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Towards a Decision-Making Approach of Sustainable Water Resources Management Based on Hydrological Modeling: A Case Study in Central Morocco

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Abstract: Water is one of the fundamental resources of economic prosperity, food security, human habitats, and the driver of many global phenomena, such as droughts, floods, contaminated water, disease, poverty, and hunger. Therefore, its deterioration and its inadequate use lead to heavy impacts on environmental resources and humans. Thus, we argue that to address these challenges, one can rely on hydrological management strategies. The objective of this study is to simulate and quantify water balance components based on a hydrologic model with available data at the R'Dom watershed in Morocco. For this purpose, the hydrologic model used is the Soil and Water Assessment Tool + (SWAT+) model. The streamflow model simulations were run at the monthly time step (from 2002 to 2016), during the calibration period 2002–2009, the coefficient of determination (R^2) and Nash–Sutcliffe efficiency (NSE) values were 0.84 and 0.70, respectively, and 0.81 and 0.65, respectively, during the validation period 2010–2016. The results of the water balance modeling in the watershed during the validation period revealed that the average annual precipitation was about 484 mm, and out of this, 5.75 mm came from the development of irrigation in agricultural lands. The evapotranspiration accounted for about 72.28% of the input water of the watershed, while surface runoff (surq_gen) accounted for 12.04%, 11.90% was lost by lateral flow (latq), and 4.14% was lost by groundwater recharge (perco). Our approach is designed to capture a real image of a case study; zooming into other case studies with similar environments to uncover the situation of water resources is highly recommended. Moreover, the outcomes of this study will be helpful for policy and decision-makers, and it can be a good path for researchers for further directions based on the SWAT model to simulate water balance to achieve adequate management of water resources.

Keywords: SWAT+ model; R'Dom watershed; streamflow; calibration; validation; water balance

1. Introduction

Water resources hold a special position among all natural resources and are the basis for the development of all life systems on the planet [1,2]. It is considered a significant economic resource and a highly distributed element on the planet and is available in all parts of the globe, although in varying quantities, it is essential to both the environment and human life [2]. However, the rapid increase in the human population and accelerating lifestyle changes due to increasing urbanization and rapid industrialization are putting heavy effects on these natural resources.

The global water cycle, or hydrologic cycle, includes water in the atmosphere, the oceans, and the landscape and under the land surface [3,4]. It can be completed by exchanges of water between these reservoirs in various phases [5,6]. Water evaporates from the oceans and the land surfaces into the atmosphere, where it is transported as water vapor above the Earth's surface [7]. It eventually condenses in clouds and returns as precipitation to the Earth's surface in the form of rain, snow, sleet, or hail [3]. Several factors interact with the hydrological cycle, such as soil, topography, vegetation cover, climate, and water bodies [8]. In response to climate changes, the hydrologic cycle is subdivided into surface runoff, which represents the water circulating on the ground surface, and lateral flow, which represents the movement of water under gravitational forces parallel to the slope of the land and groundwater recharge, which represents the water moving downward from surface water to groundwater [9]. On the other hand, several factors, including irrigation activity, land treatment, deforestation, human-induced climate change, and other human activities, affect anthropogenic practices, land development [10,11], and the hydrological cycle [5].

Previously, different approaches have been applied and used to simulate and quantify the water balance components including, Système Hydrologique Europeén (SHE) [12], Water Evaluation And Planning (WEAP) system [13], the water and energy transfer among soil, plants, and atmosphere (WetSpass) model [14,15], Topographic Hydrologic Model (TOPMODEL) [16], the Distributed Hydrology Soil Vegetation Model (DHSVM) [17], HYDRUS-1D numerical model [18], and Soil and Water Assessment Tool (SWAT) [19]. As an easy and widely used model [20], SWAT is eminently suitable for water-resource modelling [21].

The Fez-Meknes region in Morocco is responsible for approximately 21.1% of the country's gross domestic product (GDP), and so the local population is strongly linked to agricultural activities [22]. This may have a negative influence on water resources [23]. Towards the goal of the sustainable development of the local socio-economy and water management, several studies have been conducted in this region. It has been reported that farmers' safety behavior can pose negative effects related to the use of pesticides [24]. Additionally, the quantification of soil erosion with risk assessments was considered by Boufala [25]. Moreover, [26] have demonstrated that population growth and LULC changes result in increased water consumption.

R'Dom combines forestry, pastoral, agricultural, and irrigation activities, and it is sensitive to climate change and human influences, leading to heavy challenges in terms of the sustainability of its land and water resources [23].

In Morocco, several case studies using the SWAT model have been applied, with great outcomes [27–30]. However, Bouslihim et al. 2019 [31] reported that these cases studied were done without checking the effect of input data on different hydrological components of the watershed. In this context, the study developed in this paper is based on remote sensing open data and preprocessed and validated input parameters.

To the best of the researcher's knowledge, no previous study has been carried out to estimate and assess the spatial distribution of water balance components in this watershed based on validated data and open-source remote sensing inputs. The novelty of this research project is the testing and application of a SWAT+ hydrological model to quantify the water balance in its different components. The model results will serve as proof of how sensitive the water resources are to climatic changes, especially for the project area, where rainfall and temperature play a major role in determining the distribution of water in the land and in the atmosphere. The treated aspect of this work focused on the analysis of flow data during the calibration and validation periods.

