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Original Paper

Comparison of SWAT and WEPP for modeling annual runoff and sediment yield in Agewmariyam watershed, Northern Ethiopia

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***Abstract*— The Soil and Water Assessment Tool (SWAT) and the Geographic Water Erosion Prediction Project (Geo-WEPP) were applied to compare modeling of annual runoff and sediment yield in the Agewmariam watershed, eastern Amhara Region, Ethiopia. Spatial and temporal data distributions were required as inputs to run both models. Soil texture and other soil properties were measured in the field and in the laboratory, and soil maps were generated from global digital soil maps. Land use maps were created by manually digitizing Google Earth images. Watersheds were defined using watershed DEMs and gradient maps were created for each runoff event. Runoff samples were collected and analyzed for sediment concentrations in the laboratory; average annual runoff and sediment volumes were estimated using the WEPP and SWAT models. The results were satisfactory compared to the observed values, with R2 values of 0.86 and 0.91 for the SWAT and WEPP models, respectively, and NSE values of 0.54 and 0.71 for the monthly runoff. The estimated annual mean runoff and sediment yield at the watershed outlets were 65.54 mm, 146.14 mm, 43t/ha/yr and 41.7t/ha/yr for the WEPP and SWAT models, respectively. Several sub watersheds were determined to be susceptible to soil erosion and were prioritized, so more attention was given to this area to reduce runoff and soil erosion. Therefore, the SWAT and WEPP models were suitable for estimating annual runoff and sediment volumes. Sediment yields simulated from both models were high and alarming and far exceeded the allowable rate of soil loss.**

Keywords*— *Runoff, Sediment yield, SWAT, Watershed, WEPP

I. INTRODUCTION

Soil erosion is continues to be a global constraint to economic development, especially in developing countries, where soil erosion is becoming a limiting factor in expanding and maintaining agricultural production [1]. Soil erosion from agricultural lands ranges from 22 to 100 t ha-1 per year worldwide, and productivity is declining by 15 to 30% annually [2]. Sedimentation and soil erosion is a massive problem threatening many reservoirs in the northern Ethiopian highlands [3]. Tolerable soil loss levels in various agro-ecological zones in Ethiopia range from 2 to 18t/ha/year [4]. Therefore, in some sub watersheds of the Tekeze Dam watershed, simulated soil runoff values exceed the maximum allowable soil runoff of 18t/ha/year. This fact indicates that soil erosion is a serious threat in northern Ethiopia [3]. Soil erosion is a major degradation process, adversely affecting various soil functions and is the ultimate cause of irreversible impacts on soil resources with low renewable potential [5].

On-site monitoring of sediment loss is difficult, expensive, and time-consuming. In addition, soil erosion events are intermittent and require long-term documentation to adequately characterize erosion and sediment loss from a particular site. Therefore, in most cases, soil erosion modeling is the primary tool for evaluation [6]. Differential erosion modeling is applied to assess the spatial and temporal variability of soil erosion processes Geo-WEPP and SWAT models are physics-based models used to estimate annual runoff and sediment deposition. These models are selected based on their broad utility, reputation, and use of state-of-the-art technology [7 and 8].

The WEPP watershed model is a continuous simulation computer program that predicts sediment yield and deposition from the overland flow on hill slopes, sediment yield and deposition from concentrated flow in small channels, and sediment deposition in impoundments. It computes spatial and temporal distributions of sediment yield and deposition and provides explicit estimates of when and wherein a watershed or on a hill slope that erosion occurs so that conservation measure has been selected as the most effective soil erosion control measures [9]. The WEPP model has compared with USLE, the Erosion Productivity Impact Calculator (EPIC), the Areal Nonpoint Source Watershed Environment Response Simulation (ANSWERS), and other models for runoff and soil erosion [10; 11 and 12].

The Soil and Water Assessment Tool (SWAT) is one of the most widely used watershed models developed by the USDA Agricultural Research Service (USDA-ARS) [13]. The model was developed to predict the long-term effects of land management practices on water, sediment, and pesticide yields in large, complex watersheds with varying soil, land use, and management conditions [14].

The study watersheds are characterized by deforestation for agricultural food production, cultivation of marginal land, over anthropogenic interventions such as grazing and soil fertility exploitation have resulted in progressive land degradation due to soil erosion, with accelerated soil erosion and subsequent soil depletion accompanied by reduced crop productivity [15]. Lifespan of many small dam structures in the Wagimura area built for summer irrigation and water supply is threatened by massive sedimentation average annual soil loss in the Agewmariam watershed has been estimated at 25tha-1yr-1 [15].

The study watershed is characterized by steep slopes, ragged topography, erratic rainfall, slope cultivation, sparse vegetation, high poverty, lack of technology, and high population and livestock densities make soil erosion and degradation problems particularly acute in the study area. Thus, proper watershed management is needed to mitigate runoff and sedimentation problems. To address and prioritize this issue, sediment transport and runoff can be estimated using various erosion treatment models prior to implementing SWCS and impoundments within the watershed. Predicting hydrology and erosion at hill slope and watershed scales is necessary to understand the impacts of conservation practices and land use change. Therefore, this study compares the SWAT model with an improved version of Geo-WEPP to model annual runoff and sediment transport in the Agewu-maryam watershed of northern Ethiopia.

II. Material And Methodology

A. *Description of Study Area*

This study was conducted in the Agewmariam model watershed in the Sekota Woreda Waghimra zone, Amhara Region, Northern Ethiopia. The study area covers an area of 155.685 ha and is located between 38°55'10" and 38°56'10" East Longitude and 12°31'40" and 12°32'30" North Latitude. The elevation of the watershed ranges from 2108 m to 2395 m above sea level (Fig.), based on ArcGIS watershed delineation using a 30 m*30 m grid digital elevation model (DEM) generated by the Shuttle Radar Topography Mission (SRTM).

