American Journal of Environmental and Resource Economics
2022; 7(3): 72-76
http://www.sciencepublishinggroup.com/j/ajere
doi: 10.11648/j.ajere.20220703.12
ISSN: 2578-7861 (Print); ISSN: 2578-787X (Online)

Estimation and Mapping of Spatial Distribution of Reference Evapotranspiration over West Shewa Zone, Ethiopia

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To cite this article:
Nigusie Abebe, Mohammed Temam. Estimation and Mapping of Spatial Distribution of Reference Evapotranspiration over West Shewa Zone, Ethiopia. *American Journal of Environmental and Resource Economics*. Vol. 7, No. 3, 2022, pp. 72-76.
doi: 10.11648/j.ajere.20220703.12

Received: June 30, 2022; **Accepted**: August 3, 2022; **Published**: August 19, 2022

Abstract: Reference Evapotranspiration (ETo), is an important agro-meteorological parameter due to its critical role in determining the crop water requirement in irrigated agriculture. In this study, point ETo value was determined by using FAO Cropwat software. Spatial interpolation was done by using Inverse distance weighted (IDW) method and their distributions were mapped across the West Shewa Zone of Ethiopia. The results showed that both the mean daily and mean annual ETo values was varied between 3.54-3.92mm and 107.65-119.14mm, respectively. The mapped both mean daily and annual ETo distributions over west shewa zone follow similar trends, ETo values were relatively lower in eastern and southern highland of the zone, ETo is intermediate in the central, north, north east of the zone and ETo is higher in the west part of the zone. The relationship between the interpolated ETo distributions based on the IDW method with the help of the GIS tools and that on direct, calculated by using Cropwat, based on penman Monteith procedure using climatic data recorded from meteorological observation was compared. Linear regression analysis showed good fit with the value of R^2 is 0.84 indicating that, the interpolation by using GIS model has a very high potential of estimating the spatial distribution of ETo with high level of accuracy. The maps produced are useful for irrigation planning, crop water management, basin water balance, climatic characterization and climate change studies in the West Shewa.

Keywords: Evapotranspiration, IDW, West Shewa

1. Introduction

Evapotranspiration (ETo) is a significant environmental process, which connects the climatic, hydrological and ecological systems, while it is also a vital part to consider when estimating hydrologic water balance, performing appropriate water resources allocation, determining crop water requirement and irrigation water requirement, establishing efficient irrigation scheduling, and assessing the hydrological impact of changing climate conditions [3, 4, 6, 13, 14].

The FAO-56 Penman-Monteith method (FAO-56 PM) is standard method recognized by the Food and Agriculture Organization of the United Nations for estimating reference evapotranspiration ETo from climatic data [12]. The FAO-56 PM method requires daily data on maximum and minimum air temperature (Tmax and Tmin), relative humidity (RH), solar radiation (Rs) and windspeed (u) for daily ETo calculation [2]. Unfortunately, the determination of ETo by using Penman–Monteith is impossible for many locations in Ethiopia, such meteorological variables are often incomplete and/or not available. Considering the above limitation of Penman–Monteith method, it is important to determine and analyze both spatial and temporal variations in reference evapotranspiration for a given area or region using geospatial techniques such as inverse distance weighting (IDW) method to estimate missing data and to interpolate value for unknown location from known ones specially in the areas where meteorological data are scarce or missing.

There are many interpolation methods available for use in QGIS but, IDW were chosen because it has been studied by many researchers that the Inverse Distance Weighting (IDW) method is even more superior, it has the highest accuracy in prediction, easy to implement in a geographic information system (GIS) and it is also better than the other interpolation methods [5, 7, 10, 11, 15]. On the other hand, it is necessary to emphasize the spatial and temporal variation of ETo for better planning and managing of Agricultural water. Therefore, the objectives of this study were to determine reference evapotranspiration (ETo) using the data; develop spatially interpolated maps of ETo across the West Shewa Zone of Ethiopia using QGIS software for the prediction of annual and seasonal ETo in the study area.

