Effective Rainfall under Central Gezira (Sudan) Conditions

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Abstract

In its simplest sense effective rainfall means useful or utilizable rainfall, the concept of effective rainfall is suggested for use in planning and operation of irrigation projects. The irrigation water supply in a given year should be planned to compliment rainfall. This study was carried out to estimating the portion of rainfall that added to soil moisture after rainfall which is considered as an effective part of total rainfall, and to show the effects of over and under estimation of effective rainfall on crop water requirement calculations and its effects on determining areas that can be cultivated. The experiment was carried out in a field adjacent to the metrological Station at Gezira Research Station (GRS), in central Sudan. The experiment is based on a daily balance of stored water content of the soil, the samples were taken randomly over the study area for two seasons, the area was treated by the normal practice operations. Augured samples of soil by 20 cm interval were obtained daily to 100 cm depth. Oven drying of samples at 115 oC over-night was followed by the calculation of gravimetric moisture content. The results showed that the moisture changes in Gezira clay soils are confined to the top 60 cm, unless there is standing water. Effective rainfall was found to represent 83% of total rainfall in the start of rainy season and decreased to 67% towards its end. The mean value of 75% of effective rainfall can be used to calculate quantities of rainfall available to crops growing during the period under investigation in this study. If rainfall contribution to crop water requirement is considered then it is possible to increase the cropped area for the same amount of irrigation water.

Key words: Effective rainfall, Water management, Irrigation water savings.

Introduction

Early this century, Sudan was entirely dependent on rainfall for production of food crops, such as Dura, which represents the main diet of the population.

However irrigation was practiced traditionally in the Northern part of Sudan, along the banks of the main Nile.

With decreases in rain, increase in population and the need for growing new crops such as wheat, the need for irrigation has also increased. Consequently, dams have been built and pumps have been installed, but still the country's irrigated land represents only a small part of its potentially cultivable land. Nevertheless, the food the Sudan produces from the irrigated sector is far below the country's need.

The Gezira Scheme covers an area of 2.12 million Feddans (890400 Hectare) between the White and Blue Niles, South of Khartoum. The most striking feature of the Gezira plain was the flatness of the landscape which sloped northwards at 10-12 cm/km. The dominant clay mineral is montmorillonite. In the hot dry summer the parched surface develop wide deep cracks which seal in the wet months and retain pools of water from the tropical storms of July to September.

Gezira region shows significant variability in environmental factors such as temperature, rainfall, soil fertility, and pest infestation. The climate is dry with a short rainy season from July to September. The rainfall shows an increasing gradient from North to South. Irrigated agriculture in central Sudan depends partially on rain. Summer crops (groundnut, sorghum and cotton) receive 2 to 4 watering from rains. In normal seasons, water shortages, don't occur during July-August period. However, the onset, intensity and duration of rainfall affect the level of crop management practices.

Definition of Effective Rainfall:

From production point of view, the annual or seasonal effective rainfall as far as the water requirement of crops is concerned, should be interpreted as that portion of total annual or seasonal rainfall which is useful directly and /or indirectly for crop production at the site where it falls but without pumping. The concept of effective rainfall is suggested for use in planning and operation of irrigation projects. The irrigation water supply in a given year should be planned to compliment rainfall. Since annual rainfall varies from year to year, an irrigation project cannot be planned on one year's data, records are needed over a long period to calculate effective rainfall on the basis of probability of occurrence

Three main characteristics of rainfall are its amount, frequency and intensity, the values of which vary from place to place, day to day, month to month and also year to year. Precise knowledge of these three main characteristics is essential for planning its full utilization. Information about the amount, intensity and distribution of monthly or annual rainfall for important places is generally available. Long term records of daily rainfall have been compiled for years. Inspite of voluminous data of weather, all is not yet known that should be known about rainfall.

