Hydrology
2022; 10(2): 21-33
http://www.sciencepublishinggroup.com/j/hyd
doi: 10.11648/j.hyd.20221002.11
ISSN: 2330-7609 (Print); ISSN: 2330-7617 (Online)

Assessment of Water Balance Components by Using Wetspass Model: The Case of Dengego Sub-basin, Eastern Ethiopia

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To cite this article:

Seyoum Bezabih Kidane, Hayal Derb Andarge. Assessment of Water Balance Components by Using Wetspass Model: The Case of Dengego Sub-basin, Eastern Ethiopia. *Hydrology*. Vol. 10, No. 2, 2022, pp. 21-33. doi: 10.11648/j.hyd.20221002.11

Received: January 10, 2022; **Accepted**: March 23, 2022; **Published**: May 31, 2022

Abstract: The search for new water resources, as well as the development of water balance models that can be used to control and manage the resource, is at the heart of the search for new water resources in eastern Ethiopia, particularly in the Dengego sub-basin, and its socio-economic significance in terms of water demand for agriculture and domestic use. The water balance components of the Dengego sub-basin were investigated using the WetSpass hydrological model. The goal of this study is to assess the water balance components in the Dengego sub-basin. According to WetSpass, the mean annual evapotranspiration, surface runoff, and groundwater recharge were 494.2, 173.6, and 20.2 mm, respectively. Actual evapotranspiration and surface runoff accounted for 25.2 percent and 71.8 percent of precipitation, respectively and recharge made up 2.9 percent of precipitation. Annually 7.3 million m^3 of water recharges into the groundwater table as recharge from the precipitation on the entire watershed. The contribution of this study could be used as baseline information for regional water resource experts, policy makers and researchers for further investigation. It can also be concluded that integrated WetSpass and GIS-based models are good indicators for estimating and understanding of water balance components in a given watershed to implement an integrated watershed management plan for sustainable utilization and sustainable development.

Keywords: Dengego, Ethiopia, Groundwater Recharge, Water Balance, Wetspass

1. Introduction

Water is the most basic and essential component of life, and it must be available in adequate quantities and of acceptable quality to meet the ever-increasing human need for a variety of purposes [1-5]. Its availability and distribution are limited both in time and space, with 97.5% of the world's water being saline and found in the oceans, and only 2.5% is considered fresh. Freshwater locked up in glaciers accounts for 68.7%, whereas groundwater, surface water, and other fresh fluids account for 30.1%, 0.9 percent, and 0.8%, respectively [6].

Freshwater is a precious but crucial and flexible natural resource that occurs intermittently, despite the fact that the global demand for it is increasing as the world population expands. As a result, adequate resource planning and management in terms of distribution, management, usage, and environmental functions is necessary, necessitating a series of period data to sustainably optimize resource use [7].

Changes in numerous water balance components, each of which has a particular reaction to climate change, have an impact on water resources [8, 9]. Precipitation, evapotranspiration, surface runoff, groundwater flow, and soil water content are all components of the water balance. Quantifying the various water balance components of hydrological processes in a watershed is still a difficult task [10-12], because the water balance includes various unknown components, such as evapotranspiration and soil water content, which are difficult to assess [13].

The calculation of water balance components, on the other hand, is important for water resource evaluation and management, particularly in water-scarce regions, when assessing the impact of climate change. Using a continuous watershed hydrological model, the water balance

components may be realistically reproduced [14, 15]. Meanwhile, water balance models could provide an accurate estimate of runoff, relative changes in soil moisture, evapotranspiration, etc. [16].

Water balance components have been estimated at various scales using water balance models in recent years. For example, [17] calculated the spatial difference of water balance components at the regional scale, while [18] simulated the water balance components at the global scale. The water balance at the basin or watershed scale was generally the focus of research [19-21]. The water balance has been studied at various scales, including land cover types, vegetation patterns, and ecological scales. For example, in a small watershed, [22, 23] assessed the changes in each water balance component for different land cover types.

The study area is the Dengego sub-basin in eastern Ethiopia, which is located north of Dire-Dawa. The sub-basin is one of Ethiopia's most vulnerable lowland agro-climatic zones to climate change and unpredictability. Climate change and water scarcity are major concerns for the area's agriculture. However, the volume and water balance components in that specific location have yet to be assessed, which is critical for proper planning, future water resource utilization, and sustainability in the sub-basin.

As a result, the GIS-based WetSpass Model will be used to further understand the hydrological and biophysical features of the sub-basin in order to ensure effective management, wise utilization, future planning, and sustainable resource utilization in the context of sustainable development. The focus of this research is to evaluate the Dengogo sub-basin water balance components.

2. Materials and Methods

2.1. Description of the Study Area

The research was carried out in the Dengego sub-basin, which is located in the Ethiopian rift valley's region. It is located between the latitudes of 09°27′ and 09°42′ N and the longitudes of 41°43′ and 41°53′ E (Figure 1), and. With a height range of 1006–2,279 meters above sea level, it is distinguished by a remarkably wide spatial variety of topographic features (m.a.s.l). It extends over a total of 32585 hectares. The lowland component of the territory accounts for 60% of the total area, while the remaining fraction is topographically high and covers a valley.

