Original Research Article

Water balance estimation using Integrated GIS-based WetSpass Model; the case of Birki Watershed, Eastern Tigray, Northern Ethiopia

Abstract

This studyaimsto estimate long-term average annual and seasonal water balance components for Birki watershed using WetSpass model with integrated geospatialmodeling approachwith tenyears' hydro-meteorological and biophysical data of the watershed. Both primary and secondary data were collected using both field survey and disk-based data collection methods. WetSpass model were used for data analysis purposes.The finding showed that in the summer season the annual groundwater recharge is 24.1 mm year^{-1} (96.5%), winterseason mean groundwater rechargeis 0.8 mm year^{-1} (3.5%) and yearly mean groundwater recharge is 24.9 mm year^{-1}, Surface runoff yearly mean value is 40.6 mm year^{-1}, Soil evaporation yearly mean value is 10.8 mm year^{-1}, Evapotranspiration yearly mean value is 60.8 mm year^{-1}, Intersection loss yearly mean value is 17 mm year^{-1}, and Transpiration loss yearly value is 6.8 mm year^{-1} in the entire watershed. The mean annual precipitation, which is 573 mm, is contributed to7.4%, 7.1% and 85.5% recharge to the groundwater, tosurface runoff, and evapotranspiration, respectively. Annually 1.1205 million m^3 water recharges into the groundwater table as recharge from the precipitation on the entire watershed. The contribution of this study could be used as a baseline information forregionalwater resource experts, policymakersand 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.

Key Words:WetSpass, Water balance components, GIS, Birki watershed, recharge, Ethiopia

1. Introduction

1.1 Background and Justification

Water resource is the most important and crucial element of life which is needed in sufficient quantity and acceptable quality to meet the ever-increasing humans demand used for different purposes(Singh, Hari Prasad, & Bhatt, 2004; Sophia S Rwanga, 2013;Gupta, Nayak, & Choudhary, 2015; Jenifa Latha.C, 2015; SS Rwanga & Ndambuki, 2017;Yenehun, Walraevens, & Batelaan, 2017). Its availability and distributionsare limited both in time and space in which 97.5% of the global water is saline and exists in the oceans and only 2.5% is considered to be fresh water. 68.7 % is fresh water which is locked up in glaciers while 30.1% and 0.9 % represent groundwater, surface water, and other fresh waters respectively (Bate, Smailes, & Adams, 2004). It is scarce, but very crucial and multifunctional natural resource found irregularly, despite the demand for fresh water is increasingworldwide as the world population is growing(Karimi & Bastiaanssen, 2015). Due to this, proper planning and management of such resource in terms of distribution, management, utilization, and environmental functions which demands series time period data to optimizing the resource use sustainably (Karimi & Bastiaanssen, 2015).

Groundwater recharge or deep drainage or deep percolation is a hydrologic process where water moves downward from surface water to groundwater. This process usually occurs in the vadose zone below plant roots and is often expressed as a flux to the water table surface. Recharge occurs both naturally (through the water cycle) and through anthropogenic processes (i.e., "artificial groundwater recharge"), where rainwater and or reclaimed water is routed to the subsurface. In arid and semi-arid areas, its assessment is a key challenge in determining sustainable yield of aquifers (Yongxin and Beekman, 2003; Crosbie et al., 2010). Recharge is estimated by water- balance method, water budget model method or by multiplying the magnitude of water-level fluctuations in wells with the specific yield of the aquifer material. But commonly groundwater recharge is determined to a large extent as an imbalance at the land surface between precipitation and evaporative demand (Gebreryfael, 2008). Now, with the advent of Geographic Information Systems (GIS), physical-based hydrologic modeling has become important in contemporary hydrology for assessing these parameters as well as the impact of the human intervention and/or possible climatic change on basin hydrology and water resources (Alemaw and Chaoka, 2003).

Hence, WetSpass was built as a physically based methodology for estimation of the long-term average, spatially varying, water balance components: surface runoff, actual evapotranspiration and groundwater recharge (Batelaan and De Smedt, 2001, 2007). It is an acronym for Water and Energy Transfer between Soil, Plants, and Atmosphere under Quasi-Steady-State that was built upon the foundations of the time-dependent spatially distributed water balance model as cited by (Aish, Batelaan, & De Smedt, 2010)

Water resource is the crucial element of life with a limited extent, so looking to estimate the amount and water balance components of a given area is important research point of view to accurate estimations of water balance in semi-arid and sub-humid tropical regions, where water resources are scarce compared to water demand. The water balance estimation techniques, one of the main subjects in hydrology,are a means of a solution of important for both theoretical and practicalhydrological problems. On the water balance approach,it is possible to make a quantitative evaluation of water resourcesand their change under the influence of man's activities and the impact of climate change.So that, for an effective and sustainable management of water resources, understanding of the spatial and temporal variability of various water balance components and groundwater recharge are required. In this study, we applied the WetSpass model to simulate the water balance and to estimate the average annual and seasonal water balance components, such as surface runoff, evapotranspiration and groundwater recharge(Al Kuisi & El-Naqa, 2013).

InBirki watershed,there is surface water availability but the amount and the water balance components were not yet estimated in that specific area which is important for proper planning, future utilization of water resources and to sustain the watershed.The main objectives of this research paper were that i) to estimate long-term annual and seasonal groundwater recharge, surface runoff and potential-evapotranspiration using WetSpass simulation model and ii) to estimate water balance components on the entire watershed for sustainable utilization and management purpose. Therefore, this study was carried out with the above-mentionedobjectivesfor Birki watershed using integratedGIS-Based WetSpass model forfurther understanding the hydrological and biophysical elements of the watershed for proper management, wise utilization, future planning and sustainable utilization of the resource considering sustainable development. Understanding the hydrological characteristics of the watershed is also crucial for implementing integrated water resources and watershed management approach for improving water resource utilization among the upstream and downstream user communities for multipurpose benefits and minimizing conflictsof interest.

2. Literature Reviews

Hydrologic models are among those methods frequently used for groundwater investigation. Groundwater modeling techniques can be used to estimate the water balance components based on the biophysical characteristics of the watershed and climatic time-series data. The application of groundwater modeling techniques is also important for forecasting water resources for the future time horizon (Obuobie et al., 2008). A number of hydrological models are available today for estimating groundwater resources are designed to work based on spatial and temporal distributions of the complex hydrological systems.

