P-ISSN : 2598-1277
E-ISSN : 2621-3966

JOURNAL OF GREEN SCIENCE AND TECHNOLOGY

ANALYSIS OF INFILTRATION RELATIONS WITH LAND PHYSICAL PROPERTIES

Awliya Tribhuwana *, Agung Prasetyo **

*) Lecturer of Universitas Swadaya Gunung Jati (UGJ), Cirebon
**) Lecturer of Universitas Swadaya Gunung Jati (UGJ), Cirebon

ABSTRACT

Soil types have different infiltration rates and vary depending on the characteristics of the soil, how the infiltration relationship occurs with dry water content and saturated water content, infiltration relationship with the soil after being compacted and before compacted and how the infiltration rate of the two types of relationship and how infiltration water that happened. Soil tests are carried out in the laboratory, soil water content before and after the soil has been solidified, changes in the time of infiltration capacity with the Horton equation, rain hydrograph for overall infiltration analysis, including cumulative infiltration and runoff rates.

Soils experience porosity filling not as great as in normal soil conditions, normal soil conditions changes in water content reaches 5.22 mm/hour while in soil conditions that experience changes in water content compaction at 30 minutes by 0.14 mm/hour and experiences a constant rate in the 40th minute at a rate of 0.20 mm/hour, so there is a difference in water content of 5.08 mm/hour between normal soil and soil after solidification, due to compacting it causes runoff of 8.92 mm/hour, normal soil with runoff of 3.78 mm/hour.

Keyword : *Infiltration, soil physical properties, runoff.*

I. INTRODUCTION

Physically, there are four factors that affect the infiltration rate and infiltration capacity of the soil, namely: (1) soil type, (2) soil density, (3) soil moisture, (4) plant cover. However, each type of soil has different characteristic infiltration rates and varies depending on the characteristics of the soil, therefore an analysis of the relationship between infiltration and physical properties of the soil will be analyzed. By conducting laboratory testing of the water content before and after testing infiltration, soil density, infiltration capacity values and infiltration volume.

II. LITERATURE REVIEW

Rainfall intensity is defined as the height of rainfall that occurs in the period in which rainwater concentrates. This rainfall intensity can be processed based on rainfall data that has occurred in previous years. Calculation of the intensity of rainfall can be used several empirical formulas in hydrology.

Infiltrasi merupakan peristiwa masuknya air ke dalam tanah, yang umumnya (tetapi tidak mesti) melalui permukaan dan secara vertikal (Arsyad, 2010). Jika cukup air, maka air infiltrasi akan bergerak terus kebawah yaitu kedalam profil tanah. Gerakan air kebawah di dalam profil tanah disebut perkolasi.

The infiltration rate is the amount of time unity water entering the soil surface expressed in mm hour-1 or cm hour-1. When the soil is still dry, the infiltration rate tends to be high. After the soil becomes saturated with water, the infiltration rate will decrease and become constant. Surface conditions, such as pore properties and soil moisture content, largely determine the amount of infiltrated rainwater and the amount of runoff (Hakim, et al, 1986).

Content weights shows the ratio of dry soil weight to soil volume including the volume of soil pores (Hardjowigero, 2003). Content weight is an indication of soil density, the denser a soil is, the higher the weight value of its contents, which means that it is more difficult to pass on water or be penetrated by plant roots. Soil compaction can reduce the rate of infiltration, making it difficult to seep water into the soil which causes an increase in surface runoff thereby increasing erosion. In general, the weight of the contents ranges from 1.1 to 1.6 g cm-3, but some types of soil have a weight value of less than 0.90 g cm-3, one of which is andisol (Hardjowigero, 2003).
The value of content weight can be influenced by several factors, including soil processing, organic matter, soil texture, compaction by heavy equipment and soil water content. This weight value is important to be used for calculating irrigation water needs, land management and others (Sarief, 1989).

