Journal of Chemical, Environmental and Biological Engineering
2017; 1(1): 8-13
http://www.sciencepublishinggroup.com/j/jcebe
doi: 10.11648/j.jcebe.20170101.12

Water Potential in HillField Side Slope in Ireland

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To cite this article:
Aboufayed Abdulfatah F. Water Potential in HillField Side Slope in Ireland. *Journal of Chemical, Environmental and Biological Engineering*. Vol. 1, No. 1, 2017, pp. 8-13. doi: 10.11648/j.jcebe.20170101.12

Received: October 24, 2016; **Accepted**: January 17, 2017; **Published**: February 13, 2017

Abstract: The monitoring period shows that the matric potential (Ψm) in the HillField increased with depth during winter time and vice versa in summer. It appears that the transition occurred in the first three weeks of May through the soil remained wetter at depths of 70 and 90cm in the lower stations (4 and 5) but not for the top stations. In summer, the soil was wetter at 30 cm depths after heavy rainfall but the effect did not go deeper than 50 cm. The total water potential (Ψw) is the driving force of water flow, at the same depth in the different stations (slope position) showing that the general direction of water flows is from the top to the bottom of the field. Although the (Ψm) was high at the bottom of the field for depth 5 cm, the total water potential (Ψw) was lower at bottom and higher at the top field.

Keywords: Water, Potential, Water Potential, Total Water Potential, Matric Potential

1. Introduction

Water flow in soil occur under both saturated and unsaturated condition saturated conditions occur below the water table while unsaturated condition predominate above the water table (the vadose zone), localized zones of saturation can exist especially following precipitation or irrigation [3, 10]. The movement of water in soil is related to energy phenomena. Different kinds of energy are involved including potential energy and kinetic energy. The difference in energy level of water in soil from one site (wet soil) to another (dry soil) determines the direction and rate of water movement in soil. Determination of the absolute energy level of soil water is a difficult and sometimes impossible task. Fortunately, it is not necessary to know the absolute energy level of water to be able to predict how it will move in soil. Relative values of soil water energy are all that is needed. Usually the energy status of soil water in a particular location in the profile is compared to that of pure water at standard pressure and temperature, unaffected by the soil and located at some reference elevation. The difference in energy levels between this pure water in the reference state and that of the soil water is termed soil water potential, the term potential, like the term pressure, implying a difference in energy status [2, 8]. The soil water potential is due to several forces, each of which is component of the total soil water potential Ψ_t. These components are due to differences in energy levels resulting from gravitational, matric, submerged hydrostatic and osmotic forces and are termed gravitational potential Ψ_g, matric potential Ψ_m, submergence potential, and osmotic potential Ψ_o, respectively. All of these components act simultaneously to influence water behavior in soils. The general relationship of soil water potential to potential energy levels is expressed as: $\Psi_t = \Psi_g + \Psi_m + \Psi_o$ [2, 8]. Where matric potential Ψ_m is used in estimating total water potential under unsaturated condition, pressure potential Ψ_p are used under saturated condition.

Water potential could be expressed in a variety of units, including energy per unit weight, which effectively is expressed in units of length, and which is referred to as hydraulic head. Total hydraulic head is then given by the sum of the matric head and the elevation head. According to [2, 8, 10], matric potential is the best indicator of soil water status, and the tensiometer the most useful device for monitoring it, therefore it was used in Hill Field For monitoring soil matric potential the main component of total soil water potential the driving force of water movement in soil under saturated or unsaturated conditions.

2. Materials and Methods

A. Field site description

The HillField at the UCD Research Farm was chosen as it has the hilly feature, with undulating topography, on which moderate to intensive farming is practised in the drier rainfall areas of Ireland. Historically the field was included in the tillage rotation of the farm, but it has been in permanent grass for the last 25 years. The field is roughly square in shape, and occupies an area of approximately 4.5 ha with elevation ranging from 71 to 76 m O. D. (Figure. 1). Two distinct soils have been mapped in the field by [6] One (Inceptisols) is found mainly at elevations above 73.2 m O. D. It is a deep, moderately stony, well-drained soil formed on predominantly limestone till. [6, 5] has classified it as a Grey Brown Podzolic (Hapludalf) with a minimally developed textural B horizon covered the bottom of the field. The texture varies from loam to sandy clay loam within the profile. The surface horizon (Ap) is dark brown in colour, and has a uniform depth (27- 30 cm) with predominantly crumb structure. The underlying Bt horizon is brown to brownish black in colour, with strong blocky structure, and evidence of illuvial clay.