Understanding seasonal and annual variations of the water resources, especially runoff, evapotranspiration, and recharge, is indispensable for efficient and sustainable management of groundwater (Obuobie, Diekkrüger, & Reichert, 2008). Since groundwater resources are sensitive functions of climatic factors, geological formation, topography, soil properties, and land-use types (Dragoni & Sukhija, 2013), so, understanding of watershed physical and biological characteristics are important. Accurate quantification of groundwater resources and water balance components involves identification of hydrological and biophysical characteristics of the watershed. For estimating groundwater resources, a variety of methods exist (e.g. Ahmadi et al., 2012; Christoph et al., 2011; Lerner, 1997; Lerner, Issar, & Simmers, 1990; Nakashima, Zhou, & Sato, 2001; Scanlon, Healy, & Cook, 2002).

Northern Ethiopia is mainly characterized by a shortage of surface water resources due to the erratic nature of rainfall. As a result, optimum crop production is not achieved even in the rainy season. Traditionally, most people settled in the upstream part of the watershed, while the available surface water is found at the downstream part of the watershed in the form of springs and perennial river bodies. Hence, the use of groundwater is inevitable to fulfill the demands for domestic water supply and agricultural water required for sustainable economic development(Gebremeskel & Kebede, 2017).

In this study, a WetSpass model was used to estimate long-term spatial surface runoff, evapotranspiration, and groundwater recharge, since its development, WetSpass has been used worldwide (Rwanga, 2013). It has successfully applied in Belgium (Batelaan & De Smedt, 2001) and other environments such as Gaza Strip, Palestine (Aish, 2010), Geba catchment, Ethiopia (Tesfamichael et al., 2010, 2013), and Nile Delta aquifer, Egypt (Armanuos, Negm, Yoshimura, & Valeriano, 2016). Hence, we used this model to simulate water balance parameters in the Birki watershed of the Geba River basin.

3. Materials and Methods

3.1.Geographical location of Birki watershed

The study area, Birki watershed, is located in the Geba river basin of Eastern Tigray, Northern Ethiopia (Figure 1). The watershed is found in two districts which are Kilte awelaelo and Atsebi-Wenberta. Geographically, it is located at latitudes of 13.65^0 to 13.75^0 Northing and longitudes of 39.60^0 to 39.71^0 Easting with an elevation ranging from 1999 to 2514 m.a.s.l with spatial area coverage of 45 km^2 (own processing). It receives a mean annual rainfall of 573 mm. The Birki River flows from the eastern escarpment of the Eastern Zone of Tigray to the west contributing the flow of Geba River a tributary of Tekeze River. It is a perennial river, but flows are extremely low in the dry season and high floods during the wet season of July to September (personal observation).

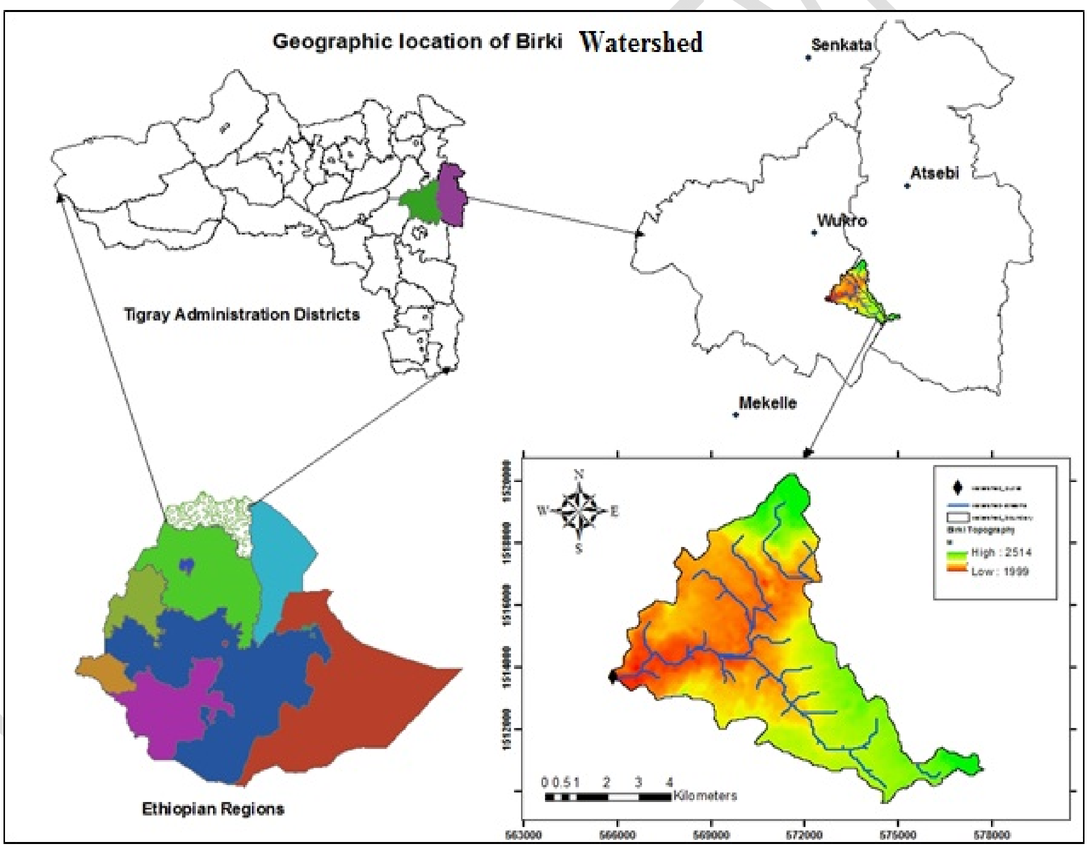


Figure 1: Map of the Birki watershed, Northern Ethiopia (Source: Autor generated map)

3.2.Research Methodology

3.2.1. Basic concepts of WetSpass model

WetSpass is an acronym which stands for Water and Energy Transfer between Soil, Plants,and Atmosphere under quasi-Steady State (Batelaan & DeSmedt, 2001; Batelaan & De Smedt, 2007). It uses both physical and hydro-meteorological input files for simulation of the long-term average spatial patterns of surface runoff, actual evapotranspiration and groundwater recharge which is suitable for studying long-term effects of land-use changes on the water regime in a watershed region (Batelaan & DeSmedt, 2001; Batelaan & De Smedt, 2007; Dams et al., 2007; A. Aish et al., 2010). The application of this model is compatible and integrated with GIS ArcView software during the simulation process. It estimates the spatial difference of groundwater recharge at the seasonal and annual basis and it was successfully applied in different countries by different authors, as a result, the findings of those authors showed that groundwater recharge estimation was successfully estimated with a good result (Al Kuisi & El-Naqa, 2013).