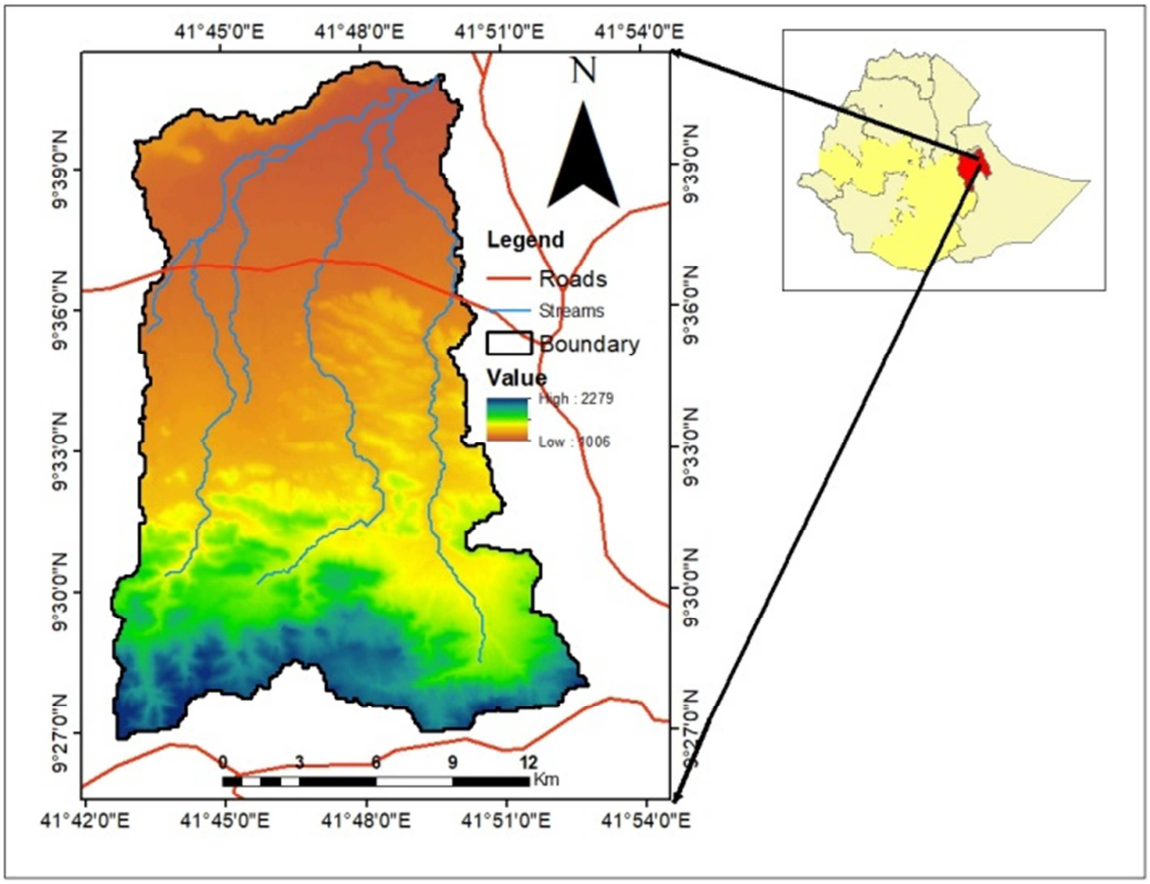

Figure 1. *Location of the study area.*

The Dengego bub-basin has a semi-arid climate in the valley plain and a sub-humid climate in the hills. The average annual temperature in the sub-basin ranges from 17.7°C to 27.2°C, with an average annual temperature of 21.4°C. Average monthly temperatures in Dire Dawa range from 22.1°C in December to roughly 29.0°C in June. Orographic phenomena influence the distribution of rainfall in the area. Furthermore, its distribution was unmistakably linked to

elevation. There are two rainy seasons in the research area. The main rainy season runs from late June to the end of September, with a short wet season running from late March to early April. The average annual rainfall in the basin is estimated to be around 688.0 mm.

2.2. Description of WetSpass Model

WetSpass is a physically based distributed methodology for estimating the long-term average, spatiotemporally variable components of the water balance: groundwater recharge, surface runoff, and actual evapotranspiration. It's an acronym for water and energy transfer between soil, plants, and the atmosphere in a quasi-steady state, based on the time-dependent spatially distributed water balance model's foundations [24]. By subtracting seasonal and yearly surface runoff and evapotranspiration from seasonal and annual precipitation, the WetSpass model estimates seasonal and annual long-term spatial distribution amounts of groundwater recharge [25].

Based on dispersed data, the model calculates several water balance components, such as surface runoff, actual evapotranspiration, and groundwater recharge. WetSpass has been successfully implemented in Belgium [24], Ethiopia's Illala watershed [26], and Ethiopia's Werii watershed [27]. Groundwater recharging was successfully replicated using those authors' work, which is the focus of this study. For their water balance estimation investigations in Ethiopia, multiple writers used the WetSpass model.

WetSpass solves the water balance equation cell by cell for the vegetated area, bare soil, open water, and impermeable surfaces, allowing for the calculation of surface runoff, actual evapotranspiration, and groundwater recharge for seasonal periods.

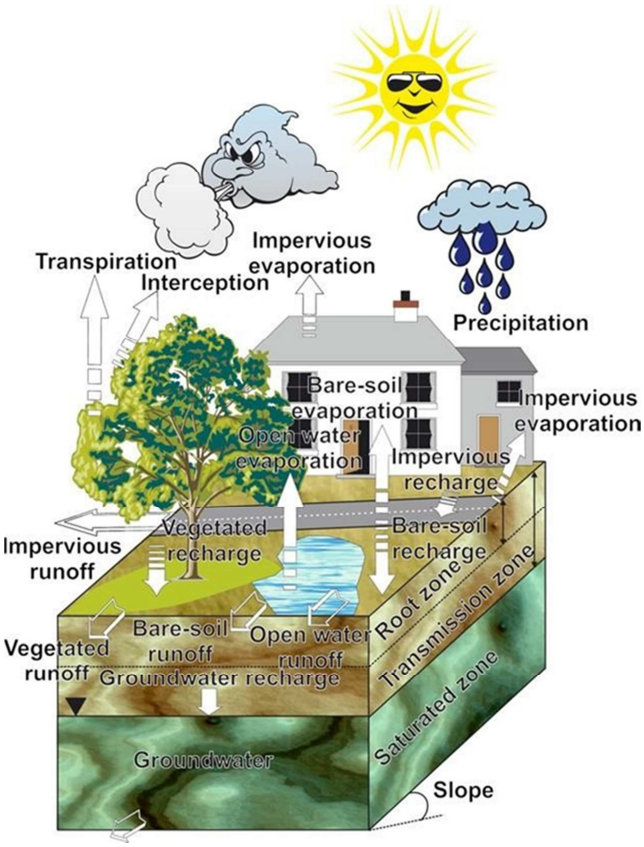

Figure 2. *Schematic water balance of hypothetical raster cell [24].*

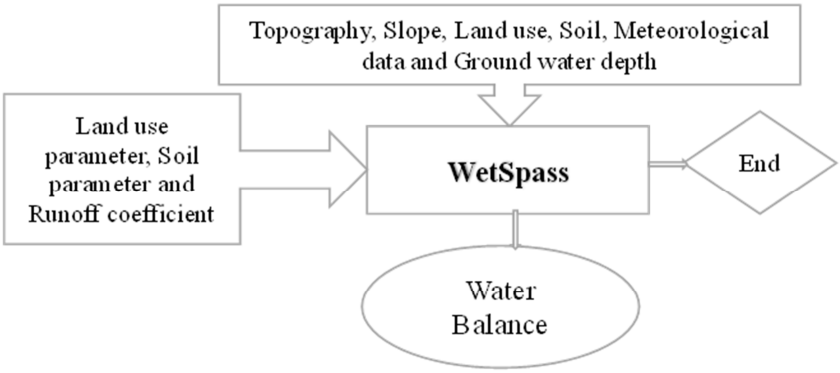

Figure 3. *Water balance assessment approach.*

For a vegetated area, the water balance is calculated according to the following equation [24];

$$P = \mathrm{I} + \mathrm{Sv} + \mathrm{Tv} + \mathrm{Rv} \quad (1)$$

where P is the average seasonal precipitation, I the interception fraction, Sv the surface runoff, Tv the actual transpiration, and Rv the groundwater recharge, all with the unit [L/T].

First, the interception (I) is calculated. It is a fixed percentage of the annual precipitation amount. It largely relies on the type of plant. Second, the relationship between precipitation amount, precipitation intensity, interception, and soil infiltration capacity is used to determine surface runoff (S). There are two stages to estimating surface runoff. To begin, calculate the potential surface runoff (Sv-pot) as follows:

$$\mathrm{S_{v-pot}} = \mathrm{C_{sv}}(\mathrm{P} - \mathrm{I}) \quad (2)$$

where CSV is a surface runoff coefficient for vegetated areas; it depends on vegetation, soil type, slope, and groundwater saturated areas, P is the average seasonal precipitation [LT^{-1}]

and I is the interception fraction [LT^{-1}]. Secondly, S is calculated by considering the differences in seasonal precipitation intensities concerning soil infiltration capacities [24].

$$S = C_{HOR} S_{v-pot} \quad (3)$$

where CHOR is a coefficient parameterizing seasonal precipitation, which contributes to the Hortonian overland flow [28]. It considers the effective precipitation contributing to the runoff.