The watershed is characterized by a very undulating topography ranging from steep slopes of more than 50% to gentle slopes of less than 5% According to [16], the two main soil types in the Agewmariam watershed are Eutric Regosols (38.73%) and Eutric Cambusols (61.268%). Soil texture in the Agewumariam watershed is dominated by sandy loams (65.9%), with the remainder being sandy loams (2.7%), loams (8.6%), loam sand (20.4%), and sand (2.4%), as shown in Table 3 and Fig. 9.

The average annual precipitation is 582 mm, the average annual minimum temperature is 12.8°C, and the average annual maximum temperature is 28°C. According to [17], Ethiopia's climate zones are classified based on altitude, precipitation, average annual temperature, and length of growing season and the study area belongs to the dry semi-arid lowlands.

B. *SWAT and WEPP Model Input Parameter*

Digital elevation model (DEM) **-** the DEM of the watershed was downloaded from the USGS, created with SRTM 30m pixels. The DEM was the main input parameter for both models to delineate the watershed. The total area of the Agewmariam watershed delineated was then 155.68 ha. The average slope area of the study watershed was 8.447% flat slope, 17.095% gentle slope, 33.49% medium slope, 28.95% steep slope, and 12.00% very steep slope in the Agewmariam watershed (Fig. 3). Using Arc SWAT multiple slope classes, the slope was classified into five slope classes. Based on the minimum, maximum, mean, and median slope statistics for the proposed watershed, five slope classes (0-8, 8-15, 15-30, 30-50, and >50%) were applied and the slope grid reclassified for further SWAT model analysis.

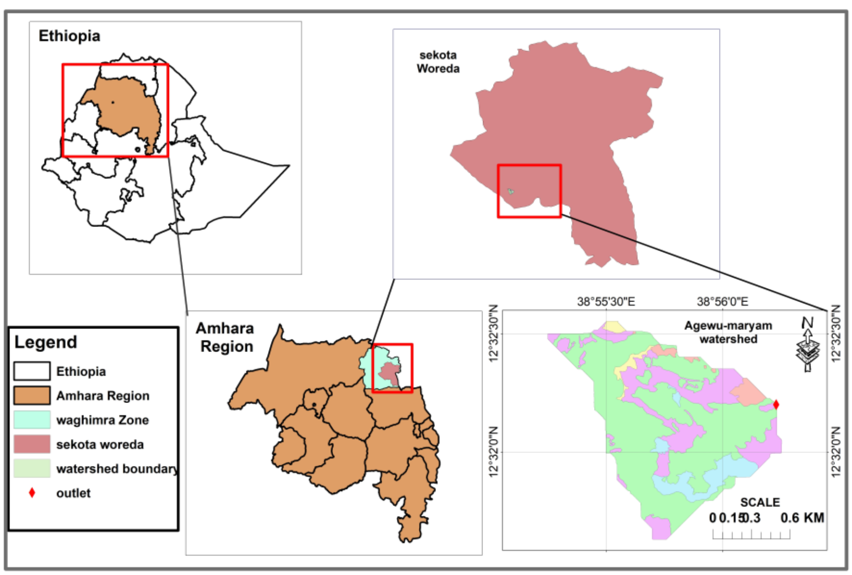

Fig. 1.Location map of Agewmariam watershed

Land use land cover -the land cover map of the Agewmariam watershed was created from the 1-meter pixel size of Google Earth Pro by manually digitizing polygons and line features for each land use type. The majority of the Agewmariam watershed is covered by cultivated land [13]. The land used in the land cover map and SWAT code for the study watershed is 63.168% agricultural land, 1.986% bare land, 23.831% bush land, 8% forest, and 3.014% settlement (Fig. 4). Agricultural land and bush land dominate the land use in the watershed, accounting for 87% of the total land use in the watershed.

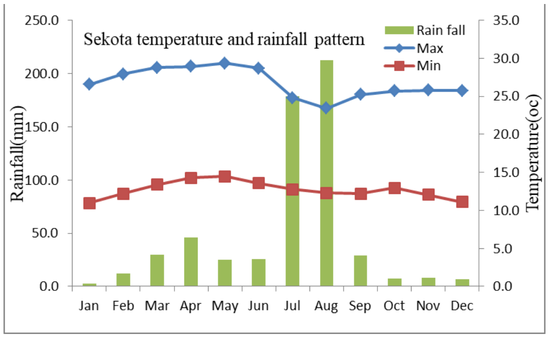

Fig 2: Mean annual rainfall and maximum and minimum temperature (Source: Combolcha metrology station data (1990- 2020))

Soil map -the soil distribution in the watershed was mainly Eutric Regosol and Eutric Cambsol (Fig. 5). The majority of the watershed is covered by Eutric Cambsol (61.268%), with the remaining 38.731 portion covered by Eutric Regosol. There are five soil types in the watershed: sandy loam, sandy clay loam, loam sand, sand, and loam. Fig. 5 (left) shows 66.71% sandy loam, 19.79% sandy loam, 8.97% sandy clay loam, 3.69% sandy loam, and 0.8% loam.

