Assessment of Infiltration Rate under Different Drylands Types in Unter-Iwes Subdistrict Sumbawa Besar, Indonesia

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Abstract

Assessment of infiltration rate for each type of soil in dryland areas need to do to get an idea of crop water requirement. The research objective was to analyze the infiltration rate on a various landuse, and the factors that affect the infiltration rate. Infiltration rate measurements were carried out on dryland areas of Unter Iwes District, Sumbawa regency; using the double ring infiltrometer. The undisturbed soil sample were used to determine physical characteristics of soil. The results showed that infiltration rate as high as 45.10 cm.h^{-1} and infiltration volume as high as 41.82 cm3 on rainfed landuse (it is the very-fast infiltration), the infiltration rate as low as 17.70 cm.h^{-1} and infiltration volume as low as 17.58 cm3 on 'Tegalan" landuse (it is the fast infiltration). Factors influencing infiltration are soil type, soil organic matter, porosity, bulk density, specific gravity and initial soil moisture content.

Keywords: Infiltration, dryland

1. Introduction

Estimating the rate of infiltration in the drylands were made to get informations on crop water needs during their growth season. Each type of soil require different estimation of water needs based on the soil physical properties. Infiltration is the hydrological parameters that are difficult to evaluate or measure accurately. Infiltration is the process flow of water into the soil profile vertically through the soil surface (Asdak, 2004; Dagadu and Nimbalkar, 2012;Bajaj,2011;Diamond, and Thomas, 2013). Infiltration is crucial in modeling of surface runoff (Suresh, 2008), and it is usually difficult to be evaluated or measured accurately (Ildefonso Pla-Sent s, 2013). The rate of infiltration is the amount of water that goes into the soil per unit of time and determine the soil moisture availability for plants. The rate of infiltration and evaporation are the two important parameters in soil water conservation (Asdak, 2004; Mawardi 2011a; Mawardi, 2012b). Infiltrability reflecting the capability of a soil profile to absorb water (Mawardi, 2012).

Measurement of soil infiltration using the with different infiltration model are empirically have been used on a various hydrology analysis relating to irrigation systems, one of which is a Model of Horton. Ramesh et al. (2008) proved that the Horton Model gives the best representation on the level of infiltration and the time of infiltration on a variety landuse of vertisol soil. Saiko and Zonn (2003) have measured and performed numerical solution of soil infiltration rate initially was dry, the infiltration rate are varied and decreased with time. According to Antigha Squad (2007), variations in the rate of infiltration are caused by precipitation, land use type, and vegetation type. The characteristics of the soil also affects the rate of infiltration (Dagadu and Nimbalkar, 1969). Some researchers have studied the effects of soil physical properties, such as distribution of particle size, bulk density, and total porosity, on the behavior of infiltration (Melvis, 2001; Shukla, 2003, Zhan and Charles, 2004; Chu and Marino, 2005; Akintoye, 1969).

Estimation of crop water requirement in drylands need informations about soil infiltration characteristics. These informations are useful in the management of dryland and can suggest an idea about the crop water requirement during their growing seasons. Wang et al. (1969) proved that water is fundamental to the biophysical processes to sustain ecosystem function and food production in drylands. Drylands are usually located on a landscape that was not flooded during certain times of the year, and relies on rain water (Abdurachman et al., 2008; Bajaj,2011). The purposes of this research are to analyze the infiltration rate on the various uses of drylands, the factors that affect the infiltration rate, and estimate the infiltration rate using the Horton Model , at the Unter Iwes, Sumbawa Regency.

2. RESEARCH METHODE

The study was conducted in the Districts Unter Iwes are located at position of 8°32.5,5'S - 8°32.315'S and 117°24.51,8' E - 117°26.312' E (BPS, 2011). Field research was conducted September until November 2012.

This Descriptive-quantitative research used field observations and survey methods to obtain data on the biophysical characteristics of the land, vegetation, and dry-land management.

2.1 Method of Data Collection

Data collection methods included field observations, interviews, and documentation. Determination of locations for infiltration measurement used the simple random sampling. Soil sampling and measurement of infiltration are performed on three different land uses, namely Tegalan in the village of Krekeh (K), Ladang in the village of Boak (B) and rainfed Sawah in the village of Kerato (Kr), six replications in each location.