Open-water evaporation and the vegetation coefficient, which is the ratio of reference vegetation transpiration to potential open-water evaporation [24], are used to determine evapotranspiration. First, a fraction of open-water evaporation is used to determine the reference transpiration:

$$T_{rv} = cE_0 \quad (4)$$

where Trv is the reference transpiration of a vegetated surface [LT^{-1}], E0 is the potential evaporation of open water [LT^{-1}] and c is the vegetation coefficient which can be calculated as the ratio of reference vegetation transpiration to the potential open-water evaporation [24].

When the groundwater is above the root depth, WetSpass considers the root depth and the tension saturation height to calculate evapotranspiration in vegetated regions; otherwise, evapotranspiration is calculated as a function of water content. Finally, the result of the water balance is used to compute the groundwater recharge for the vegetated area:

$$Rv = P - Sv - ETv - Es - I \quad (5)$$

where R is the groundwater recharge, P is the precipitation, Sv is the surface runoff, ETv is the actual evapotranspiration, and I the interception fraction, all with the unit [LT^{-1}].

In the computation of the water balance for bare soil, open water, and impervious surfaces, however, there is no interception and transpiration term because there is no vegetation, so the ETv becomes Es. The following equations [24] are used to determine the total water balance utilizing the water balance components of each area:

$$ETa = avETv + asEs + aoE0 + aiEi \quad (6)$$

$$Sa = vSv + asSs + aoRo + aiRi \quad (7)$$

$$R\,a = vRv + asRs + aoRo + aiRi \quad (8)$$

Where ET, S, and R are the whole evapotranspiration, surface runoff, and groundwater recharge of a raster cell respectively, each having vegetated, bare-soil, open water, and impervious area components denoted by av, as, ao, and ai, respectively.

2.3. Model Input Data Preparation

Grids of topography, slope, and soil texture, as well as seasonal grids of groundwater depth, land use, and meteorological data (precipitation, wind speed, temperature, and potential evapotranspiration), are among the input data. The attribute tables for land use and soil are linked to the model [29]. The input datas were prepared by using ArcGIS and ArcViewGIS.

The cells are 30 m by 30 m and include 624 and 887 columns and rows, respectively. The winter /dry/ and summer /wet/ seasons, which correspond to the months of October to May and June to September, respectively, were chosen for the processing of meteorological data (precipitation, evapotranspiration, temperature, and wind speed), with an average value for each seasonal time step, i.e., the months of October to May and June to September. The input files for land use, soil texture, and runoff coefficients were created as parameter tables, which were then converted to database file format (DBF).

Table 1. *Model input parameters.*

Input variables		Sources
1	Topography	DEM (12.5*12.5m) resolution
2	Slope	DEM (12.5*12.5m) resolution
3	Land use land cover	Landsat 8 and own processing
4	Temperature (summer & winter)	National meteorological agency
5	Precipitation (summer & winter)	National meteorological agency
6	PET (summer & winter)	Estimated by using R-programming
7	Wind speed (summer & winter)	National meteorological agency
8	Depth to groundwater	The direct measurement from existing boreholes
9	Soil texture	FAO soil database
10	Soil parameter, runoff coefficient, and Land use parameters	WetSpass user guide

The average seasonal precipitation for three metrological stations was calculated (Dire Dawa, Dengego, and Haremaya stations). It was derived from daily precipitation data collected over 21 years from 2000 to 2020. The spatial precipitation is created using the inverse distance weighting (IDW) method. Because it is straightforward and delivers generally excellent results, it is the most extensively utilized procedure [13]. When the rainfall network is unevenly spread, it's especially effective. Figure 4(a) shows that winter precipitation ranges from 320.9 mm to 335.2 mm, with a mean of 327.9 mm, and summer precipitation ranges from 287.80 mm to 427.93 mm, with a mean of 360.1 mm (Figure 4(b)).

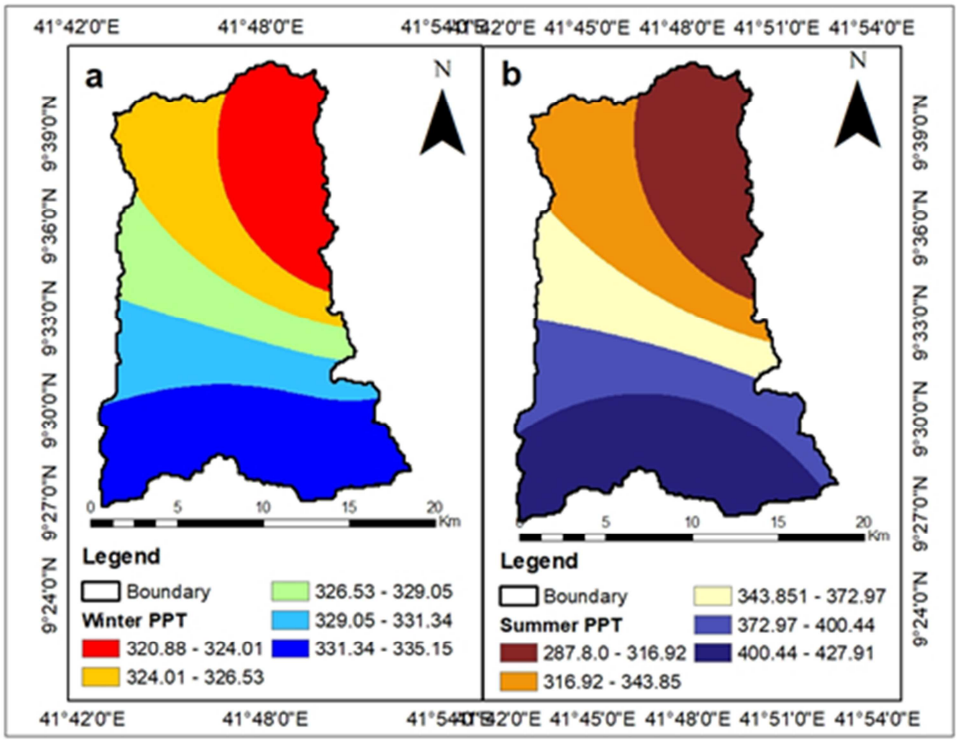

Figure 4. *Rainfall distribution map of Dengego sub-basin.*

The average monthly PET was calculated for three (3) locations from 2000 to 2020 using monthly average temperature readings. The highest value (1208 mm) was recorded during the dry season /winter/ (October to May). The minimum and maximum values for the winter /dry/ season are 970.89 mm and 1208.03 mm, respectively, with a mean value of 1089.99 mm (Figure 5(a)), whereas the minimum and maximum values for the summer /wet/ season are 559.10 mm and 659.17 mm, respectively, with a mean value of 593.39 mm (Figure 5(b)) (Figure 5(b)). Monthly measured values from 2000 to 2020 were used to calculate the average temperature for the same weather station. Minimum and maximum temperatures in the dry season ranged from 17.7°C to 24.5°C (Figure 6(a)), with a mean of 20.8°C, whereas minimum and maximum temperatures in the summer ranged from 18.3°C to 27.2°C (Figure 6(b)), with a mean of 22.4°C.

