ISSN: 2469-4134
Journal of Remote Sensing & GIS

OPEN ACCESS Freely available online

Research Article

Estimation and Mapping Spatiotemporal Variability of Crop Water Requirement for Sugarcane in Arjo Dedessa Sugar Factory and its Surrounding

Etefa Tilahun Ashine[1*], Mamuye Busier Yesuf[2], Andualem Shigute Bokke[3]

[1]Department of Agricultural Science, Ethiopian Institute of Agricultural Research, Jimma Agricultural Research Center, Jimma, Ethiopia; [2]Department of Hydraulic and Water Resources Engineering, Jimma University, Jimma, Ethiopia; [3]Department of Hydraulic and Water Resources Engineering, Jimma University, Jimma, Ethiopia

ABSTRACT

To meet the ever-growing demand of sugar, a great focus has to be given to its input, which is a sugar cane crop, and management of the crop's water requirements. This study was initiated with the objective of estimating and mapping the spatiotemporal variability of ratton sugar cane (*Saccharum officianarum*) crop water requirements at the Arjo-Dedessa sugar factory and nearby areas. Arc GIS 10.4.1 and CROPWAT 8.0 software were the materials used. Fourteen meteorological stations were delineated, and data from ten stations were used for analysis. The measured data and predicted value proved the geostastical tool's applicability. According to the mapping, the annual crop water need varied from 1296.5 millimetres to 1752.36 millimetres using the inverse distance weighting method. The apparent regional variation in the yearly water need of sugar cane crops was attributable to variation in reference evapotranspiration caused by elevation. The influence of altitudinal variations, higher elevation as opposed to lowland areas, was the result for the likelihood of a rise in crop water demand values from a high elevation to a relatively low elevation location.

Keywords: Arjo dedessa; CROPWAT; Geostatistical tool; Millimetre; Sugar cane; Water depth

INTRODUCTION

Background and justification

Improved water resource management and planning are required to ensure proper water consumption and distribution among competing users. Natural scarcity has been exacerbated by man-made desertification and water shortages, while the population is growing and there is greater competition for water among water-using industries. For efficient irrigation scheduling, water balancing, canal design capacities, regional drainage, water resources planning, reservoir operation studies, and crop production potential assessment, scientific crop water requirements are necessary.

Accurate estimation of crop water requirements in irrigated agriculture is essential for effective planning and management of water resources. Crop water requirements are the amount of water needed to compensate for evapotranspiration losses from a cropped field over a given time period and are commonly stated in millimeters per day, millimeters per month, or millimeters per season depth of water [1]. It is the depth of water required to meet the water consumed by evapotranspiration by a disease-free crop growing in large fields under non-restricting soil conditions such as soil water and fertility, and achieving full production potential under the given growing environment [2-4].

Stated that crop output is a result of water, nutrients, climate, and soil environment, provided that all other prerequisites for optimum development and production are met [5]. Only when the water supply is enough for biological needs can efficient crop production and optimum yield be achieved. The crop is well-supplied with nutrients for full development and is well-adapted to its surroundings [6]. There is no crop without water; the requirements are in place, and timely delivery of adequate precipitation might considerably boost agricultural crop productivity.

Correspondence to: Etefa Tilahun Ashine, Department of Agricultural Science, Ethiopian Institute of Agricultural Research, Jimma Agricultural Research Center, Jimma, Ethiopia, Tel: +251917345569; E-mail: etefatilahun@gmail.com

Received: 02-May-2022, Manuscript No. JGRS-22-16768; **Editor assigned:** 04-May-2022, Pre QC No. JGRS-22-16768 (PQ); **Reviewed:** 20-May-2022, QC No JGRS-22-16768; **Revised:** 27-May-2022, Manuscript No. JGRS-22-16768 (R); **Published:** 03-Jun-2022, DOI: 10.35248/2469-4134.22.11.232.