2. Materials and Methods

2.1. The Study Area

West Shewa is one of the twenty two administrative zones of Oromia Regional State. It is located between astronomical grids of 9°09'60.00" N and 37°49'59.99" E. It extends from north to south and east to west for 184km and 193km respectively. West Shewa is bordered on the south by the Southwest Shewa Zone and the Southern Nations, Nationalities and Peoples Region, on the southwest by Jimma, on the west by East Wollega Zone, on the northwest by Horo Gudru Wollega Zone, on the north by the Amhara Region, on the northeast by North Shewa, and on the east by Oromia Special Zone Surrounding Finfinne. Its highest point is Mount Wenchi (3386 meters); other notable peaks include Mount Mengesha and Mount Wechacha.

The capital of West Shewa zone is Ambo town, which is located 125 km away from Addis Ababa, the capital of Ethiopia. It has an area coverage of about 14,788.78 square kilometers, which comprises of 52.3% cultivated land, 15.3% forest land, 21% pasture land, and 11.4% is mountainous, bushy and hilly. Topographically, it is characterized by variable topography, which extends from steep mountain slopes (19%) to flat (60%). On average, the annual rainfall ranges from 800 to 1700 mm. The minimum and maximum temperature ranges from 22.9 to 29.9°C. The agro-ecology, it consists of three major agro-ecologies; namely, high land (25%), midland (57%), and low land (18%). The map of the study area is indicated in Figure 1.