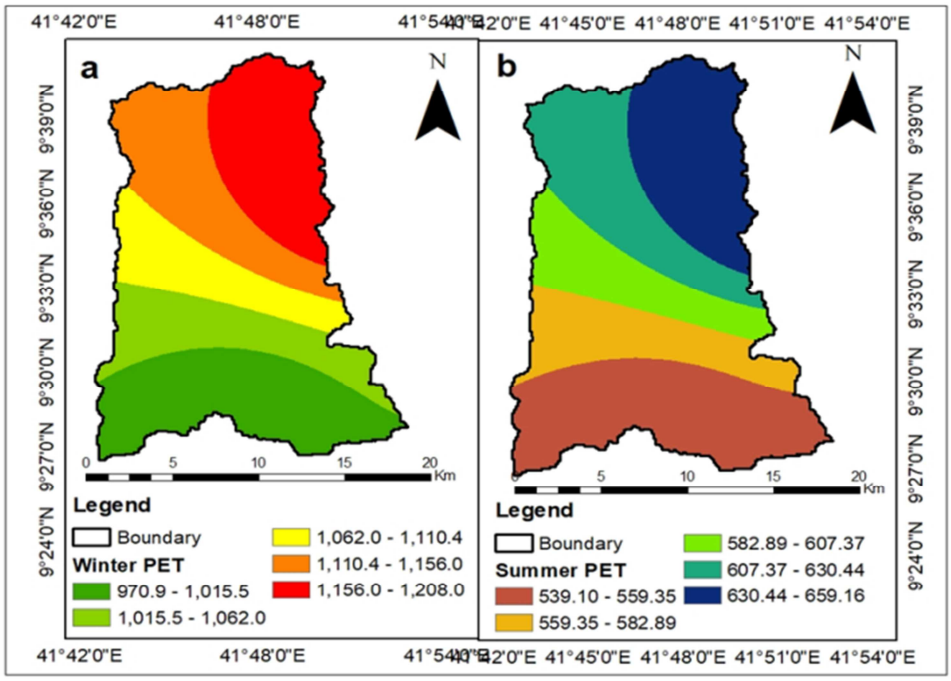

Figure 5. *Potential evapotranspiration of Dengego sub-basin.*

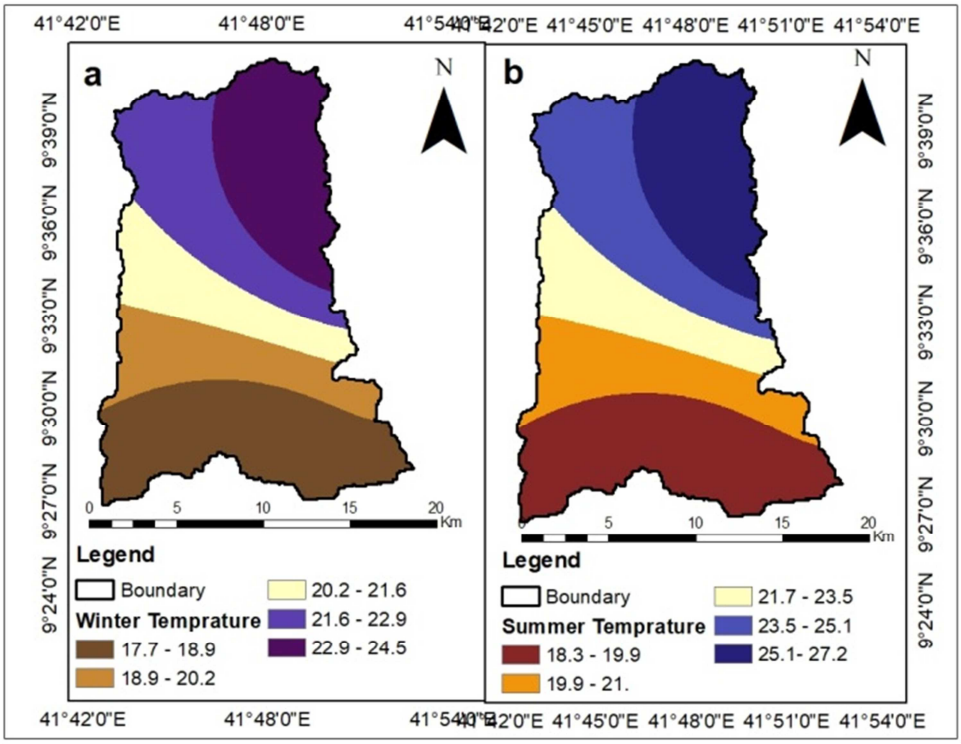

Figure 6. *The average temperature of Dengego sub-basin.*

The wind speed of the area was determined using monthly recorded values from three meteorological stations from 2000 to 2020, which is one of the parameters used in the Wetspass model. The average summer wind speed in the Dengego sub-basin is 2.357 m/s, with minimum and maximum values ranging from 2.30 m/s to 2.399 m/s (Figure 7(b)), and an annual average wind speed of 2.05 m/sec. The average winter wind speed is around 1.75 m/s, with minimum and maximum values ranging from 1.74 m/s and 1.77 m/s (Figure 7(a)).