The objectives of this study were: (i) to create a hydrological model of the R'Dom watershed, (ii) to calibrate and validate the SWAT+ model R'Dom river basin, and (iii) to estimate and assess the spatial distribution of water balance components and water yield. We therefore hypothesized that the SWAT model could be used for representing hydrological processes with promising results in this watershed.

The SWAT + model was developed and applied to predict the impact of land management practices on water, agricultural chemicals yields and irrigation systems, and sediment in large complex watersheds with varying LULC, soil proprieties, and management conditions over long periods of time [32–34]. We chose the SWAT+ model because of its availability and ease of use in processing the input data, and its suitability to different parts of the world has been well established [35]. This model requires several input data, such as geospatial and weather data records from local stations [36]. The results obtained from this work can facilitate the estimation of the spatial distribution of water balance components in response to climatic, pedologic, and topographic factors. Concerning irrigation farming, several factors determine crop water demand, such as soil properties (available water-holding capacity), hydrological processes (precipitation and infiltration) distribution, and crop characteristics (leaf area and rooting depth) [37]. Ultimately, the contribution of this research aligns with the Sustainable Development Goals (SDGs), which may represent a first path to reducing adverse impacts on water resources in this region. Through this important study, the application of the SWAT+ model can be at the heart of the policy of water management and land development and is in the context of the major objective of the quantitative and qualitative preservation of water resources. It must also consider the interactions of water resources with the environment within the framework of a global policy of regional development.

The structure of the paper is organized as follows. Section 2 gives a description of the study area, the data, and the methodology used in this study. Section 3 provide the results and discussion, and conclusions are given in the last section.

2. Materials and Methods

2.1. Research Site

The R'Dom watershed is located in the northwestern region of Morocco (Figure 1), covering an area of 1970 km^2. It extends from the longitudes 5.29°–5.75° W and the latitudes between 33.47°–34.01° N [23]. Located 140 km to the east of Rabat city and 60 km to the west of Fez city [38]. Topographically, the study area has a moderate flatland in its central parts and mountainous lands in the northern and southern parts, with a maximum altitude of 1778 m at the southern end and a minimum altitude of 29 m in the northwestern parts. The climate of the R'Dom watershed is semi-arid, with average annual precipitation varying between 300 and 500 mm. The annual mean temperature is 17.6° with a minimum of 9.4 °C in January (coldest months) and a maximum of 26.3 °C in August (warmest months). From a hydrological point of view, the R'Dom watershed has a large network of streams that have a very low discharge during the prolonged dry season.

2.2. SWAT+ Input Datasets

The implementation of the SWAT model is based on site-specific information, including weather, topography, land use, soil properties, and the land management practices considered in the watershed. The physical aspects are linked to sediment movement, water movement, nutrient cycling, and crop growth. Table 1 presents the input data used to run the SWAT+ model in the R'Dom area. Land use/land cover maps, digital elevation models, soil maps, climate data (precipitation, maximum, and minimum daily air temperatures, relative humidity, solar radiation, and wind speed), and streamflow data were used in this study.