Citation: Ashine ET, Yesuf MB, Bokke AS (2022) Estimation and Mapping Spatiotemporal Variability of Crop Water Requirement for Sugarcane in Arjo Dedessa Sugar Factory and its Surrounding. J Remote Sens GIS. 11:232.

The production of sugar is one of the crucial works to meet the ever-growing sugar demand in Ethiopia. Accordingly, its production is prioritized by the Ethiopian government, and in 2015 there is a plan to make the country one of the world's ten largest sugar producers and exporters by 2023 [7,8]. The plan includes boosting the annual sugar production from the current level of 0.3 to 2.25 million tons and generating 181 million liters of ethanol and also expected to contribute about 448-Megawatt electric power through cogeneration [9]. Even though sugarcane is a long-duration crop-producing vast amount of biomass, it is classed among those plants with a high-water requirement [10]. To confront the water management challenge, great attention must be paid to its input, which is a sugarcane crop, as well as how to control the crop's water requirements. Managing agricultural water requirements allows for optimal yields by reducing any water deficiency problems such as insufficient water at the root zone, soil salinity, and water stress on plants that can affect crop output [11].

Determination of the crop water requirement which requires meteorological data is essential for agricultural water planning and management in a dry and semi-dry area. This depends on the availability of gauged meteorological stations and hydrological characteristics of the cultivation area. Unfortunately, the non-consistency and unavailability of meteorological data at some stations was a challenge for determining the crop water requirement of the crop and was possible by estimating from known stations with a data. Therefore, this study was organized to estimate and map the spatiotemporal variability of sugar cane (*Saccharum officianarum*) crop water requirement in Arjo-Dedessa sugar factory and nearby areas, for agricultural water management.

MATERIALS AND METHODS

Description of the study area

The study region is located in South Western Ethiopia, in Oromia Regional State, including Eastern Wollega, Ilu Ababora, and Jimma Zones, 540 kilometres from the capital along the Addis Ababa-Jimma-Nekemt road. The location has an elevation of 1,350 meters above mean sea level. It is found in 7°36'00" to 9°36'00" North and 35°32'00" to 37°34'00" East.

The study areas have a mean annual rainfall of 1400 millimetres. Its rainy season extends from May to October. The monthly mean maximum temperature varies from 21.16°C to 33.75°C, and the monthly mean minimum temperature varies from 7.01°C to 14.89°C. The rainfall distribution of the study area reveals that the distribution is not uniform in some months. The rainfall is deficient, and even no rainfall up to four to five months continuously, and in some months, there is continuous rainfall, mainly during the summer season (Figure 1).

Arc GIS 10.4.1, CROP WAT 8.0, XLSTAT software, Aqua Crop software, Microsoft Word, and Microsoft Excel were utilized to conduct this study. The spatial and temporal variability of crop water requirements was mapped using GIS. Because the meteorological data includes a missing value, the XLSTAT2019 software was used to fill in the blanks [12]. The crop's water needs were calculated using the CROPWAT 8.0 model. The crop attributes, such as planting date, harvesting date, Crop Coefficient (KC), and climate data, were required as input data.