B. Field Survey

The HillField was surveyed using standard GPS techniques with the captured data processed cartographically by AutoCAD 14 (Figure. 1).

During September and October 2003 four monitoring stations were set up in the HiliFeld at meter contour intervals at the locations shown in Figure. 1. Tensiometers were installed in pre-drilled holes at depths of 30, 50, 70 and 90 cm in each Station.

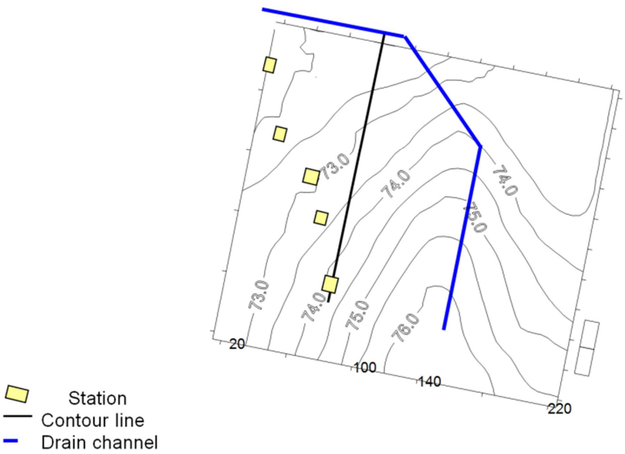

Figure 1. *Shows contour lines and five stations and the drainage canal on the HillField.*

C. Preparation and installation of tensiometers

The bungs were removed; then tensiometers were soaked for 8 hours in a container of de-gassed water. After soaking, the tensiometer were taken out of the water and allowed to drain through the ceramic cup for around 30 min. After then refilled with de-gassed water, and the silicone bungs replaced, the ceramic cups of the tensiometers were wrapped in paraffin film until installation in the field. Weekly readings of soil matric potential (-cm) were taken by insertion of the hypodermic needle of a tensimeter (SMS2500S) through the silicone bung and recording the reading displayed.

3. Results and Discussion

A. Climate of Lyons Estate

Relatively warm waters and prevailing south-westerly winds coming from the Atlantic Ocean give Ireland an equable climate with fairly uniform temperatures over the whole country. The general impression is that it rains quite a lot of the time in Ireland but in fact two out of three hourly observations will not report any measurable rainfall. The average number of wet days (days with more than 1mm of rain) ranges from about 150 days a year along the east and south-east margins, to about 225 days a year in parts of the west. Average hourly rainfall amounts are quite low, ranging from 1 to 2 mm, short-term rates can be much higher; for example, an hourly total of 10 mm is not uncommon and total of 15 to 20 mm in an hour may be expected to occur once in 5years, hourly total exceeding 25 mm are rare in this country and when they do occur they are usually associated with heavy thunder storms [7]. The number of wet and very wet days is becoming of more interest to many people, knowledge of the likelihood of days with 5, 10, 15 or more millimeters of rain in a day is needed by those who manage and monitor runoff from land and pollution of water. A value of 10 mm of rainfall or more has been used to define the standard of very wet day, long-term records collected by the meteorological service show that Delphi Lodge in west Mayo is amongst the highest in this scale with 88 days and Casement Aerodrome (near Dublin) the lowest with a mere 17 very wet days per year on average [4, 7].

B. Rainfal and evapotranspiration

Lyons Estate situated within twenty miles of the Irish Sea, has a typical maritime climate, with relatively mild, moist winters and cool, cloudy summers. It has a lower average rainfall and longer periods of bright sunshine than most other parts of Ireland. Data obtained from the synoptic weather station at Casement Aerodrome, about 6 km from Lyons Estate, shows that the farm is situated in one of the lowest rainfall areas in the country, with total mean annual rainfall being just over 700 mm. While the figures show no marked periodicity, on average, the driest months are April and July, with December and January being the wettest. The estimates of mean annual potential evapotranspiration for the area around Lyons Estate fall in the range 400-450 mm, approximately 80% of which occurs in the April to September period. The excess of rainfall over evapotranspiration results in an annual water surplus of approximately 300 mm, which is predominantly confined to the winter period. The level of surplus water available to leach through the soil profile is quite low compared to other parts of the country, for example along the west coast or on high ground such as the Wicklow mountains, a surplus of 1200-1600 mm may occur annually [7, 4]. The long-term mean and actual monthly rainfall in Casement Aerodrome, nearby the field of study (HillField) in UCD research farm station, and estimated mean Penman potential evapotranspiration (ETp) values, for (1970-2000) for Irish meteorological inland stations are shown in Table 1.

