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Analysis of Evapotranspiration and Developing Crop Coefficient for Plantation Sugarcane Using Lysimeter Experiment under Melkassa Climatic Conditions, Ethiopia

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Abstract

Sugarcane is one of the important industrial crops produced all over the tropical areas. Sugarcane production is highly expanding in developing countries like Ethiopia. However, sugarcane is characterized by very high crop evapotranspiration. This requires determination of its crop evapotranspiration to apply with accurate crop water requirement throughout the growth period. The main purpose of the current study was to determine sugarcane evapotranspiration and develop its crop coefficient using Lysimeter experiment. Weather parameters required for CROPWAT 8.0 model used to determine reference evapotranspiration were collected during the study time. The sugarcane evapotranspiration was computed throughout the growing period of the crop from lysimeter experiment. The result indicated that crop evapotranspiration obtained ranges from 1.63 to 7.13mm/ day. The study found that sugarcane crop coefficients were 0.42, 0.93, 1.26 and 1.05 at emergence, tillering, grand formation and ripening growth stages respectively. The variation of sugarcane crop coefficient obtained were 2%, 1% and 30% greater than FAO recommendation at emergence, grand formation and ripening growth stages respectively but 33% lower at Tillering growth stage. Therefore, from the findings so far it can be concluded that these crop coefficient values can be used in the sugarcane estates until further improvements are made.

Keywords: Crop coefficient • Crop evapotranspiration • Lysimeter experiment • Neutron probe • Sugarcane

Introduction

Globally agriculture contributed to more than 80% use of fresh water available especially for irrigated crop production. Agricultural ecosystems are the main consumer of water resources worldwide. The use agricultural water consumption may from region to as a result of economic development and climatic factors. The irrigation water consumption approximately estimated as 60% and 90% of available water resources in developed and developing countries respectively [1]. In some regions of the world, the expansion of irrigation increased stressing water bodies and aquifers that depleting from time to time. As a result it faces the water scarcity condition, in which the demand of freshwater resource exceeds the availability freshwater resource [2]. But the availability of irrigation water is decreasing from time to time because the demand for fresh water resource by different sectors increasing in the opposite. In the context of global water scarcity for agriculture, the precise management of available water for irrigation is important [3].

The sugar cane is a crop of great social, economic and environmental importance almost all over the world. It is the world largest crop by production in quantity and produced in 120 countries. The ten (10) largest sugar producing nations represent roughly 75% of world sugar production [4]. In production, Brazil still remains on the top with (33%) of global sugar production followed India (23%), China (7%) and Pakistan (4%). Africa contributed less than 5% of the world sugarcane production. In world, sugarcane is grown between the latitude 36.70 N and 31.00 S of the equator extending from tropical to subtropical zones. About 80% of sugar is obtained from sugarcane and the remaining 20% is produced from sugar beet [5,6].

Worldwide, sugarcane occupies area coverage of 20.42 Mha with a total production of close to 1.6 billion tons per year with the average productivity of 59.4 ton/ha. Sugarcane also produced in Africa with a total area coverage of 1.5 Mha with a productivity of 53.2 ton/ha. South Africa is the leading country in sugarcane production in Africa with the total production of 1.8 million tons/year and productivity of 58.7 ton/ha from Africa, Ethiopia sugarcane area coverage is 0.32 Mha with average productivity of 45.2ton/ha [7]. The annual per

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capita consumption of sugar in the world (24 kg), in Africa (16.3 kg) and in Ethiopia (5.1 kg) which is very low even as compared to African standards as international sugar organization cited by [6].

Sugarcane is a perennial water intensive crop and with water becoming increasingly scarce resource particularly due to high competition on water resources from different sectors. In the global context, around 80% of sugarcane is grown in the regions that have a history of water scarcity in rift valley of the country [7]. On average 3000 - 4000 mm of water is applied to sugarcane depending on the method of irrigation while water requirement based on evapotranspiration is less than 2000mm [1]. But water requirement of sugarcane varies from 1200 to 3500 mm depending on soil types, crop growing duration and the climatic conditions of the area [4]. Scarcity and growing competition for fresh water resource reduce water availability for irrigation. To increase the efficiency of irrigation, especially for surface irrigation, an accurate estimation of crop water requirements in irrigated agriculture is essential for effective planning and management of water resources [5].