In its simplest sense, effective rainfall means useful or utilizable rainfall, just as total rainfall varies so does the amount of effective rainfall. The importance of precise knowledge on the subject of effective rainfall needs little elaboration. The useful portion of rainfall is stored and supplied to the user, the unwanted part needs to be conveyed or removed speedily. Most rain water is used in agriculture for crop production, therefore, the first point which arises is whether the available rainfall is adequate and well distributed for crop rising. The greater the precision of long term data on rainfall patterns and greater the care taken in interpreting them, the higher will be the efficiency of water management projects. Agriculturists may consider as effective that portion of total rainfall which directly satisfies crop water needs and also the surface run-off which can be used for crop production on their farms by being pumped again from ponds or well. In the field of dry land agriculture, when the land is left fallow, effective rainfall is that which can be conserved for the following crop.

The main objective of this study is to estimate the portion of rainfall that is added to soil moisture after rainfall which is considered as an effective part of total rainfall; other objectives are to study the effects of over and under estimation of effective rainfall on crop water requirements calculations and its effect on determining the cultivable areas.

Materials and Methods

This experiment was carried out in a field adjacent to the agroclimatological station at Gezira Research Station, Sudan. Full meteorological data is available for the site, from which it is possible to establish some empirical relationships between the observed soil moisture and the main weather factors concerned. The experiment is based on a daily balance of stored water content of the soil. The experiment was conducted for two rainy seasons. In the 2nd season the experiment was repeated for a longer period to cover most of the rainy season.

In the first season the land was flat, uncultivated and untreated by any practice, samples were taken randomly from the study area. In the second season the experiment began (before the first rain in the season) to know the initial moisture content of the soil.

In the 2nd season the samples were taken randomly, the soil was bare and has been left fallow for two years. The land was treated by deep disc harrowing and leveling (which is the normal practice in the Gezira Scheme) to avoid the variation in replicates results which occurred in the previous season. Augured samples of soil by 20cm intervals were obtained daily to 100cm depth, which is maximum depth that will be attained from previous experience to exceed the effective rooting zone of most crops. Then the replicates of 0-20 cm and 20-40 cm were increased from 5 to 10 replicates at the end of the period to ensure that the inherent variability of the field plot was well covered. The usual time of sampling was between 6.00 –8.00 am Sudan's local time.

Sampling Procedure:

Many types of augers were used depending on the dryness of the soil, soil samples at each interval was taken in a tin of about (20x15x10cm) in volume and all the depth of (20 cm) was taken in a tin, then the tin was sealed by plastic cover and wet cloth to avoid losses in the period between sampling and weighing.

Oven drying of samples at 115^{o}C over-nights to check for complete drying of rather bulky samples of (500-1500 g) was followed by the calculation of gravimetric percentage according to the following equation:

$$\text{MC (\% by weight w/w)} = \frac{\text{Fresh weight of soil-Oven dry weight of soil}}{\text{Oven dry soil weight}} \times 100$$

MC (% by volume v/v) = MC(% by weight w/w) x BD

MC = moisture content

BD = bulk density

i.e MC(% by volume v/v) =

$$\frac{\text{weight of water}}{\text{weight of dry soil}} \times \frac{\text{weight of dry soil}}{\text{total volume of soil}} = \frac{\text{weight of water}}{\text{total volume of soil}}$$

(Landon, 1991)

Because Gezira clay is a highly swelling montmorillonite soil, the value of the dry bulk density to be used as conversion factor changes significantly with both depth and moisture content at which the sample was taken (Table1).

Table 1: Changes in volume weight of Gezira clay with depth and moisture

Moisture content (%)	Depth intervals, cm				
	0-40	40-60	60-80	80-100	100-200
50	1.11	1.13	n.o.	n.o.	n.o.
40	1.15	1.19	1.25	1.29	1.30
30	1.19	1.26	1.32	1.38	1.40
20	1.23	1.32	1.46	1.53	1.54
10	1.25	1.35	1.53	n.o.	n.o.
0	1.25	n.o.	n.o.	n.o.	n.o.

Source :(Farbrother 1975)

n.o. denotes that samples of these moisture contents were not observed in the field.