***Table 1.** Actual andlong-termmeanmonthly rainfall (mm) at casement meteorological station and estimated monthly etp values (mm).*

	Rainfall in (mm)				ETp
Month	2003/04	2004/05	2005/06	Mean	(mm)
Nov	154.2	43.8	50.6	65.9	3.1
Dec	75.4	51.1	61.9	73.6	0.5
Jan	94.4	75.1	17.9	63.9	1.7
Feb	18.4	48.4	40.5	48.6	14.3
Mar	48.5	15.4	53.5	50.3	28.6
Apr	44.4	47.2		50.8	51
May	26.4	49.6		58.1	71.8
Jun	50.7	27.5		52.6	78
Jul	48.2	77.6		46.9	75.6
Aug	113.9	32.1		68.5	60.3
Sep	55.3	50.2		63.3	38.2
Oct	177.4	83.5		68.6	16.5
Annual	907.2	601.5		711.2	439.6

C. Temperature

While the mean daily air temperature at Casement station is 9.3°C, there is a difference of 10.6°C between the coldest month, February, (4.6°C) and the warmest month, July (15.2°C). The highest mean maximum temperatures occur in July and August (19°C) with the lowest in January and February (2°C). Mean daily air temperature recorded at Casement station during study period and the long-term daily mean air temperatures are presented in the Table 2.

***Table 2.** Mean daily air temperature (°C) at casement meteeorological station during the study period and long-term daily mean air temperature (°C).*

Year	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
2003/04	7.0	4.9	5.5	4.9	6.6	8.7	11.1	14.6	14.6	16.0	13.9	9.1
2004/05	7.9	6.6	6.8	4.8	7.9	8.4	10.3	17.9	19.1	17.1	14.8	11.4
2005/06	6.1	5.9	5.1	4.7	5.8	8.0						
Mean	6.5	5.4	4.6	4.6	5.9	7.4	10.1	13.1	14.9	14.5	12. 6	10.2

D. Sunshine

At Casement the mean daily duration of sunshine is 3.64 h, with May and June having the longest mean duration (5.6 h) and December the shortest (1.4 h). The mean number of days with no sun follows a similar trend. July is the month with the lowest number of days (1) whereas December has the highest number of days (11) with no sunshine. The duration of sunshine affects the level of solar radiation received. [4] showed mean annual solar radiation for the Lyons Estate area to be 10-11 mj/m/day, with a seasonal variation from 2 mj/m/day in December to 20 mj/m/day in June.

E. Soil water potential in HillField side slope

Water potential is the driving force for water flow. Water potential could be expressed in a variety of units, including energy per unit weight, which effectively is expressed in units of length, and which is referred to as hydraulic head. Total hydraulic head is then given by the sum of the matric head and the elevation head.

E.1. Soil matric potential in HillField side slope

According to [10, 9], matric potential is the best indicator of soil water status, and the tensiometer the most useful device for monitioring it. The pattern of installation of tensiometers in the Hill Field side slope was designed to monitor soil moisture status from its higher to lower elevations and within the soil profile itself. Initially (November 2003) readings were taken at four depths (30, 50, 70 and 90 cm) in four stations located across the field slope. Reading at the fifth Station commenced in November 2004, and tensiometers were replicated at Stations 1, 3 and 5 from that time. Readings of matric potential at 0-5 cm depth in stations 1, 3 and 5 were also taken from November 2004. During the monitoring period, tensiometers were topped-up with de-gassed water as necessary, but during the summer months readings sometimes fell below -750 cm and they effectively became dry and inoperable. This occurred most frequently at shallow depth, especially at the higher elevations towards the top of the field. In general tensiometers reading in the Hill Field support an annual separation into two soil moisture periods, namely, wet from November to April and dry from May to October confirm what mention by [1].