Soil permeability is the ability of soil to drain water or air expressed in cm/hour. (Handayanto, 2009) Soil quality to pass water or air which is measured based on the amount of flow through a unit of land that has been fulfilled before a certain time unity. (Susanto, 1994). Soil permeability is described as the nature of the soil that drains water through the pore cavity of the soil. Determination of soil permeability is done to measure/determine the ability of soil through which the water passes through its pores. Hillel (1980) says that permeability is influenced by soil texture, structure, total porosity and pore size distribution. A large enough aggregate pores will increase hydraulic conductivity. Hydraulic conductivity increases when soil grain aggression becomes crumbs, the presence of decomposed ex-root canal channels, the presence of organic matter and high porosity of the soil.

III. METHODOLOGY

Sampling and laboratory implementation include sand cone sampling and laboratory testing including soil density test, filter analysis test, water content test, atterberg limits test, hydrometer analysis, and compaction test.

Laboratory testing is carried out at the Engineering Laboratory, Swadaya Gunung Jati University. 1. Preparation Phase: Rainfall data, soil sampling, laboratory test physical model making, 2. Research Stage Preparation of tools to be used in laboratory research, data collection on laboratory results, 3. Analysis Phase, 4. Discussion and Conclusion Stage.

Changes in Test Object Due to Water Infiltration

After experiencing the process of rain, the soil water content changes, where the process of testing the test object has the same pattern as wetting, which results in an increase in soil water content.

Effect of Water Infiltration on Degree of Saturation

The presence of rainwater infiltration in the soil, resulting in changes in the test object's water content. When the water content changes, the degree of soil saturation also changes. A soil mass consists of soil grains and pore spaces between soil grains. Where this pore space can be filled with water or air or a combination of the two. If all pore space is filled with water, the soil mass is in saturated condition. Meanwhile, if some of the pore space is occupied by water and the rest is filled with air, the soil is not saturated.

Effect of Water Infiltration on Pore Ratio

When there is a change in numbers while raising the water content due to rainwater infiltration. This shows that, there is a change in the volume at which the soil will expand with increasing air content.

Infiltration Measurement

Infiltration rate is influenced by texture and structure, soil moisture, content of suspended material in water as well as time. The highest infiltration rate is reached when water first enters the ground and decreases with increasing time. The inflation rate can be calculated using the Horton Model formula.

$$f = fc + (fo - fc)e\text{-}kt \; ; \; i \geq fc \qquad (1)$$

where;

- f = infiltration capacity (cm/h)
- fc = infiltration capacity at the time of constant infiltration (cm/h)
- fo = initial infiltration capacity (cm/h)
- k = constant for a certain soil
- t = time (minute)

IV. RESULT AND DISCUSSION

Analysis of Relationship between Soil Physical Properties and Rain Intensity

Examination of soil physical properties is carried out by using 3 soil samples so that different soil physical properties can be obtained for 3 samples as in the table below, from the results of this laboratory will be used to determine the relationship of intensity with soil physical properties in the 3 soil samples tested.

Table 4.1. Laboratory Results of Soil Physical Properties

Soil Sample	BTKO	Total Soil Volume (cm^3)	Bulk Density (gr/cm^3)	Pasticle Density (gr/cm^3)	Porosity (%)	Water Content (%)
1	31.89	49.81	1.073	2.6	61.688	10.505
2	31.75	48.09	1.068	2.6	57.887	10.142
3	26.69	46.23	0.898	2.6	64.132	11.428

Source: Laboratory Testing Results

Changes in Water Content Due to Infiltration

Groundwater Content Check. Soil sampling for water content inspection is carried out before testing at a depth of ± 10 cm from the soil surface. The following is an example of calculating groundwater content at the GT campus location:

$$w \text{ (cup 1)} = \frac{(45{,}18 - 41{,}83)}{(41{,}83 - 9{,}82)} \, x \, 100\%$$

$$= 10{,}47 \%$$

w (cup 2) = 10,10 %

w (cup 3) = 10,18 %

water content (w) = 10,47 +10,10 +10,18

= 10,248 %

Following are the results of the calculation of water content at the GT campus location:

Table 4.2. The results of the calculation of ground water content at the GT campus location

	Undisturb		
	1	2	3
moist soil weight + cup (gr)	45.18	44.9	42.65
dry soil weight + cup (gr)	41.83	41.68	39.6
water weight (gr)	3.35	3.22	3.05
cup weight (gr)	9.82	9.8	9.63
dry soil weight (gr)	32.01	31.88	29.97
water content (W) (%)	10.47	10.1	10.18
average water content	10.248		