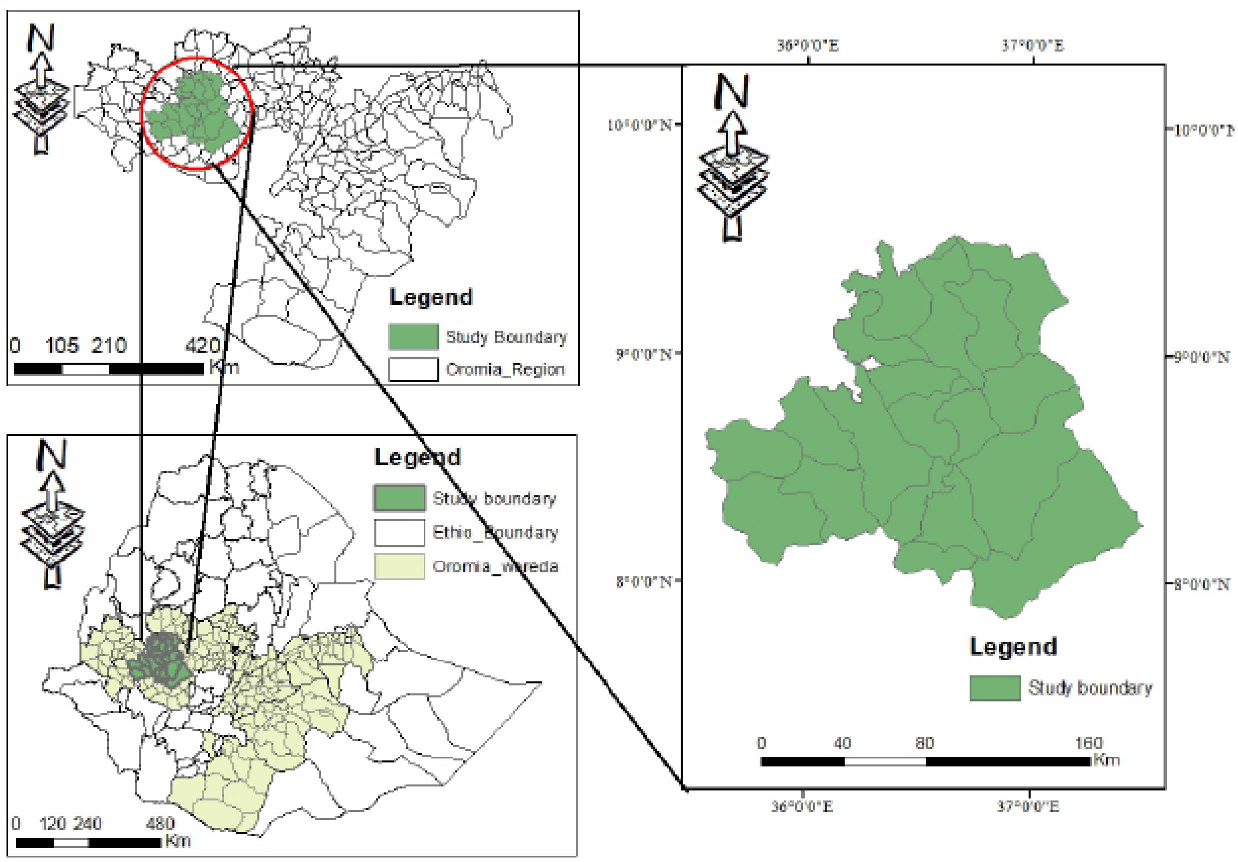

Figure 1: Location of the study area.

Secondary data have been collected from the responsible organization. They were collected from Ministry of Water Irrigation Electricity and Energy (MoWIEE), and National Meteorological Service Agency (NMSA). The required data for this study includes Digital Elevation Model (DEM) and Meteorological data, and the data was collected using the following methods: Field visit, inspection and observation, Internet and library, Downloading DEM, Google earth and soil type data.

Fourteen meteorological stations in Oromia regional states that surround the Dedessa River and the Arjo Dedessa sugar factory, namely the AbasanJoger, Anger, Arjo, Atnago, Bedele, Chora, Dedessa, Dembi, Limu-Genet, Metu-Hospital, Nekemite, Toba, Yanfa and Yayo stations were delineated. From these, meteorological data from ten stations, namely Anger, Nekemt, and Arjo in the Northern, Bedele, Yanfa and Dembi in the Southern, Atinago and Limu-Genet in the Eastern, and Yayo and Chora station in the Western of the study area (Arjo-Dedessa Sugar Factory) were used for analysis. The basic data quality checking, mainly filling the missing data, checking the consistency of the rainfall, and checking the homogeneity of the data, was done.