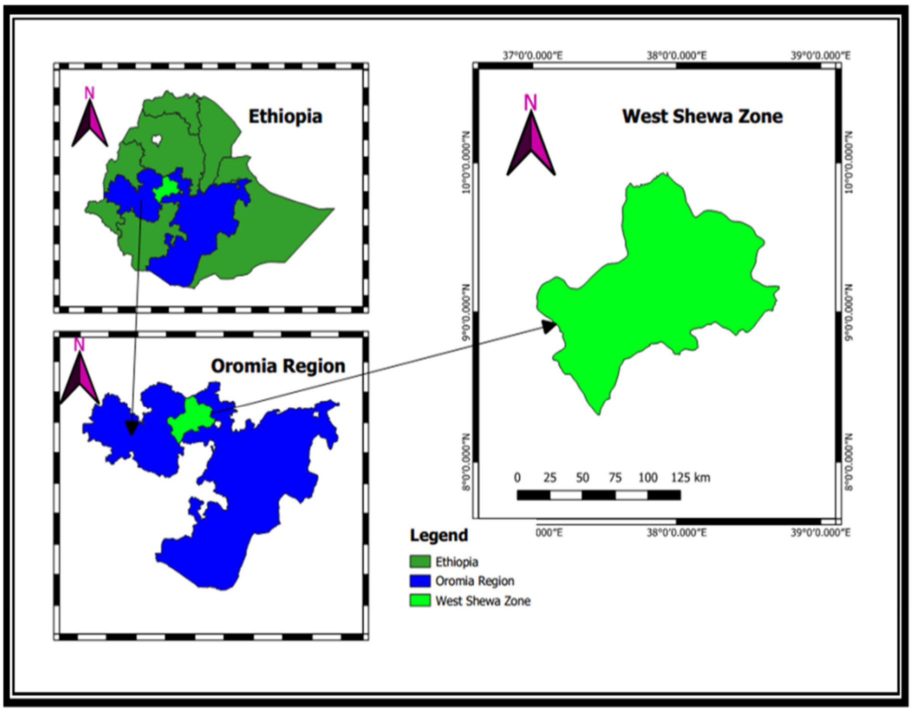


Figure 1. *Map of the study area.*

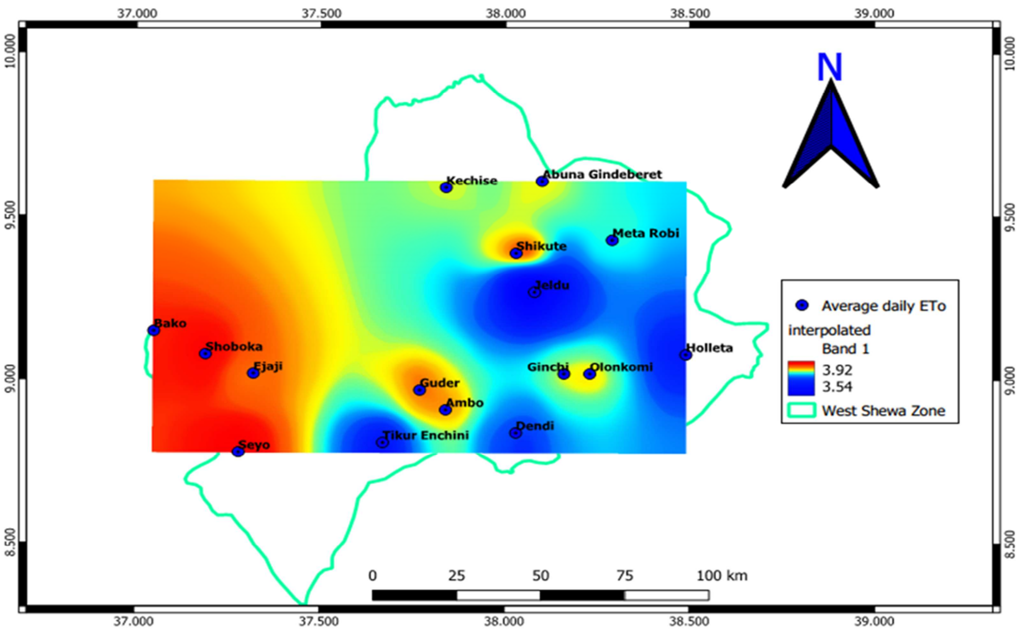
2.2. Procedures for Mapping of Spatial Distributions of ETo

Long term climatic daily data were obtained from 11 meteorological stations were used to determine ETo by using CropWat model. The data include rainfall (mm), maximum and minimum temperature (°C), wind speed (m s^{-1}), relative humidity (%) and solar radiation (MJ m^{-2} day^{-1}). In the case of six points where meteorological stations are not available, the New-LocClim version 1.10 model was used to determine the climatic data by inserting the appropriate geographical coordinate of the selected point in the west sea. The determined climatic data by using New-LocClim was exported the Cropwat software to determine ETo by using Penman- Monteith procedures. The daily determined ETo data were processed into monthly and annual [2]. An interpolation technique, which is an inverse distance weighting (IDW) method was used. QGIS 3.18 software package was used to implement the interpolation and mappings of daily and annual ETo of the study area.