Over the whole monitoring period, even the deepest tensiometers gave negative readings, including those in Station 5 at the lowest point of the field. This means that the water table never entered the soil profile, even though the soil in the vicinity of Station 5 is classified as a Gley (Skeagh). On the other hand, the shallowest tensiometers, at 5 and 30 cm depth, did give readings of zero, or very close to it on several occasions, indicating that the surface layer of the HillField was saturated, or nearly saturated episodically which confirm what mention by [2, 10] unsaturated condition predominate above the water table (the vadose zone), localized zones of saturation can exist especially following precipitation or irrigation. The seasonal variation in tensiometer readings during the monitoring period for the five stations is clearly evident in Figures 2 to 6.

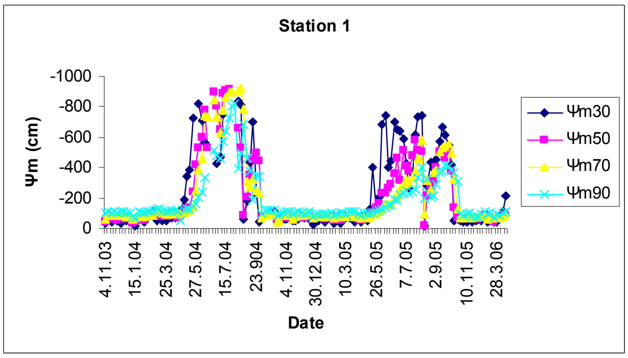

***Figure 2.** Soil matric potential (Ψm) at different depths in station 1 (Hill Field).*

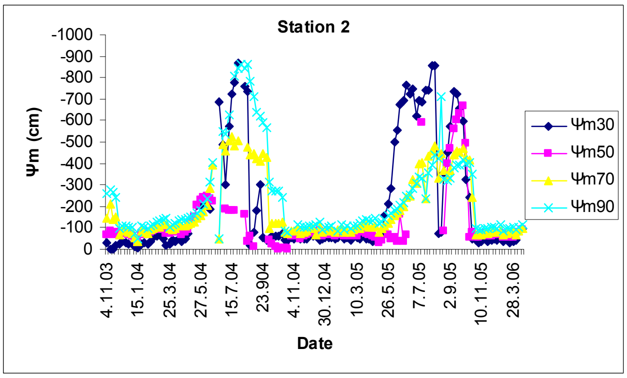

Figure 3. *Soil matric potential (Ψm) at different depths in station 2 (Hill Field).*

In general the matric potential in the HillField increased with depth during winter time and vice versa in summer. It appears that the transition occurred in the first three weeks of May though the soil remained wetter at depths of 70and 90cm in the lower stations (4 and 5) than in the top stations. In summer, the soil was wetter at 30 cm depths after heavy rainfall but the effect did not go deeper than 50 cm as for the rain events of 26th Aug 2005 and 4th Aug 2005 (Figs 4 to 7).

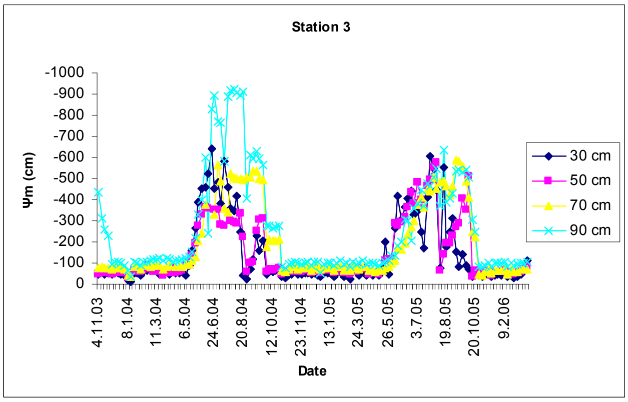

Figure 4. *Soil matric potential (Ψm) at different depths in Station 3 (Hill Field).*