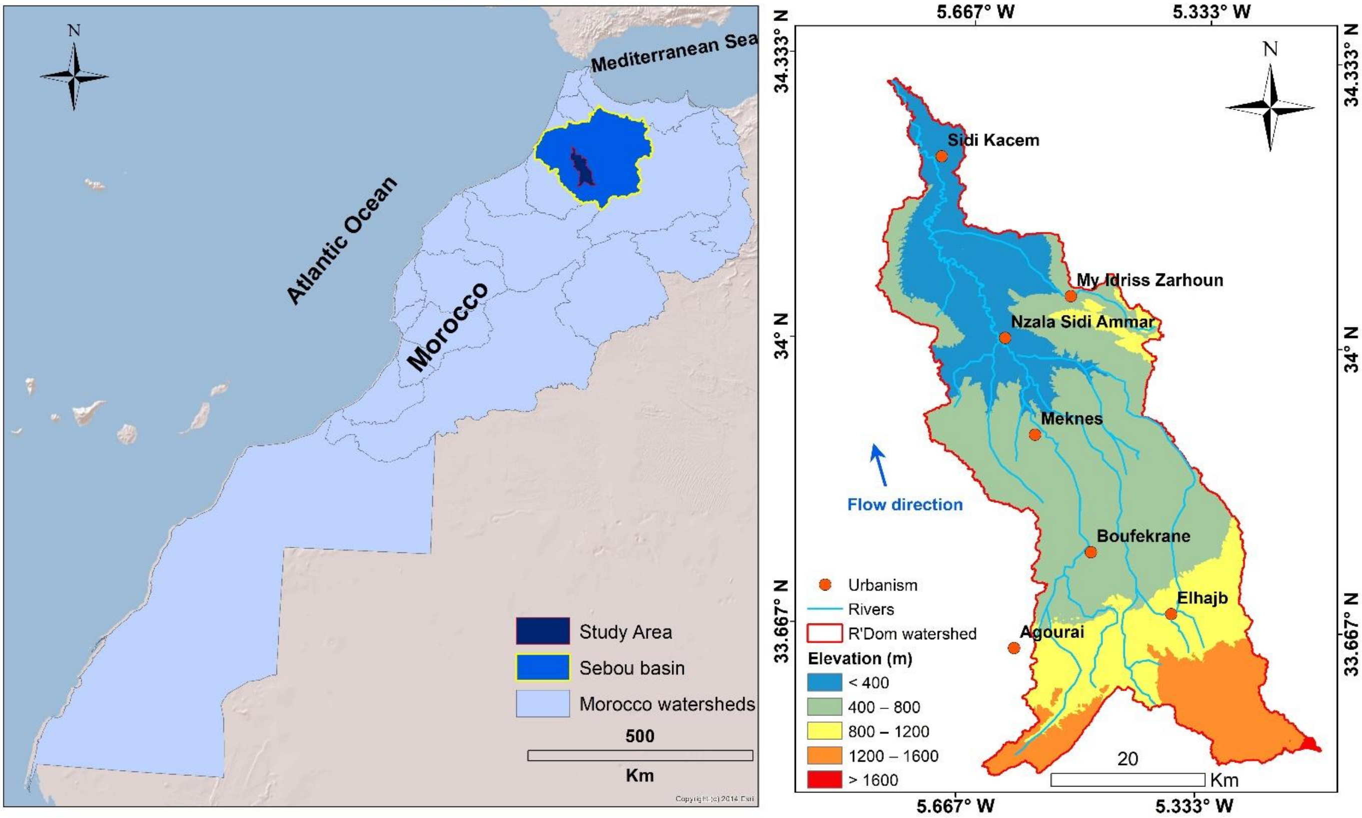

Figure 1. Location of the Study Area.

Table 1. Data description.

Data Type	Source	Spatial Resolution	Temporal Resolution
Digital elevation map (DEM)	Shuttle Radar Topography Mission (SRTM), https://earthexplorer.usgs.gov, (accessed on 3 August 2021)	30 m	-
Land use	sentinel-2 image, 2016 https://scihub.copernicus.eu/dhus/#/home (accessed on 18 May 2021)	10 m	-
Soil	National Institute of Agronomic Research	30 m	–
Climate data	Sebou Hydraulic Basin Agency (SHBA)	Point dataset	Daily
River discharge	Sebou Hydraulic Basin Agency (SHBA)	Point dataset	Monthly
Irrigated areas	Food and Agriculture Organization	0.000992°	–

2.3. Crop and Irrigation Water Requirement

The SWAT+ model is a tool used for understanding hydro-agronomic processes, and it is considered a complete and reasonable model suitable for most conditions of irrigation districts to estimate irrigation water requirements [39]. The land use in the R'Dom watershed is relatively diversified, with a dominance of cereals; the rest is occupied by fruit crops, legumes, industrial crops, oil crops, vegetable crops, and forage crops. Surface irrigation is the common method of irrigation used in the R'Dom catchment, and most irrigation schemes' water are distributed by gravity. Drip and short furrows are commonly used in the study area, and the furrows are used to irrigate vegetables and some cereal crops, such as maize. Irrigation water sources include river diversions and shallow aquifers. The total irrigated area was 2649.29 ha, which is 1.37% of the total arable land in the region, and the water used was about 5.75 mm (Figure 2).