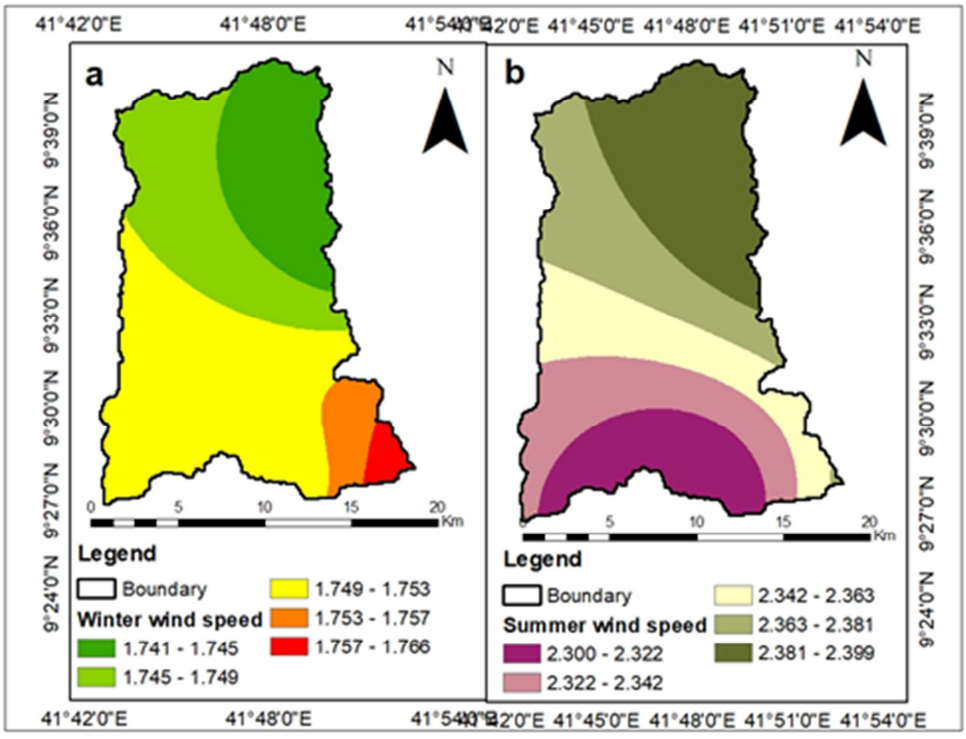

Figure 7. *Average wind speed of Dengego sub basin.*

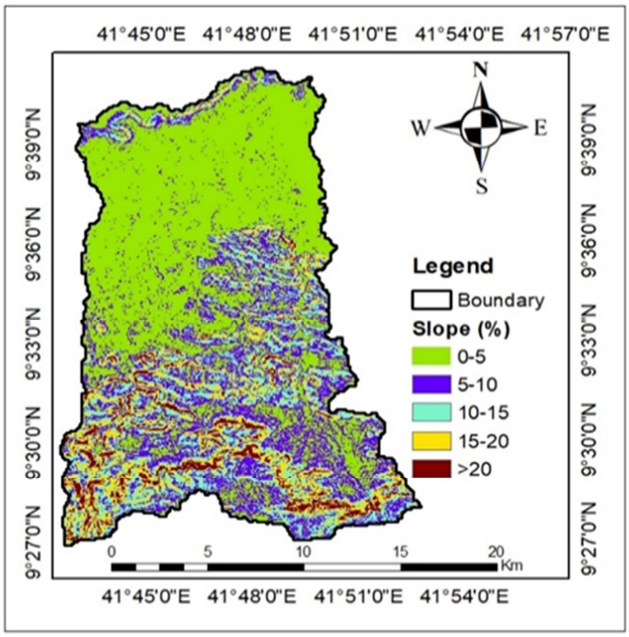

Figure 8. *Slope of Dengego sub basin.*

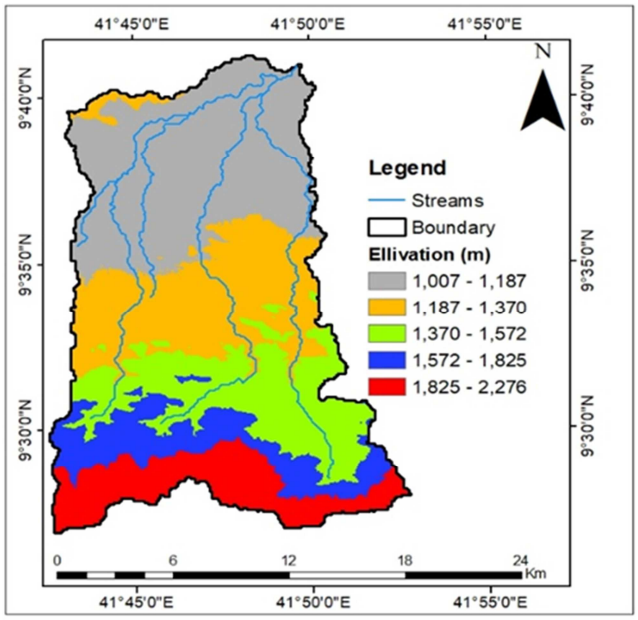

Figure 9. *Elevation and slope map of Dengego Dire Dawa watershed.*

The Alaska satellite facility (ASF) data set was used to construct an elevation map of the research region. The ASF provides a Digital Elevation Model with a resolution of 12.5*12.5m (DEM). The highest point in the watershed is 2276 meters upstream on the southern escarpment, while the lowest position is 1007 meters in the norther/downstream portion. The watershed's average elevation is 1386.5 meters (Figure 9). Slope is an important aspect in determining a watershed's hydrological features. The watershed's steep slopes serve as recharge zones, while its moderate slopes serve as discharge zones. It usually has a direct relationship with geography. The research area's slope map was likewise created using ArcGIS and a 12.5m*12.5m DEM. It is classified according to its degree of steepness, which runs from 0 to 38°. The value 0° represents gentle/lowland terrain, whereas 38° represents steep/escarpment terrain. The Dengego sub basin is made up of a high slope/steep escarpment that is not suitable for agricultural operations and a flat/gentle slope of lowland area/plane that is suitable for agriculture.

Table 2. *Slope classification of dengego sub-basin.*

Slope class (%)	Description	Area coverage	
		Ha	%
0-5	Nearly level to Gentle sloppy	16040.1	49.2
5-10	Sloppy	7065.3	21.7
10-15	Moderate sloppy	4846.7	14.9
15-20	Strong sloppy	3194.5	9.8
>20	steep to Very steep slope	1438.3	4.4

Land-use/cover data is important in hydrological modeling because it helps identify model variables that account for runoff volume, timing, and quality. Land use and management affect a variety of processes in the watershed, including surface runoff, erosion, and evapotranspiration. WetSpass needs land-use data to figure out how much of each land category should be reproduced inside each sub-basin. The Ethiopian Geospatial Institute provided land use and land cover data for the area at a resolution of 30 meters. Extensive field tests were conducted to link the ground information of a certain land category to its imaging properties. Using a GPS device, several independent reference locations (representative of the entire watershed) were collected at random for each land use category. Table 3 and Figure 10 show the area covered by each land use type in the project area. The LULC of the project area is categorized into seven groups. Even though there have been marked changes in coverage but in both reference, land uses shrubs and grass land were the dominant land uses in the project area. Grass land and Shrubs and bush were practiced on 20.8% and 19.8% respectively of the catchment area.

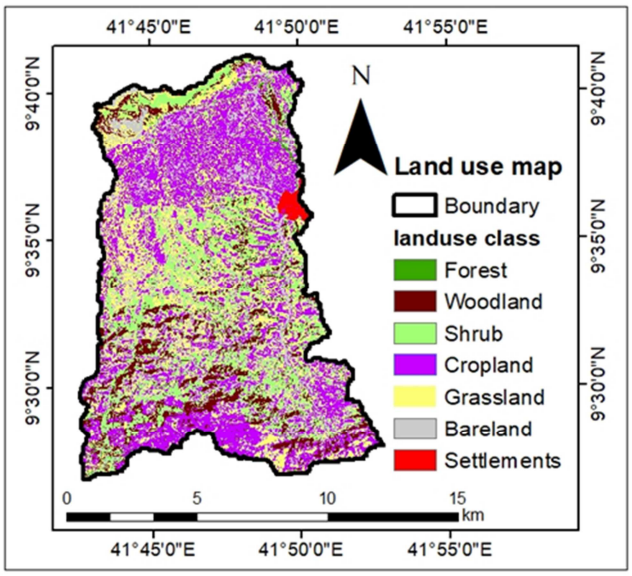

Figure 10. *Land use land cover map.*

Soil texture is the second most important and sensitive component in the WetSpass water balance estimation method. The dengego sub basin soil texture map was obtained from the FAO's (Food and Agriculture Organization) website (http://www.fao.org). Using USDA textural categorization guidelines, the soil texture of the research region was divided into four classes: sandy loam, silty clay loam, loam, and clay loam (Figure 11). The sandy loam covers the majority of the terrain. An attribute table for recognizing soil and other biophysical maps has been generated in the WetSpass model handbook. The model code was used to construct the texture class provided by USDA.

