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ORIGINAL ARTICLE

Study of Soil Moisture on Coffee Plantation in Dry Land Using Neutron Probe in Malang, East Java

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ABSTRACT
Water is a limiting factor in the production of dry land agriculture. Improved soil cover and terracing is one of the techniques of water conservation in dryland. The objective of the research was to know the ability of soil profile to retain water for Coffee plantation in relation to the condition of rainfall. The research was conducted on Coffee plantation area of Coffee Research Center Sumber Asin and in the garden of PT. Perkebunan XXIII Pancursari, Sumbermanjing Wetan, Malang. There were two types of Coffee planting i.e. Coffee (A) planted in arranged terrace, free from weeds and Coffee (B) in unarranged terrace, full of weeds. Lamtoro and Glyricidae were used as shade. Field observations are done for soil moisture measurement and rainfall measurement. Laboratory studies was done in the Laboratory of Soil Physics, Faculty of Agriculture, Brawijaya University for analysis pF curve, soil texture, saturated and unsaturated hydraulic conductivity. Results of laboratory analysis showed that increasingly to the bottom layer of soil it will be dominated by clay particles. The bulk density was between 0.82 and 10.6 g cm^{-3} with particle density of 2.48 and 2.61 g cm^{-3} and total porosity of 57.26 and 67.72 %. The field capacity to retain moisture (pF 2) was higher in deeper soil layer. Soil moisture is highest in January and February, in which the total volume of soil moisture layer 00-200 cm in treatment Coffee plantation (A) higher (3343-3353 mm) when compared with the treatment Coffee plantation (B) that is equal to 3316-3326 mm.
Keywords: *soil moisture, rainfed, terracing, weeds*

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INTRODUCTION

Water is a limiting factor in crop yield of dryland [27, 28, 40,42, 45, 20, and 54]. The water availability from rainfall in dry land is lower when compared with the use of water to evaporation and transpiration [11, 33, 34, 40, and 46], so that charging water storage in the soil commonly through seepage [40]. In addition, the distribution pattern of rainfall on dry land commonly not equal causing water stress in plants and even to trigger high surface runoff and erosion potential on dry land [34]. The level of water stress experienced by plants in dry land varies depending on the distribution pattern of rainfall, soil water-holding capacity [11 and 28], crop water requirements, initial soil moisture and water absorption capacity of the soil by plants. [28]. Additionally, the use of agricultural machines also affect the groundwater regime in the drylands [24]. Therefore, water conservation practices in dryland considered very important [31 and 42] especially with the increase of efficiency use of rainfall [42] to reduce the potential risk of water stress, to press erosion potential and increasing soil productivity [31]. Water conservation in dryland can be done by soil tillage practices [17] and utilization of crop residue [17 and 31].

The terrace is a modifications of soil construction which made to the sloping agricultural land. Some goals of terracing is reduce surface runoff, reduce of erosion potential, increase infiltration capacity, increase soil moisture [9,16, 25 and 55], as a shelter when erosion and surface run off [32] and increasing the nutrient content in the soil [9 and 25]. The terrace can collect and save water for longer so that water infiltration also experiencing more when compared to land without terrace [9]. Therefore making the terrace is a rain harvesting practices [19] and is expected to reduce of soil and land degradation, especially on dryland. Bernas [9] showed that the coffee plantation without terracing, resulting in increased potential for erosion. Results of research by Priatna [36] state that the coffee plantation in sloping land with a slope of 9-15% erosion of 60 Mg ha^{-1} year^{-1} (1-year-old coffee plantation); 37 Mg ha^{-1} year^{-1} (3-year-old coffee plantation) dan 5 Mg ha^{-1} year^{-1} (6-year-old coffee plantation). Therefore, the terrace application is recommended on coffee plantations with slopes of 15% [9].

Weeding is an common activity undertaken by farmers in order to reduce competition of components of plant growth i.e. water, O_2, nutrient elements, etc. However, weeding the garden the coffee was not recommended because it will increase the potential for erosion, increasing the potential for leaching of nutrients, increase surface temperature of soil and reduce soil moisture status [23]. Increased weed populations can be reduced by planting cover crops. Afandi et al. [3] stated that ground cover with cover crops or weeds is an agricultural conservation practices that can improve the ability of the soil. Ground cover management is a key to water catch in dryland farming [46]. Ground cover by cover crops or weeds can improve soil morphology and affect the character of the soil chemical i.e. increasing soil organic matter content, increasing total N, improve soil pH, increasing the cation exchange capacity (CEC), increasing capacity of Calcium exchange, and to press Al exchange capabilities [3]. Crop residue on the soil surface that acts as a mulch has benefits for protecting soil aggregate by reducing the kinetic energy of rainfall so that soil pore remains intact [46], reduce of evaporation, reduce of surface runoff, reduce of erosion [17], increasing of infiltration [1 and 17], and improve soil fertility [1].

Sumbermanjing Wetan is one of the districts in Malang. In Malang District Regulation No. 2 in 2011 [6] stated that the sub-district Sumbermanjing Wetan classified in the region that has a wavy topography. Agriculture in this region included in dryland agriculture which only rely rainfall to meet the water needs of crops. One of the many types of plants cultivated in the district Sumbermanjing Wetan is coffee plants, where water needs are also only rely rainfall. This condition is different with the opinions Kharche et al. [21] that said coffee plants can produce the maximum yield in the region with rainfall of 2000-3000 mm year-1 and dry months of 2-3 months. The objective of the research was to know the ability of soil profile to retain water for Coffee plantation in relation to the condition of rainfall

METHODOLOGY

The research was conducted on Coffee plantation areas of Coffee Researh Centre Sumber Asin and in the garden of PT Perkebunan XXIII Pancursari, sub-districts Sumbermanjing Wetan, Malang District. The research was done for a year. There were two types of Coffee planting i.e. Coffee (A) planted in arranged terrace free from weeds and Coffee (B) in unarranged terrace full of weeds. Lamtoro and Glyricidae were used as shade. The research was done in two ways i.e. field research and laboratory studies.