To increase estimation accuracy, a linear regression equation was built between observed data and station elevation. First, the residuals of ETc were computed using linear regression as the difference between observed and anticipated values at gage locations. The residuals of the ETc value were then interpolated throughout the entire region using inverse distance weight. The final estimate of ETc at any point was obtained by combining the residual interpolated map of the study region, from which all essential meteorological data were gathered. Finally, the measured data and anticipated value proved the reliability and applicability of the geostatistical method for the mapped crop water requirement (ETc).

RESULTS AND DISCUSSION

The mapping of the crop water requirement for the Arjo Dedessa sugar factory and the surrounding area reveals an annual crop water requirement variation from 1296.5 mm to 1752.36 mm depth of water by the inverse distance weighting method of the Geostatistical tool of Arc GIS. The CWR was high in the Northern part of the study area and relatively lower in the South Western part.

Sugar cane's (*Saccharum officianarum*) annual crop water requirement ranges from 1297 millimetre to 1752 millimetre geographically. The crop's annual crop water needs in the northern section of the study region, such as Anger, Arjo, and Nekemt, were 1752-millimetre, 1452 millimetre, and 1500 millimetre, respectively. The annual crop water requirement of the crop in the southern part of the research region was 1297-millimetre, 1430 millimetre, and 1437 millimetre, respectively, at Bedele, Dembi, and Yanfa. The annual crop water requirement of the crop in the western section of the research region was 1472 millimetre and 1310 millimetre in the Yayo and Chora areas, respectively. At the Atinago and Limu-Genet stations in the eastern part of the research region, the annual crop water requirement was 1447 millimetre and 1448 millimetre, respectively.

The temporal crop water requirement depth for the Northern area of Anger was 44.3 millimetres, 196.6 millimetres, 998.2 millimetres, and 512.9 millimetres for the initial development, mid-season, and late season, respectively. At Nekemit, the crop water requirement depth was 37.1 millimetres, 150.5 millimetres, 858.7 millimetres, and 454.4 millimetres for the initial, development, mid-season, and late season, respectively. The Arjo area was 37 millimetres, 164 millimetres, 834.7 millimetres, and 415.8 millimetres, respectively. The seasonal crop water requirement depth for the southern part of the study area at Yanfa was 35.4 millimetres, 148.5 millimetres, 836.7 millimetres, and 416.1 millimetres for the initial, development, mid-season, and late season. At the Bedele area, the crop water requirement depth was 33.1 millimetres, 140.3 millimetres, 759.3 millimetres, and 364.3 millimetres for the initial, development, mid-season, and late season, respectively. For the Dembi area, the crop water requirement depth was 34.7 millimetres, 145.3 millimetres, 835.3 millimetres, and 414.1 millimetres, respectively. The crop water requirement at the mid-season for all the stations was high. The Western station at Yayo and Chora was 36.4 millimetres, 158.5 millimetres, 864 millimetres, and 413.7 millimetres, and 33.4, 143.6, 770.2, and 362.1 millimetres for the initial, development, mid-season, and late-season for the two stations, respectively. When the Eastern station of the study area was considered, the crop water requirements were 35.7 millimetres, 151.3 millimetres, 846.3 millimetres, and 413.9 millimetres for Atinago station, and 35.9 millimetres, 147.9 millimetres, 841.8 millimetres, and 422 millimetres for Limu-Genet station for the initial, development, mid-season and late season, respectively.

The crop water requirement at the mid-season was high. The apparent spatial variation of annual sugar cane ETc values was due to ETo variation as affected by elevation. The possibility of an increase in the ETc values from the high elevation to a relatively low elevation area was the influence of altitudinal differences, higher elevation compared to lowland areas. At an elevation above 2300 m, the annual evapotranspiration values are gradually reduced by the low atmospheric demand because of low temperatures as the elevation increases [13]. With increasing height, the air temperature drops uniformly with altitude at the rate of approximately 6.5°C per 1000 meters [14]. Therefore, altitude was the major factor that affects the ETc of the crops because it directly affects temperature. This was also verified by, who reported that an increase in temperature directly influences the evapotranspiration rate and water requirement [15].

