.Y., Tibri, T., Lismawaty, L., Fitrah, A., Azan, S., & Sembiring, J.A. (2019). Analisa pengaruh sifat fisik tanah terhadap laju infiltrasi air. *Seminar Nasional Teknik (SEMNASTEK) UISU 2019*, 86-90.

Barkatullah, A.H., Syahrida, S., & Ifrani, I. (2016). Perlindungan lahan pertanian subur dalam kerangka ketahanan pangan di Kabupaten Barito Kuala, Kalimantan

Selatan. *Prosiding SNaPP2016 Sosial, Ekonomi, dan Humaniora*, ***6***(1), 260-266.

Destra, H., Afandi, A., Buchari, H., & Banuwa, I.S. (2014). Pengaruh sistem olah tanah terhadap infiltrasi pada Lahan bekas alang-alang (Imperata cylindrica) yang ditanami kedelai (Glycine max L.) musim kedua. *Jurnal Agrotek Tropika*, ***2***(3), 470 – 474.

Direktorat Statistik Tanaman Pangan, Hortikultura, dan Perkebunan. (2022). *Luas Panen Dan Produksi Padi Di Indonesia 2021*. Jakarta: Kementerian Pertanian.

Endarwin, E., Hadi, S., Tjasyono, B.H.K., Gunawan, D., & Siswanto, S. (2014). Modified convective stratiform technique (CSTm) performance on rainfall estimation in Indonesia. *Journal of Mathematical and Fundamental Sciences*, ***46***(3), 251-268. DOI: 10.5614/j.math.fund.sci.2014.46.3.4

Hafif, B. (2016). Optimasi potensi lahan kering untuk pencapaian target peningkatan produksi padi satu juta ton di Provinsi Lampung. *Jurnal Litbang Pertanian*, ***35***(2), 81-88.

Hanafiah, K.A. (2012). *Dasar-Dasar Ilmu Tanah*. Jakarta: Rajawali Press.

Hao, Z., Zheng, J., Ge, Q., & Guo, X. (2008). Relationship between precipitation and the infiltration depth over the middle and lower reaches of the Yellow River and Yangtze-Huaihe River Valley. *Progress in Natural Science*, ***18***, 1123–1128.

Haryanto, A., Suharyatun, S., Rahmawati, W., & Triyono, S. (2019). Energi terbarukan dari jerami padi: Review potensi dan tantangan bagi Indonesia. *Jurnal Keteknikan Pertanian*, ***7***(2), 137 -144.

Jian, S., Zhang, X., Li, D., & Wang, D. (2018). The effects of stemflow on redistributing precipitation and infiltration around shrubs. *Journal of Hydrology and Hydromechanics*, ***66***(1), 79–86. DOI: 10.1515/johh-2017-0043

Kroulík, M., Hůla, J., Šindelář, R., & Illek, F. (2007). Water infiltration into soil related to the soil tillage intensity. *Soil & Water Res*., ***2***(1), 15–24

Marwanti, M. (2022). *Peningkatan Produktifitas Tanaman Padi Lahan Kering*. Kementerian Pertanian, Direktorat Jendral Tanaman Pangan Jakarta. https://tanamanpangan.pertanian.go.id/detil-konten/iptek/45

Mulyani, A., Kuncoro, D., Nursyamsi, D., & Mulyani, F.A. (2016). Analisis konversi lahan sawah: Penggunaan data spasial resolusi tinggi memperlihatkan laju konversi yang mengkhawatirkan. *Jurnal Tanah dan Iklim*, ***40***(2), 121-133.

Mulyaningsih, E.S. & Indrayani, S. (2014). Keragaman morfologi dan genetik padi gogo lokal asal Banten. *Jurnal Biologi Indonesia*, ***10***(1), 119-128.

Nadal-Romero, E., Lasanta, T., Regüés, D., Lana-Renault, N., & Cerdà, A. (2011). Hydrological response and sediment production under different land cover in abandoned farmland fields in a Mediterranean mountain environment. *Boletín de la Asociación de Geógrafos Españoles*, ***55***, 303-323.

Osanyinpeju, K.L., & Dada, P.O.O. (2018). Soil porosity and water infiltration as influenced by tillage practices on Federal University of Agriculture Abeokuta, Ogun State, Nigeria Soil. *International Journal of Latest Technology in Engineering, Management & Applied Science (IJLTEMAS)*, ***VII***(IV), 245-252.

Purbiyanti, E., Yazid, M., & Januarti, I. (2017). Konversi lahan sawah di Indonesia dan pengaruhnya terhadap kebijakan harga pembelian pemerintah (HPP) gabah/ beras. *Jurnal Manajemen & Agribisnis*, ***14***(3), 209-217. https://doi.org/10.17358/jma.14.3.209

Rusdiansyah, R, Rohaeni, N., & Trikoesoemaningtyas, T. (2001). Evaluasi beberapa kultivar padi gogo asal Kalimantan Timur untuk ketahanan terhadap aluminium menggunakan metode kultur hara. *Bulutin Agronomi*, ***29***(3), 73-77.

Saleh, Y., Zainiyah, W., & Yunianti, I.F. (2021). Prospek pengembangan padi gogo mendukung lumbung pangan di wilayah perbatasan Pulau Morotai. *Agritech*, ***XXIII***(2), 1411-1063.

Sugiyono, S. (2019). *Metode Penelitian Pendidikan Pendekatan Kuantitatif, kualitatif, dan R&D*. Bandung: Alfabeta.

Suratha, I.K. (2014). Dampak alih fungsi lahan pertanian terhadap ketahanan pangan. *Media Komunikasi Geografi*, ***15***(2), 52-61.

Thies, B., Nauß, T., & Bendix, J. (2008). Precipitation process and rainfall intensity differentiation using Meteosat Second Generation Spinning Enhanced Visible and Infrared Imager data. *Journal of Geophysical Research*, ***113***, D23206. DOI: 10.1029/2008JD010464.

Thoriq, A., & Sampurna, R.M. (2016). Evaluasi potensi pengairan calon lokasi perluasan sawah di Kabupaten Tulang Bawang Provinsi Lampung. *Jurnal Teknik Pertanian Lampung*, ***5***(3), 185 – 190,

Wang, W., Hocke, K., & Mätzler, C. (2021). Physical retrieval of rain rate from ground-based microwave radiometry. *Remote Sensing*, ***13***, 2217. https://doi.org/10.3390/rs13112217

Wei, L., Yang, M., Li, Z., Shao, J., Li, L., Chen, P., Li, S., & Zhao, R. (2022). Experimental Investigation of Relationship between Infiltration Rate and Soil Moisture under Rainfall Conditions. *Water*, ***14***, 1347. https://doi.org/10.3390/w14091347

Widata, S., Gunarso, G., Nugroho, F., & Herahli, A. (2011). Rekayasa mesin pengkabut air (humidifier control) untuk peningkatan produksi bibit klengkeng pingpong. *Inotek*, ***15***(1), 18-29.

Wischmeier, W.H., & Smith, D.D. (1958). Rainfall energy and its relationship to soil loss. *Transactions, American Geophysical Union*, ***3***(2), 285-291.

Yulianto, Y. (2020). Lahan kering, potensi untuk perluasan areal terbuka lebar. *Tabloid Sinar Tani*, **08 Jul 2020**. https://tabloidsinartani.com/detail/indeks/agri-sarana/13617-Lahan-Kering-Potensi-untuk-Perluasan-Areal-Terbuka-Lebar