The WetSpass model(Asefa, Wang, Batelaan, & de Smedt, 1999; Batelaan & DeSmedt, 2001; Aish, Batelaan, & De Smedt, 2010; Pandian, Rajasimman, & Saravanavel, 2014; Yueqiu Zhang, Shiliang Liu, 2015) was used in their study to simulate temporal average and spatial differences of surface runoff, actual evapotranspiration, groundwater recharge and other water balance components in seasonal and annual basis for Birki watershed. Generally, to run the WetSpass model two basic input parameters were needed (hydro-meteorological and biophysical data) related to the watershed and they should be prepared in grid and database file (DBF) formats.

3.2.2. WetSpass Model description

The total water balance for a given raster cell (Figure 2) is split into independent water balance components for the vegetated, bare-soil, open-water and impervious parts of each cell. This allows one to account for the non-uniformity of the land-use per cell, which is dependent on the resolution of the raster cell. The processes in each part of a cell were set in a cascading way. This means that an order of occurrence of the processes, after the precipitation event, is assumed. Defining such an order is a prerequisite for the seasonal timescale with which the processes will be quantified. The quantity determined for each process is consequently limited by a number of physical and hydro-meteorological constraints of the given area under investigation (Batelaan & DeSmedt, 2001).

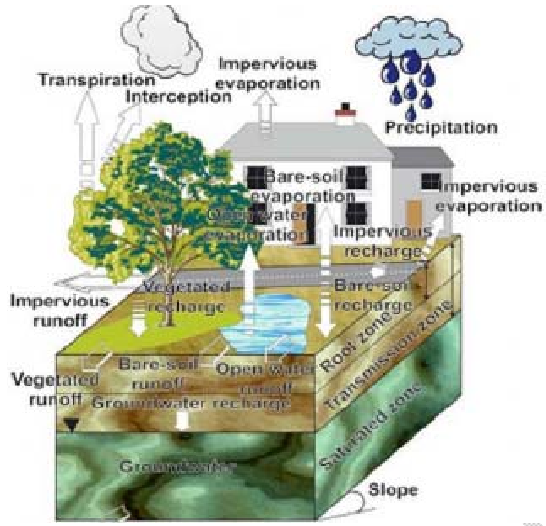


Figure 2: Schematic representation of the water balance of a hypothetical raster cell showing surface and sub-surface processes, after Batelaan and De Smedt (2001).

3.2.3. Water balance calculation using WetSpass Model

Water balance components of vegetated, bare-soil, open water and impervious surfaces are used to calculate the total water balance of a raster cell as follows;

ET_{raster}= avETv + asEs + aoEo + aiEi………………1

S_{raster}= avSv + asSs + aoSo + aiSi…………………..2

R_{raster}= avRv + asRs + aoRo + aiRi……………….....3

Where ETraster, Sraster, Rraster are the total evapotranspiration, surface runoff, and groundwater recharge of a raster cell respectively, each having a vegetated, bare-soil, open-water and impervious area component denoted by av, as, ao, and ai, respectively.

Precipitation is taken as the starting point for the computation of the water balance of each of the above-mentioned components of a raster cell, the rest of the processes, like interception, surface runoff, evapotranspiration, and recharge follow in an orderly manner.

3.2.4. Vegetated area

The water balance for a vegetated area depends on the average seasonal precipitation (P), interception fraction (I), surface runoff (Sv), actual transpiration (Tv), and groundwater recharge (Rv) all with the unit of $[LT^{-1}]$, with the relation given below

P = I + Sv + Tv + Rv…………………………………4

3.2.5. Surface runoff

Surface runoff is calculated in relation to precipitation amount, precipitation intensity, interception and soil infiltration capacity. Initially, the potential surface runoff (Sv - pot) is calculated as

S_v– pot = C_{sv} (P – I) ……………………………….5

Where, Csvis a surface runoff coefficient for vegetated infiltration areas, and is a function of vegetation, soil type,and slope. In the second step, actual surface runoff is calculated from the Sv-pot by considering the differences in precipitation intensities in relation to soil infiltration capacities.

$S_v = C_{Hor} S_v$ – pot…………………………………….6

Where CHor is a coefficient for parameterizing that forms part of a seasonal precipitation contributing to the Hortonian overland flow. CHor for groundwater discharge areas is equal to 1.0 since all intensities of precipitation contribute to surface runoff. Only high-intensity storms can generate surface runoff in infiltration areas.

3.2.6. Evapotranspiration

A reference value of transpiration is obtained from open-water evaporation and a vegetation coefficient for the calculation of seasonal evapotranspiration:

T_{rv} = cEo………………………………………………………………7

Trv = the reference transpiration of a vegetated surface [LT^{-1}];

E_o= potential evaporation of open water [LT^{-1}] and c= vegetation coefficient [-]

This vegetation coefficient can be calculated as the ratio of reference vegetation transpiration as given by the Penman-Monteith equation to the potential open-water evaporation, as given by the Penman equation,

$$C = \frac{1+\frac{\gamma}{\Delta}}{1+\frac{\gamma}{\Delta}\left(1+\frac{r_c}{r_a}\right)} \quad \text{……………………………… 8}$$

Where; γ= Psychometric constant [$ML^{-1} T^{-2} C^{-1}$];

Δ = Slope of the first derivative of the saturated vapor pressure curve [$ML^{-1} T^{-2} C^{-1}$];

r_c= Canopy resistance [TL^{-1}] and

r_a= aerodynamic resistance [TL^{-1}] given by;

$$r_a = \frac{1}{k^2 u_a}\left(\ln\left(\frac{z_a - d}{z_o}\right)\right)2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 9$$

3.3. WetSpass model data inputs preparation and their sources

GIS-based hydrological models integrated with WetSpass model was used for analyzing the biophysical, hydrological and metrological data of the study area in order to estimate the hydrological systems in a steady state condition. However, this demands long-term average hydro-meteorological data and spatial patterns. The model needs the parameters in seasonal basis, as a result, four months of June, July, August, and September are considered as summer (main rainy season) and the remaining eight months are considered as winter (dry season) in the case of Ethiopian condition particularly in the study area. Grid maps and parameter tables are required as inputs for the model and they are prepared with the help of ArcGIS tools and Erdas Imagine software. These grid maps were a land-use and land cover, soil texture, slope, topography, groundwater levels, precipitation, potential evapotranspiration and wind speedand in line with these grid maps lookup tables of soil type, land use and runoff coefficient were prepared. Detail input parameters was mentioned on theoverall research methodology framework adopted for estimation of water balance components using GIS-based WetSpass model for Birki watershed as illustrated in (Figure 3) and used nineteen input parameters to stimulate the model, and out of these, fifteen parameters were in the form of grid data and four in database file format.

