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Soil Moisture Content in Hill-Filed Side Slope

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***Abstract*—**The soil moisture content is an important property of the soil. The results of mean weekly gravimetric soil moisture content, measured for the three soil layers within the A horizon, showed that it was higher for the top 5 cm over the whole period of monitoring (15/7/2004 up to 10/11/05) with the variation becoming greater during winter time. This reflects the pattern of rainfall in Ireland which is spread over the whole year and shows that light rainfall events during summer time were compensated by loss through evapotranspiration, but only in the top 5 cm of soil. This layer had the highest porosity and highest moisture holding capacity due to the high content of organic matter. The gravimetric soil moisture contents of the top 5 cm and the underlying 5-15 and 15-25 cm layers show that bottom site of the Hill Field had higher soil moisture content than the middle and top sites during the whole period of monitoring.

***Keywords*—**Soil, Soil moisture, Gravimetric soil moisture content.

I. Introduction

WATER in soil occupies pore spaces that arise from the physical arrangement of the particulate solid phase, competitively and often concurrently with the soil gas phase, therefore water stored in soil especially in top soil profile is essentially for plant growth and macro and micro organisms live in soil. Soil water content and its energy status affected many soil mechanical properties including strength, compatibility, and penetrability, and may cause changes in the bulk density of swelling soils. The water content percent affect the soil gaseous phase and the rates of exchange between these phases (water and gaseous), as well as other important soil properties such as the hydraulic conductivity which play essential role in rate of water and soluble chemical flow. Soil water content is a highly dynamic entity, exhibiting substantial variation in both time and space [6]. The precipitation is the main source of water on earth and the climate factors essentially precipitation and temperature play great role in soil water content, and the topography of the ground surface play essential role in water distribution over and through soil profile, therefore soil water content were monitored in Hill Field side slope located in UCD farm research in Lyone estate county Dublin Ireland.

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II. Material and Methods

A. Survey and Sampling

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

During September and October 2003 four monitoring stations were set up in the Hill Field at meter contour intervals at the locations shown in Fig. 1.

Throughout the monitoring period soil moisture at a depth of 15 cm was recorded weekly in Station 3 by means of a Trime TDR Moisture Meter. In addition, to follow changes in soil moisture content by gravimetric analysis, three soil samples from depths of 0 – 5 cm, 5 – 15 cm and 15 - 25 cm in the soil profile were collected weekly using a small auger from areas in the proximity of Stations 1, 3 and 5.

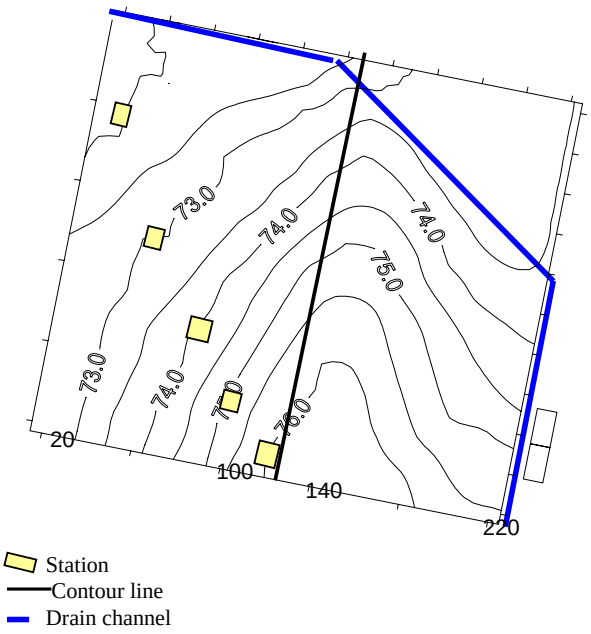

Fig. 1 contour lines and five stations and the drainage canal on the Hill-Field

B. Soil Properties Analysis

Gravimetric soil moisture contents for the 0-5, 5-15 and 15-25 cm soil layers were calculated from weight loss of samples dried at 105 °C over night. Loss on ignition was calculated from weight loss of oven-dry samples heated at 450^{o}C for 24 hours. Soil pH was measured in H_20 and 0.1 M KCI using a glass electrode, and mean values were tabulated in Table III.