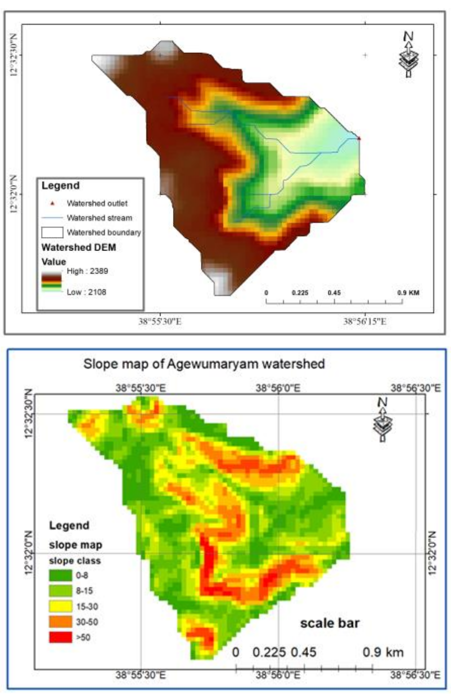

Fig.3. Watershed DEM and Slope map of Agewmariam watershed

TABLE I. AREA DISTRIBUTION OF LAND COVER IN THE AGEMARIAM WATERSHED

No	Land-use type	SWAT CODE	Area coverage(ha)	Area coverage (%)
1	Agricultural land	AGRL	98.343	63.168
2	Bare land	BARR	3.092	1.986
3	Bush land	RNGB	37.101	23.831
4	Forest land	FRSD	12.456	8.000
5	Settlement	PEAS	4.692	3.014
6	Total		155.684	100

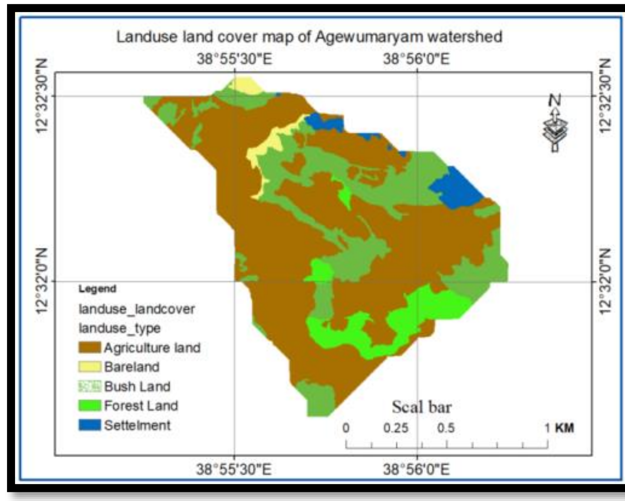

Fig.4. Land use land cover map of Agewmariam watershed

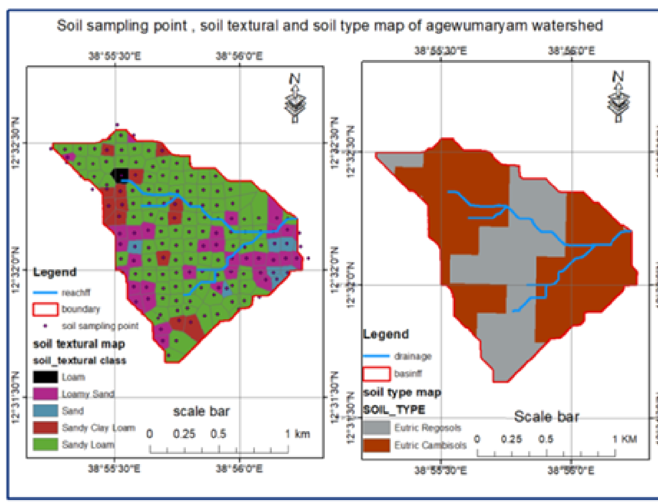

Fig.5. Soil textural map (Left) and soil type map (Right) of Agewmariam watershed

C. Hydrological data collection

The model requires climate data, including daily values of precipitation, runoff, and sediment data collected at the watershed experimental station. Other required daily climate data (solar radiation, maximum and minimum temperatures, relative humidity, wind speed, and sunshine hours) were obtained from the Combolcha weather station, SWAT weather generator, and Climate Explorer model The SWAT weather generator was used to simulate missing daily climate data [18]. These data were used to compare and validate simulation results from both SWAT and Geo-WEPP models.

To determine runoff volumes in the study area, runoff and peak runoff volumes were manually recorded by stage reading at rectangular hydrologic weirs located at the outfalls of the watershed within an interval time of 10 to 15 minutes. Total discharge (Q) and peak discharge (qp) were determined from the collected data using an evaluation curve of the stage-discharge relationship; the evaluation curve for the Agewmariam watershed was developed from frequent measurements of flow velocity and channel geometry, and peak flow and discharge were based on Equation 1 recommended for rectangular top weir sections [19 and 20]. The developed stage versus discharge graph represents the relationship between stage and discharge in a power-law regression line known as the rating curve of R2 (0.97). The developed rating curve equation takes the following form (Fig. 6).

$$Q = A*V$$

Where Q =discharge over the weir (m3/s), A = cross-sectional area of weir (m), V = Velocity of runoff

Sediment volume was determined from sediment concentration and total runoff volume, while sediment concentration was determined from runoff samples collected manually using plastic bottles. Sediment concentrations for each manually collected sample were measured in the laboratory. Sediment was filtered through a flask bottle with filter paper. Samples were dried at room temperature, and the dried sediment was weighed to determine the sediment volume of each runoff sample. Thus, a total of eight bottles per event were collected and submitted to the Soil Laboratory for sediment concentration analysis. Sediment volume was calculated by multiplying the runoff volume by the average sediment concentration.