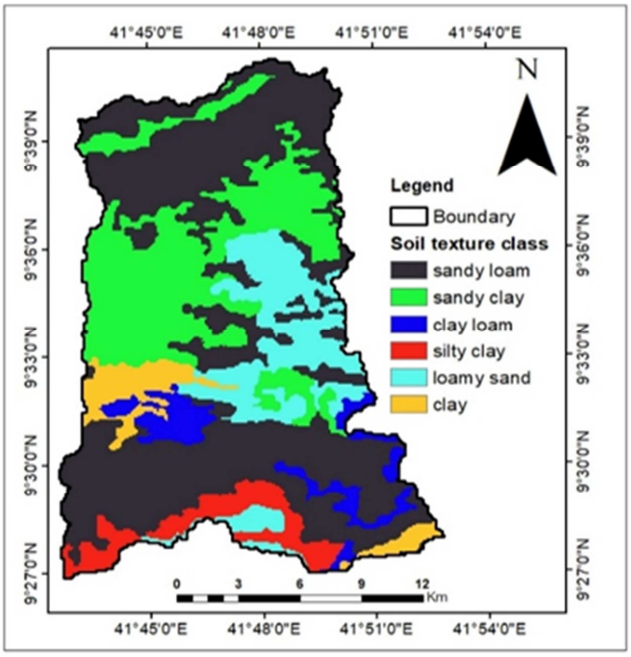

Figure 11. *Soil textural map.*

The groundwater level grid map is critical when using the WetSpass model to predict water balance. The Dengego subbasin's groundwater level was changing. Borehole data from 68 boreholes was collected. The groundwater level was interpolated using the ArcGIS Inverse Distance Weighing (IDW) spatial interpolation technique. Topographically low elevation sites have shallow groundwater levels since most water tables in unconfined aquifers follow topography. The static water level in the watershed ranges from 17.5 to 88.2 meters below the surface after interpolation, showing a low raised section of the watershed.

For smooth functioning, the WetSpass model requires different biophysical parameter tables in addition to grid maps. The runoff coefficient, land use/land cover, and soil parameter are three of them. Those parameter tables were properly and thoroughly created. The parameter values for Dengego sub-basin parameters were adjusted and developed using the WetSpass user guide and some additional literature research. The model was processed after the appropriate grid map and parameter tables were prepared.

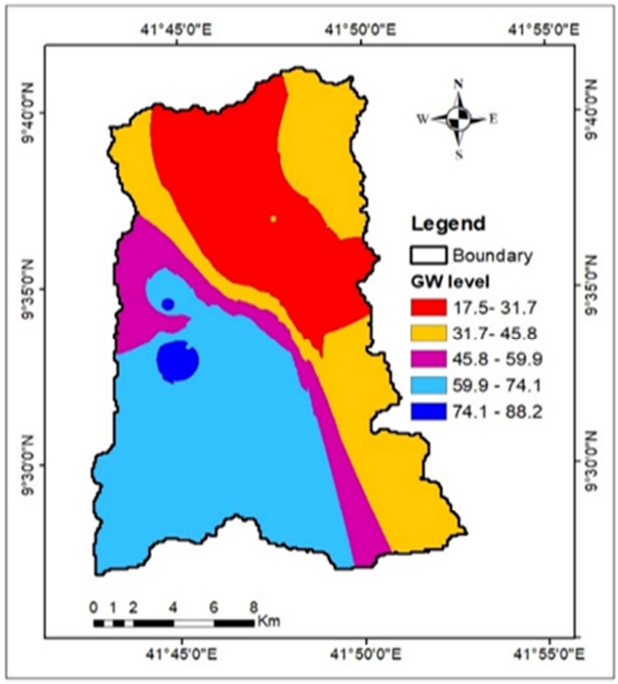

Figure 12. *Groundwater depth map of the Dengego sub-basin.*

3. Results and Discussion

3.1. WetSpass Model Simulation

The spatial average grid maps for the sub-basin were simulated for the winter, summer, and annual phases after running the WetSpass model. Various grid maps are generated by the model during simulation. As a result, surface runoff, actual evapotranspiration, interception, transpiration, soil evaporation, and recharge were generated as water balance components for the sub-basin. The magnitude of the water balance component is shown by each pixel on these watershed-based physiographic maps, which are raster maps. As a result, the watershed-simulated values were calculated as an average of the values in each raster cell.

Table 3. *Long-term annual and seasonal averages of Wetspass simulated water balance parameters.*

Hydrological parameters	Seasonal average		
	Dry/winter/(mm)	wet/summer/(mm)	Annual average (mm/yr)
Precipitation	327.9	360.1	688.0
Runoff	84.2	89.4	173.6
AET	232.6	261.7	494.2
Groundwater recharge	11.2	9.0	20.2

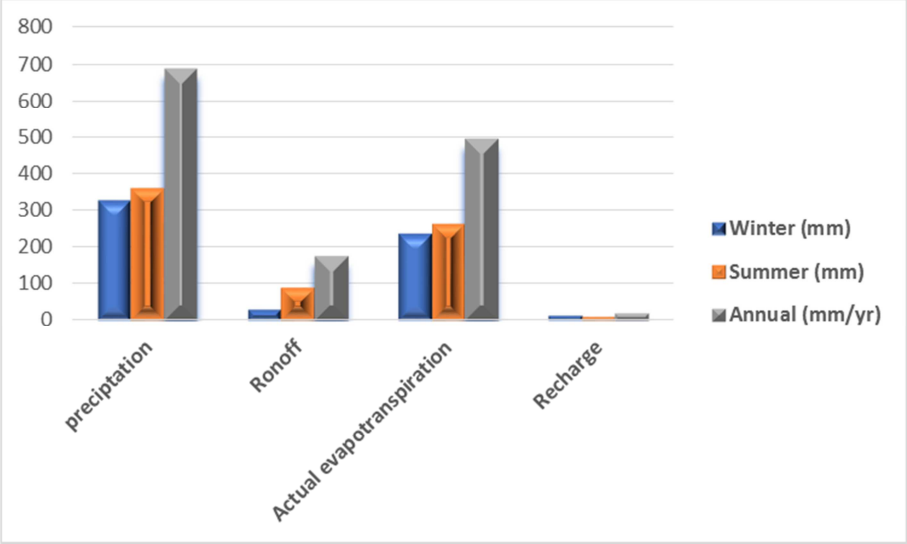

Figure 13. *Comparison of precipitation with model-simulated runoff, actual evapotranspiration, and recharge for winter (October-May), summer (June-September), and annual averages.*

3.2. Water Balance Components

From the WetSpass model simulations result, around 71.8 percent of the precipitation is lost due to evapotranspiration. The modeled evapotranspiration values varied from 193.9 to 680.4 mm/year (Figure 14(c)), with a mean of 494.2 mm/year, and the seasonal average evapotranspiration was projected to be 232.6 and 261.7 mm for the dry and wet seasons, respectively. The dry season's minimum and maximum evapotranspiration values were 107.7 mm and 293.3 mm, respectively (Figure 14(a)), whereas the wet season's minimum and maximum values ranged from 86.1 mm to 389.1 mm (Figure 14(b)).

In the Werii watershed of the Tekeze River Basin, Ethiopia, [14] estimated that actual evapotranspiration is 90.7 percent of annual precipitation. Results of [2], the Geba basin in Northern Ethiopia receives 90.7 percent of the annual precipitation. In the Birki Watershed, Eastern Tigray, Northern Ethiopia, [30] get 85.5 percent of yearly precipitation. [31] simulated 69.8% of annual precipitation in the Upper Bilate Catchment, Southern Ethiopia, and [26] reported 81 percent in the Illala Catchment, Northern Ethiopia. As a result, evapotranspiration eliminates the bulk of annual precipitation [32, 33].

Considering the area of the sub-basin (32585 ha), the average annual evapotranspiration (494.2 mm) is equivalent to $1.6*10^8 m^3$ $year^{-1}$. Due to active solar radiation, greater surface temperatures, and dry winds in the watershed, evapotranspiration plays a crucial role in water losses. About 63% of the annual actual evapotranspiration occurs in the summer season and the remaining 37% is released in winter.