The basic problem concerning efficient use of water for sugarcane is to apply the required amount of irrigation water uniformly with minimum loss throughout the growth period to obtain the maximum yield of the crop [6]. A variety of approaches are available for estimating crop evapotranspiration. The most widely accepted two step approaches which include the quantification of the atmospheric demand through the calculation of reference evapotranspiration (ETo) and the incorporation of the surface characteristics through crop factor called crop coefficient (Kc) is generally followed in the estimation of crop evapotranspiration [7].

Even if the sugarcane is highly demanded, due to many factors its production and productivity is not much attractive especially in developing countries particularly, Ethiopia. From many factors affecting sugarcane production in Ethiopia, mismanagement of irrigation, inadequate knowledge of irrigators, lack of regular operation and maintenance are main factors in Ethiopia [8]. Surface irrigation is the most dominant irrigation methods practiced in sugarcane production in area however, sugarcane evapotranspiration is not accurately determined. Generally, in Ethiopia there was a very limited scientifically organized research conducted on sugarcane evapotranspiration and its crop coefficient. A few research conducted on the sugarcane evapotranspiration depends on sugarcane crop coefficient recommended by FAO [9]. Therefore, this study focused on determination of sugarcane evapotranspiration and developing its crop coefficient under central rift valley of Ethiopia. The main objective of the current study was to analysis sugarcane evapotranspiration and developing its crop coefficient using lysimeter experiment under Melkassa climatic condition.

Materials and Methods

Description of the study area

The experiment was conducted under central rift valley of Ethiopia, East shoa zone, Adama district, Melkassa Agricultural Research Center. The study area located at latitude 8°24' N and longitude 39°21' E and the agro ecological zone of the area categorized as semi-arid with minimum and maximum temperature of 13.8 and 28.70C, respectively. The annual average rain fall of area is 810.3 mm which located at an altitude of 1550m.a.s.l. and 117km far from capital city of the country, Addis Ababa. Melkassa Agricultural Research Center (MARC) was established in 1969 focusing on National Horticulture and Irrigated Agriculture Research Center [10]. The important research programs contributed to improved rain fed and irrigated agricultural development with a main focus on dry and lowland areas of moisture stress and irrigable areas of the country. The experiment was conducted at MARC which located under the same agro ecological zone side by side with Wonji shoa sugar estate. But the experiment was conducted under MARC due to lack of lysimeter at Wonji shoa sugar estate. Sugarcane produced at Wonji shoa as mono crop under two production systems, estate and out grower production system. The total area coverage of wonji shoa sugarcane production is 12,000 ha of which 5,000 and 7,000ha at estate and out grower production system in which dominantly produced with surface irrigation and some with sprinkler irrigation methods (Figure 1).

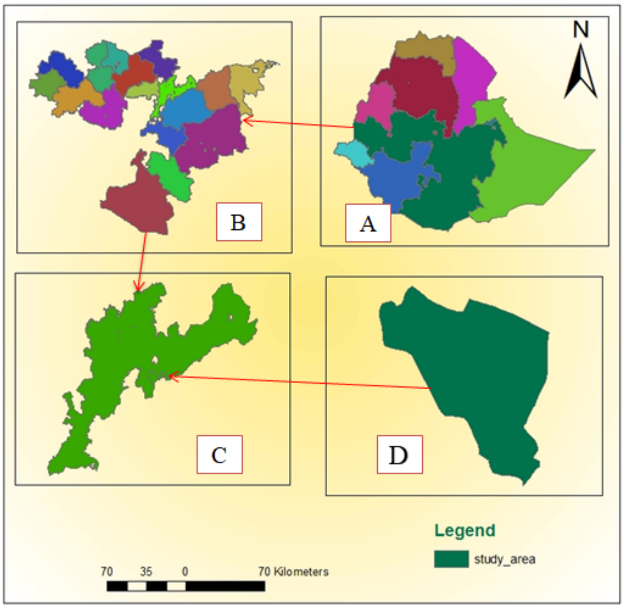

Figure 1. Map of the study area A) Ethiopia, B) Oromia and C) East Shewa Zone and D Melkassa agricultural research center, experimental site.