1. Field research

   Soil moisture measurement

   Three to five aluminium tubes were installed up to 215 cm deep to measure the soil moisture using guide tube method. Calibration checks were made by gravimetric method [8]. Measurement of soil moisture was done using neutron probe type IH III-DIDCOT [52] with intervals of 7-21 days according to the condition of rainfall.

   Reading of the neutron probe was done in each 10 cm interval from 10 to 200 cm deep, each depth was observed 3 times in 16 seconds. Calibration equation was used to measure volumetric water content :

   $$VWC = 0.867 \frac{R}{RW} - 0.016$$

   Where: R= reading from the soil (cps), RW= standard reading in water (cps), VWC= volumetric water content ($cm^3\ cm^{-3}$)

   Rainfall measurement

   Rainfall was measured daily using rain gauge/umbrometer [8] of the climatological station Sumber Asin (SA-90) located in 8.230S, 1050E and altitude 550 m.

   Determination of reference evapotranspiration (ETo)

   Reference evapotranspiration was determined from the climatology data obtained from the climatology station (SA-90) consisting of: air temperature, wind speed, sunshine duration and humidity. The above data would be used to calculate ETo using Modified Penman method [15]. Furthermore the value of potential ET and crop coefficient were used to calculate the crop water requirement.

2. Laboratory studies

   From three locations of the experiment undisturbed soil cores and composite soil samples were taken from 0-120 cm depth for the analysis of soil physical properties. The analysis was done in the Laboratory of Soil Physics, Faculty of Agriculture, University of Brawijaya, Malang. The pF curve were analysed using Sand box method [37] and Pressure plate method [49]. The texture/distribution of particle size was measured using pipette method [7]. Saturated hydraulic conductivity was measured using constant head method [12] and unsaturated hydraulic conductivity was measured using Hot Air method [37].

RESULT AND DISCUSSION

TABLE 1: PARTICLE DISTRIBUTION ANALYSIS

Soil sample (cm)	Sand 2.00 – 0.05 mm (%)	Silt 0.05 – 0.002 mm	Clay < 0.002 mm	Texture
0 – 20	12.9	52.0	35.1	Silty clay loam
20 – 40	10.0	48.2	41.8	Silty clay
40 – 60	5.4	51.3	43.3	Silty clay
60 – 80	8.6	47.6	47.6	Silty clay
80 – 100	6.4	38.2	55.4	Clay
100 – 120	8.7	37.4	53.9	Clay

From the results of analysis of particle size distribution presented in Table 1. It can be stated that the deeper the soil layer the higher the clay content. This would mean that there was a possibility that the ability to retain the available moisture was greater the deeper the soil, but the movement was very slow. Soil texture has a dominant effect against character of soil moisture [43]. Clays have the ability to hold more water per unit volume if compared with sandy soils [50]. A similar statement is a soil with a clay mineral content it also has a lot more soil moisture retention higher [29]. However, the movement of water in clay particles is very slow, this is in accordance with the opinion Schuhmann et al. [44] stated that the main factor affecting the rate of water movement in the soil is the particle size, clay particles are particles that have a size of < 0.002 mm, where the smaller the particle size, the smaller the pore space so that water movement increasingly hampered.

TABLE 2: SOIL PHYSIC ANALYSIS

Soil sample (cm)	Moisture content at pF 0 % vol	pF 1	pF 2	pF 2.5	pF 3	pF 4.2	Bulk density (g cm^{-3})	Particle density (g cm^{-3})	Porosity (%)
0 – 20	59.09	57.56	44.44	41.11	40.48	31.06	0.93	2.55	63.53
20 – 40	56.37	46.99	40.57	37.98	37.34	28.53	0.82	2.54	67.72
40 – 60	60.60	60.55	54.13	51.51	50.85	38.00	0.95	2.55	62.75
60 – 80	62.22	59.66	55.20	52.81	52.02	36.95	0.99	2.61	62.07
80 – 100	63.68	62.79	59.58	57.36	56.47	40.48	10.6	2.48	57.26
100 – 120	58.93	57.76	52.42	50.46	49.61	35.85	0.94	2.59	63.71

Table 2 presents the results of analysis of soil physical properties i.e. bulk density, particle density, total porosity and moisture content in different potential. Soil texture, porosity and bulk density affect soil moisture status [8]. The bulk density was between 0.82 and 10.6 g cm^{-3} with particle density of 2.48 and 2.61 g cm^{-3} and total porosity of 57.26 and 67.72 %. In the 80-100 cm soil layer, the bulk density of 10.6 g cm^{-3}, while the porosity of 57.26%. In contrast to the 20-40 cm soil layer, the bulk density of 0.82 g cm-3, but porosity is high that is equal to 67.72%. The results of the analysis in accordance with some research previous that showed that the bulk density is inversely related to soil porosity [4, 5, 8, 22, 31, 47, 48 and 51,]. Increase of bulk density that characterized by soil compaction can inhibits water movement in soil [51], this is in accordance with the soil texture at a depth of 80-100 cm (Table 1).