Primary data includes infiltration and soil physical properties. Secondary data includes the documents owned by the relevant stakeholders; Statistics Office of Sumbawa District, Department of Foodcrop Agriculture, Soil Research Institute, Regional Development Planning Board, Agricultural Extension Office, Fisheries and Forestry Regional Office, as well as the Local Government Offices. Infiltration rate measurement is done by the Method of SNI RSNI T-06-2004 (Indonesian National Standard), i.e. measurements of the infiltration rate of soil in the field using the Double Ring Infiltrometer.

2.2 Method of Data Analysis

Estimation of the infiltration rate uses the Model Horton. The Horton Model is an empirical model that says the infiltration capacity as a function of time, so the infiltration rate is determined by the initial conditions of soil moisture at the time of soil infiltration is started to happen. Horton Model suitable for field experiments conducted at various landuses. Data analysis for estimating the capacity of soil infiltration uses the Horton Infiltration Model:

$$f = fc + (fo - fc)\ e^{-kt}$$

f = infiltration capacity (mm h-1); fc = infiltration capacity at the time of constant infiltration; fo = initial infiltration capacity (at $t = 0$); k = constant for a certain soil; t = time; $e = 2{,}71828$.

Process of the model fitting refers to the equation $ft = fc\ (f_0\text{-}fc)e^{-kt}$. The fc value is estimated from plotting of the relationship between the infiltration rate and time. Determination of the K value is performed using the equation: $K = 1/\ (t_2\text{-}t_1)\ \ln(f_1\text{-}fc)/(f_2\text{-}fc)$. The K values for subsequent points can be done in the same manner. Analysis of soil characteristics include soil texture, soil structure (feeling method), bulk desity (Sample Ring method), soil porosity, soil moisture content, and soil organic matter (SOM).

3. RESULTS AND DISCUSSION

3.1 Parameter of Infiltration

Results of field measurements are used to estimate parameter of infiltration rate. Horton Infiltration Model has three parameter determining the process of infiltration, that are K, initial infiltration (fo) and constant infiltration (fc). The maximum rate of infiltration (Infiltration Capacity) at the constant infiltration rate (fc) indicates amount of water that can be infiltrated into the soil per unit time. The time it takes to achieve. constant infiltration rate varies according to locations, the range 0.75 hours - 1.50 hours.

Table 1. Results of field measurement and estimation of Infiltration rate based on Horton Model

Drylands type	Location	Infiltration Rate (cm/h)		Volume (cm³)	Infiltration Classes	Stage
	Soil Sample	Field Measurement	Estimation using Horton Model			
Tegalan	K1	18,60	17,21	16,78	Rapid (Fast)	1
	K2	17,70	17,65	17,58	Rapid (Fast)	1
	K3	18,40	17,96	17,95	Rapid (Fast)	1
	K4	18,80	16,94	16,94	Rapid (Fast)	1
	K5	19,00	17,29	16,83	Rapid (Fast)	1
	K6	19,50	19,34	19,12	Rapid (Fast)	1
Ladang	B1	24,70	21,91	21,74	Rapid (Fast)	1
	B2	25,53	20,89	20,98	Rapid (Fast)	1
	B3	22,73	17,63	17,56	Rapid (Fast)	1
	B4	24,60	21,05	21,00	Rapid (Fast)	1
		23,40	21,41	21,50	Rapid (Fast)	1
	B5				Rapid (Fast)	
	B6	22,85	19,86	19,98	Rapid (Fast)	1
Rainfed Sawah	KR 1	42,18	38,21	38,78	Very Rapid	2
	KR 2	41,70	34,58	34,93	Very Rapid	2
	KR 3	45,10	40,15	41,82	Very Rapid	2
	KR 4	44,30	37,08	37,61	Very Rapid	3
	KR 5	38,50	31,95	33,00	Very Rapid	3
	KR 6	38,20	31,00	32,15	Very Rapid	3

Results showed that the highest initial infiltration (fo) in 12.3 cm/hour in the rainfed sawah, and lowest infiltration 5.1 cm/hour in the 'Ladang' dryland. Results of infiltration measurement and estimation using the Horton Model are presented in Table 1.