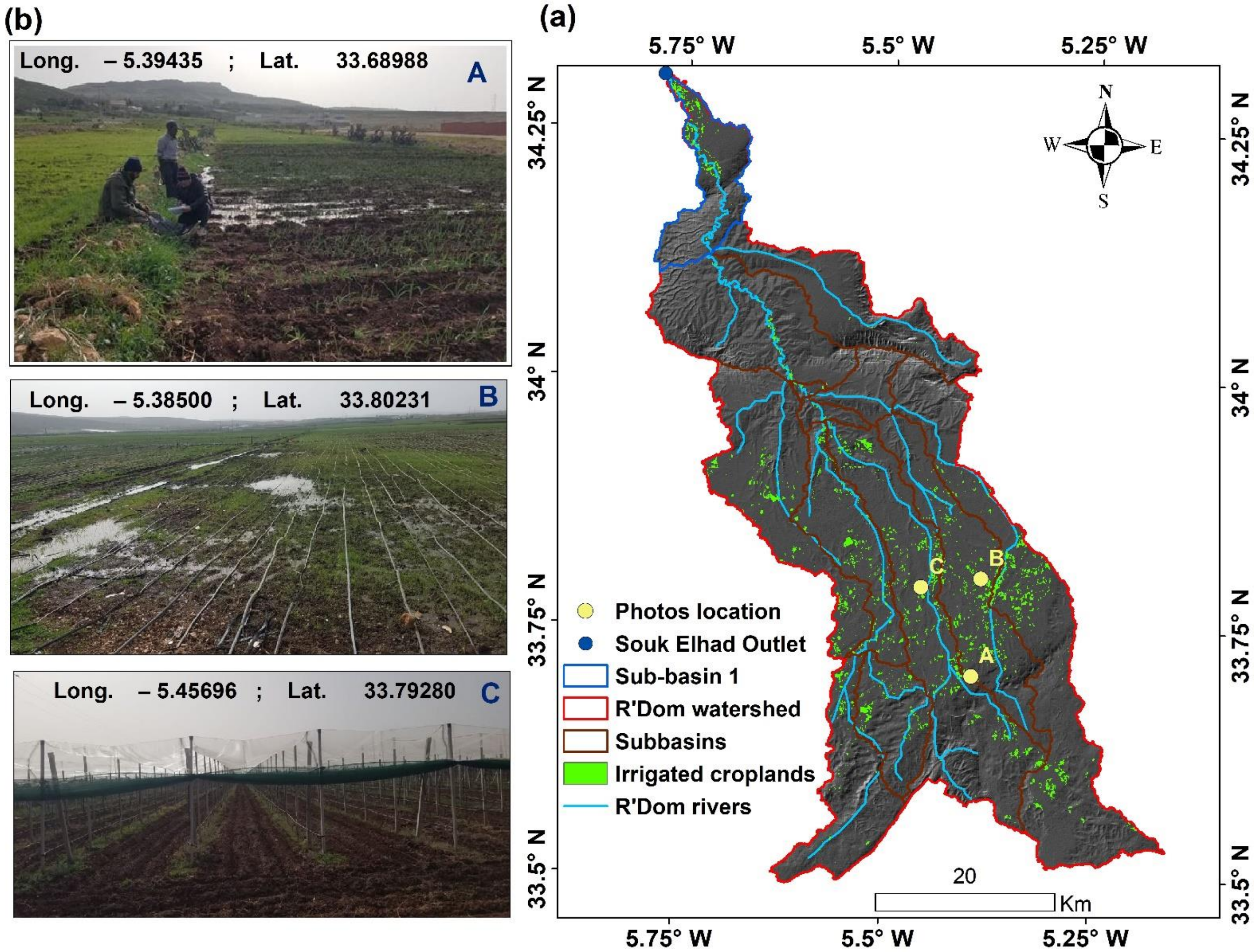

Figure 2. (**a**) Map showing irrigated areas in R'Dom catchment, (**b**) Photograph of irrigated areas taken on 30 January 2022.

2.4. Methodology

The SWAT model is a physically based, semi-distributed, and continuous-time step hydrologic model that permits the manipulation and analysis of numerous hydrological and agronomic data. Based on land use/land cover, soil type, and slope classes, the catchment is divided into hydrological response units (HRUs), which are areas of unique properties of slope, soil, and land use/land cover classes within each sub-basin [39]. The SWAT model, like other modeling tools, requires many geospatial data for water models and solute flow in different watershed scales [40]. The linkage of SWAT with GIS allows for managing and processing raster, vector, and alphanumeric data. GIS provides easy and automated preparation of SWAT input data.

Figure 3 illustrates the detailed methodology applied in this study, and the hydrological modeling simulated by the SWAT+ model is based on the following equation:

$$SW_t = SW_0 + \sum_{i=1}^{n} \left(R_{day} - Q_{surf} - W_{seep} - E_a - Q_{gw} \right) \quad (1)$$

where:

SW_t represents the humidity of the soil (mm),
SW_0 is the base humidity of the soil (mm),
t is the time (days),

R_{day} is the rainfall volume (mm),
Q_{surf} represents the value of surface runoff,
E_a represents the value of evapotranspiration (mm),
W_{seep} represents the value of seepage of water from the soil into deeper layers,
Q_{gw} represents the value of underground runoff (mm).