Absorption of water in the soil is regulated by macro pore space on the surface, where the pore space is influenced by soil aggregate size [46]. High porosity on the surface of the ground is necessary to increase soil infiltration capacity. Fine-textured soil generally has a macro pore space in a small amount so that the infiltration capacity is low [46]. This is in accordance with the results of the analysis on layer of 80-100 cm where the clay texture have a low percentage porosity (Table 1 and 2)

The field capacity to retain moisture (pF 2) was higher in deeper soil layer. This was in accordance with the result of the analysis on particle distribution (Table 1), increasingly to the bottom, a layer of soil more dominated by clay particles that have a high water retention. Soil moisture at field capacity conditions depending on the texture and structure of the soil [31]. In the soil layer of 80-100 cm known soil texture is clay (Table 1) and have the highest field capacity conditions are 59.58% by volume (Table 2). This is in accordance with the statement English et al. [14] which states that the soil with a high clay content has soil-water potential a higher than the soil with a high sand content. A similar statement also was stated by Rab et al. [38] that the condition of field capacity is influenced by the content of clay particles and organic matter in the soil, while the permanent wilting point simply influenced by the content of clay particles in the soil. Results of research Rab et al. [38] to soil in South-Eastern Australia show the soil moisture textured of clay at field capacity conditions of 45% by volume, while the sand soil textured of 8% by volume.

FIGURE 1: PROFILE WATER CONTENT ON COFFEE PLANTATION (A) AT EARLY DRY SEASON

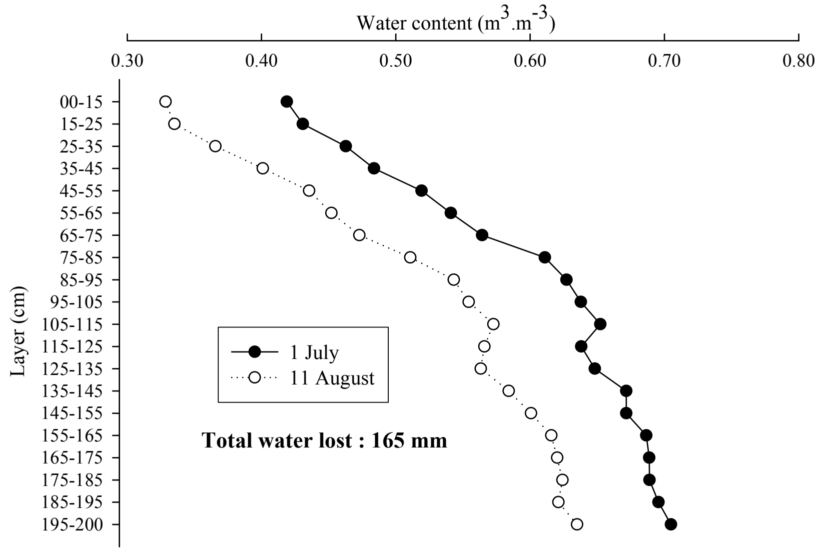
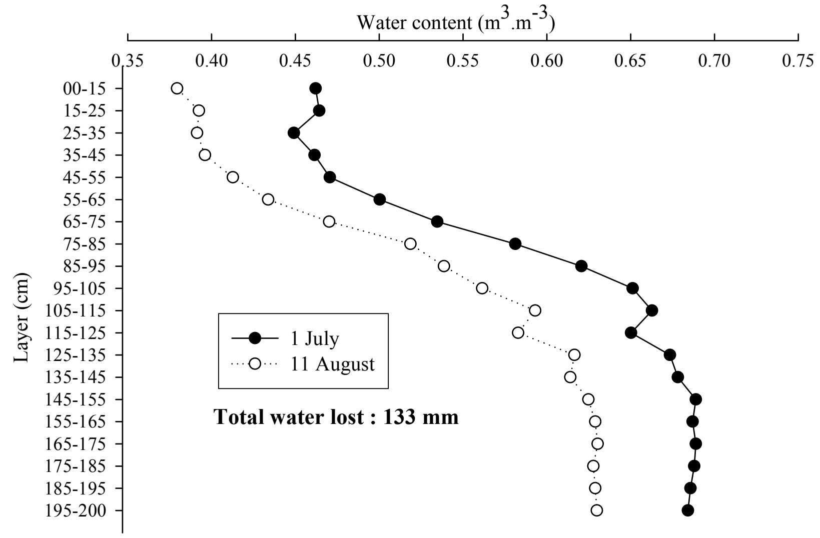


FIGURE 2: PROFILE WATER CONTENT ON COFFEE PLANTATION (B) AT EARLY DRY SEASON



Figures 1 and 2 describe the soil profile moisture in the root zone of Coffee plantation (A) and Coffee plantation (B) which represents the beginning of the observation period of the dry season. Coffee plantation (A) or coffee plantation (B), the observations of soil moisture on 1 July is higher compared to that observed 11 August, this happens because 1 July to 11 August did not happen rain so no additional deposits of soil moisture. Total water lost during the period 1 July - 11 August on the rooting zone coffee plantation (A) higher at 165 mm when compared to coffee plantation (B) that is equal to 133 mm. Increased soil moisture status on the coffee plantation (A) is constant when compared to the coffee plantation (B) where an increase in soil moisture status is high on the soil depth of 45-55 cm to 145-155 cm layer. In general, soil moisture status increases with the depth of the soil layer [51]. These results contradict the results of other studies which suggest that the volume of water lost from the land full of weeds Corn is higher when compared with corn land clean of weeds [41] so the soil moisture status on land clean of weeds higher than the land is full of weeds as a result of the high water requirements of plants either by staple crops or weeds. The high water lost in the rooting zone coffee plantation (A) due to the high rate of evaporation, whereas the rooting zone coffee plantation (B) the rate of evaporation is lower because the land covered by the presence of weeds that can serve as a cover crop.