III. Results

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 5 years, hourly total exceeding 25 mm are rare in this country and when they do occur they are usually associated with heavy thunder storms [5]. 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 [5].

1. Rainfall 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.

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 [1]-[2]. The long-term mean and actual monthly rainfall in Casement Aerodrome, nearby the field of study (Hill Field) 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 I.

TABLE I
Actual and Long-Term Mean Monthly 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

2. 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 II.

TABLE II
Mean Daily Air Temperature (°C) at Casement Meteorological 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

3. 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 [5]. Mean annual solar radiation for the Lyons Estate area is 10-11mj/m/day, with a seasonal variation from 2mj/m/day in December to 20mj/m/day in June [1].

4. Relative Humidity

The relative humidity figures for the area are high, being normally between 70 and 90%, with the highest values in winter.

B. Soil Moisture Content in Hill Field Monitoring Results

Due to the major effect of soil moisture content on infiltration rate and different water flow types and grass production several methods had been used in monitoring soil moisture content including gravimetric measurement, time domain reflectrometery (TDR) and indirectly using tensiometry (values increasing with moisture content until zero when the soil is at saturation, and conversely values decreasing as the soil becomes drier).

1. Hill Field Side Slope Topsoil Properties Description

The mean of value of gravimetric soil moisture content (GMC%), estimated for summer and winter months, and related soil properties for soil samples collected from Hill Field are presented in Table III.

2. Hill Field Side Slope Soil Moisture Content Results

The gravimetric method technique is probably the most widely used means of measuring soil moisture and is the standard for the calibration of all other soil moisture determination techniques. Therefore, it was used to monitor soil moisture content in the Hill Field and to calibrate the other methods employed. The results of mean weekly gravimetric soil moisture content, measured for the three soil layers within the A horizon, showed that it was higher for the top 5 cm over the whole period of monitoring (15/7/2004 up to 10/11/05) with the variation becoming greater during winter time, as can be seen in the Fig. 2. This reflects the pattern of rainfall in Ireland which is spread over the whole year and shows that light rainfall events during summer time were compensated by loss through evapotranspiration, but only in the top 5 cm of soil. This layer had the highest porosity and highest moisture holding capacity due to the high content of organic matter.

TABLE III
PROPERTIES OF SOIL IN HILL FIELD

Soil	Kearnystown			Skeagh		
A horizon layers (cm)	0-5	5-15	15-25	0-5	5-15	15-25
*Summer GMC%	37	24.5	20.7	44.2	31.2	27.3
*Winter GMC%	60	31.3	26.6	70.4	43.8	34.3
LOI%	8.6	7.2	6.9	10.0	7.4	6.3
Bulk density g/cm^3	1.12	1.39	1.4	1.0	1.32	1.45
Particle density g/cm^3	2.48	2.57	2.58	2.44	2.54	2.55
Pore space%	54.9	45.9	45.8	59.1	47.9	43.2
Sand%	42.5	44.9	45.9	33.9	34.6	36.6
Silt%	30.4	27.4	26.9	35.5	35.9	37.1
Clay%	27.2	27.7	27.2	30.6	29.5	26.3
pH	6.4	7.1	7.2	6.4	7.1	7.2

* Where Summer months are (June- July-August) and winter months are (December-January-February)

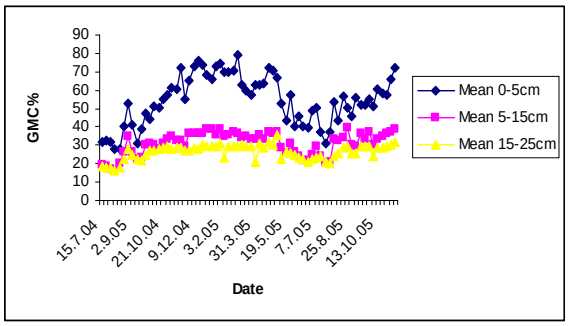

Fig. 2 Mean GMC% in topsoil layers of the Hill Field

The gravimetric soil moisture contents of the top 5 cm (Fig. 3) show that bottom site of the Hill Field had higher soil moisture content than the middle and top sites during the whole period of monitoring. This was probably due to down slope flow as surface (overland) flow occurring as sheet flow, and subsurface (Inter) flow. The same pattern was found for the top 25 cm as shown in the Fig. 4.