Source: Laboratory Calculation Results

Table 4.3. The results of the calculation of ground water content at the GT campus location

	Undisturb		
	1	2	3
moist soil weight + cup (gr)	50.83	50.89	47.8
dry soil weight + cup (gr)	46.2	46.07	43.42
water weight (gr)	4.63	4.82	4.38
cup weight (gr)	9.82	9.8	9.63
dry soil weight (gr)	36.38	36.27	33.79
water content (W) (%)	12.73	13.29	12.96
average water content	12.993		

Source: laboratorium calculation result

Effect of Infiltration on the degree of saturation

Field Soil Density In this test using a sand cone. The following is an example of calculating field density values.

calibration $= \frac{sand\ weight\ in\ funnel}{Vold\ Pycnometer}$

calibration $= \frac{1245}{355.98} = 3.497$ gr/cm^3

cavity volume $= \left(\frac{(W1 - W2 - W3)}{calibration}\right)$

cavity volume $= \left(\frac{(7782 - 1245 - 2285)}{3.497}\right)$

cavity volume = 1215.756 cm^3

soil content weight $= \frac{W4}{cavity\ volume}$

$= \frac{3582}{1215.765}$

= 2.946

- α = W5/W4 = 1545/3582

  = 0.4313

- β $= \frac{\text{soil specific gravity x } \alpha}{Gs}$

  = (2.946 x 0.4313)/2.801

  = 0.454

- Correction

  $\frac{(W1-\alpha)}{(W1-\beta)} = \frac{(7782-0.4313)}{(7782-0.454)} = 1.000003$

- Corrected soil weight

  = soil weight x correction

  = 2.946 x 1.000003

  = 2.9460 gr/cm^3

- Material dry weight

  $= \frac{\text{corrected soil weight}}{(1 + original\ water\ content)}$

  $= \frac{2.9460}{1+12.933} = 0.21144$ gr/cm^3

- Dry content weight

  $= \frac{\text{corrected soil weight}}{(1 + optimum\ water\ content)}$

  $= \frac{2.9460}{1+12.933} = 0.21144$ gr/cm^3

Table 4.4 The results of the calculation of soil density at the GT campus location

Number	Data	Unit	1	2	3
1	sand weight + funnel + bottle (W1)	gr	7782	7740	7724
2	sand content weight (calibrated)	gr/cm³	3.497	3.287	3.323
3	sand weight in funnel (W2)	gr	1245	1170	1183
4	sand residual weight in bottle (W3)	gr	2285	2275	2250
5	cavity volume [(1)-(3)-(4)]/(2)	cm³	1215.765	1306.781	1291.217
6	sample weight inside cavity (W4)	gr	3582	3625	3618
7	soil content weight (6)/(5)	gr/cm³	2.946	2.774	2.802
8	weight of sample passed sifter number 40 (W5)	gr	1545	1545	1545
9	α (8)/(6)		0.431	0.426	0.247
10	β [(7)xα]/Gs		0.454	0.466	0.478
11	correction		1.000003	1.000005	1.000007
12	corrected soil content weight	gr/cm³	2.946	2.774	2.802
13	original water content	%	12.933	12.933	12.933
14	material dry content weight	gr/cm³	0.2115	0.1991	0.2011

Source: Laboratory Calculation Result

Relationship Between Infiltration with Water Content

After experiencing the process of rain, the soil water content changes, the rain process has the same pattern as wetting, which results in an increase in soil water content. Seen in Figure 4.1 below due to rain, infiltration occurs when the normal soil content, normal soil content still has porosity based on the laboratory test, the table below.