Infiltration rate measurement results on the 'Tegalan" land is 18.58 cm/h, in the 'Ladang' dryland is 23,92 cm/h and in rainfed sawah is 41,66 cm/h. Infiltration rate estimation according to the Horton Model in 'Tegalan' land is 17,73 cm/h, in 'Ladang' dryland is 20.45 cm/h, and in rainfed 'sawah' is 35,49 cm/h. The highest infiltration rate happens on the field measurement at a location KR3 on rainfed sawah, the infiltration rate is 45,10 cm/h.

Based on the Horton Model estimation, the highest rate of infiltration is 40,15 cm/h and its infiltration volume is 41,82 cm³. The lowest infiltration rate are on the field measurement at location K2 'Tegalan' Krekeh village is 17.70 cm/h; estimation of infiltration rate is 17,65 cm/h and its infiltration volume is 17,58 cm3 (Table 1).

The amount of water that can be stored in a soil is influenced by the rain intensity, rain duration, and depth of soil profile; the infiltration rate is also influenced by initial conditions soil moisture. Landuses with the different vegetation and different soil tillages suggested the differences infiltration rate; characteristics of soil and vegetation are also affecting the rate of infiltration (Asdak, 2004).

3.2 Infiltration Curve

Infiltration curve are presented in Figure 1. The field measurement of infiltration rate and estimation of infiltration rate (Horton Model) show a similar asymptotic pattern; the rate of infiltration decreases up to a maximum limit of the soil to absorb water; the soil infiltrability is high early in the process and then gradually decreased to a constant. The cumulative infiltration and the time required to achieve constant infiltration are affected by initial soil water content, soil texture and structure, and uniformity of soil profile and roughness of land surface (Mawardi, 1969).
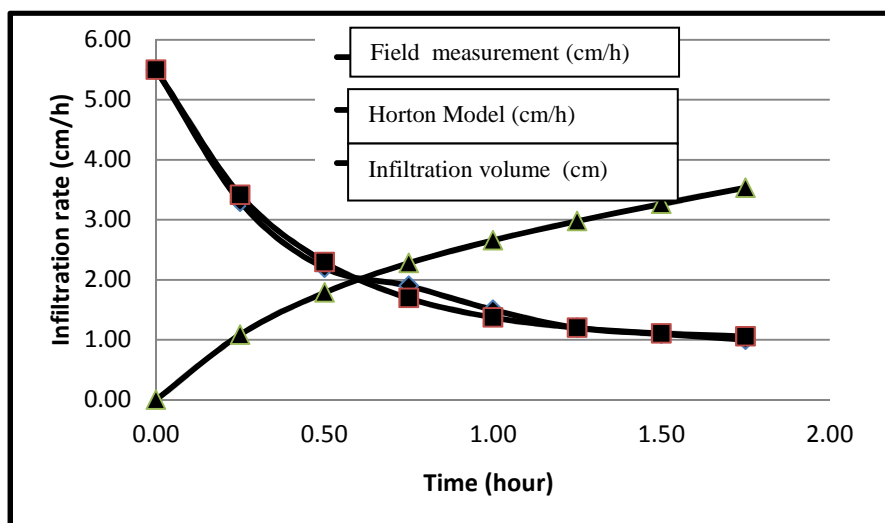
Figure 2. Curves of Infiltration rate and Infiltration volume at the location of K2 Krekeh village.

The infiltration measurement results indicate that rain water infiltrated into the soil during the rate of water supply have not exceeded the ability of the soil to absorb water; infiltration rate decreases with time, it is influenced by rain intensity, and soil physical properties (Mawardi, 1969). The analysis of soil infiltrability showed that maximum limit of the soil ability to absorb water is reached when the infiltration flow is getting bigger, and the most rain water into the surface runoff.

Multiple linear regression analysis on the relationship between soil infiltrability and soil properties shows the coefficient of determination $R^2 = 0.922$, the regression model is :

Infiltrability = 8.740 + 0.787 Sand - 0.04 Clay + 6.480 SOM + 1.038 C-organic - 0.240 Soil Porosity - 27.174 BD + 5.709 PD - 0.121 SMC - 0.71 AT

3.3 Effects of Soil Physical Properties on Infiltration Rate

Soil properties affecting infiltration rate in the research locations are sand and clay percentages, soil moisture content, bulk density, particle density, soil organic matter, and soil porosity.