*Sediment concentration = ∑ (Total duration of runoff(s)*discharge (l/s)*average concentration of sediment (gr/l))*

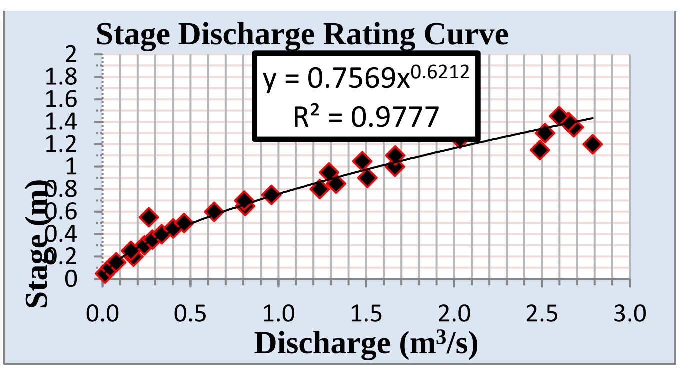

Fig.6. Rating curve develop for Agewmariam watershed

Three years of rainfall, runoff, and sediment data were used in this study for observational data analysis of the storm events occurring from June 2018 through September 2020, daily rainfall depths greater than 12.7 mm, and the daily rainfall threshold developed by [6]. Thirty events with a daily rainfall depth of 12.7 mm or greater, the daily rainfall threshold developed by [6], were selected. Runoff and peak flows were derived from the time series data using the respective weir equations for the Agewmariam watershed. The average depth of runoff observed for the selected events was 93.47 mm, and the average daily peak runoff in the Agewu-Maryam watershed was 1.39m^3/s.

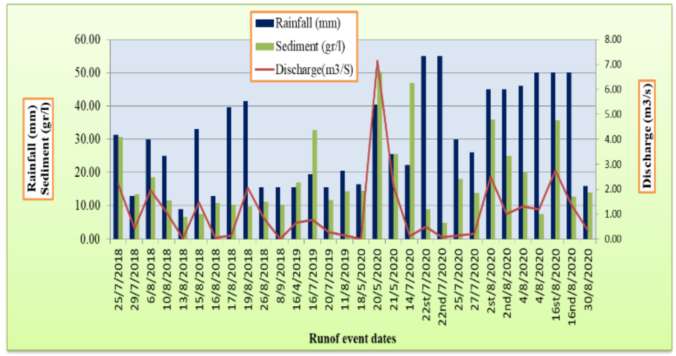

Fig.7. Observed runoff, rainfall, and sediment on Agewmariam watershed

D. *Soil data collection and analysis*

Field Soil sampling was conducted in a 100m x 100m grid in the watershed to determine soil properties. A total of 159 soil samples were collected from the topsoil layer (0-20 cm) at each location to analyze the physical and chemical properties of the soil. The collected soil samples were sieved to 2 mm and 0.5 mm sieves for physical and chemical analysis of the soil according to standard laboratory procedures.

E. *SWAT model setup and hydrologic response unit (HRU) analysis*

Modeling of runoff and sediment yield in the Agewmariam watershed was constructed using the SWAT model; SWAT is an interface to GIS software and uses readily available GIS input data. The model was designed using data extracted and appropriately predicted for the Agewu-maryam watershed, including DEM, 2008 LU/LC, soil maps, and meteorological data. After reclassification of land use, soils, and gradient grids, an overlay operation was performed. Once the overlay was completed, the catchment was divided into HRUs based on soil type, land use, and slope class; an HRU analysis is a lumped land area with a unique combination of land cover, soils, and management within a sub watershed. The definition of HRUs in this study was determined by assigning multiple HRUs to each slope, land use/land cover, meteorological data, and soil map; the SWAT user manual suggests using more HRUs, with a maximum of 10 HRUs in a single sub watershed is recommended. In this case, threshold levels of 5%, 10%, and 5% were applied for land use, soil, and slope classes, respectively, to encompass spatial detail. The analysis of soils, land use/land cover, and gradient in the watershed resulted in 134 HRUs and 11 sub watersheds.

The SWAT model predicts surface runoff from daily rainfall using the Soil Conservation Service's curve number method, and the model estimates peak runoff for each HRU using the modified rational equation [5]. Runoff flow through the channel system was estimated using the variable storage factor method developed by Williams, and the SWAT model estimates erosion and sediment yield from rainfall and runoff for each HRU using the modified universal soil loss equation (MUSLE).

Sedi = 11.8($Q_{surf} \cdot q_{peak} \cdot A_{hru}$)$^{0.56}$ $*$ K_{USLE} $*$ $C_{USLE}$$*$ P_{USLE} $*$ LS_{USLE} $*$ C_{FGR}

where 11.8 is the unit conversion factor, Sed is the sediment yield in ton per day (ton/day), Qsurf is the surface runoff volume (mm/ha), qPeak is peak runoff rate in m3/s, Ahru is the area of HRU (ha), KUSLE is the soil erodibility factor, CUSLE is cover and management factor, PUSLE is support practice factor, LS is topographic factor, CFRG is course fragment factor.