FIGURE 3: PROFILE WATER CONTENT ON COFFEE PLANTATION (A) AT EARLY RAINY SEASON

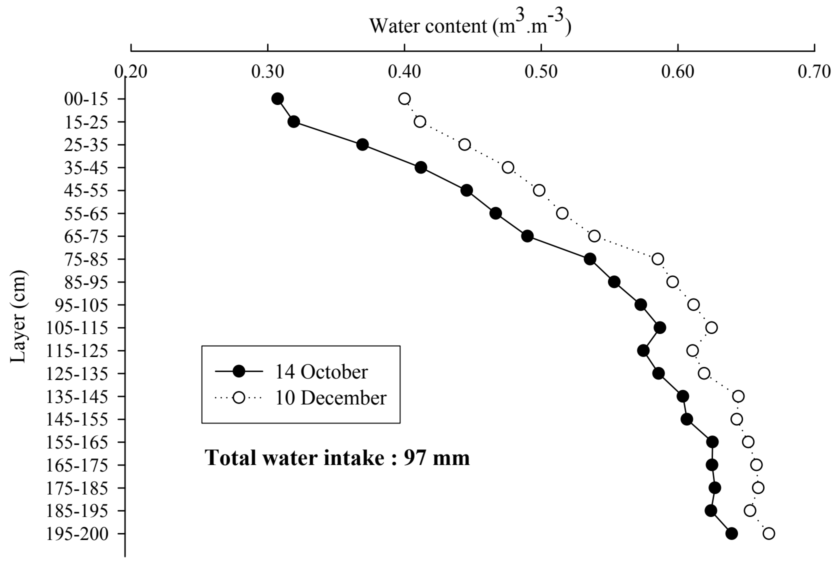
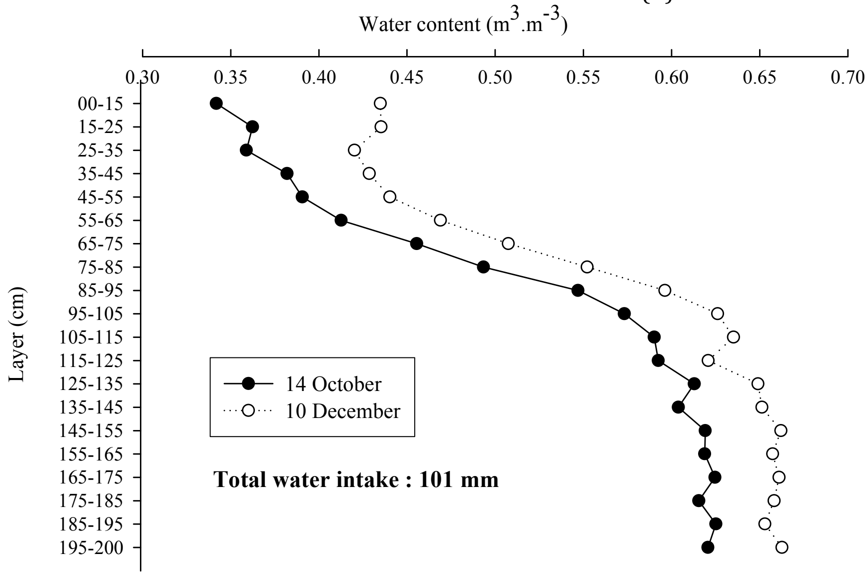


FIGURE 4: PROFILE WATER CONTENT ON COFFEE PLANTATION (B) AT EARLY RAINY SEASON



Figures 3 and 4 present the moisture of the soil profile in the root zone of coffee plantation (A) and coffee plantation (B) which represents the beginning of the observation period in rainy season. Figure 3 and 4 show that the current status of soil moisture at observations of 10 December is higher than observations of 14 October, at the rooting zone to treatment of coffee plantation (A) and (B), this occurs because during 14 October - 10 December there is additional deposit of soil moisture through the addition of rainfall. Differences in soil moisture has a correlation with the amount of rainfall received [54]. Total water intake during the period 14 October - 10 December at the rooting zone of coffee plantation (A) is 97 mm a lower when compared to coffee plantation (B) that is equal to 101 mm. The results of this study showed that the low water uptake occur in the root zone of coffee plantation (A) with terracing application. This contrast with the results of previous research that says that the application of terrace can reduce runoff and erosion significant when compared with no terrace [9] so that land with a terrace can collect rainfall more and improve soil infiltration capacity. Terracing can increase soil moisture deposits, especially at a depth of 40-180 cm [25]. Water intake in the rooting zone of coffee plantation (B) is higher than the coffee plantation (A) due to land on a coffee plantation (B) covered by weeds which also functions as a cover crop. The existence of cover crops can increase soil moisture through increased interception of rainfall and its ability to reduce the rate of evaporation. This is in accordance with the opinion Xu et al. [56] that said the influence of precipitation on soil moisture depends on the intensity of rainfall and evapotranspiration. Kuit et al. [23] not recommend weeding clean the coffee plantations because it will increase the potential for erosion, increase the potential leaching of nutrient elements, improve soil surface temperature and decrease soil moisture.