Results and Discussion

Moisture content of the soil determined for each depth throughout the experimental period, changes in the moisture content for different layer were plotted in figure (1) to study the progress in moisture content in response to the rainfall events.

From figure (1) it can be observed that the surface layers of the profile has clear build up in soil moisture content with time. In the 0-20 cm depth the increase started on the 11th day of sampling. In the 20-40 cm zone the moisture increase was noticeable on the 17th day. In contrast to this, in the 60-80 cm and 80-100 cm zones moisture content at the start of the study period were greater than those in the top layers, the values were 9.5 , 9.9 , 15.1 , 19.2 and 19.8% for the five layers from top to bottom, respectively.

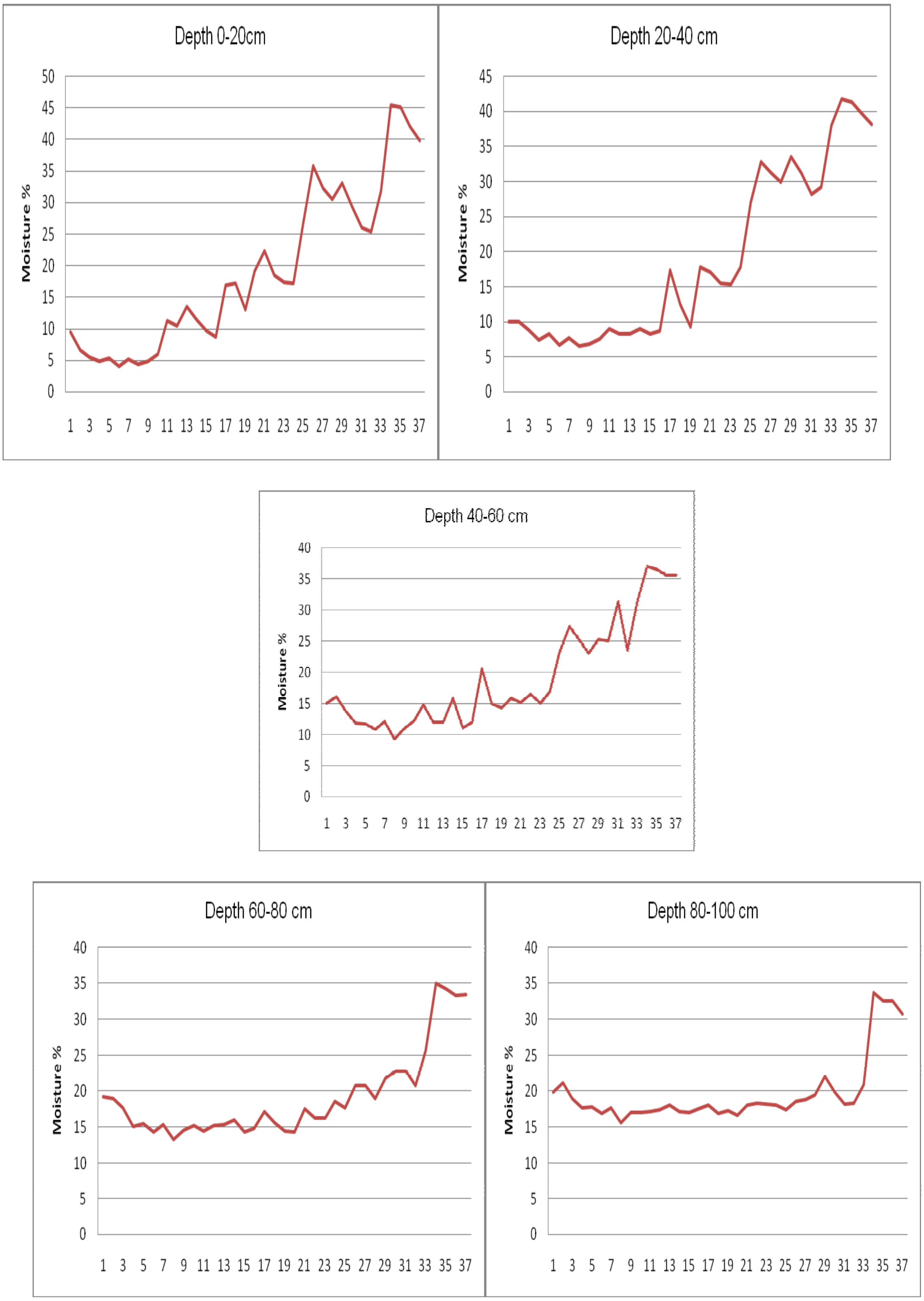

Fig. 1: Changes in soil moisture pattern with depth

Despite the amount of rainfall recorded throughout most of the experimental period the moisture content of the lower zones did not show any substantial increase before the 33rd day. The sharp increase in soil moisture content of these layers observed on the 34th day of sampling and sustained after that date could possibly be attributed to the accumulation of rainfall throughout the preceding periods especially the rainfall of 53 mm recorded one week before the jump shown. The 40-60 cm layer was intermediate between the layers of profile above and below it. These results showed that although the lower layers of the profile held greater moisture initially, they were not affected by rainfall as quickly as the surface layers. It is also possible to conclude here that the moisture changes are confined to the top 60 cm depth, unless there is standing water.

Assessment of Effective Rainfall:

To assess the effectiveness of the rainfall recorded under the conditions of this study, soil moisture contents for the profile were expressed in (mm) and plotted against the days of observation in figure (2).

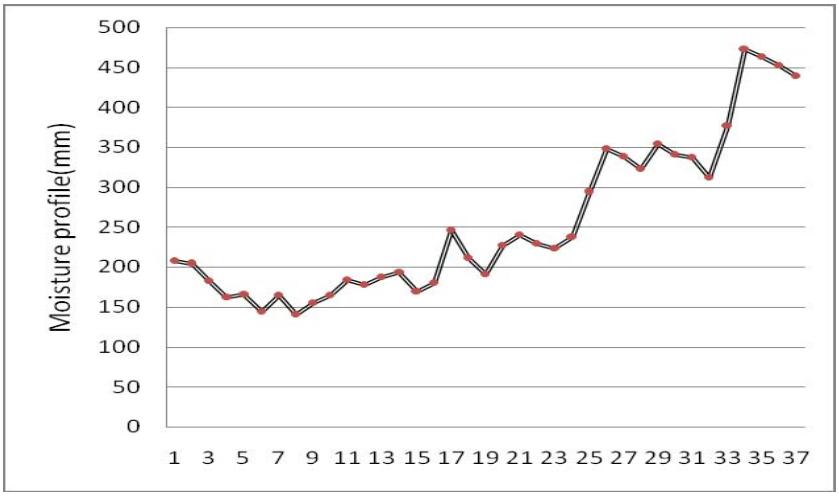

Fig. 2: soil moisture contents profile through the study period

Accepting the assumption that after an effective rainfall the soil moisture content should increase, the plot was divided into three segments. Each segment contains a cluster of points after which the soil moisture content has clearly increased. The first zone represented the period 13th to 27th of July, the second was from 10th to 16th of August and the third zone was from 8th to 11th of September. The average moisture content of the soil profile was calculated for each of the three periods namely, 207 mm, 336 mm and 458 mm for the three periods, respectively. This gives a change of 129 mm in the soil moisture content between the first and the second zones (336-207), and a change of 122 mm between the second and third zones (458-336). Taking the soil moisture content for the first period as an initial value, the increase of 129 mm measured in the second period corresponds to a total rainfall of 155.4 mm, while the rainfall recorded between this period and the third one was 182 mm resulting in an increase of 122 mm in the soil moisture content.

As there was no other source of water apart from rain, therefore, the increase in soil moisture content has to be attributed to rainfall effect. In this section effectiveness was taken as the ratio of change in soil moisture to a total rainfall contributing to that change. Thus for the period from mid - July to mid - August where the change in soil moisture was 129 mm and total rainfall was 155 mm the effective rainfall represents (83%) of the total rainfall (129/155), while for the period after that effectiveness of rainfall was 67% (122/182).