Table 4.5. Laboratory Results of Soil Physical Properties

Soil Sample	BTKO	Total Soil Volume (cm³)	Bulk Density (gr/cm³)	Pasticle Density (gr/cm³)	Porosity (%)	Water Content (%)
1	31.89	49.81	1.073	2.6	61.688	10.505
2	31.75	48.09	1.068	2.6	57.887	10.142
3	26.69	46.23	0.898	2.6	64.132	11.428

At 0 minutes when rain infiltration occurs with the rate of water entering the ground an average of 6 mm/hour, with the entry of water into the soil during the time of 0 minutes, there has not been any change in water content, after running time until the 20th minute, it can only be seen that changes in soil water content reaches 5.22 mm/hour with infiltration of 3.00 mm/hour. The change in infiltration of 3.00 mm/hour is due to changes in porosity filling so that the infiltration rate decreases when it reaches 20 minutes. Changes in groundwater content follow the infiltration that occurs so that if there is no infiltration or infiltration begins to decrease the water content follows according to time.

The presence of infiltration of rainwater in the soil, resulting in changes in water content. When the water content changes, the degree of soil saturation also changes. A soil mass consists of soil grains and pore spaces between soil grains. Where this pore space can be filled with water or air or a combination of the two. If all pore space is filled with water, the soil mass is in saturated condition. Meanwhile, if some of the pore space is occupied by water and the rest is filled with air, the soil is not saturated.

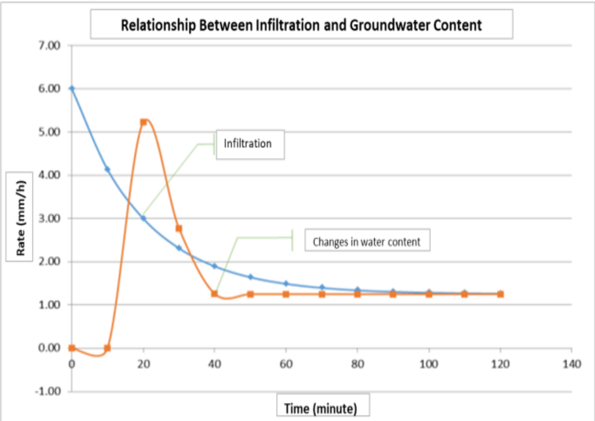

Figure 4.1. Relationship of Infiltration and Normal Water Content

For soils that experience compaction will affect the rate of infiltration into the soil due to changes in soil porosity that is the ability of the soil to absorb water, a small porosity will result in changes in water movement ie water that should seep into the ground cannot enter resulting in surface runoff. See Figure 4.2 below.

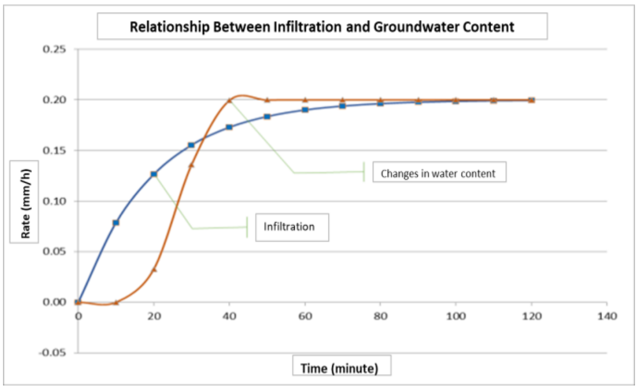

Figure 4.2. Relationship of Infiltration and Moisture Content After Compaction

In soil that experiences compaction, the porosity filling is not as big as in normal soil conditions in figure 4.1 under normal soil conditions the change in water content reaches 5.22 mm/hour while in soil conditions that experience compaction changes in water content at 30 minutes by 0.14 mm/hour and experiencing a constant rate at minute 40 at a rate of 0.20 mm/hour.

Effect of Water Infiltration on Degree of Saturation

The presence of infiltration of rainwater in the soil, resulting in changes in water content. When the water content changes, the degree of soil saturation also changes. A soil mass consists of soil grains and pore spaces between soil grains. Where this pore space can be filled with water or air or a combination of the two. If all pore space is filled with water, the soil mass is in saturated condition. Meanwhile, if some of the pore space is occupied by water and the rest is filled with air, the soil is not saturated.

In Figure 2 and 3 show the changes caused by the condition of normal soil and soil conditions that experience compaction, in normal soil conditions the degree of saturation is seen at a constant infiltration rate at 1.25 mm/hour see in table 6. in the table there is still an infiltration difference with soil saturation of 0.01 mm/hour this is because infiltration has decreased so that it does not reach normal soil saturation limits.