This finding is in a similar range to that of, who studied the seasonal water requirement of sugarcane at Finchaa valley [16]. According to their study, the average seasonal water requirement of sugarcane planted in any month of the year in Finchaa Valley was 1614.45 millimetres. The maximum and minimum seasonal crop water requirements were 1677.8 and 1554.6 millimetres per season for sugarcane first watered in August (harvested in July) and March (harvested in February). Further analysis showed that the total seasonal water requirements of ratoon sugarcane plants harvested in November, December, January, February, March, and April were less than the average of all first watering months' total water requirements 1614.45 millimetres.

Discovered a similar range of crop water requirements for the sugar cane crop (*Saccharum officianarum*) a long time before [17]. According to him, the yearly water use of sugar cane is between 1100 and 1800 millimetres, depending on the location of the research area. The IDW reflects the same range as the CWR, which was between 1296.95 millimetres and 1752.36 millimetres. A sugarcane crop requires 1564 millimetres of water across the entire growing cycle, according to a study conducted in India [18]. According to their findings, the crop's water requirements drop considerably throughout the last stages of development. Also estimated a crop water requirement of sugarcane in Coimbatore to be 1438.7 mm [19]. According to their observation, at least 850 mm of water per year is required for sustainable rain fed production of sugarcane. High yielding crops like sugarcane produce heavy biomass and economic yield. Higher biomass needs more water for its production. Hence supplementation of water as irrigation is essential. For commercial production, full irrigation was practiced when annual rainfall is less than 800 mm and supplemental irrigation is applied when annual rainfall is less than 1000 mm. Therefore, the CWR mapping for the Arjo-Dedessa sugar factory and adjacent area ranged from 1296.95 millimetres to 1752.36-millimetres of water depth, confirming approximately the same finding.

On the estimation and mapping of the crop water requirement, the availability of meteorological stations has a high impact on the accuracy of the data and hence on the spatial information generated. In an area where the meteorological stations are closer, the spatial data obtained was accurate, and in a station that covers a large area, the accuracy was relatively low. This observation agreed with [20-24], they observed that for specific rainfall spatial mapping, the denser the rain gauge measurements, the higher the estimation accuracy for rainfall and its application, such as hydrological modelling (Figure 2).