TABLE 3: MOISTURE CONTENT (mm) ON COFFEE PLANTATION (A)

layer (cm)	Moisture content (mm)	Feb	Mar	Apr	Mei	Jun	Jul	Aug	Sep	Oct	Nov	Dec
00 – 55	Total	727	724	436	431	202	503	444	443	201	412	243
	Gradient		-3	-288	-5	-229	301	-59	-1	-242	211	-169
55-105	Total	835	838	541	513	260	589	527	541	262	506	286
	Gradient		3	-297	-28	-253	329	-62	14	-279	244	-220
105-155	Total	913	918	597	570	300	653	589	603	296	578	313
	Gradient		5	-321	-27	-270	353	-64	14	-307	282	-265
155-200	Total	868	873	562	554	285	624	556	572	283	556	295
	Gradient		5	-311	-8	-269	339	-68	16	-289	273	-261
00 - 200	Total	3343	3353	2136	2068	1047	2369	2116	2159	1042	2052	1137
	Gradient		10	-1217	-68	-1021	1322	-253	43	-1117	1010	-915

TABLE 4: MOISTURE CONTENT (mm) ON COFFEE PLANTATION (B)

layer (cm)	Moisture content (mm)	Feb	Mar	Apr	Mei	Jun	Jul	Aug	Sep	Oct	Nov	Des
00 – 55	Total	716	720	422	436	207	510	455	445	200	393	238
	Gradient		4	-298	14	-229	303	-55	-10	-245	193	-155
55-105	Total	809	805	519	502	247	575	519	525	248	472	276
	Gradient		-4	-286	-17	-255	328	-56	6	-277	224	-196
105-155	Total	933	938	613	604	305	669	612	618	301	585	322
	Gradient		5	-325	-9	-299	364	-57	6	-317	284	-263
155-200	Total	858	863	570	565	285	622	568	572	280	556	296
	Gradient		5	-293	-5	-280	337	-54	4	-292	276	-260
00 - 200	Total	3316	3326	2124	2107	1044	2376	2154	2160	1029	2006	1132
	Gradient		10	-1202	-17	-1063	1332	-222	6	-1131	977	-874

Based on Table 3 and 4 it is known that the volume of soil moisture is highest in January and February. On the treatment of Coffee plantation (A) and Coffee plantation (B) the highest volume of soil moisture found in the 105-155 cm soil layer is 913-918 mm to Coffee plantation (A) and 933-938 mm to Coffee plantation (B). While the volume of soil moisture lowest found in the 00-55 cm soil layer is 727-724 mm to Coffee plantation (A) and 716-720 mm to Coffee plantation (B). Table 3 and 4 showed that the total volume of soil moisture in soil layer at 00 – 200 cm in treatment Coffee plantation (A) as long January – February is highest (3343-3353 mm) when compared to Coffee plantation (B) is 3316-3326 mm.

Soil moisture in the land scale is influenced by factor of the soil, topography [13] and vegetation [13, 54 and 57]. The main orientation of land management practices in the dryland is to improve soil conditions [42] by increasing the capacity of infiltration and reserve moisture in the soil profile, reduces evaporation and create appropriate conditions for root growth thereby increasing the efficiency of soil water use by crop [11] as well as increased crop production in dryland [42].

Making terracing is one land management practices on dry land with a slope Topographic to control erosion, although not directly able to provide water in the soil [53]. However, Widomski [55] said that making terracing done to control erosion, increase soil moisture status through increased infiltration capacity at the soil surface. Results of previous studies concluded that the application of terracing on coffee plantations can significantly reduces surface runoff by 79% and decrease erosion by 78% [9]. Terracing on sloping land with a slope of 50-100 able to improve the status of soil moisture of 20.7%, reduces soil leaching by 57.9-89.8% well as reduces leaching of nutrient elements by 89.3-95.9% [26]. Making terracing in the Loess Plateau can increase soil moisture reserve and soil fertility status, especially in 40-180 cm soil layer [25]. While the research results of Ramos et al. [39] said that available water capacity (AWC) on terraced land made in Northeastern Spain is very low due to the loss of rock fragments at the time of making the terrace so that reduced soil porosity and pressure the soil infiltration rate.

Based on Table 3 and 4 it is known that the total soil moisture on the land Coffee clean of weeds (Coffee plantation (A) is higher when compared to land Coffee full of weeds (Coffee plantation (B). In some cultivation practices, presence of weeds in fact act as a competitor in the use of water, nutrients and sunlight elements [41] would be harm to the principal crops when weeds are not cleaned. As the results of the study which concluded that the soil moisture content at soil layer 0-20 cm in the plot land that is clean of weeds higher than the land plots un-weeds [30]. This is because the results of weeding that is returned to the soil acts as organic mulch that serves to improve the infiltration capacity and reduce the rate of evaporation thus increasing soil moisture status. The results of another study stated that the presence of vegetation land cover associated with a decrease in the volume of soil moisture when compared to bare ground [10]. While the results of another study concluded that the deposits of soil moisture in the vegetation-covered land is higher than the land without vegetation (bare soil) in the 0-10 cm soil layer and the difference is more pronounced in the deeper soil layers, where at the soil layer 0-40 cm, soil moisture reserve on land covered vegetation 1.8-2 times higher than the bare soil [20]. Vegetation cover on the soil surface affecting soil moisture status [10]. Improved soil cover is a common treatment to reduce evaporation rate [35], pressing surface runoff and erosion [18]. At previous research results, Afandi et al. [2] concluded that the soil cover using grass (*Paspalum conjugatum*) and other weeds significantly can suppressed the surface runoff and erosion. Sadeghi et al. [41] concluded that the soil cover significantly can improve the infiltration capacity and reduce the rate of evaporation. Treatment of no-weed control in coffee plantations proven very effective as soil protection because it can protect the soil surface from rainfall kinetic energy, reduce erosion and surface runoff [7] so that improve the soil moisture status.