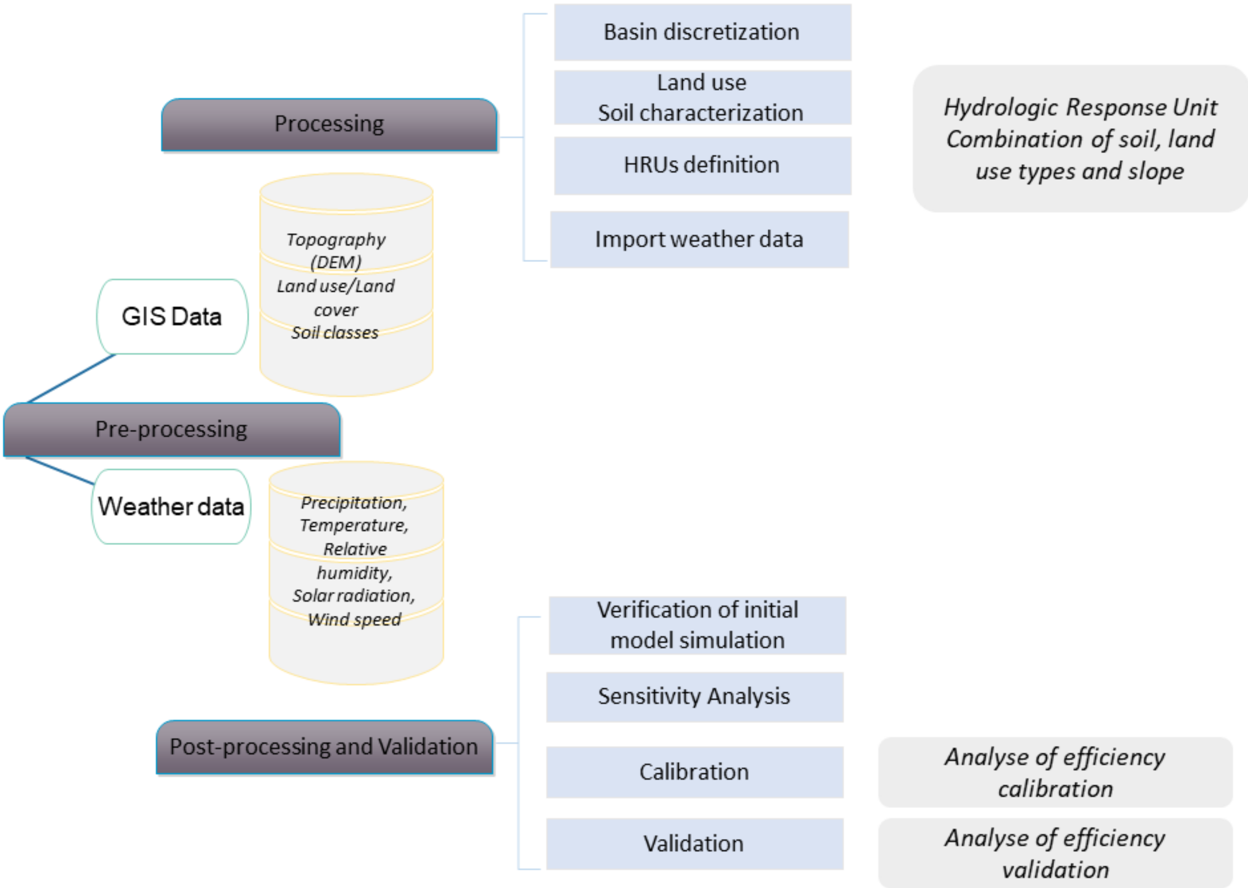

Figure 3. Workflow of the methodology followed in this study.

2.4.1. Streamflow Data

Runoff is generated mainly from cold mountainous regions; the flow occurs along a sloping surface when the rate of rainfall is greater than the infiltration rate. The runoff rate in the R'Dom area is a function of the proportion of daily precipitation that falls during the sub-basin concentration time, daily surface runoff volume, and sub-basin concentration time. In general, flows are high from January to April, reaching their maximum in February. The flow of water in the southern rivers of the basin continues in spring in association with springs resulting from snowmelt. Minimal flows were observed in the summer. The R'Dom River is an intermittent river with a mean monthly discharge of 3.74 m^3/s measured at Souk El had outlet for the period of 2002/2016.

2.4.2. SWAT+ Model

The SWAT+ model was applied in this study to achieve the sustainable use of water resources, such as the evaluation of the stream flow at the Souk Elhad gauge and to estimate the spatial distribution of the water balance in the R'Dom watershed. The model is ready for simulation when all data files have been prepared and all model inputs have been completed. The simulation was run for 17 years (2000/2016), and the estimated and measured flows were evaluated at the Souk Elhad station (catchment outlet) sub-basin 1.

2.4.3. Model Performance Evaluation

The evaluation of the model performance can be applied by combining goodness of fit statistics and graphical plots. These statistics include Nash-Sutcliffe Efficiency (NSE) and Determination Coefficient (R2). The NSE [41] is a performance indicator of the predictive power of models by comparing modeled flows to observed flows. The coefficient of determination is a concept used in regression analysis and analysis of variance. It is a measure of the proportion of variance in the data that can be explained. Their equations are shown below:

$$NSE = 1 - \frac{\sum_{i=1}^{n} \left(Q_{sim}^{i} - Q_{obs}^{i}\right)^2}{\sum_{i=1}^{n} \left(Q_{obs}^{i} - Q_{obs}^{mean}\right)^2} \quad (2)$$

$$R^2 = \frac{\sum_{i=1}^{n} \left(Q_{obs}^{i} - Q_{obs}^{mean}\right)\left(Q_{sim}^{i} - Q_{sim}^{mean}\right)}{\sqrt{\sum_{i=1}^{n} \left(Q_{obs}^{i} - Q_{obs}^{mean}\right)^2 \sum_{i=1}^{n} \left(Q_{sim}^{i} - Q_{sim}^{mean}\right)^2}} \quad (3)$$

where:

Q_{obs}^{i} is the observed parameter's value,
Q_{sim}^{i} is the simulated parameter's value,
Q_{obs}^{mean} is the mean of observed parameters,
Q_{sim}^{mean} is the mean of simulated parameters,
n is the number of time intervals.