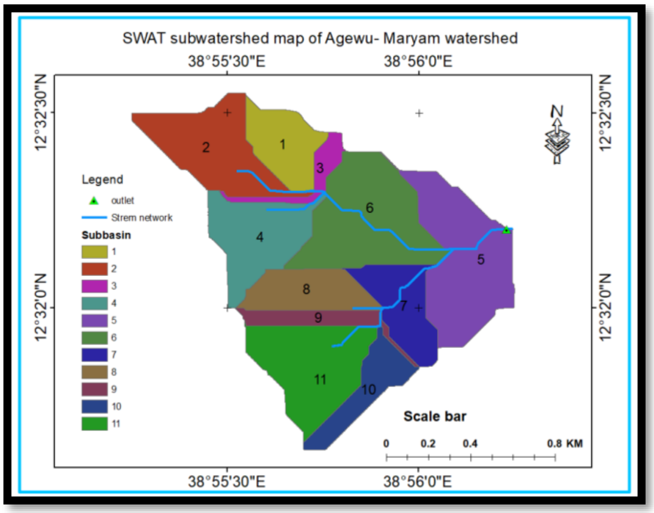

Fig.8. SWAT HRUs sub-watershed map of Agewmariam watershed

F. *Geo-WEPP Channel and Hill slope analysis*

The inputs used for the Geo-WEPP model were a 30*30 m DEM with no missing measurements in each cell, soil type, and land use land cover data file type in ASCII format required to run the model. The Critical Source Area (CSA) and Minimum Source Channel Length (MSCL) were 5 ha and 100 m, respectively. The next task of Geo-WEPP was to specify the watershed outlets to delineate the watershed. One cell of the watershed network is selected and the UTM zone (in my case, UTM zone 37N) is automatically specified; the Geo-WEPP model is then used to add new observed climate data in the WEPP interface, after adding the daily organized metrological data according to the WEPP model requirements, input Geo-WEPP was activated along with the parameters (ASCII DEM, land use, and soil type).

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G. *Performance Evaluation of Model Efficiency*

The performance of the model was evaluated to assess how the model simulated values fitted with the observed values. Several statistical measures are available for evaluating the performance of a hydrologic model. The goodness of the model fit related to annual runoff and sediment yield was assessed based on Nash–Sutcliffe efficiency (NSE) and coefficient of determination (R^2). The Nash-Sutcliffe efficiency is calculated as:

$$NSE = 1 - \frac{\sum_{i=1}^{n}(E_i - O_i)^2}{\sum_{i=1}^{n}(O_i - \bar{O})^2}$$

The range of E lies between $-\infty$ and 1.0 with E=1 describing a perfect fit. Values between 0-1.0 are generally viewed as acceptable levels of performance, whereas values <0.0 indicate that the mean observed value is a better predictor than the model [22]. The coefficient of determination R^2 is defined as the squared value of the coefficient of correlation [23]. It is calculated as follows:

$$R^2 = \left[\frac{\sum_{i=1}^{n}(O_i - \bar{O})(E_i - \bar{E})}{\sqrt{\sum_{i=1}^{n}(O_i - \bar{O})^2}\sqrt{\sum_{i=1}^{n}(O_i - \bar{E})^2}}\right]^2$$

Where n is the number of observations or samples; Oi are observed values; Ei are estimated values; $\bar{O}$ is the mean of observed values; $\bar{E}$ is the mean of estimated values; i is the counter for individual observed and predicted values. The range of R^2 lies between 0 and 1 and describes how much of the observed value is explained by the predicted value [22]. A value of 1 means the predicted value is equal to the observed value, whereas a value of zero means there is no correlation between the predicted and observed values.

III. Results And Discussion

A. *Runoff and Sediment loss prediction with SWAT and WEPP model*

The highest monthly average runoff and sediment yield generated by SWAT in the watershed were 41.4 mm and 24.62t/ha/yr respectively in August (Table 2); the long-term average annual precipitation, runoff, and sediment yield for the watershed by the SWAT model were 513.5 mm, 65.54 mm, and 41.7t/ha/yr, respectively (Table 2). The high long-term average sediment yield may be due to the uneven distribution of rainfall and the fact that 41% of the watershed has slopes of 30% or more and cultivated land. These results indicate that soil erosion is associated with slope gradient, with the degree of major erosion increasing with slope gradient for all land use types. This result is consistent with the finding that the degree of erosion increases with increasing slope gradient [24]. Acceptable soil loss to maintain economic viability and high levels of production [25] is 5 to 11 t/ha/year. However, soil loss from the watershed exceeds this range, making the area susceptible to soil loss.

The sediment yield estimated by the SWAT model for the Agewu-Maryam watershed (41.7) t/ha/yr is consistent with the sediment yield of 32.57 t/ha/yr exported from the Tekeze Dam sub watershed reported by another study [23], while [20] found the treated SWAT model predictions from watersheds and untreated watersheds (33.5 t/ha/yr and 44.8 t/ha/yr) reported satisfactory results, although another study using USLE [15] found that 25 t/ha/yr underestimated soil loss rates, still exceeds the soil loss tolerance limit (18 t/ha/yr) reported by [2].

TABLE II. SWAT PREDICTED AVERAGE MEAN MONTHLY RUNOFF AND SEDIMENT YIELD

Months	Rain (mm)	Surface Q(mm)	Lateral Q(mm)	Water yield (mm)	ET (mm)	Sediment yield(t/ha/month)
Jan	1.97	0.01	0.12	0.31	6.06	0.01
Feb	11.02	1.58	0.58	2.28	8.22	1.93
Mar	16.78	0.88	0.88	1.86	32.63	0.55
Apr	20.68	1.33	1.37	2.77	42.08	0.87
May	30.57	1.41	2.06	3.53	26.78	1.2
Jun	19.31	0.13	1.11	1.28	18.81	0.25
Jul	158.16	13.85	11.4	25.27	61.5	9.14
Aug	198.79	41.4	19.22	60.78	76.78	24.62
Sep	43.77	4.34	4.83	10.66	48.21	2.95
Oct	6.49	0.45	0.47	3.19	24.58	0.15
Nov	3.09	0.01	0.16	1.63	11.17	0.01
Dec	3.05	0.15	0.16	0.81	7.52	0.06
Total	513.68	65.54	42.36	114.37	364.34	41.74