CONCLUSION

Results of laboratory analysis showed that the bottom layer of the soil particles is dominate by clay particles. The bulk density was between 0.82 and 10.6 g cm^{-3} with particle density of 2.48 and 2.61 g cm^{-3} and total porosity of 57.26 and 67.72 %. The field capacity to retain moisture (pF 2) was higher in deeper soil layer. The volume of soil moisture is highest in January and February. In the treatment of Coffee plantation (A) planted in arranged terrace, free from weeds has a total volume of soil moisture is higher when compared to Coffee plantation (B) in unarranged terrace, full of weeds. The total volume of soil moisture layer 00-200 cm in treatment Coffee plantation (A) of 3343-3353 mm, while the total volume of soil moisture layer 00-200 cm in treatment Coffee plantation (B) of 3316-3326 mm.

CONFLICT OF INTEREST: Nil

REFERENCES

1. Adeniyan, B.O., Ojeniyi, & S.O., Awodun, M.A. (2008). Relative effect of weed mulch types on soil properties and yield of yam in Southwest Nigeria. *J. Soil. Nature*; 2(3):01-05.
2. Afandi, Manik, T.K., Rosadi, B., Utomo, M., Senge, M., Adachi, T., & Oki, Y. (2002). Soil erosion under coffee trees with different weed managements in humid tropical hilly area of Lampung, South Sumatra, Indonesia. *J. Jpn. Soc. Soil Phys.*; 91:3-14.
3. Afandi, Wiharso, D., Senge, M., Tawiah, A.J., Oki, Y., & Adachi, T. (2003). The change of morphology in red acid soil after four years treatment of coffee plantation with different weeds management in a hilly area of Lampung, South Sumatra, Indonesia. *J. Jpn. Soc. Soil Phys.*; 95:55-62.
4. Aikins, S.H.M., & Afuakwa, J.J. (2012). Effect of four different tillage practices on soil physical properties under cowpea. *Agric. Biol. J. N. Am.*; 3(1):17-24.
5. Alam, Md.K., Islam, Md.M., Salahin, N., & Hasanuzzaman, M. (2014). Effect of tillage practices on soil properties and crop productivity in wheat-mungbean-rice cropping system under subtropical climatic conditions. *The Scientific World Journal*; 2014:1-15. http://dx.doi.org/10.1155/2014/437283
6. Anonymous. (2011). Peraturan Daerah Kabupaten Malang No. 2 Tahun 2011. Pemerintah Kabupaten Malang. Malang. (in Indonesia)
7. Araujo-Junior, C.F., Rodrigues, B.N., Chaves, J.C.D., & Yada Junior, G.M. (2013). Soil physical quality and carbon stocks related to weed control and cover crops in a Brazilian oxisol. In: Soloneski, S., & Larramendy, M. (eds.). *Weed and pest control – conventional and new challenges*. Shanghai, Cina: InTech. 214p. http://dx.doi.org/10.5772/54363
8. Bana, S., Prijono, S., Ariffin, & Soemarno. (2013). The effect of soil management on the availability of soil moisture and maize production in dryland. *International Journal of Agriculture and Forestry*; 3(3):77-85.
9. Bernas, S.M. (2011). Effect of coffee pulp compost and terrace on erosion, run off and nutrients loss from coffee plantation in Lahat Regency, South Sumatra. *J. Trop. Soils*; 16(2)161-167.
10. Brant, V., Pivec, J., Venclová, V., Soukup, J., & Holec, J. (2006). The influence of different soil vegetation covers onto the volumetric water content in upper soil layers. *Plant Soil Environ.*; 52(6):275–281.
11. Brunel, N., Seguel, O., & Acevedo, E. (2013). Conservation tillage and water availability for wheat in the dryland of Central Chile. *Journal of Soil Science and Plant Nutrition*; 13(3):622-637.
12. Dariah, A., Yusrial, & Mazwar. (2006). Penetapan konduktivitas hidrolik tanah dalam keadaan jenuh : metode laboratorium. In: Kurnia, U., Agus, F., Adimihardja, A., & Dariah, A. (eds.). *Sifat fisik tanah dan metode analisisnya*. Balai Besar Litbang Sumberdaya Lahan Pertanian. Jakarta: Badan Penelitian dan Pengembangan Pertanian, Departemen Pertanian. pp:177-186. (in Indonesia)