3. Results and Discussion

3.1. Hydrologic Parameter Assessement

The Curve Number (CN2) and available soil moisture content (AWC) are some of the key parameters for the generation of surface runoff [42]. To allow for the best concordance between the simulated and observed variables, it is necessary to adapt some parameters of the model by calibration. It focuses on the soil parameters that have an essential impact on the simulations. The first control variable of calibration concerns the flow rate of the measuring station at the monthly time step. CN2, AWC, and ESCO were identified as the most influential susceptible parameters in the response of runoff generation. The ESCO, EPCO, Perco, and K were all identified as parameters that had a significant effect on water balance during the calibration process. More details are given in Table 2.

Table 2. Summary of the model calibration parameters.

Parameter	Definition	Unit	Range	Type of Change	Best Value	References
CN2.hru	Initial SCS CN II value	null	25–98	Percentage	−22.80795	[43]
cn3_swf.hru	Soil water factor for cn3	null	0–1	Percentage	8.89045	[43]
Ovn.hru	Manning Coefficient	null	0.1–30	absolute value	0.74993	[43]
ESCO.hru	Soil evaporation compensation factor	null	0–1	absolute value	0.04	[43,44]
EPCO.hru	plant uptake compensation factor	null	0–1	absolute value	0.00785	[43,44]
Perco.hru	Percolation	(mm H_2O)	0–1	absolute value	0.80787	[43]
Alpha.aqu	Baseflow alpha factor	day	0–1	absolute value	0.03163	[43,44]
bf_max.aqu	Baseflow rate when the entire area is contributing to Baseflow, default =1	mm	0.1–2	absolute value	1.63215	[43]
flo_min.aqu	Minimum aquifer storage to allow return flow	mm	0–5000	absolute value	48.52915	[43,44]

Table 2. *Cont.*

Parameter	Definition	Unit	Range	Type of Change	Best Value	References
AWC.hru	Available Water Capacity	mm_H$_2$0/mm	0.01–1	absolute value	0.87555	[43]
K.hru	Saturated Hydraulic Conductivity	mm/h	0.0001–2000	absolute value	68.14435	[43]

3.2. Calibaration and Validation

The SWAT+ model was calibrated using an automatic calibration technique. The monthly observed streamflow data from 2002–2009 were used for model calibration, and those from 2010–2016 were used for model validation. The data from 2000–2002 were kept as a warming-up period, which allowed the model to initialize and approach reasonable initial values of the state variables of the model. The performance of the developed model during calibration and validation was evaluated using selected statistical indicators, NSE, R^2, and graphical indicators. The model was evaluated to have the simulated flow series be as close to the observed (Measured) flow series (Figure 4), and the maximum values of both flows for the calibration period were about 40 m^3/s and high as 25 m^3/s for the validation period. These flow values are more concentrated, as low as 10 m^3/s (Figure 5). Figures 4 and 5 illustrate an almost similar distribution of the observed and simulated streamflow hydrographs for both the calibration and validation periods. The results of the model performance are summarized in Table 3 and Figures 4 and 5.