Table 1: Input parameters and their sources for WetSpass Model

Id	Input parameter	Sources	Resolution
1	Soil Texture	Map from soil sample analysis	30*30M
2	DEM (Topography and Slope)	Glovis.usgs.gov & own processing	30*30M
3	Land use/cover(Summer & winter)	Glovis.usgs.gov & own process	30*30M
4	Temperature (Summer & winter)	NMA & own-processing	30*30M
5	Precipitation (Summer & winter)	NMA & own-processing	30*30M
6	PET (Summer & winter)	NMA & own-processing	30*30M
7	Wind speed (Summer & winter)	NMA & own-processing	30*30M
8	Groundwater depth (Summer & winter)	Regional water resources	30*30M
9	Soil parameter lookup table	WetSpass User Guide & Literature review	
10	Runoff Coefficient lookup table	WetSpass User Guide & Literature review	
11	Land use parameters (Summer & winter) lookup table	WetSpass User Guide & Literature review	

Table 2: Characteristics of Landsat-8OLI downloaded from glovis.usgs.gov for land use land cover map preparation

Winter Landsat-8OLI			Summer Landsat-8OLI		
Id	Characteristics	Descriptions	Id	Characteristics	Descriptions
1	Path/Row	168,51	1	Path/Row	168,51
2	Cell size	30*30meter	2	Cell size	30*30meter
3	Date of capturing	2015-01-05	3	Date of capturing	2015-09-02
4	Map projection	UTM	4	Map projection	UTM
5	Datum	WGS84-Zone-37N	5	Datum	WGS84-Zone-37N
6	Source	Glovis.usgs.gov	6	Source	Glovis.usgs.gov

3.4. Materials and Software

The materials and software used in the entire research work were presented as follows in Table 3

Table 3: Materials and software used in this research

No	Software's and Materials	Functions/ used for
1	GPS-Garmin-60	GCP data, outlet and soil sample data collection.
2	ArcGIS software 10.3	Grid data preparation, spatial data analysis, interpolation of point data and interpretation of the simulated Results.
3	Erdas Imagine	Layer stacking, LULC classification, and Accuracy assessment.
4	Arc Hydro tools	Dem Hydro-processing, flow direction, flow accumulation, Streams network, Watershed Delineation.
5	Arc View 3.2 and WetSpass Extensions	Running the WetSpass model.
6	Cropwat-8	Evapotranspiration estimation.
7	Google Earth	Ground truth collection and features Identification, and to take GCP for inaccessible areas.
8	XLS to DBF Converter software	To prepare lookup parameter tables of Soil texture, Land use land cover, runoff coefficient in DBF format.
9	Ms-Office-2010	Reporting and presentation of results

The overall research methodology framework adopted for estimation of water balance components using GIS-based WetSpass model for Birki watershed was mentioned as illustrated in (Figure 3)

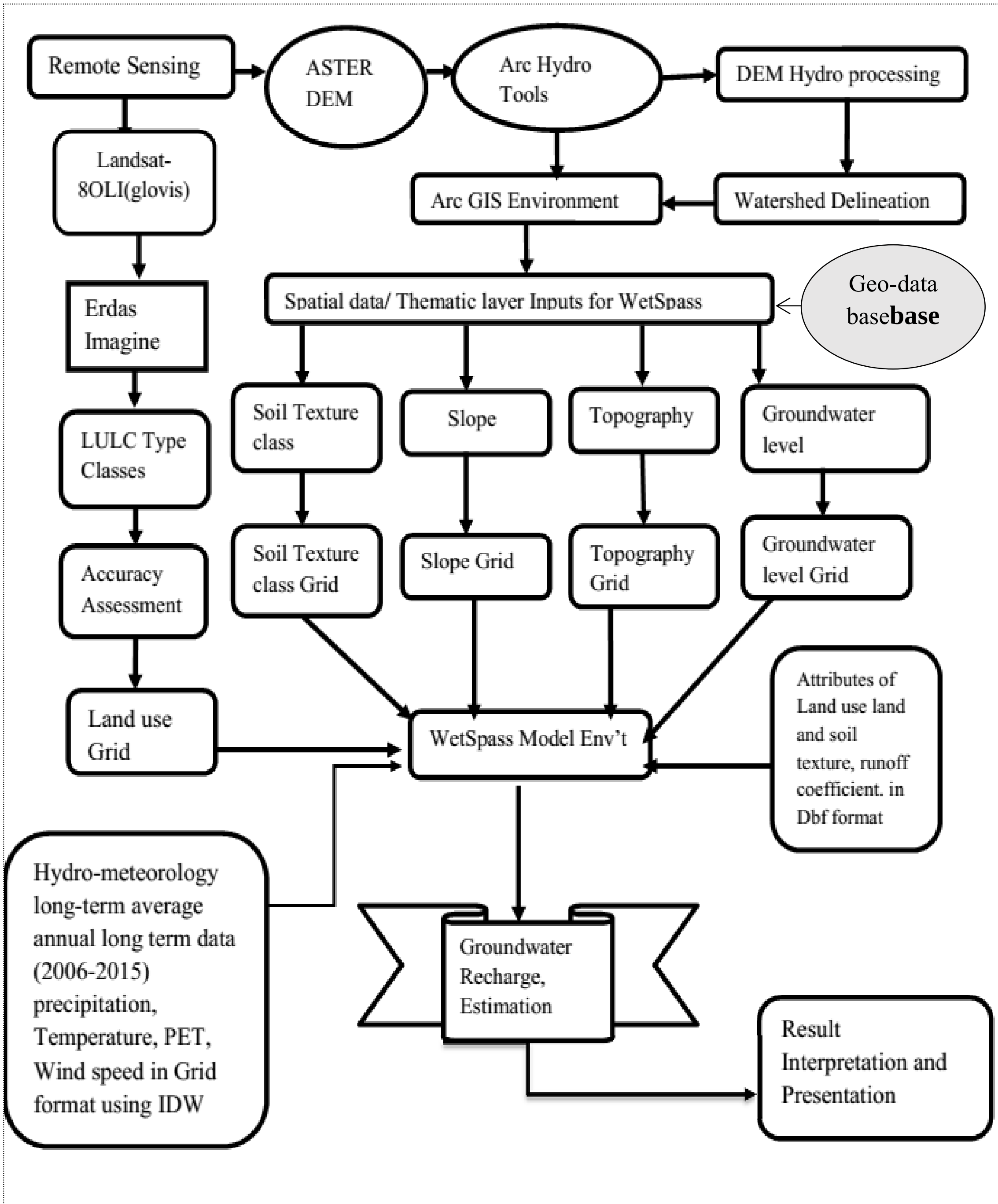


Figure:3Research methodology frameworks, different activities, and tools used to achieve the research objectives.