TABLE III. SEDIMENT YIELD LOSS AND SEVERITY CLASS OF AGEWMARYAM WATERSHED

Annual sediment loss rate t/ha/yr	Sub-watershed	Severity class	Area covered	Area %	Priority class
0-11	7, 8, 10	Lower	30.46	19.56	5
12-18	3, 4, 6, 11	Moderate	65.88	42.32	4
19-30	9	High	5.23	3.36	3
31-50	5	Very high	25.03	16.08	2
>50	1, 2	Sever	29.076	18.68	1
Total			155.685	100	

TABLE IV. GEO WEPP PREDICTED AVERAGE MEAN MONTHLY RUNOFF AND SEDIMENT YIELD

Month	Precipitation mm	Average runoff(mm)	Average peak flow(m^3/s)	Sediment t/ha/month
January	0.32	0.04	0.004	0
February	0.00	0.35	0.0001	0
March	8.00	0.34	0.026	0
April	34.18	2.54	0.150	0.035
may	52.07	1.78	0.110	0.006
June	1.32	0.78	0.051	0.000
July	78.02	2.76	0.156	0.575
August	261.12	37.29	1.607	39.507
September	66.35	6.59	0.357	3.047
October	8.48	1.55	0.099	0.001
November	4.58	0.47	0.033	0.000
December	7.52	0.22	0.016	0.000
Total	522	54.38	2.609	43.1

B. *Spatial Distribution Map of Sediment Yield*

The degree of erosion hazard in the Agewu-Maryam watershed was reclassified into five (Table 3) different erosion hazard classes based on [15]. According to prioritization map, sediment loss categorized into five (5) classes, such that 0-11, 12-18, 19-30, 31-50 and >51 t/ ha/yr.

According to this study, sub watersheds 9, 5, 1, and 2 are classified as having large, very large, and severe sediment losses and represent 38.12% of the watershed (Table 3 and Fig. 8). Sediment loss from these sub watersheds is greater than the maximum allowable soil loss rate (>18 t/ha/yr), and the high volume of surface runoff generated from these sub watersheds identified the Agewmariam watershed as an erosion-prone area (Table 3 and Fig. 8). The main reasons for the high runoff and sediment volumes can be attributed to land degradation, poor land cover, improper land management, and cultivation of undulating slopes without conservation. The acceptable soil loss to sustain the economy and high levels of production [25] is 5-11 t/ha/yr. However, sediment losses from these sub watersheds exceed this range; the region is susceptible to soil loss.

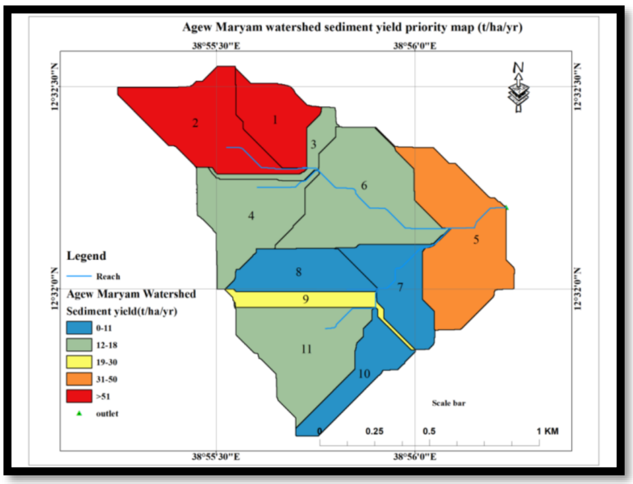

Fig 8: Sediment loss priority map for the planning of Agewmariam watershed

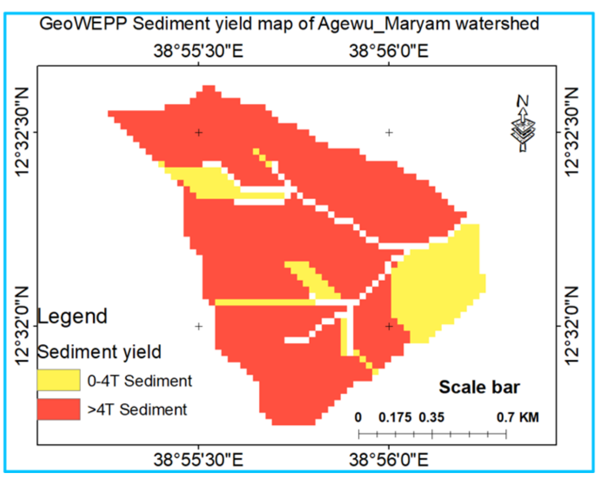

Fig 9: WEPP sediment yield map of Agewmaryam watershed

The highest monthly mean runoff and sediment volumes generated by Geo-WEPP in the watershed were 1.607m3/s and 39.5t/ha/yr in August, respectively, as shown in (Table 4). The long-term mean monthly precipitation, runoff and sediment volumes generated in the watershed by the WEPP model were 522 mm, 54.38 mm, and 43.1 t/ha/yr, respectively (Table 4, Fig. 10). The high long-term average sediment yield may be attributed to the uneven distribution of rainfall and the fact that 41% of the watershed is cultivated land with slopes greater than 30%. These results indicate that soil erosion is associated with slope gradient, with the degree of major erosion increasing with slope gradient for all land use types.