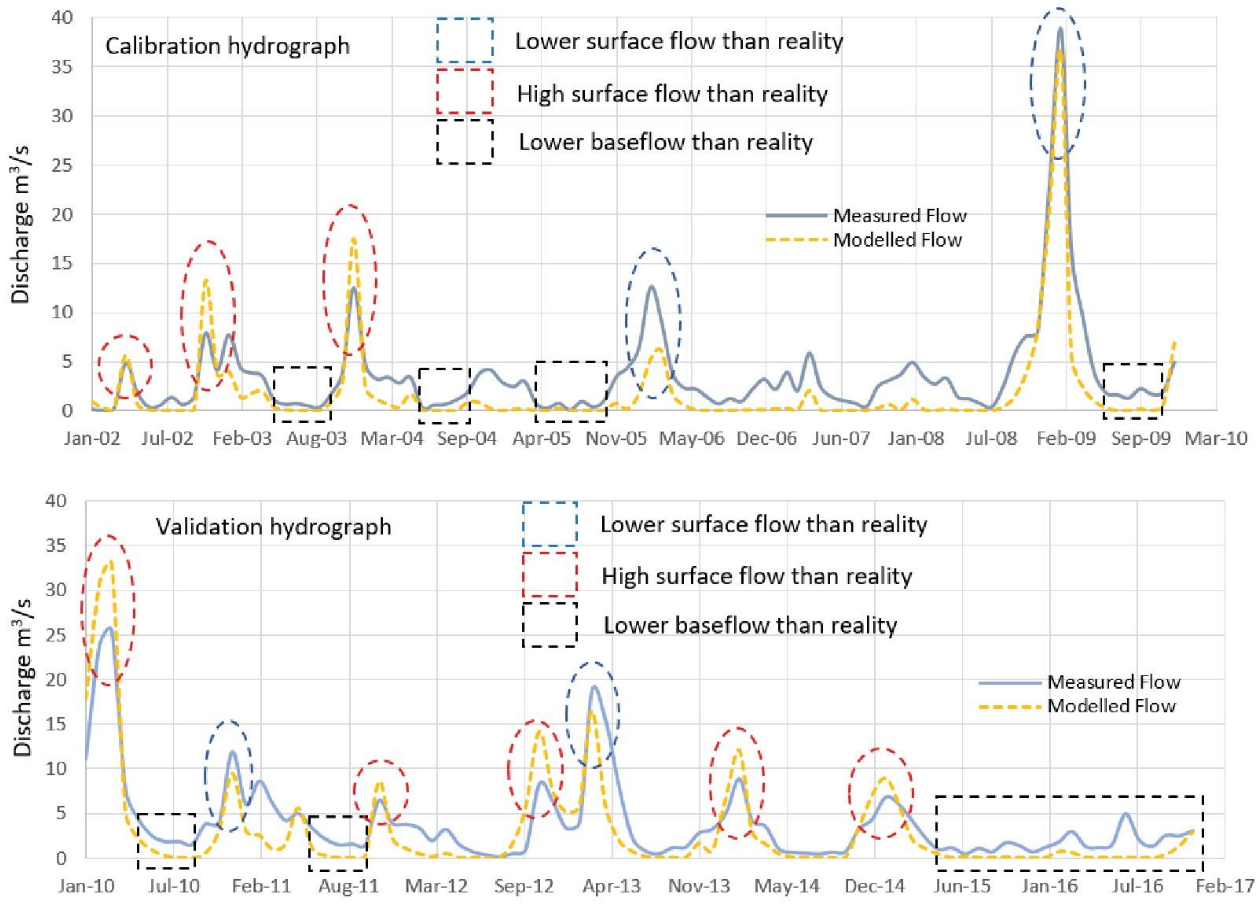

Figure 4. Comparison of Monthly Streamflow Hydrographs of the model calibration and validation.

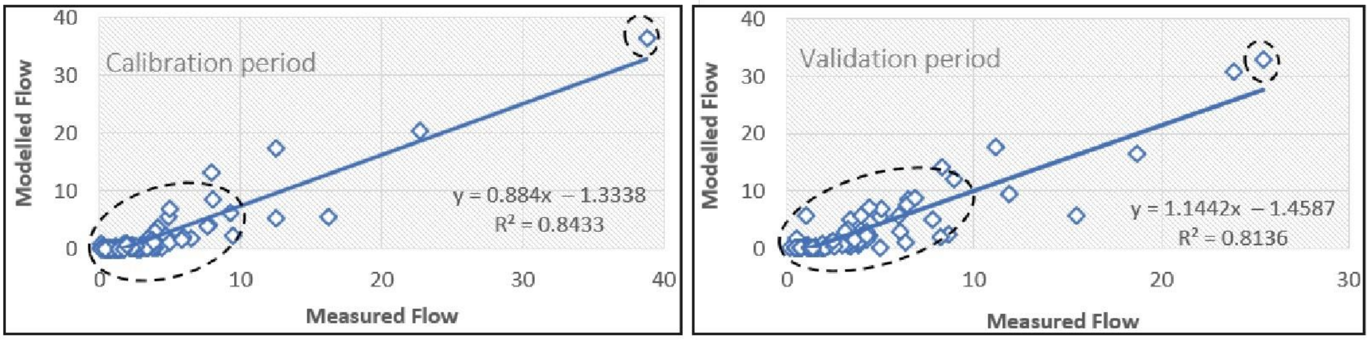

Figure 5. Correlation between monthly observed and simulated flows.

Table 3. Model performance statistics for simulating monthly streamflow.

Statistical Indicators	Calibration Period (2002–2009)		Validation Period (2010–2016)	
	Observed	Simulated	Observed	Simulated
Mean (m^3/s)	3.55	1.80	3.95	3.06
STDEV (m^3/s)	5.03	4.84	4.62	5.85
NSE	0.70		0.65	
R^2	0.84		0.81	
Pearson Correlation Coefficient	0.69		0.71	

3.3. Spatial Distribution of Water Balance

The R'Dom watershed is divided into sub-watersheds, which are divided into landscape units. The input layers for each sub-basin are climate, land use/land cover, soil, ponds/wetlands, groundwater and the main channel draining the sub-basins. Furthermore, the processes in the watershed are governed by the water balance, in which the hydrologic cycle must be consistent with what is happening in the watershed.

The simulation of the hydrologic cycle for the period 2002–2016 is divided into the land phase processes and the water or routing phase [41]. The hydrological components that are simulated in this process include precipitation, surface runoff, evapotranspiration, lateral flow, and percolation. The potential for water movement simulated in SWAT+ is shown in the maps in Figure 6.

3.3.1. Rainfall

The obtained SWAT water balance results show that the precipitation distribution varies between 409 and 609 mm (Figure 6a); the maximum value was simulated in the south (upstream) and decreases toward the north (downstream).

3.3.2. Evapotranspiration

The annual average of evapotranspiration (ET), which includes evaporation from a variety of surfaces, such as rivers, irrigation water basins, soils, and transpiration from within the leaves of plants. The options offered by SWAT+ for calculating potential evapotranspiration (PET) are Penman-Monteith [45] and Hargreaves [46,47]. The spatial distribution of ET ratios showed the same gradient as rainfall, with the highest ET values dominating the southern and central areas of R'Dom due to dense vegetation, barren land, and many irrigated areas. The average minimum and maximum ET are 330 and 530 mm, respectively, with a decreasing gradient from south to north (Figure 6b).