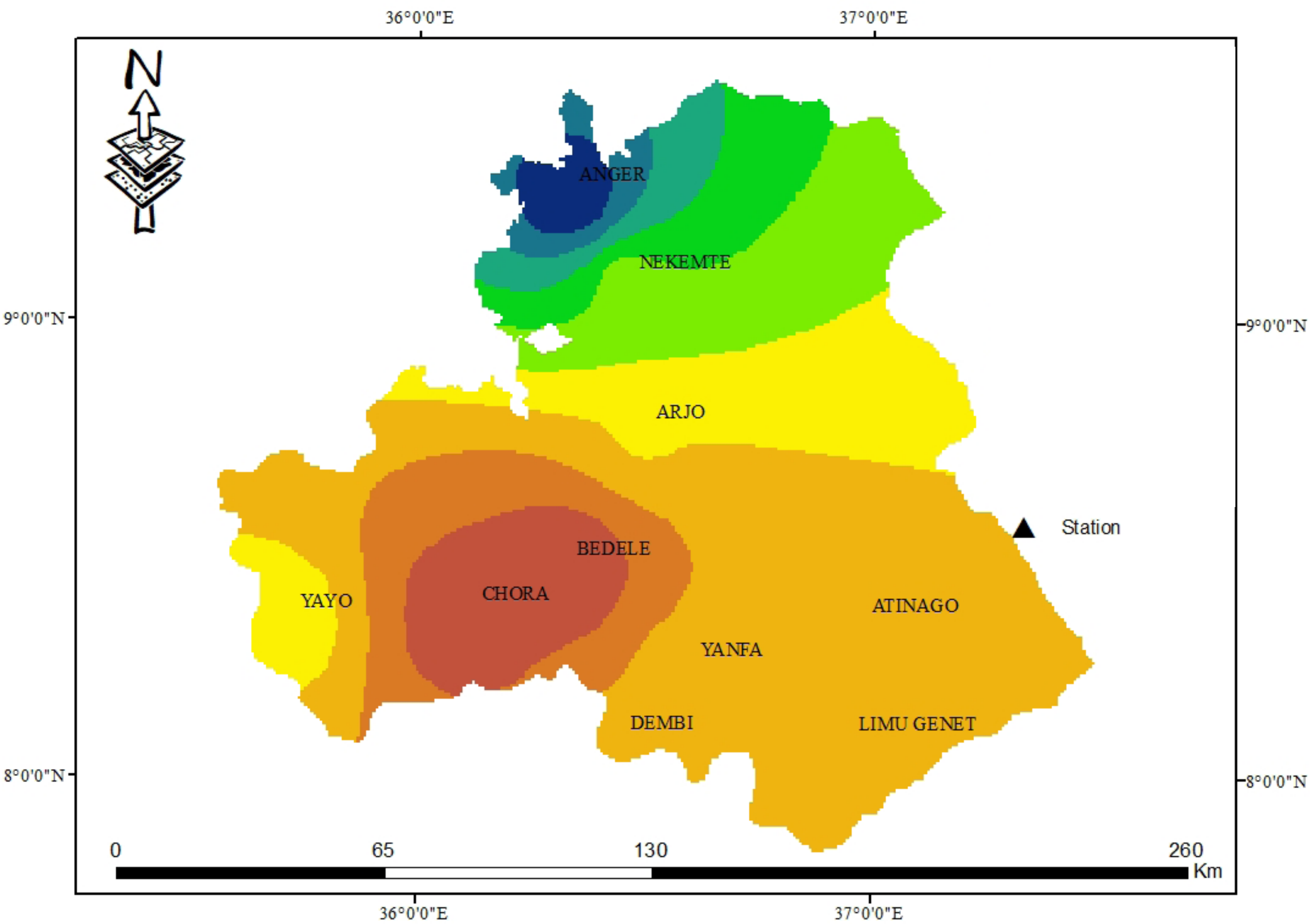

Figure 2: Spatial map of Crop water requirement of sugarcane for Arjo-Dedessa Sugar factory and the surrounding area. **Note:** ( ) 1,296.95-1,364.82, ( ) 1,364.82-1,414.82, ( ) 1,414.82-1,448.75, ( ) 1,448.75-1,479.11, ( ) 1,479.11-1,518.40, ( ) 1,518.40-1,561.26, ( ) 1,561.26-1,620.20, ( ) 1,620.20-1,688.06, ( ) 1,688.06-1,752.36.

CONCLUSION

Accurate information about the crop water requirement of sugar cane (*Saccharum officianarum*) is the basis for scientifically understanding global or regional changes in the processes involving water and its associated materials and energy, which is of great significance for the hydrological monitoring and to enhance the capability to cope with natural disasters and optimize water resources management in Arjo Dedessa sugar factory and the surrounding area.

From the study conducted and different literature reviews, it can be concluded that the water requirement of sugarcane in the agro ecology of the Arjo-Dedessa sugar factory and the surrounding areas is 1297 millimetre up to 1752-millimetre depth of water for the full development of the crop. More experimental research is recommended and has to be conducted to determine the effect of water and land productivity on the yield and growth parameters of the crop.

DATA AVAILABILITY STATEMENT

The data sets analysed during the study are available from the corresponding author on request.