4. Resultsand discussions

4.1.Annual and seasonal groundwater recharge estimation

The recharge rate during the main rainy season from June to September ranges from 0 to 41.09 mm year^{-1}with a mean value of 24. mm year^{-1}(look Figure 4A), while the recharge during the long dry season varies from 0 to 1.53 mm year^{-1}with mean value of 0.82 mm year^{-1}(Figure 4B),similarly, the mean annual groundwater recharge ranges from 0 to 42.6 mm year^{-1}with mean value of 24.9 mm year^{-1}, which accounts 7.4% of the total long-term mean annual precipitation 573 mm on the entire watershed as shown in (Figure 4C). The recharge rate was higher in the summer season than winter because of high rainfall amount, intensity, durationthan the winter season(Zarei, Ghazavi, Vli, & Abdollahi, 2016; Yenehun et al., 2017)and due to intensive watershed management interventions, which is important for water resource development activities like creating boreholes, springs by the regional water resource experts and could be a baseline information for policymakers for the future intervention.

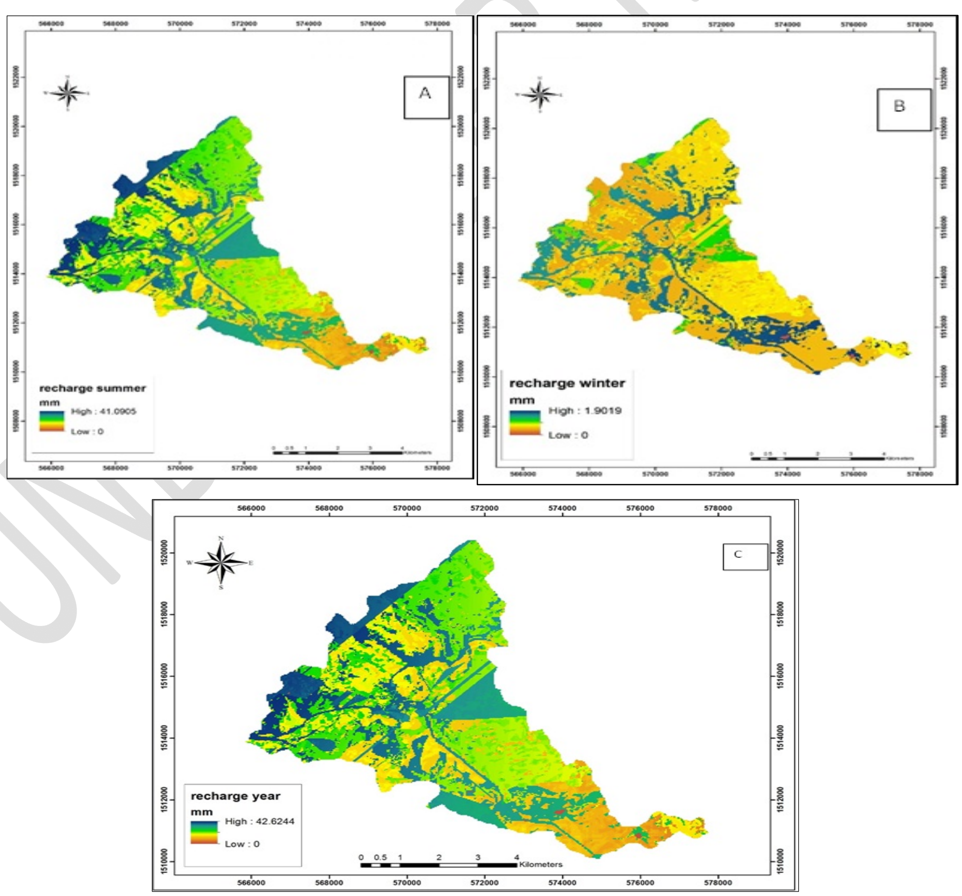


Figure 4: WetSpass model-basedgroundwater recharge simulation during summer season (A), winter season (B) and annual (C).

4.2.Annual and seasonal surface runoff estimation

The surface runoffduring the main rainy season from June to September ranges from 0 to 40.5 mm year^{-1}with a mean value of 10.9 mm year^{-1} (Figure 5A), while the surface runoff during long dry season was found from 0 to 4.5mm year^{-1}with mean value of 0.4mm year^{-1} (Figure 5B), and mean annual surface runoff ranges from 0 to 40.6 mm year^{-1}with mean value of 10.9mm year^{-1}, which accounts 7.1% of the total long-term mean annual precipitation 573 mm on the entire watershed as shown in (Figure 5C). The surface runoff is higher in summer season than winter as the biophysical and hydro-meteorological characteristics vary in seasons and directly related to rainfall amount(Yenehun et al., 2017) and this is used for implementing conservation practices to reduce runoff and soil erosion on the watershed.