13. Das, N.N., Mohanty, B.P., & Njoku, E.G. (2010). Profile soil moisture across spatial scales under different hydroclimatic conditions. *Soil Science*; 175(7):315-319.
14. English, N.B., Weltzin, J.F., Fravolini, A., Thomas, L., & Williams, D.G. (2005). The influence of soil texture and vegetation on soil moisture under rainout shelters in a semi-desert grassland. *Journal of Arid Environments*; 63:324–343.
15. Doorenbos, J. &. Pruitt, W.O. (1977). Guidelines for predicting crop water requirements. In: *FAO irrigation and drainage paper no. 24*. Rome, Italy: FAO. 145p.
16. FAO (Food and Agriculture Organization). (2000). Manual on integrated soil management and conservation practices. *FAO Land and Water Bulletin No. 8*. Rome. Italy: FAO. 214p.
17. Fuentes, J.P., Flury, M., Huggins, D.R., & Bezdicek, D.F. (2003). Soil water and nitrogen dynamics in dryland cropping systems of Washington State, USA. *Soil & Tillage Research*; 71:33–47.
18. Gardner, R.A.M., & Gerrard, A.J. (2003). Runoff and soil erosion on cultivated rainfed terraces in the middle hills of Nepal. *Applied Geography*; 23:23–45.
19. Goto, A., Nishimaki, R., Suzuki, S., Watanabe, F., & Takahashi, S. (2012). Terrace development applied as a water harvesting technology for stable NERICA production in Uganda. *Journal of Arid Land Studies*; 22(1):243-246.
20. Huang, J., Wu, P., & Zhao, X. (2012). Effects of rainfall intensity, underlying surface and slope gradient on soil infiltration under simulated rainfall experiments. *Catena*, http://dx.doi.org/10.1016/j.catena.2012.10.013
21. Kharche, V.K., Sehgal, & Challa, O. (2000). Characterisation of coffee growing soils in Karnataka. *Agropedology*; 10:59-66.
22. Kishor, P., Ghosh, A.K., & Claramma, P.V. (2013). Influence of tillage on soil physical environment. *International Journal of Agronomy and Plant Production*; 4(10):2592-2597.
23. Kuit, M., Jansen, D.M., & Van Thiet, N. (2004). Coffee handbook: manual for arabica cultivation. Vietnam: Tan Lam Agricultural Product Joint Stock Company. 219p.
24. Li, Y.X., Tullberg, J.N., Freebairn, D.M., McLaughlin, N.B. & Li, H.W. (2008). Effects of tillage and traffic on crop production in dryland farming systems: I. Evaluation of PERFECT soil-crop simulation model. *Soil & Tillage Research*; 100:15–24.
25. Liu, X., He, B., Li, Z., Zhang, J., Wang, L., & Wang, Z. (2010). Influence of land terracing on agricultural and ecological environment in the Loess Plateau Regions of China. *Environ. Earth Sci.*; doi:10.1007/s12665-010-0567-6. Published online: 14 May 2010
26. Lű, H., Zhu, Y., Skaggs, T.H., & Yu, Z. (2009). Comparison of measured and simulated water storage in dryland terraces of the Loess Plateau, China. *Agricultural Water Management*; 96:299–306.
27. Malagnoux, M., Sène, E.H., & Atzmon, N. (2007). Forests, trees and water in arid lands: a delicate balance. *Unasylva 229*; 58:24-29.
28. Mandal, U.K., Victor, U.S., Srivastava, N.N., Sharma, K.L., Ramesh, V., Vanaja, M., Korwar, G.R., & Ramakrishna, Y.S. (2007). Estimating yield of sorghum using root zone water balance model and spectral characteristics of crop in a dryland alfisol. *Agricultural Water Management*; 87:315-327.
29. Mile, M., & Mitkova, T. (2012). Soil moisture retention changes in terms of mineralogical composition of clays phase. In: Valaškova, M., & Martynkova, G.S. (eds.). *Clay minerals in nature – their characterization, modification and application*. Shanghai, Cina: InTech. pp:101-118. Available at: http://dx.doi.org/10.5772/48098
30. Mohammed, S.A.A. (2013). Contribution of weed control and tillage systems on soil moisture content, growth and forage quality of (clitoria & siratro) mixture under- rainfed conditions at Zalingei - Western Darfur State – Sudan. *ARPN Journal of Science and Technology*; 3(1):80-92.
31. Moradi, A., Sung, C.T.B., Goh, K.J., Hanif, A.H.M., & Ishak, C.F. (2014). Effect of four soil and water conservation practices on soil physical processes in a non-terraced oil palm plantation. *Soil & Tillage Research*; 145:62–71.
32. Mulyoutami, E., Stefanus, E., Schalenbourg, W., Rahayu, S., & Joshi, L. (2004). Pengetahuan lokal petani dan inovasi ekologi dalam konservasi dan pengolahan tanah pada pertanian berbasis kopi di Sumberjaya, Lampung Barat. *Agrivita*; 26(1):98-107. (in Indonesia)
33. Noellemeyer, E., Fernández, R., & Quiroga, A. (2013). Crop and tillage effects on water productivity of dryland agriculture in Argentina. *Agriculture*; 3:1-11.
34. Oweis, T., & Hachum, A. (2009). Water harvesting for improved rainfed agriculture in the dry environments. In: Wani, S.P., Rockstrőm, J., & Oweis, T. (eds.). *Rainfed agriculture: unlocking the potential*. Oxfordshire, UK: CAB International. pp:164-181.
35. Passioura, J.B., & Angus, J.F. (2010). Improving productivity of crops in water-limited environments. *Advances in Agronomy*; 106:37-75.
36. Priatna, S.J. (2001). Indeks erodibilitas dan potensi erosi pada areal kebun kopi rakyat dengan umur dan lereng yang berbeda. *J. I. Pert. Indonesia*; 3:84-88. (in Indonesia)
37. Prijono, S. (2008). Teknik analisis sifat fisik tanah. Malang: Cakrawala Indonesia. 132p. (in Indonesia)
38. Rab, A., Fisher, P., Robinson, N., Kitching, M., Aumann, C., Imhof, M., & Chandra, S. (2010). Plant available water capacity of dryland cropping soils in the South-Eastern Australia. In: 2010 19th World Congress of Soil Science, Soil Solutions for a Changing World. 1 – 6 August 2010, Brisbane, Australia. pp:133-136.
39. Ramos, M.C., Cots-Folch, R., & Martínez-Casasnovas, J.A. (2007). Effects of land terracing on soil properties in the priorat region in Northeastern Spain: a multivariate analysis. *Geoderma*; 142:251–261.
40. Roy, M.M., Tewari, J.C., & Ram, M. (2011). Agroforestry for climate change adaptations and livelihood improvement in Indian hot arid regions. *Intl. J. Agri. Crop Sci.*; 3(2):43-54.
41. Sadeghi, A.M., Starr, J.L., Teasdale, J.R., Rosecrance, R.C., & Rowland, R.A. (2007). Real-time soil profile water content as influenced by weed-corn competition. *Soil Science*; 172(10):759-769.