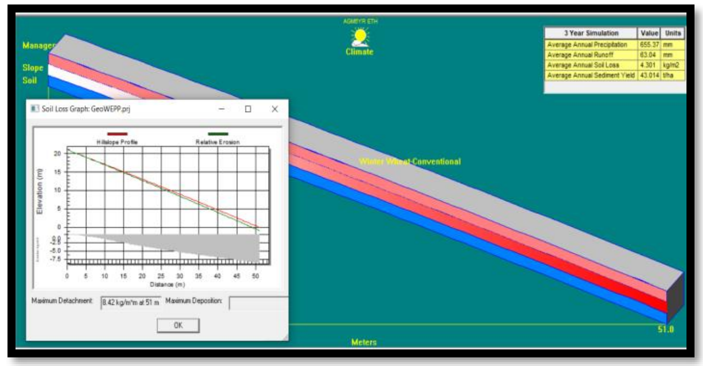

Fig.10. WEPP hill slope erosion

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The WEPP model projections clearly show that the majority of the watershed is discharging more than 4 tons/hectare/year of sediment. 67.4% of the watershed discharges more than 4 tons/hectare/year of sediment (Fig. 9). In contrast, 32.6% of the watershed discharges less than 4 t/ha/yr of sediment outside the watershed. In general, the long-term average annual runoff of the WEPP is 146.14 mm and the amount of sediment generated in the watershed is 43 tons/hectare/year. This result is due to the uneven distribution of rainfall, with 41% of the watershed having a slope of 30% or more, and 63.16% of the watershed being cultivated land.

This watershed is characterized by steep slopes and sparse vegetation (Fig. s 3 and 4), and the WEPP model simulation results reported that the 64.1 t/ha/yr predicted by the WEPP model from the untreated watershed was satisfactory for the northern Ethiopian highlands [26], which is consistent with the results of the study. The above results reported a significant correlation between estimated and observed sediment yield based on R2 (0.99) and NSE (0.92) in wastes from northern Tehran, Iran [27].

The relative soil erosion increases across the hill slope. WEPP model predicts 8.42 kg/m^2 was simulating at 51 m in the hill slope (Fig. 10). The annual rainfall of 655.37 mm generates 63.04 mm of runoff and 43.014 t/ha sediment yield (Fig. 10). The results showed that the soil losses increase along the hill slope. The result agrees with [26] reported that the WEPP model predicts 8.11 kg/m^2 was observed at 20 m in the hill slope.

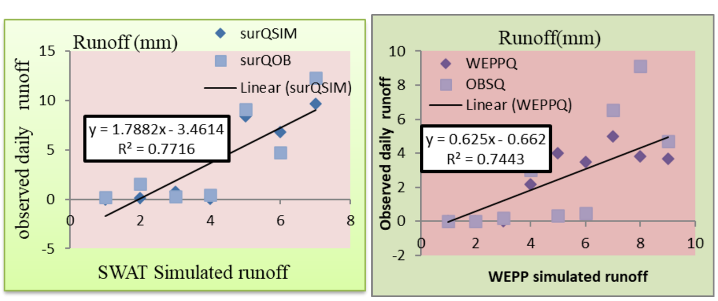
The sediment yield estimation of the WEPP model for the Agewu-Maryam watershed (43t/ha/yr) was in agreement with [26] reported that the WEPP model predicts from the treated and untreated watershed (39.9 and 64.1 t/ha/yr) was a satisfactory result in the northern highland of Ethiopia.

C. *Comparison of model simulated and observed annual runoff and sediment yield*

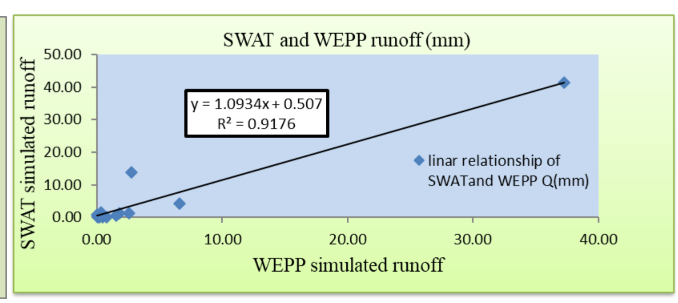
The simulated monthly mean runoff values of the WEPP and SWAT models for the simulation periods were compared with observed values. The observed and simulated monthly mean runoff values along with the 1:1 line for the simulation periods are shown in (Fig. 12 and Fig. 13). The high coefficients of determination (Fig. 11 and Fig. 12) indicate a positive relationship (how much, model explain observed variable) between the measured and simulated runoff for most selected days, months, and year. Furthermore, reasonably the regression R^2 values for the simulation periods selected days (0.74 and 0.77 for WEPP and SWAT, respectively) indicated the satisfactory performance of both models simulated daily runoff (Fig. 11 (a) and Fig. 12 (a). The simulated monthly mean runoff and sediment yield of the SWAT and WEPP model compared graphically (Fig. 11 (b) and Fig. 12 (b)) the estimated result shows that SWAT and WEPP simulated very well with R^2 (0.91) for runoff and (0.88) for sediment yield. These results along with other criteria indicate a satisfactory overall prediction of monthly mean runoff by the WEPP and SWAT models during the simulation period. The simulated and observed value comparison result agrees with the finding [26] reported that R^2 value 0.68 for untreated watershed and 0.61 for the treated watershed and [28] reported that R^2 0.73 and 0.82 for Maki watershed stream flow and sediment yield analysis using SWAT model.