Table 4.6. Result of infiltration, saturation and runoff capacity counts

TIME (hour)	RAINFALL INTENSITY (mm/h)	RAIN HEIGHT (mm)	COMULATIVE RAIN (mm)	INFILTRATION CAPACITY $f=f_c+(f_0-f_c)e^{-kt}$ (mm/h)	COMULATIVE INFILTRATION $F(t)=f_c t+\frac{f_0-f_c}{k}(1-e^{-kt})$ (mm/h)	ACTUAL INFILTRATION CAPACITY $F(t)=f_c t_p+\frac{f_0-f_c}{k}(1-e^{-kt})$ (mm/h)	SOIL SATURATION (mm/h)	RUNOFF (mm/h)
0.000	0.50	0.08	0.08	6.00	0.00	0.00	0.00	0.00
0.167	1.50	0.25	0.33	4.13	0.62	0.00	0.00	0.00
0.333	6.75	2.25	2.58	3.00	1.00	0.33	5.22	-1.53
0.500	4.00	2.00	4.58	2.31	1.23	2.75	2.77	-1.23
0.667	1.50	1.00	5.58	1.89	1.37	5.38	1.26	-0.24
0.833	1.00	0.83	6.42	1.64	1.45	3.67	1.25	0.25
1.000	0.30	0.30	6.72	1.49	1.50	2.08	1.25	0.95
1.167	0.00	0.00	6.72	1.39	1.54	1.30	1.25	1.25
1.333	0.00	0.00	6.72	1.34	1.55	0.35	1.25	1.25
1.500	0.00	0.00	6.72	1.30	1.57	0.00	1.25	1.25
1.667	0.00	0.00	6.72	1.28	1.57	0.00	1.25	1.25
1.833	0.00	0.00	6.72	1.27	1.58	0.00	1.25	1.25
2.000	0.00	0.00	6.72	1.26	1.58	0.00	1.25	1.25

Source: Calculation Result

Relationship of Infiltration with Soil Physical Properties

If there is a change in the pore number with increasing water content due to rainwater infiltration. This shows that, there is a change in volume where the soil will expand with increasing water content.

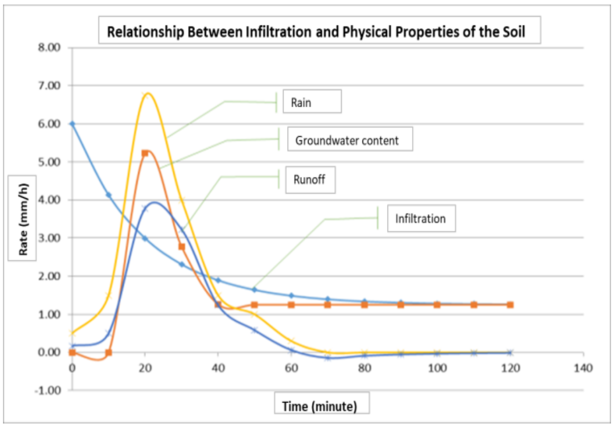

Figure 4.3 Relationship between Infiltration and Physical Soil Normal

In Figure 4.3 In normal soil conditions visible rain followed by infiltration and the occurrence of replenishing water content. Under these conditions the condition of the soil is still normal and there is no compaction of the soil so that the filling of water content by infiltration is still large to reach 5.22 mm/hour so that runoff occurs at 3.78 mm/hour. From events like the above, the physical condition of the soil greatly influences changes in the movement of water for groundwater and the movement of surface runoff.