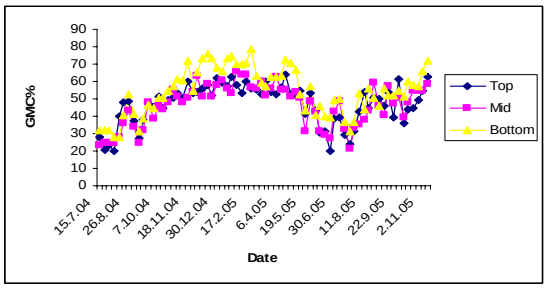

Fig. 3 Mean GMC% of the top 5 cm of soil in the Hill Field over the period of monitoring

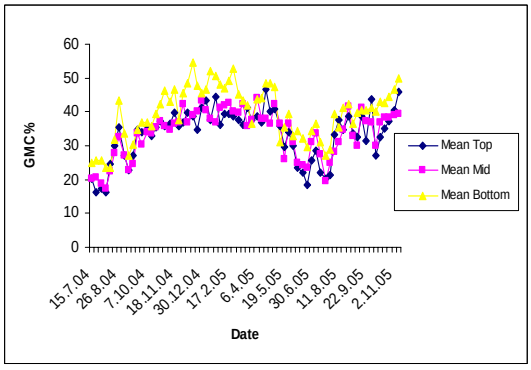

Fig. 4 Mean GMC% of the top 25 cm of soil in the Hill Field over the period of monitoring

Simple linear regression was used to study the relationship between weekly readings of VMC% obtained with a TDR probe inserted at 15cm depth in Station 3 and measured

GMC% in the top 5cm and the top15 cm of soil. The relationship with GMC% at 15 cm (r^2 = 0.83) was a little better than between TDR readings and GMC% at 5cm depth (r^2=0.82). GMC% in the top 5 cm is more changeable than in the underlying soil layers. TDR readings also had a good overall relationship with mean GMC% in the top 5cm for the top, mid and bottom sites (r^2=0.76).

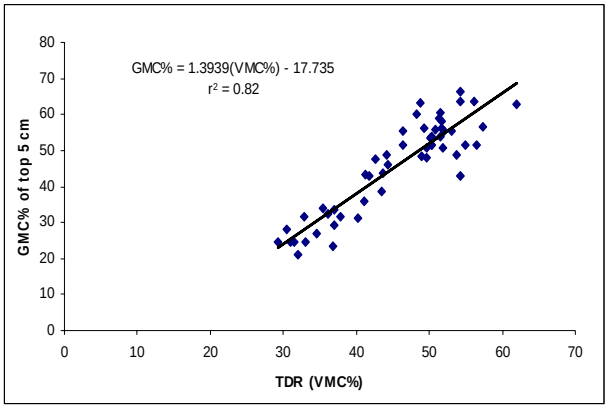

Fig. 5 Relationship between TDR VMC% and measured GMC% (0 – 5 cm) at Station 3

A comparison of MC% in the top 5 cm of soil in the Hill Field and soil temperature 10 cm depth at nearby Casement Meteorological Station is shown in Fig. 5. It can be seen that there was a very high relation between these parameters. It shows that the soil seems to be moist from November to April and dry from May to October. This fits with the classification of annual seasons cold season (November to April) and warm season (May to October) suggested by [3], [4].