Simulated values of monthly mean sediment yield from the WEPP and SWAT models during the simulation period were compared to observed values (Table 5). Observed and simulated values of monthly mean sediment yield during the simulation period are shown in (Fig. 11) along with a 1:1 line. The high coefficient of determination indicates a positive relationship between the simulated and observed values (Fig. s 11 and 12); the NSE values for the simulated period for WEPP (0.54 and 0.64, respectively) and SWAT (0.71 and 0.56, respectively) runoff and sediment volumes indicate that the model is performing well The NSE values of the WEPP model meant more annual sediment volume than the SWAT model (Table 5), and the WEPP had better sediment volume prediction performance than the SWAT. However, the overall prediction of monthly average sediment yield by the WEPP and SWAT models during the simulation period was satisfactory and was used for further analysis.

The Geo-WEPP model simulation results predicted monthly runoff and sediment yield for the watershed well, with R^2 values of 0.86 and 0.85; the SWAT model simulation results predicted monthly runoff and sediment yield for the Agewu-Maryam watershed with R^2 0.91 and 0.57. In general, the Geo-WEPP and SWAT models performed well in simulating both surface runoff and sediment yield in the watershed with NSE, WEPP performed well in predicting both runoff and sediment yield with R^2 , and SWAT performed well only in predicting runoff in the Agewu-Maryam watershed with SWAT only performed well in predicting runoff in the Agewu-Maryam watershed. This result is consistent with the findings reported [29] that (0.667 and 0.809 for SWAT and 0.832 and 0.816 for WEPP showed satisfactory good results). Another study in northern Ethiopia [30] reported that R^2 (0.84) in the SWAT model showed good runoff.



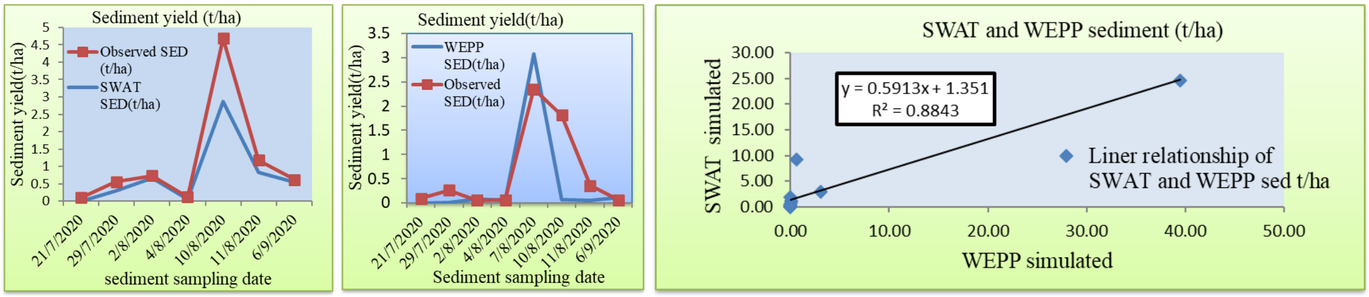
(a)



(b)

Where, surQ SIM = surface discharge simulated, sur OBQ = surface observed discharge WEPPQ = WEPP discharge and OBSQ =observation discharge

Fig.11. Simulated and observed runoff (mm) SWAT and WEPP (a) and simulated SWAT and WEPP runoff (b)



(a) (b)

Where SWAT SED = SWAT sediment yield, WEPP SED = WEPP sediment yield, and observed SED = observed sediment yield.
Fig 12: Simulated and observed sediment yield (t/ha) SWAT and WEPP (a) and simulated SWAT and WEPP runoff (b)

TABLE V. GEO WEPP PREDICTED AVERAGE MEAN MONTHLY RUNOFF AND SEDIMENT YIELD

Models	Precipitation (mm)	Runoff (mm)	R2	NSE	Sediment yield t/ha	R2	NSE
WEPP	782.2	146.14	0.86	0.54	43.1	0.85	0.64
SWAT	782.2	148.42	0.91	0.71	41.7	0.57	0.56
Observed	626.26	93.4			33.36		
Mean	730.22	129.27			39.35		
*SD	90.032	31.12			5.23		
CV	12.32	24.07			13.29		

IV. CONCLUSION

In this research, Soil and Water Assessment Tool (SWAT) and geo-reference water erosion prediction project (Geo-WEPP) models have been used to predict annual runoff and sediment yield for the Agewu-Maryam watershed in the eastern Amhara, the northern part of Ethiopia. The mean average runoff depth, peak discharge and sediment yield for 3 observed year was 93.47mm, 1.39 m3/s and 33.36 t/ha for the Agewu-Maryam watershed. The model simulated mean monthly runoff and sediment yield result was 54.56mm, 43.1t/ha for WEPP model and 65.1mm 41.7 t/ha for SWAT model for 24 simulation year. The SWAT simulation study showed good model performance for monthly runoff prediction at the watershed with acceptable R^2 (0.91) and satisfactory NSE (0.71) values. However, the model performance was poor in terms of predicting sediment loss with lower R^2 (0.57) and satisfactorily NSE (0.56) values. Similarly, the results of the Geo-WEPP simulation study showed satisfactory model performance for runoff prediction at the watershed with acceptable R^2 (0.86) and NSE (0.54) values. Overall, the watershed modeling results indicated that the sediment yield in the entered watershed is above the soil loss tolerable limit (18t/ha/yr). Both the SWAT and Geo-WEPP simulated and the observed results showed that soil erosion is still severe and above the soil loss tolerable limit in the Agewmariam watershed. To sustain agricultural production and minimize the risk of soil erosion and sediment yield in the watershed should be an implementation biological SWC measures and Slope greater than 30% no need of conducting any agricultural activities, rather the area should be protected and conducting rehabilitation such as afforestation and area closure. The SWAT and Geo-WEPP model can be used as decision-making tools in Agewu-Maryam watershed and other watersheds with similar agro-ecologies in the eastern Amhara to predict runoff and sediment yield.

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