Experimental set up

Lysimeter is for most devices, typical tankers or container (net area of 2m2, 1m*2m with a boundary of 6*6m) that permit measurement of vertically percolated volume of water beyond the crop root zone from the lysimeter drainage hole. From the lysimeter, the soil samples were taken to analysis the most important physical properties related to irrigation. The soil physical properties considered were bulk density and soil texture but soil moisture content at field capacity and wilting point were taken from Melkassa Agricultural Research center that recently analysed by the institution[11].

The sugarcane variety used for the experiment was taken from Wonji Shoa sugar estate. Among many sugarcane varieties currently cultivated at Wonji Shoa, NCO-334 variety was selected because of short maturity and widely cultivated at Wonji Shoa sugarcane plantation. In the lysimeter including the boundary area, furrow layout was prepared with a furrow width of 1m. The sugarcane setts with two buds were planted in rows in the lysimeter as well as the boundary area. The lysimeter layout on which the experiment conducted was presented in the (Figure 2) [12].

Figure 2. Partial view of lysimeter: A) Soil sampling from lysimeter, B) Sugarcane germinated in the lysimeter C) Sugarcane at tillering stage, D) Lysimeter drainage hole and E) Measuring deep percolated water from lysimeter drainage hole.

Neutron probe calibration and soil moisture analysis (FC and PWP)

A head of the experimental measurement, neutron probe calibration was performed to manage the soil moisture in the lysimeter. The soil moisture above 30cm monitored using gravimetric method and beyond this soil depth (30-60cm and 60-90cm) monitored using neutron probe [13].

Results and Discussions

Soil moisture analysis

A few of soil physical properties were analysed by taking the soil samples from the lysimeter field. The soil samples taken from four depths (0-15, 15-30, 30-60 and 60-90cm) were analysed in the Melkassa Agricultural Research Center soil laboratory. The selected soil physical properties were those that affect the irrigation or affected by irrigation directly or indirectly. The result of those selected soil properties were presented in (Table 1).

Depth	ρβ (γ/χμ3)	Percentage of soil particles (%)				FC	PWP
		Sand	Silt	Clay	soil texture	(%, vol)	(%, vol)
0-15	0.99	53	35	12	Sandy loam	25.4	12.6
15-30	1.01	43.8	38.6	17.6	Loam	23.7	9.3
30-60	1.06	47	37	16	Loam	25.7	12.6
60-90	1.15	45.7	37	17.3	Loam	25	11.5

Table 1. Soil moisture analysis (FC and PWP).

The soil texture in the lysimeter was loam soil except at upper part of the soil profile which was sandy loam. This may be due to the repeated application of irrigation water that contains very fine sand transported with irrigation water applied.in general as the obtained revealed that, the soil in the lysimeter the appropriate soil for irrigation.

Neutron calibration

Neutron probe was calibrated and used to monitors soil moisture. The coefficients were determined from the moisture data collected from wet and dry access tubes. After the analysis, the following linear equation was developed and stored in the neutron probe (Figure 3).

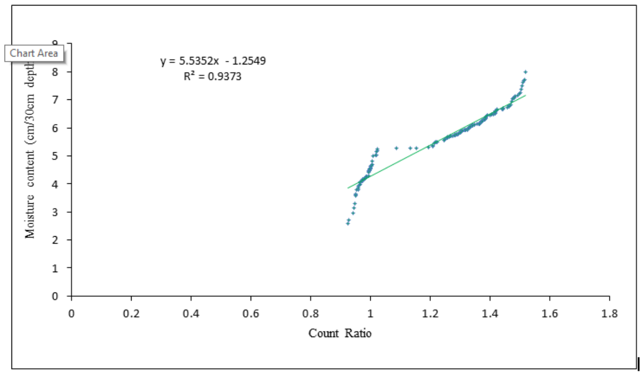

Figure 3. Analysis of linear equation.

The soil moisture lost as deep percolation from 0-30cm slightly more at early growth stages of the crops but the irrigation water applied was less at this growth stages. The soil moisture lost in the form of deep percolation in the crop root zone after mid-season of tillering growth stage was not much varies throughout the crop growth stages. The soil moisture depleted in the form of deep percolation from 30-60 and 60-90cm in the crop root zone were fluctuated but in the deceasing trends throughout the growth stages. But in the vice versa irrigation water applied was fluctuated in the increasing trend up to the end of grand formation growth stages of the crop. The result obtained indicated, less soil moisture lost in the lower depth in form of deep percolation even if more irrigation water applied as the crop growth stages increased. The volume of water deep percolated was more in the early growth stages of the crop because at this growth stages the crop root zone more shallower and soil water stored in the deeper soil depth lost as drainage water [13].