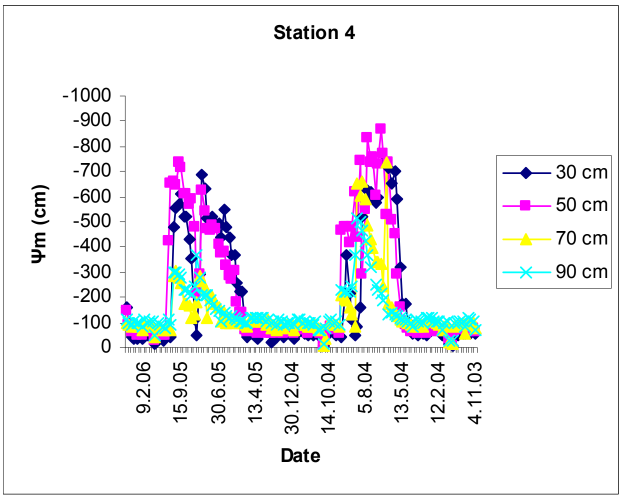

Figure 5. *Soil matric potential (Ψm) at different depths in Station 4 (Hill Field).*

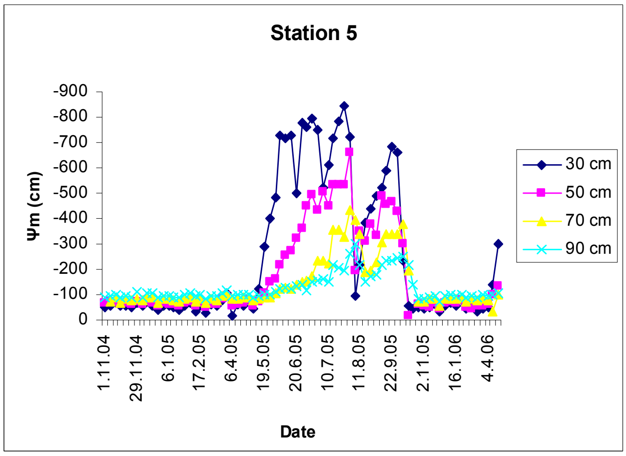

Figure 6. *Soil matric potential (Ψm) at different depths in Station 5 (Hill Field).*

The mean of soil matric potential at different depths in the Hill Field stations are shown in Figure. 7. Simple linear regression showed that there was no relation between matric potential at the different depths with rainfall amounts at the nearby Casement Station but it had a good correlation with soil temperature where r=0.82, r=0.77, r=0.81 and r=0.78 between Ψm at depth 30 cm, 50cm, 70cm and 90cm and soil top 10 cm temperature from Casement Station.

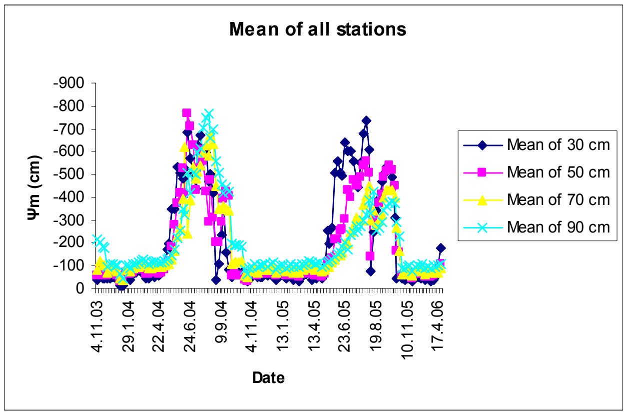

Figure 7. *Mean soil matric potential (Ψm) at different depths in Hill Field stations.*

E.2. Total water potential (Ψ_w)

Difference in total water potential (Ψ_w) is the driving force for the water flow from point to point; it could be in any direction, but always from the point of high water potential towards the lower one. Assuming no change in osmotic potential, the total water potential at any point is the algebraic sum of matric potential at that point and its gravitational potential at that point, with reference to a convenient arbitrary datum line. Water potential may be expressed in a variety of units, including energy per unit weight, which effectively is expressed in units of length, and which is referred to as hydraulic head. Total hydraulic head is then given by the sum of the matric head and the elevation head. Using the ground surface of the HillField at Station1 as the datum line, Figure. 8 shows the mean value for total hydraulic head varied with depth during the monitoring period. The values indicate that downward movement of water was favored in winter time, while the direction was upward in summer time.