We can explain this variation in the ratios of effective rainfall during the season that in the beginning of the season the soil was dry so the water infiltrated rapidly through the soil and also the presence of deep wide cracks during that period facilitated penetration of water into the soil, while the ratio of effective rainfall decreased late in the season due to saturation of soil which has lead to decreased infiltration and hence more standing water increasing evaporation losses.

Based on the above discussion the 75% values of effective rainfall normally used to calculate quantities of rainfall available to crops growing during the period under investigation in this study is reasonable. Fractions of effective rainfall under Gezira conditions were calculated using different ratios for effective rainfall. Rainfall data was taken from the recorded normal of Wad Medani Meteorological Station for the period (1961-1990). The ratios of effective rainfall taken were 50%, 75% of rainfall and 83% or 67% ratios suggested in this study. Table (2) shows values of effective rainfall (mm) for each decade when the ratios mentioned about were used. It is clear that taking 50% of rainfall as effective rainfall greatly under estimates the effective rainfall when compared with other ratios, while if all the rain is taken as effective, this may not be realistic as there are fractions of rain that are evaporated or lost in run-off and run-on.

Table 2: Effective rainfall calculated using normal's (1960-1991)

Period	Normal rainfall (mm**)**	Effective rainfall (mm)		
		50%	75%	83 or 67% *
1-10 July	25	12.5	18.8	20.8
11-20 "	30	15	22.5	24.9
21-31 "	33	16.5	24.8	27.8
1-10 Aug.	37	18.5	27.8	30.7
11-20 "	39	19.5	29.3	32.4
21-31 "	36	18.0	27.0	24.1
1-10 Sep.	18	9.0	13.5	12.1
11-20 "	15	7.5	11.3	10.0
21-30 "	12	6.0	9.0	7.9
Total	245	122.5	183.8	190.7

* 83% effective rainfall was taken from the start of the season 1 July – 10th of August, after that a ratio of 67% was used.

If 75% and 83% or 67% values were compared, there seems to be a reasonable agreement between them, though at 75% there was a small under estimation at the start of the season and a small over estimation towards the end of the season. The advantage of the ratios suggested in this study is that more than a single ratio is used and this gives the chance of taking into consideration changes in rainfall effectiveness with time as the moisture profile of the soil changes.

Other important decisions are associated with rainfall intensity and effectiveness such as area under cropping. If rainfall contribution to crop water requirement (CWR) is considered, it is possible to increase the cropped area for the same amount of irrigation water in the canals. If rainfall is not taken into consideration when calculating (CWR) huge amount of water released in canals in addition to rainfall may cause breakage of canals, and accumulation of water in the field which leads to losses of water by evaporation, this in addition to the possible environmental hazards.

This study has thrown light on effectiveness of rainfall under the specific conditions of Gezira Research Farm and extrapolation of these results to other areas of Gezira must be considered with care. The type of soil, land preparation, rainfall intensity and distribution must be taken into consideration.

Conclusions

From the results of this study it is possible to conclude here that within the normal irrigation cycle in Gezira clay moisture penetration is confined to the top layers of the soil profile and percolation beyond the layer of 40–60 cm depth takes place only under conditions of standing water. Under conditions of this study inspite of greater increase in soil moisture in top soil layers, the changes in available water were not always positive. This study gave two values of effective rainfall, 83% in the first part of the season and 67% towards the end of the season. The average value of 75% is in agreement with other empirical methods. Using two ratios for effective rainfall has the advantage of considering changes in rainfall effectiveness with time as the moisture content of the soil changes.

There are some important decisions which are associated with effective rainfall such as area under cropping which increases or decreases with increase or decrease of rainfall effectiveness.

This study has thrown light on effective rainfall under GRS farm conditions and extrapolation of results to other areas of Gezira must be considered with care.

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