Transpiration from the vegetation cover and evaporation from the water and soil surfaces cause evapotranspiration. These elements are each simulated separately. The average transpiration and evaporation were simulated using the WetSpass model. Transpiration occurs at a rate of 294.4 mm per year on average in the watershed, with minimum and maximum values of 109.4mm and 409.4mm, respectively. The average annual soil evaporation was estimated to be 32.4 mm yr1 with minimum and highest values of 0 and 73.0 mm, respectively.

Surface runoff is influenced by the availability of vegetation, soil type, and slope of the watershed [28]. Spatially explicit annual and seasonal values of surface runoff simulated by the model are presented in Figure 15 and compared with annual precipitation in Figure 13. Seasonal and annual average values of surface runoff are also shown in Table 3. The surface runoff during the main rainy season from June to September ranges from 32.1 to 220.6 mm with a mean value of 89.4 mm (Figure 15(b)), while the surface runoff during the long dry season was found 29.3 to 214.7mm with a mean of the value of 84.2 mm respectively (Figure 15(a)), and the annual surface runoff ranges from 61.4 to 435.2 mm with a mean value of 173.6 mm year-1 which accounts 25.2% of the total long-term mean annual precipitation 688 mm on the entire watershed as shown in (Figure 15(c)). Because biophysical and hydro-meteorological parameters vary by season and are strongly related to rainfall amount, surface runoff is higher in the summer than in the winter. Considering the area of the watershed (32585 ha), the average annual surface runoff (173.6 mm) is equivalent to $5.66*10^7$ m^3 $year^{-1}$.

Similar results are reported in different watersheds in Ethiopia; 20.8% of precipitation, Upper Bilate Catchment, Southern Ethiopia [31], 7.1% of precipitation, Birki Watershed, Eastern Tigray, Northern Ethiopia [30], 6% of annual precipitation, Werii watershed of the Tekeze River Basin, Ethiopia [14], 7.2% of annual precipitation, Geba basin, Northern Ethiopia [2] and 7% of precipitation, Illala Catchment, Northern Ethiopia [26]. About 51.5% of the surface runoff from the Dengego sub-basin occurred in the summer season, and the remaining 48.5% occurred in the winter season. The sub basins' yearly interception rate is

determined to be between 12.2 and 45.6 millimeters per year, with an average of 33.6 mm per year.