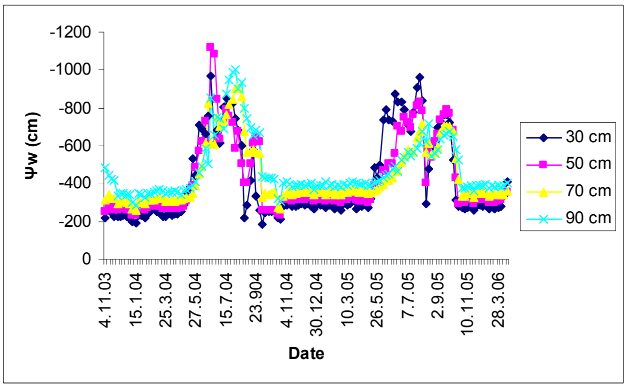

Figure 8. *Seasonal variation in mean total water potential (Ψ_w) at different depths in Hill Field.*

The graphs below (Figs 9 to 14) shows seasonal change in total water potential (driving force of water movement, Ψw) at the same depth in the different stations (slope position) showing that the general direction of water flows is from the top to the bottom of the field.

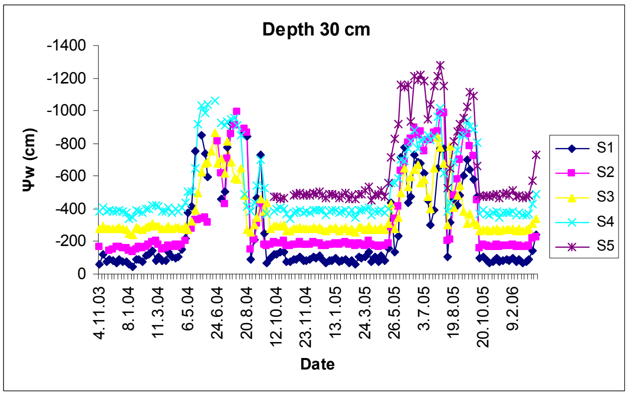

Figure 9. *Mean of total water potential at 30 cm depth in Hill Field stations.*

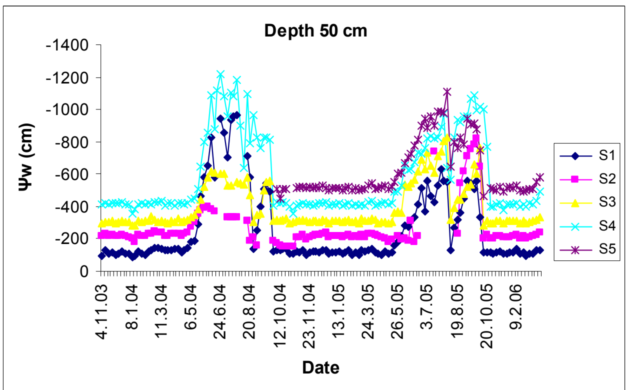

Figure 10. *Mean of total water potential at 50 cm depth in Hill Field stations.*

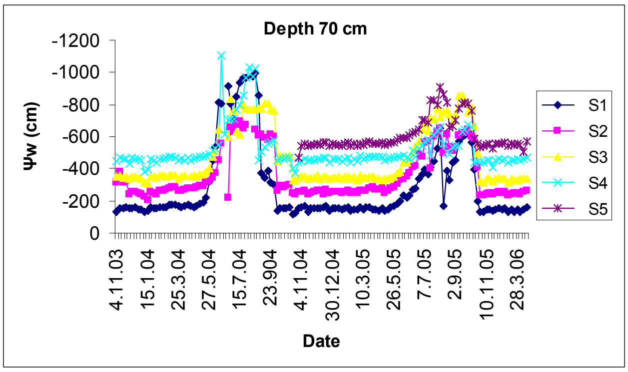

Figure 11. *Mean of total water potential at 70 cm depth in Hill Field stations.*

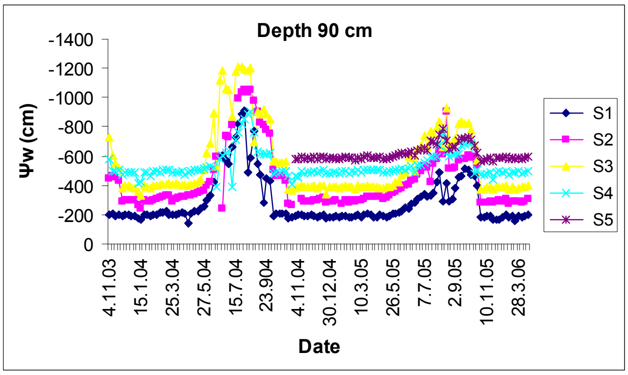

Figure 12. *Mean of total water potential at 90 cm depth in Hill Field stations.*