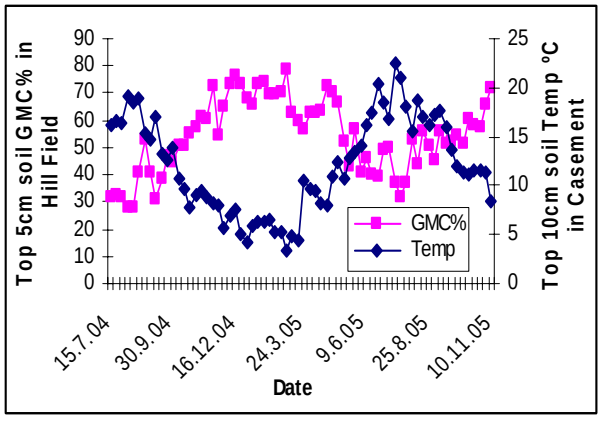

Fig. 6 Temporal variation in GMC% in the Hill Field top 5 cm and in soil temperature in (10 cm) at Casement Meteorological Station

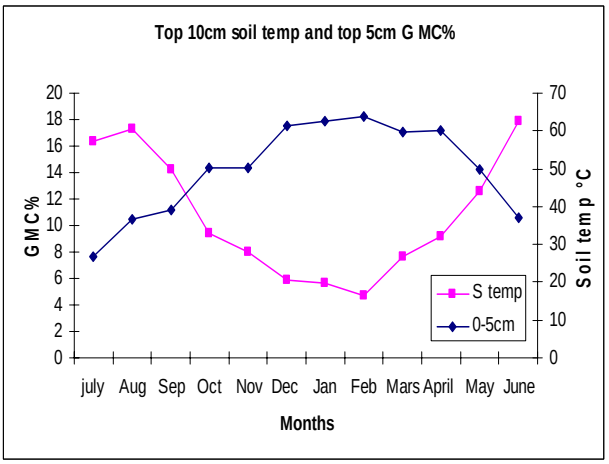

Fig. 7 Monthly top 5 cm GMC% in Hill Field and monthly top10cm soil temp in casement aerodynamic station

Simple linear regression showed that there was a good relationship between MC% of the top 5 cm and soil temperature (r = 0.83). Thus MC% could be estimated from soil temperature using the following regression equation:

$$MC\% = -2.0\ T\ (soil) + 73\ (r^2 = 0.69) \quad (1)$$

Similar estimations can be made using air temperature in the equation:

$$MC\% = -2.4\ T\ (air) + 77\ (r^2 = 0.64) \quad (2)$$

The strength of the relationship with soil temperature decreased in the underlying soil layers (5-15 and 15-25 cm) with the correlation coefficients dropping to 0.69 and 0.63 respectively". Under the Irish climate with rainfall spread over the whole of the year, soil remains moist over most of the year but changes in response to change in temperature rather than to rain as in the arid climate regions. Under winter conditions when soil is at or very close to its field capacity, any additional rain drains away after rain has ceased without effecting in the soil water content and because air and soil temperatures are low there is no big variation on a weekly or even a daily basis, and the soil moisture content remains constant near to field capacity. By the end April the soil and air temperature start to increase and soil moisture content starts to decrease. During the summer the soil moisture content become more changeable in response to temperature and rainfall amounts, as shown in Fig. 8.

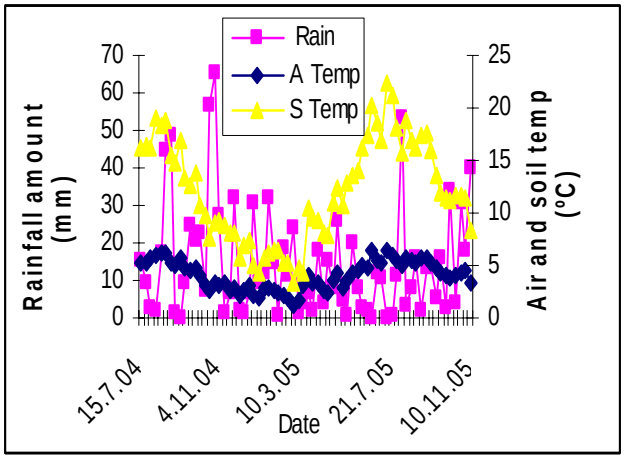

Fig. 8 Weekly rainfall amounts in (mm) and air and soil temperature at Casement Meteorological Station during the monitoring period

IV. Conclusion

Under the Irish climate with rainfall spread over the whole of the year, soil remains moist over most of the year but changes in response to change in temperature and it get dry only at summer time when potential evapotranspiration was greater than rainfall amounts. The top 5cm soil layer had the highest moist content ant it was the most exchangeable in moisture content.

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