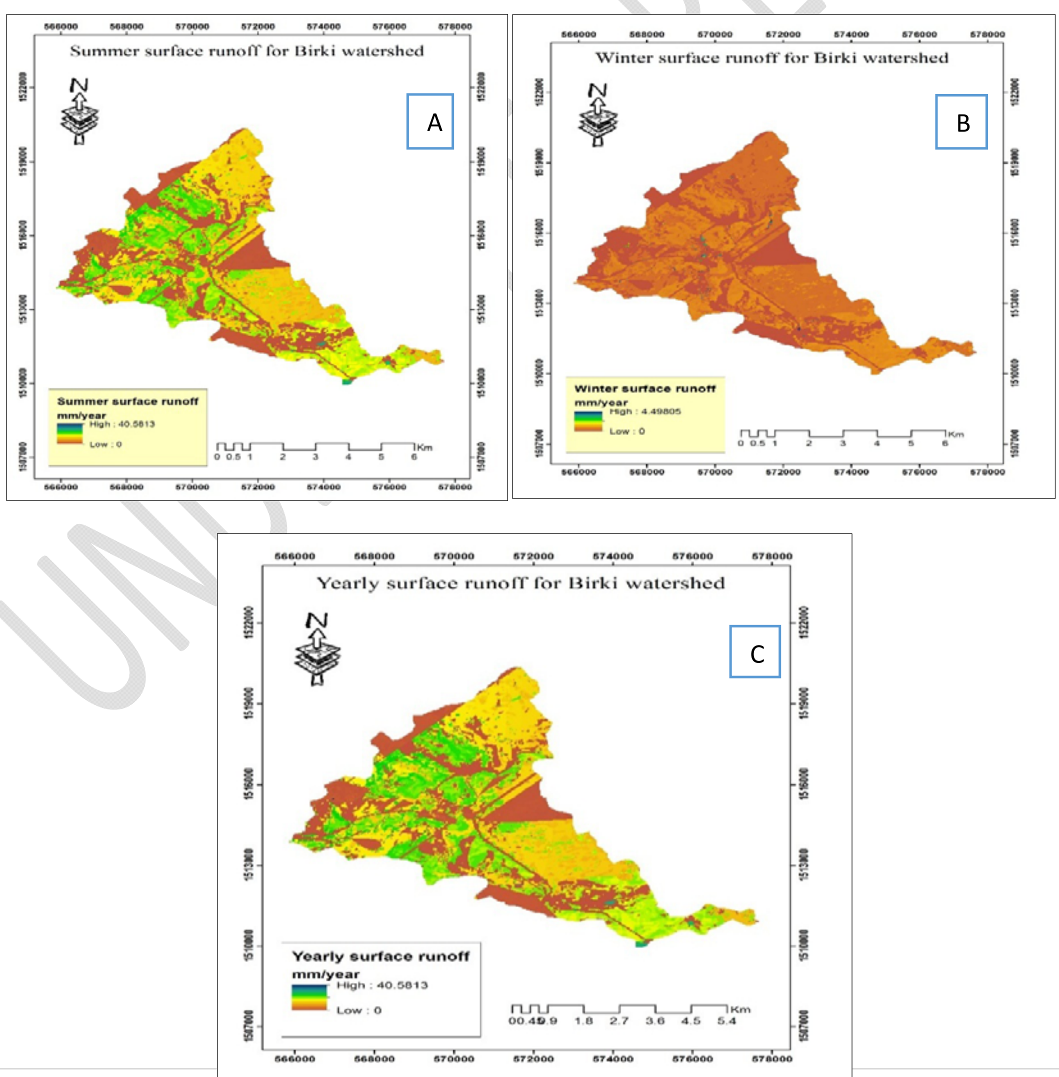


Figure 5: Summer (A), winter (B) and annual (C), surface runoff simulated for Birki watershed

4.3. Annual and seasonal evapotranspiration estimation

The evapotranspiration during the main rainy season (June to September) ranged from 8.2 to 22.9 mm year^{-1}with a mean value of 14.4 mm year^{-1}(Figure 6A). Evapotranspiration during thelong dry season was ranged from 3.1 to 39.4mm year^{-1}with amean value of 6.7mm year^{-1}(Figure 6B). Overall, the mean annual evapotranspirationranged from 12.8 to 60.8mm year^{-1}with amean value of 21.1mm year^{-1}, which accounted85.5% of the total long-term mean annual precipitation 573 mm on the entire watershed as shown in (Figure 6C).

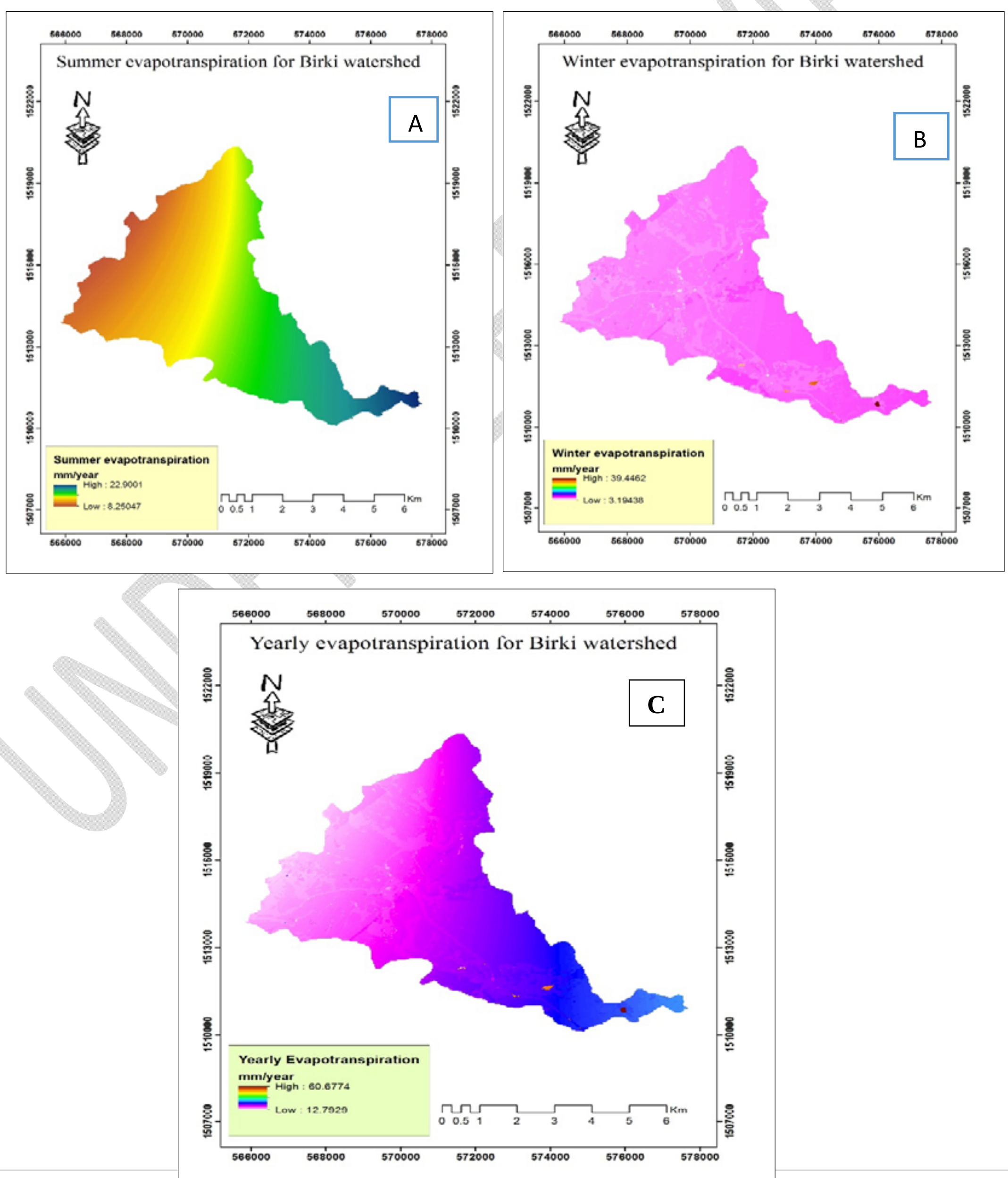
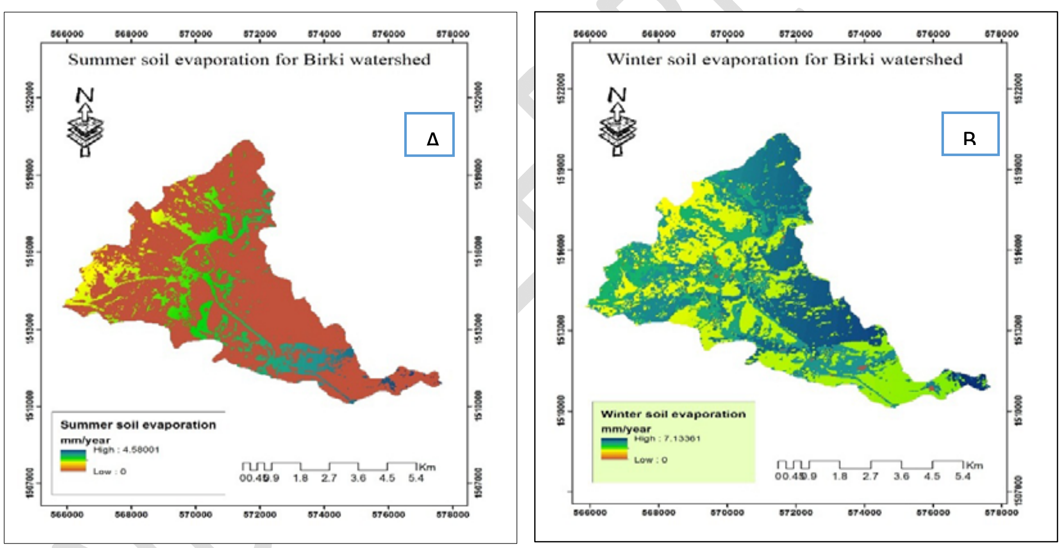