Matric potential at 5 cm depth was variable as shown in Figure. 13. There was a tendency for it to be higher in Station 5 at the bottom of the HillField where the organic matter content was higher this confirm what mention by [1] The soil moisture contents in top 5 cm show that bottom site of the HillField had higher soil moisture content than the middle and top sites during the whole period of monitoring. Although the Ψm was high at the bottom of the field, the total water potential (Ψw) was lower at bottom and higher at the top field stations, as shown in the Figure 14.

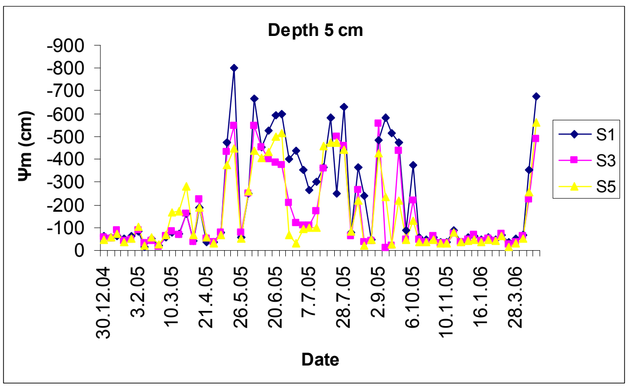

Figure 13. *Matric potential (Ψm) at 5cm depth (station 1,3 and 5) in Hill Field during the monitoring period from 30.12.04up to 30.4.06.*

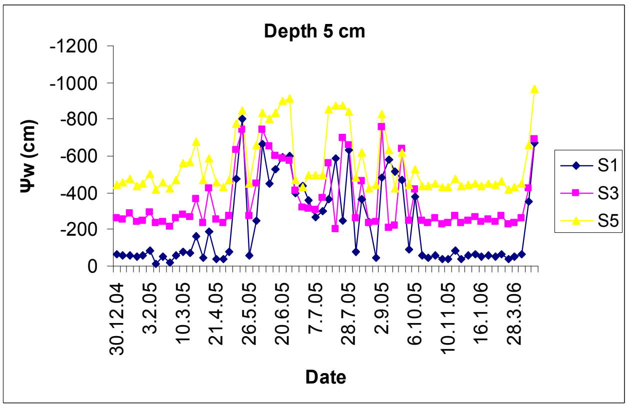

Figure 14. *Total water potential (Ψw) at 5cm depth (Station 1, 3 and 5) in the Hill Field during the monitoring period.*

4. Conclusion

Water potential is the driving force for water flow from point of high water potential to another point of low water potential. Over the whole monitoring period, even the deepest tensiometers gave negative readings, including those in Station 5 at the bottom of the field. This means that the water table never entered the soil profile. On the other hand, the shallowest tensiometers, at 5 and 30 cm depth, did give readings of zero, or very close to it on several occasions, indicating that the surface layer of the HillField was saturated, or nearly saturated episodically. The tensiometer readings show seasonal variation during the monitoring period for the five stations. In general the matric potential in the HillField increased with depth during winter time and vice versa in summer. It appears that the transition occurred in the first three weeks of May though the soil remained wetter at depths of 70 and 90cm in the lower stations (4 and 5) than in the top stations. In summer, the soil was wetter at 30 cm depths after heavy rainfall but the effect did not go deeper than 50 cm as for the rain events of 26th Aug 2005 and 4th Aug 2005. Using the ground surface of the HillField at Station1 as the reference datum line, shows that the mean value for total water hydraulic head varied with depth during the monitoring period. The values indicate that downward flow of water was favored in winter time, while the direction was upward in summer time. There was a tendency for the matric potential at depth 5cm to be higher in Station 5 at the bottom of the HillField where the organic matter content was higher. Although the Ψm was high at the bottom of the field, the total water potential (Ψw) was lower at bottom.

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