42. Sadegh-Zadeh, F., Abd Wahid, S., Seh-Bardan, B.J., Seh-Bardan, E.J., & Bah, A. (2011). Alternative management practices for water conservation in dryland farming: a case study in Bijar, Iran. In: Manoj Jha (ed.). *Water conservation*. Shanghai, Cina: InTech. pp:47-66.
43. Saxton, K.E., & Rawls, W.J. (2006). Soil water characteristic estimates by texture and organic matter for hydrologic solutions. *Soil Sci. Soc. Am. J.*; 70:1569–1578.
44. Schuhmann, R., Königer, F., Emmerich, K., Stefanescu, E., & Stacheder, M. (2011). Determination of hydraulic conductivity based on (soil) - moisture content of fine grained soils. In: Elango, L. (ed.). *Hydraulic conductivity - issues, determination and applications*. Shanghai, Cina: InTech. pp:165-188.
45. Sharma, K.D. (2011). Rain-fed agriculture could meet the challenges of food security in India. *Current Science*; 100(11):1615-1616.
46. Shaver, T.M., Peterson, G.A., & Sherrod, L.A. (2003). Cropping intensification in dryland systems improves soil physical properties: regression relations. *Geoderma*; 116:149–164.
47. Smatana, J., Macák, M., & Demjanová, E. (2010). The influence of different tillage practices on soil physical characteristics. *Research Journal of Agricultural Science*; 42(3):315-319.
48. Smatana,J., Macák, M., Demjanová, E., & Smatanová, N. (2011). Tillage practices and their influence on soil physical characteristics in South-West of Slovakia. *Research Journal of Agricultural Science*; 43(3):206-211.
49. Soil Survey Staff. (2011). Soil survey laboratory information manual. In: Burt, R. (ed.). *Soil survey investigations report no. 45, version 2.0.* USA: U.S. Department of Agriculture, Natural Resources Conservation Service. 530p.
50. Sojka, R.E., Lehrsch, G.A., Kostka, S.J., Reed, J.L., Koehn, A.C., & Foerster, J.A. (2008). Soil water measurements relevant to agronomic and environmental functions of chemically treated soil. *Journal of ASTM International*; 6(1), Available online at www.astm.org, Paper ID JAI101497.
51. Sornpoon, W., & Jayasuriya. H.P.W. (2013). Effect of different tillage and residue management practices on growth and yield of corn cultivation in Thailand. *Agric. Eng. Int.: CIGR Journal*; 15(3):86-94.
52. Sukerta, I.M., Prijono, S., Soelistyono, R., & Soemarno. (2013). Soil moisture balance in the root zone under different cropping systems at Pecatu Village, Bali-Indonesia. *J. Basic. Appl. Sci. Res.*; 3(7):920-927.
53. Sumarjo Gatot, I., Duchesne, J., Forest, F., Perez, P., Cudennec, C., Prasetyo, T., & Karama, S. (2001). Rainfall-runoff harvesting for controlling erosion and sustaining upland agriculture development. In: D.E.Stott, Mohtar, R.H., & Steinhardt, G.C. (eds.). *Sustaining the global farm.* Selected papers from the 10th international soil conservation organization meeting held May 24-29, 1999 at Purdue University and the USDA-ARS National Soil Erosion Research Laboratory. pp:431-439.
54. Wang, S., Fu, B.J., Gao, G.Y., Yao, X.L., & Zhou, J. (2012). Soil moisture and evapotranspiration of different land cover types in The Loess Plateau, China. *Hydrol. Earth Syst. Sci.*; 16:2883–2892.
55. Widomski, M.K. (2011). Terracing as a measure of soil erosion control and its effect on improvement of infiltration in eroded environment. In : D. Godone (ed.). *Soil erosion issues in agriculture*. Shanghai, Cina: InTech. pp:315-334.
56. Xu, Q., Liu, S., Wan, X., Jiang, C., Song, X., & Wang, J. (2011). Effects of rainfall on soil moisture and water movement in a subalpine dark coniferous forest in Southwestern China. *Hydrological Processes*. Available at www.wileyonlinelibrary.com, DOI: 10.1002/hyp.8400
57. Zhao, N., Yu, F., Li, C., Wang, H., Liu, J., & Mu, W. (2014). Investigation of rainfall-runoff processes and soil moisture dynamics in grassland plots under simulated rainfall conditions. *Water*; 6:2671-2689.

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