Figure 6: Summer (A), winter (B) and annual (C), evapotranspiration simulated by WetSpass model

4.4.Annual and seasonal soil evaporation estimation

The soil evaporation during the main rainy season ranged from 0 to 4.6mm year^{-1}as shown in (Figure 7A), and during thelong dry season,it ranged from 0 to 7.1mm year^{-1}with amean value of 4.9mm year^{-1}(Figure 7B). The mean annual soil evaporation ranged from 0 to 10.8mm year^{-1} on the entire watershed as shown in (Figure 7C). The main driver for all hydrological processes is precipitation and soil evaporation is directly related to rainfall amount, soil type, land use land cover type and other biophysical characteristics of a given watershed(Yenehun et al., 2017). This information was used to understanding the soil moisture status of the soil for irrigation purpose, the lowest soil evaporation has high soil moisture and vice versa.



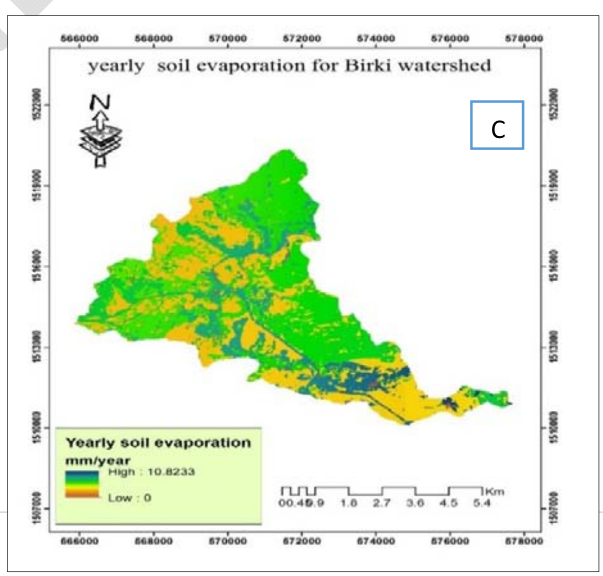


Figure 7: Summer (A), winter (B) and annual (C), Soil evaporationsimulated for Birki watershed.

4.5.Water balance components estimated

The WetSpass model has thecapabilityto simulate water balance components of a given watershed. Annual and seasonal surface runoff, evapotranspiration, interception loss, soil evaporation, and transpiration losses were simulated for Birki watershed. As a result, high values of surface runoff, interception, and transpiration losses were observed in the summer season but low values in thewinter season. High values of evapotranspiration were observed in the summer season than the winter season as illustrated in (Figure 8) which is related to the high rainfall amount, duration and intensity during this season compared to the dry season(Graf & Przybyłek, 2014; Zarei et al., 2016; Yenehun et al., 2017). Understanding the water balance of a given watershed is important for water budgeting and pricing purpose to conserve the resource for sustainable utilization on the area and to implement integrated watershed management approach by the community to sustain the watershed as it is.