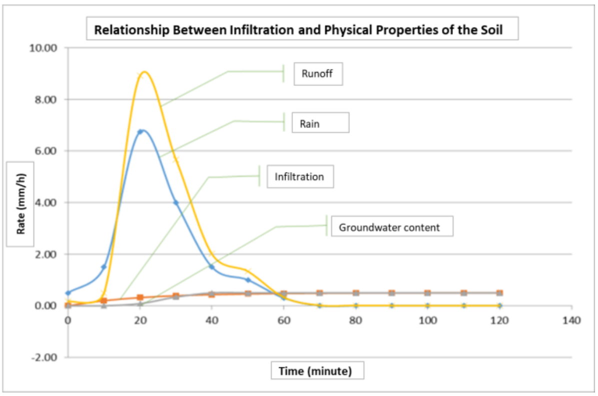

Figure 4.4. Relationship between Infiltration and Physical Solid Soil

On soils that experience compaction The intensity of the rain falling exceeds the infiltration capacity, after the infiltration rate is fulfilled the water will fill the basin on the ground surface. The condition is shown in Figure 4.4. Very high rainfall occurs while infiltration is very small between 0.20 mm/hour to 0.50 mm/hour resulting in surface runoff of 8.92 mm/hour. This is due to the physical soil cannot receive rainwater supply due to soil compaction which results in reduced soil porosity so that the existing pore space cannot accept incoming water due to infiltration.

V. CONCLUSION AND RECOMMENDATION

a. Relationship of infiltration with water content. After experiencing the process of rain, the soil water content changes, the rain process has the same pattern as wetting, which results in an increase in ground water content. due to rain infiltration arises, when the normal groundwater content still has a porosity of 61.68% based on the laboratory test, at 0 minutes when the infiltration rain occurs with the average rate of water entering the ground at 6 mm/hour, the entry of water into the ground at when the time of 0 minutes has not seen any change in the water content, after running time until the 20th minute, it can be seen that there is a change in soil water content reaching 5.22 mm/hour with infiltration of 3.00 mm/hour. The change in infiltration of 3.00 mm/hour is due to changes in porosity filling so that the infiltration rate decreases when it reaches 20 minutes. Changes in groundwater content follow the infiltration that occurs so that if there is no infiltration or infiltration begins to decrease the water content follows according to time.

b. Relationship between infiltration and water content after soil solidification. In soil experiencing compaction, the porosity filling is not as big as in normal soil conditions, normal soil conditions changes in water content reaches 5.22 mm/hour while in soil conditions that experience compaction changes in water content at minute 30 of 0.14 mm/hour and experience a constant rate in the 40th minute at a rate of 0.20 mm/hour, so there is a difference in water content of 5.08 mm/hour between normal soil and soil after compacting.

c. Runoff due to compacted soil causes runoff of 8.92 mm/hour while for normal soil with runoff of 3.78 mm/hour.

VI. REFERENCES

Arsyad, Sitanala. 2010. Konservasi Tanah dan Air. Insitut Pertanian Bogor Press. Bogor

Asdak, C., 2002. Hidrologi dan Pengelolaan Daerah Aliran Sungai, Gadjah Mada University Press. Yogyakarta.

Handoko, 1994. Klimatologi Dasar. PT Dunia Pustaka Jaya, Jakarta.

Hakim, Nurhajati, dkk. 1986. Dasar-Dasar Ilmu Tanah. Penerbit Universitas Lampung. Lampung

Hardjowigeno, S. 2003. Ilmu Tanah. Penerbit Akademik Pressindo. Jakarta

Hillel, D. 1980. Fundamentals of Soil Physics. Academic Press. New York.

Kodoatie, Robert J..2012. Tata Ruang Air Tanah. Penerbit Andi,Yogyakarta.

Lakitan, B, 1994, Dasar-Dasar Klimatologi. Perguruan Tinggi, Jakarta.

Mawardi, M,. 2012. Rekayasa Konservasi Tanah dan Air. Bursa Ilmu. Yogyakarta.

Sosrodarsono Suyono, Kensaku Takeda, 1978. Hidrologi Untuk Pengairan, Pradnya Paramita, Jakarta.

Subagyo, S. 1990. Dasar-Dasar Hidrologi. Gajah Mada University Press, Yogyakarta.

Suroso, 2006. Analisis Curah Hujan untuk Membuat Kurva Intensitas – Durasi – Frekuensi (IDF) di Kawasan Rawan Banjir Kabupaten Banyumas. Jurnal Teknik Sipil 3(1) : 37 – 40.

Susanto, 1994. Pelestarian Sumber Daya Tanah dan Air. Andi Offset. Yogyakarta

Syarief, S.1989. Fisika-Kimia Tanah Pertanian. Bandung: Pustaka Buana.