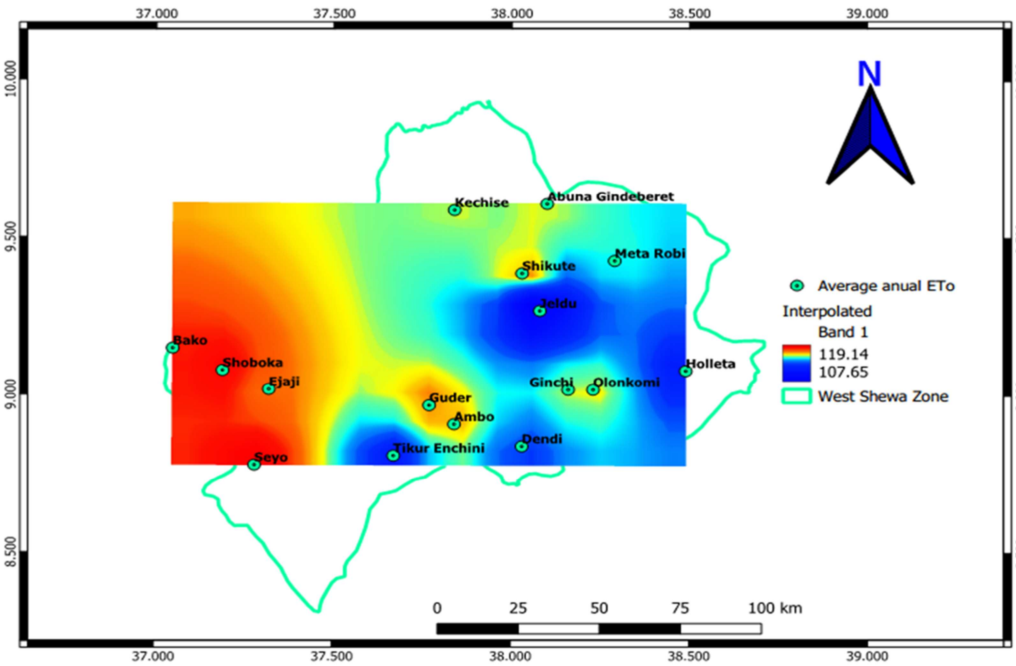
3. Results and Discussion

3.1. Spatial Variation of Mean Daily and Mean Annual Reference Evapotranspiration

Spatial distribution of mean daily and mean annual reference evaporation (ETo) is shown in Figure 1 a and b. The IDW interpolation methods were also used to map annual and seasonal ETo across the study area. The average daily and average annual ETo varied from 3.54 to 3.92mm and from 107.65 to 119.14mm respectively. The results showed that both the mean daily and mean annual ETo distribution over west shewa follow similar trends it is low in eastern and southern highland of the zone, ETo is intermediate (medium) in the central, north, north east of the zone and ETo is higher in the west part of the zone as shown on the map (Figures 2a and b). The variation in ETo strongly affected by the regional conditions such as changing wind speed, surface air temperature, topography and elevation [1, 9]. The study result similar with [8] who reported that the lower annual ETo values were mainly distributed at high elevations and higher ETo values were mainly distributed at low elevations.



(a)



(b)

***Figure 2.** (a) spatial variation of the average daily ETo over west shewa.(b) spatial variation of the average annual ETo over west shewa.*

3.2. Regression Analysis

The linear regression model was applied to quantify the strength of the relationship between the interpolated ETo distributions based on the IDW method with the help of the GIS tools and that of direct, calculated by using Cropwat, based on penman Monteith method using climatic data recorded from meteorological observation. The linear regression analysis (Figure 3) showed good fit with a slope of 0.83 and R^2 of 0.84. The outcome revealed that 84% of the variations in the observed field measurement of ETo fitted perfectly well with ETo distributions generated by the GIS model. Thus, indicating that the interpolation by using GIS model has a very high potential of estimating the spatial distribution of ETo within the study area with high level of accuracy.

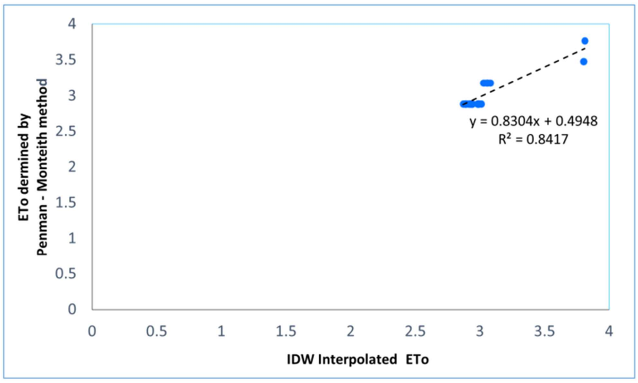


Figure 3. *Linear regression model between ETo calculated by using Cropwat, based on penman Monteith method and interpolated ETo.*

4. Conclusion

Mapping of the spatial distribution of reference evapotranspiration is important in areas where climatological parameters are often not available or inadequate or have doubtful quality. This study was attempted for mapping, spatial variation of reference evapotranspiration over the west sea zone of Ethiopia. The daily and annual ETo distribution over West Shewa was done by using the IDW interpolation method. The spatial mapping of distributed ETo has been successfully undertaken. In this study, the monthly ETo was predicted using FAO 56-Penman– Monteith procedure based on data recorded from 11 weather stations in west shewa. The results showed that both the mean daily and the mean monthly ETo distribution of west shewa is low in eastern and southern highland of the zone, ETo is intermediate (medium) in the central, north, north east of the zone and ETo is higher in the west part of the zone. The results of this spatial analysis of ETo and the maps produced are useful for irrigation water management and for improving water use efficiency in irrigated agriculture through improved scheduling. In addition, the provided information is useful for irrigation planning, water management, basin water balance, climatic characterization and climate change studies in the West Shewa zone of Ethiopia.

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