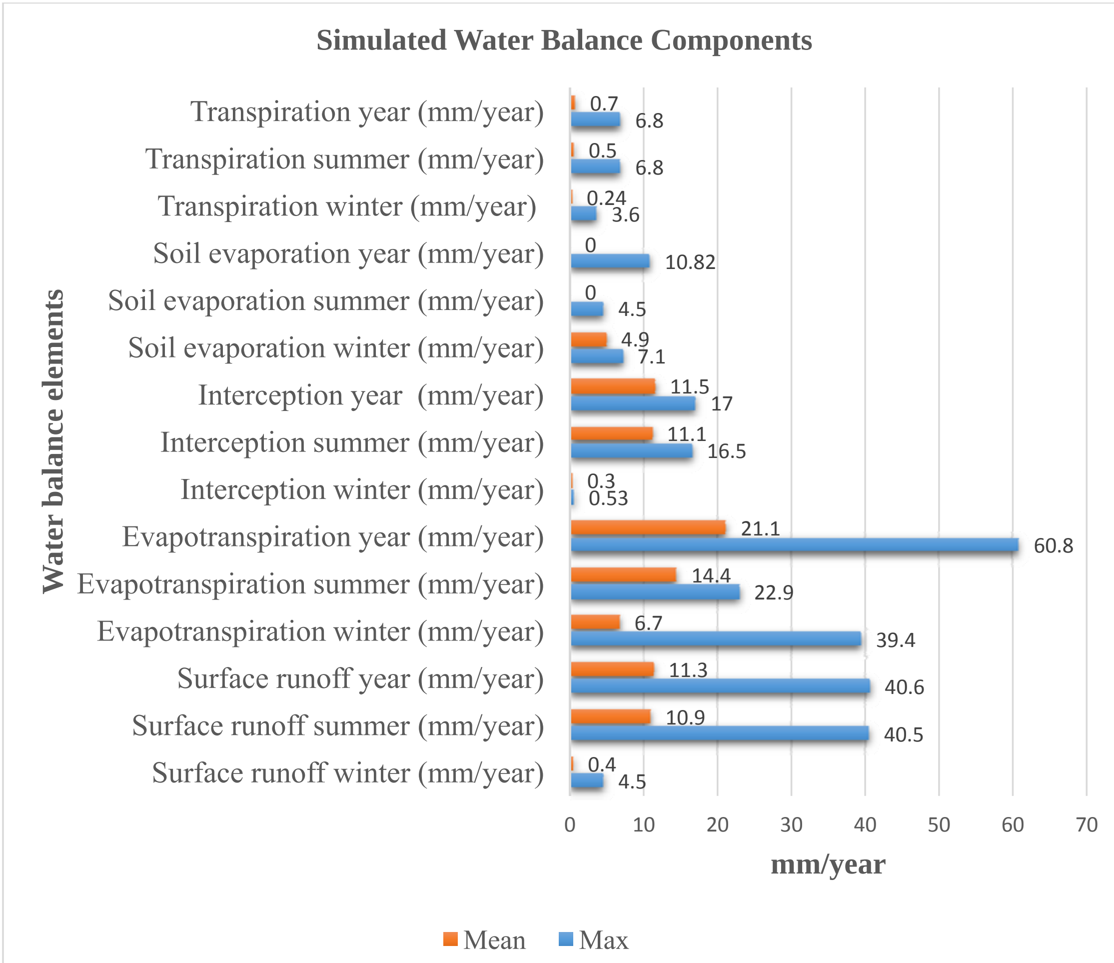


Figure 8: Water balance components simulated using WetSpass model for Birki watershed

5. Conclusions and Discussions

This research paper aimed to estimate long-term annual and seasonal groundwater recharge, surface runoff, potential evapotranspirationand other water balance components using GIS-based WetSpass model for Birki watershed. The result showed that the long-term annual and seasonal groundwater recharge for Birki watershed was found to be 42.6 mm $year^{-1}$, in the summer which is the main rain season is 41.09 mm $year^{-1}$. Whereas in the winter season it was found to be 0.82 mm $year^{-1}$ and about 96.5% of the recharge was happened during thesummer season and the remaining 3.5% occurs during the winter seasonbecause of precipitation, temperature, potential evapotranspiration, and soil moisture variations. Moreover, there is high duration, intensity and amount of precipitation distribution, high soil moisture and evapotranspiration in the summer season which accelerated groundwater recharge. The mean annual precipitation of (573 mm) contribute to 7.4% as groundwater recharge, 7.1% as surface runoff and the remaining 85.5% is lost as evapotranspiration in the Birki watershed and annually, 1.1205 million m^3 water is recharging to the groundwater from the total annual precipitation.

The development and application of GIS and remote sensing techniques coupled with other hydrological models like WetSpass model makes the assessment and understanding of water resources easy and effective to maximize its wise utilization, proper management for sustainable use of the resource. The WetSpass model, a simulation model based on biophysical and hydro-meteorological properties, is robust to estimate long-term annual average water balance components in terms of seasonal and annual basis to see pattern and status of the resource. And also used for a future master plan of water resources development for a given watershed for easily practically implementing.

There are high groundwater recharge and evapotranspiration with low surface runoff in the watershed because of the watershed isconserved type of watershed with high coverage of shrublands in which this facilitates infiltration rate and evapotranspiration, but decreases runoff production.This information wasdriven based on GIS-based physical simulation model, WetSpass model on the arid and semi-arid regions of Tigray, itwas used for implementing soil and water conservation strategies, implementing integrated watershed management approach and for preparing future planning program by policymakers, regional water resource experts and researchers for proper management, wise utilization and sustainable development using the resource within the watershed.

6. Recommendations

- GIS and RS technology play a great role for spatial and temporal data collection, store, manipulation, analysis and presentation in an efficient and effective way, within a short period of time and low cost which is used as input for estimation of water balance components and groundwater recharge modeling and mapping studies.
- Integrated GIS-based hydrological models are important methods of exploring, identification and mapping groundwater resources potential, distribution for management and wise utilization of the resource sustainably.
- The WetSpass model needs intensive hydro-meteorological and bio-physical input data to simulate water balance components such as evapotranspiration, runoff and groundwater recharge of a given watershed, so it needs accurate and timely input data to simulate effectively.
- This result serves asbaseline information for policymakers and water resource experts for further investigation on groundwater recharge modeling and future planning of the watershed.
- Lack of hydro-meteorological data is the main problem in running hydrological models, so hydro-meteorological data handling system should be improved at a country level.
- Awareness creation on integrated watershed management for the community is important for thesustainable use of water resources and to sustain the ecosystem healthy.
- Model results validation is important to check the goodness of the model, this should be considered in doing groundwater recharge modeling and hydrological components estimation using hydrological models.
- The watershed is theconserved type of watershed this improves groundwater recharge and reduces surface runoff, so the community should keep up such conservation practices/mechanism to minimize soil erosion and to enhance groundwater recharge rate in the watershed.
- The main limitation of this current research is that the model is designed only for the temperate regions of the world only, but it is better to develop for all the world countries and in this research work we implement the model by changing the input parameters from temperate conditions to semi-arid conditions based on the agro-ecological classification of the watershed and using literature reviews which is implemented this model in arid and semi-arid conditions.

7. References

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