The study conducted on determination of sugarcane water requirement and crop coeficient indicated that the soil moisture lost in the form of deep percolation was decreased as the crop evapotranspiration increased. This study finding was similar with the current study findings in wich more water lost in the form of drainage in the early crop growth stages in wich the crop evapotranspiration is low. The study conducted on determination of sugarcane crop coefficient and water requirement in Brazil revealed that the volume of soil moisture lost in the form of deep percolation at early crop growth stage was lower than as the crop growth stages more developed. In opposite to this study result, the current study indicated more volume of soil moisture was lost in the form of drainage during the early crop growth stages.

The study conducted indicated that the soil moisture lost in the sugarcane root zone increased as the crop evapotranspiration increased. As the result of those study revealed, the crop evapotranspiration increased with crop growth stages up to the peak point and then become reduced thoroughly. Finally, those study findings concluded as soil moisture status in the lower soil depth increased with the crop growth stages in opposite to the current study findings in which it increased up to the end of grand formation growth stages and then become decreased.

The concept of fraud

The concept of fraud is seen as the whole set by which an organization can effectively manage to increase its financial performance. Fraud does not only affect the institutions but also deter investors from putting their investment in a particular venture. Portfolio investors who are not directly involved in the management of the company are most concerned about cases of frauds. According to them, what normally happens in the ideal situation is that, the investors provide capital to the firm, and the managers regulate the firm in the interest of the investors for compensation for their service. However, the issue of fraud reduces the level of trust in management and ownership that may be detrimental to the interest of the shareholders [14].

Analysis of sugarcane crop evapotranspiration from lysimeter

Sugarcane crop evapotranspiration was directly measured from the lysimeter experiment based on the soil water balance analysis. In the process most of the soil water balance components, surface and subsurface inflow and out flow as well as ground water contribution were neglected because they are controlled by the lysimeter. The sugarcane crop evapotranspiration directly measured from lysimeter experiment ranges from 1.63mm/day to 7.13mm/day throughout growing season [15].

Conclusion

Sugarcane is perennial water intensive crop and produced for commercial purpose all over the world. It is a crop which is very sensitive to both high and low water application throughout the growing season. Since the crop is highly demanding and requires more amount of water to produce yield throughout the year. Thus it requires determination of appropriate water requirement of the crop in the main production area. In case of Ethiopia, the main rainy seasons ceased only from three to four months of the year (June to September). This requires application of irrigation water for longer time of the crop growing periods from the precious scarce water resources. Due to those conditions, the current study was focused on the determination of sugarcane water requirements and its crop coefficient which is very expensive and time consuming experiment. To determine the water requirement of the crop, lysimeter experiment was conducted at Melkassa Agricultural Research Center. The soil water status in the crop root zone was monitored throughout the growing season of the crop by neutron probe. After the sugarcane evapotranspiration was determined from the lysimeter experiment and reference evapotranspiration was determined using CROPWAT 8.0 model from climatic parameters collected from the study area, the sugarcane crop coefficient was developed as the ratio of the two parameters. The measured average sugarcane evapotranspiration were 2.34 mm/day at emergence and germination, 4.02 mm/day at tillering, 5.58 mm/day at grand formation and finally 4.89 mm/day at ripening growth stage. The sugarcane crop coefficients obtained from the current experiment were 0.42, 0.93, 1.26 and 1.05 at emergence and germination, Tillering, grand formation and ripening growth stages respectively. The obtained sugarcane Kc value is similar with FAO-56 recommendation at grand formation growth stage and greater than at emergence and ripening growth stages while lower at Tillering growth stages. The variation might be due to the specific location of the study because the FAO-56 recommendation based broader consideration. This conclusion is not only on the current study findings but also the same to others study conducted at different locations. Hence, to apply the optimum water requirement for the sugarcane plantation, determination of sugarcane Kc at specific location is very crucial. From the current study result it can be concluded as wonji shoa sugar estate could use these findings for saving irrigation water and getting maximum yield until further improvements could made under this specific condition. Similarly, it is better to use these findings in the country which have similar climatic condition to harvest the potential yield of the crop rather than using the black recommendation in the broader climatic conditions by FAO-56.

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