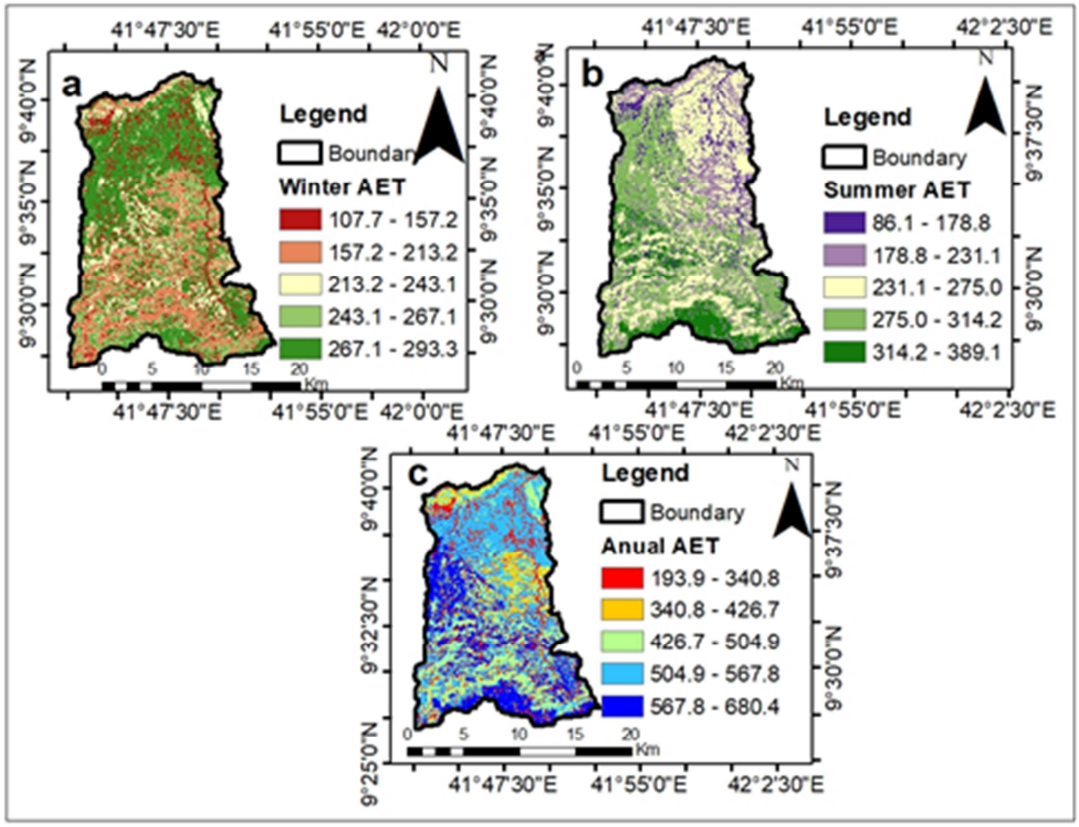

Figure 14. *Actual evapotranspiration from Dengego sub-basin.*

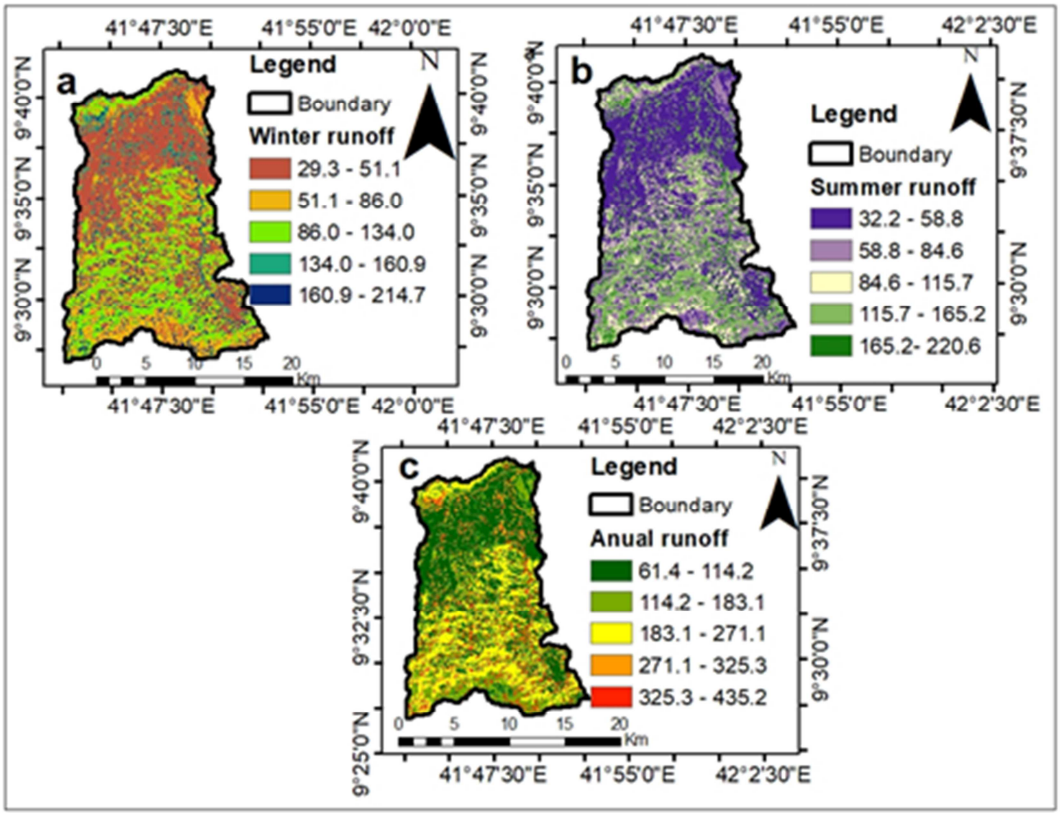

Figure 15. *Runoff a map of the Dengego sub-basin.*

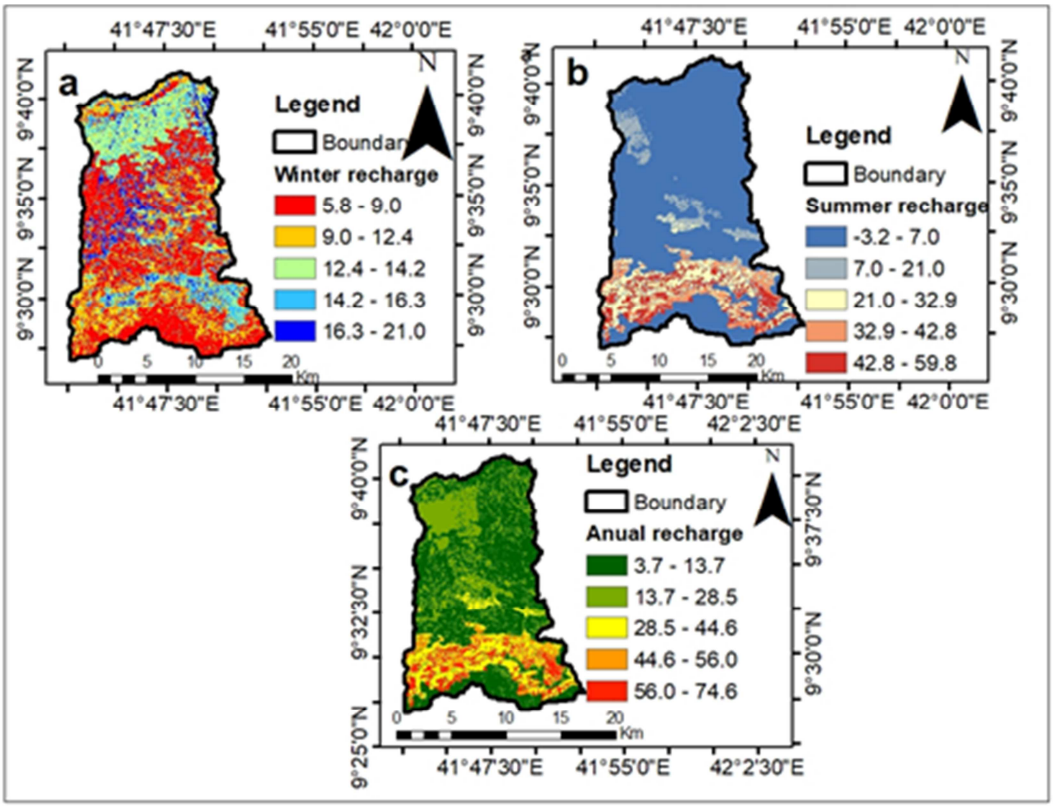

Figure 16. *Recharge maps of Dengego sub-basin.*

3.3. Groundwater Recharge

The amount of infiltration-percolation into groundwater replenishment is influenced by slope, land use, soil texture, and groundwater level [34]. Multiple methods for assessing recharge in a specific area exist, depending on the actual areal conditions. The WetSpass model is used in this study to estimate the seasonal long-term spatiotemporal distribution of groundwater recharge in the Dengego sub-basin using diverse biophysical and hydrometeorological input data.

The simulation resulted in an average recharge of 11.2, 9.0, and 20.2 mm for the winter, summer, and yearly periods, respectively. Dry /winter/ values are 5.8 and 21.0 mm, wet /summer/ values are -3.1 and 59.8 mm, and yearly values are 3.7 and 59.8 mm. As a result, 20.2 mm of water is added to the available groundwater per year. The watershed's average annual long-term groundwater recharge is around 2.9 percent of the annual precipitation (688 mm) (Figure 13). Considering the area of the sub-basin (32585ha), the average annual recharge (20.2 mm) is equivalent to $7.2*10^6 m^3$ $year^{-1}$.

The wet season (summer) accounts for 44.6 percent of yearly groundwater recharge, with the dry season (winter) accounting for the remaining 55.4 percent. The variation in several climatological and biophysical input parameters, primarily rainfall, causes this temporal variation. Similar investigations have been carried out in different research locations to estimate average groundwater recharge using the WetSpass model.

As a result, an average recharge of 28 mm 5% of annual precipitation [33], 37 mm 6% [26], 24.9 mm 7.4% [30], 30.06 mm 4.2% [14], 116 mm 9.4% [31], and 66 mm 12% [26]. In comparison with these findings, the simulated recharge is consistent and reliable in this semi-arid sub-basin. The distribution of groundwater recharge in the Dengego sub basin varies spatially as well. The south, south eastern, and south western parts of the sub-basin, which receives greater rainfall, have a higher rate of annual groundwater recharge, as illustrated in Figure 14.

4. Conclusion

In the Dengego Sub-basin, a scientific study was not conducted following the quantification of groundwater recharge. The water balance components were not well specified. The water balance component of the Dengego sub-basin was assessed using WetSpass. The model considers all of the area's meteorological, hydrological, and biophysical aspects. The area's land use, soil texture, topography, and slope were researched to estimate groundwater recharge and other water balance components of the watershed hydrometeorology.

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other water balance components of the watershed hydrometeorology.

The distributed WetSpass model was used to simulate the seasonal and annual water balance components of the Dengego sub-basin successfully. The highly variable distribution of the climatic inputs (parameters) associated with variation of land use/land cover, soil texture, topography, and slope are responsible for variations of the water balance components within the catchment. Based on the model output, the annual groundwater recharge in the Dengego sub-basin is 3.7 and 74.6 mm as a minimum and maximum value with a mean of 20.2 mm, which represents 2.9% of the total annual rainfall. 45% (9.0mm) of the recharge is occurred in summer (Jun to September) and the rest 55% (11.2mm) of recharge percolate in winter (October to May).

The minimum and maximum values of annual actual evapotranspiration of the Dengego sub-basin are 193.9 mm and 680.4 mm with a mean value of 494.2 mm which accounts for 71.8% of total rainfall (688 mm). 53% (261.7mm) was found in the wet and the rest 47% (232.6 mm) occurred in the dry season. The annual runoff from the model was 61.4 to 435.2 mm with a mean of 173.6 mm which represents 25.2% of annual precipitation (688 mm). 51.5% (89.4 mm) of runoff occurred in the wet season and the remaining 48.5% (84.2 mm) occurred in the dry season.

Acknowledgements

The AWARD, fellowship for women researchers at the Ethiopian Institute of Agricultural Research (EIAR) sponsored this work. Thus, the authors acknowledge AWARD, fellowship for women researchers at the Ethiopian Institute of Agricultural Research (EIAR) for the funding of the research project.

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