3.3.1 Content of Sand and Clay in Soil

Shape, size and stability of soil aggregates may affect the soil ability to absorp rainwater and the infiltration rate. Soils in 'Tegalan' and 'Ladang' have a low aggregate stability. Whereas rainfed sawah soils have a stable aggregates. Soil aggregate stability has a significant relation with the content of soil organic matter. Bagarello et al. (2004) States that the difference of soil structure due to various management, can affect the water holding capacity of soil, water movement in unsaturated and saturated soil. Shape of soil aggregates on 'Tegalan' is granular, crumbs with a weak stability; 'Ladang' soils have a low aggregate stability; 'Rainfed sawah' have soil aggregates of angular blocky and granular with a high degree of stability.

Based on the shapes and sizes of soil aggregates, the order from large up to small are Tegalan, Ladang and Rainfed Sawah. Results of analysis showed that the Tegalan soil and Ladang soil have a sandy loam texture and the Rainfed sawah soils have a sandy clay loam texture. Results of the regression analysis shows that when the sand content increases the soil infiltrability tends to increase and if the clay content decrease the soil infiltrability tend to decline.

3.3.2 Soil Moisture Content (SMC)

Initial soil moisture content significantly affects infiltration rate. Infiltration rate was higher when the initial condition of soil is drier. Results of the regression analysis suggests that when the initial condition of SMC is lower then the soil infiltrability is higher. Water movement in the soil profile is also influenced by the properties of precipitation (Edwards et al., 1992; Toor et al., 2004).

3.3.3 Bulk Density and Particle Density

Analysis of soil bulk density (BD) and particle density (PD). The highest value of bulk density and particle density are on the rainfed sawah soils. Regression analysis showed that when BD decreases then the soil infiltrability tends to decline and if PD increases then the soil infiltrability tends to increase.

3.3.4 Content of Soil Organic Matter (SOM)

Results of soil analysis showed that soil organic matter (SOM) content in the research locations are varied. The Soil organic matter content is 0.18-2.71% and soil C-organic content is 0.30-2.31%, these values include the very low to moderate criteria . The rainfed 'sawah' land has SOM content of 2.71%. The lowest content of soil

organic matter on the ‚Tegalan' land and 'Ladang' of 0.32%. The 'Tegalan' and 'Ladang' drylands have a lower organic matter and C-organic, it due to this land has not been cultivated and the minimum input of organic matter into soil. Results of the regression analysis suggests that if SOM has increased the soil infiltrability tend to increased.

3.3.5 Soil Porosity

Soil porosity analysis showed that soils at the research locations have a sufficient pore . Soil structure varies greatly between locations, as well as its porosity in the range of 42.2% - 49,4%. Difference of soil surface conditions, soil texture, soil structure, soil porosity and vegetation cover, is the factors causing differences in the capacity of infiltration. According to Perfect et al. (2002), the rate of soil moisture movement affects the nutrients solubility and water distribution into the soil, so the nutrients are distributed in the rooting zone.

Results of soil porosity analysis show that the soil's ability to store water depending on the soil porosity; the order of landuse based on soil porosity from highest to lowest is 'Tegalan – Ladang – Rainfed Sawah'. Sandy soil of Tegalan dan Ladanh have a high porosity, making it difficult to store available water. The water moves more quickly through macro-pores on sandy soils, with a high percentage of the total pore, rainwater infiltrates very quickly.

Sandy soil has a very low capacity to store available water, the plant quickly absorbs all of available water, and become wilt quickly. Rainfed sawah soil contains clay which suggests a swell-shrinkage properties; in wet conditions the soil swell and in dry conditions the soil shrinkage.

4. CONCLUSION

Estimated value of soil infiltrability using Horton Model are similar with the value of infiltration measurement in the field. The highest infiltration rate occurs in lowland rainfed (*rainfed sawah landuse)* and lowest rate of infiltration on the dryland (*Tegalan landuse)*. Soil infiltrability was influenced by the rainfall, vegetation type, soil water content and soil characteristics. Soil properties that affect the process of infiltration are soil structure, texture, soil organic matter content, bulk density, particle density, and initial soil moisture content.

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