ACKNOWLEDGEMENT

The authors would like to thank the Ethiopian meteorological service agency and Ministry of water irrigation and electricity for providing the necessary data.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

REFERENCES

1. Todorovic M. Crop water requirements. Water Encyclopedia. 2005;3:557-558.
2. Subedi A, Chavez JL, Andales AA. ASCE-EWRI standardized Penman-Monteith Evapotranspiration (ET) equation performance in southeastern Colorado. Agric Water Manag. 2017;179:74-80.
3. Hedley CB, Knox JW, Raine SR, Smith R. Water: Advanced irrigation technologies.2014;378-406.
4. Kukal SS, Jat ML, Sidhu HS. Improving water productivity of wheat-based cropping systems in South Asia for sustained productivity. Adv Agron. 2014;127:157-258.
5. Hordofa T, Menkir M, Awulachew SB, Erkossa T. Irrigation and rain-fed crop production system in Ethiopia. Impact of irrigation on poverty and environment in Ethiopia. 2008:27-36.
6. Evans RG, Sadler EJ. Methods and technologies to improve efficiency of water use. Water Resour Res. 2008;44(7).
7. EIA (Ethiopian Investment Agency). Investment opportunity profile for sugar cane plantation and processing in Ethiopia. 2012.
8. Kecha M. Assessment of sugarcane brown rust (*Puccinia melanocephela*) disease intensity in finchaa sugar estate, horo-guduru wollega, Oromia, Ethiopia. Int J Biochem Mol. 2020;5(2):39.
9. Tena E, Mekbib F, Shimelis H, Mwadzingeni L. Sugarcane production under smallholder farming systems: Farmers preferred traits, constraints and genetic resources. Cogent food agric. 2016;2(1):1191323.
10. Degefa A, Bosie M, Mequanint Y, Yesuf E, Teshome Z. Determination of crop water requirements of sugarcane and soya bean intercropping at metahara sugar estate. ACST.2016; 13:1-4.
11. Katerji N, Rana G. Crop evapotranspiration measurements and estimation in the Mediterranean region. 2008.
12. Addinsoft XS. Data Analysis Solution. 2019.
13. Kiptala JK, Mohamed Y, Mul ML, Van der Zaag P. Mapping evapotranspiration trends using MODIS and SEBAL model in a data scarce and heterogeneous landscape in Eastern Africa. Water Resour Res. 2013;49(12):8495-8510.
14. Jocik AM. Estimate ambient air temperature at regional level using remote sensing techniques. ITC. 2004.
15. Rasul G, Farooqi AB. Recent Water requirement of cotton crop in Pakistan. J of Engg & App Sci. 1993;4(2):154-165.
16. Geleta CD. Effect of first watering month on water requirement of sugarcane using CROPWAT Model in Finchaa Valley, Ethiopia. IJWREE. 2019; 11(1):14-23.
17. Thompson GD. Water uses by sugarcane. The South African Sugar Journal. 1976; 60:593–600, 627–635.
18. Verma IJ, Das HP, Ghanekar MG. A study of water requirement of sugarcane (*Saccharum officianarum* L.) in gangetic plains. Mausam. 2004;55(2):339-344.
19. Aravind P, Ponnuchakkammal P, Thiyagarajan G, Kannan B. Estimation of crop water requirement for sugarcane in Coimbatore district using FAO CROPWAT. Madras Agric J. 2021;108(4-6):1.
20. Li J, Heap AD. A review of spatial interpolation methods for environmental scientists.2008; 137.
21. Chaplot V, Saleh A, Jaynes DB. Effect of the accuracy of spatial rainfall information on the modeling of water, sediment, and NO_3–N loads at the watershed level. J Hydrol. 2005;312(1-4):223-234.
22. Xu H, Xu CY, Chen H, Zhang Z, Li L. Assessing the influence of rain gauge density and distribution on hydrological model performance in a humid region of China. J Hydrol. 2013;505:1-2.
23. Xu H, Xu CY, Sælthun NR, Xu Y, Zhou B, Chen H. Entropy theory based multi-criteria resampling of rain gauge networks for hydrological modelling: A case study of humid area in southern China. J Hydrol. 2015;525:138-151.
24. Dirks KN, Hay JE, Stow CD, Harris D. High-resolution studies of rainfall on Norfolk Island: Part II: Interpolation of rainfall data. J Hydrol. 1998;208(3-4):187-193.