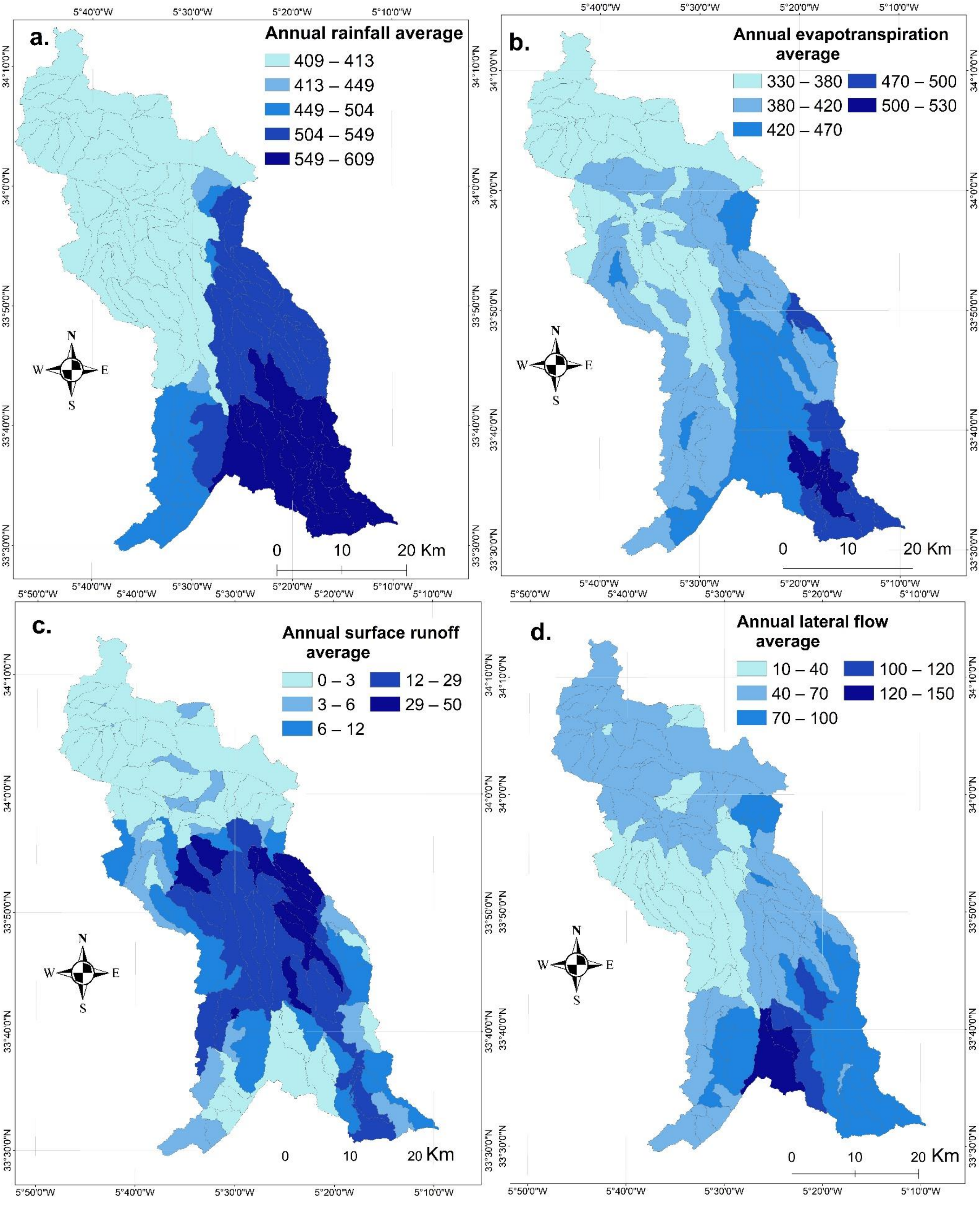

Figure 6. Spatial distribution of water balance components (mm) per landscape (2000/2016): (**a**) Annual rainfall average, (**b**) Annual evapotranspiration average, (**c**) Annual surface runoff average, and (**d**) Annual lateral flow average.

3.3.3. Surface Runoff

According to the results (Figure 6c), the minimum and maximum annual average runoff ranges between 0 mm and 50 mm, respectively. The factors that influence the spatial distribution of surface runoff include the land's topography, soil permeability, and water supply for agricultural irrigation, which increase water residence time, evaporation, and groundwater recharge.

3.3.4. Lateral Flow

The lateral flow map generated by the SWAT+ hydrological model shows that the value of the latq factor varies from 10 to 150 (Figure 6d). High values are observed in the areas of high topography and hydraulic conductivity of the soil provided by the existence of many forests and trees upstream and downstream of the basin, while low values are observed in the central part of the basin.

3.3.5. Percolation

The resulting percolation map (Figure 7a) shows the amount of water percolating to the groundwater (recharge of the aquifer), ranging from 0 to 80 mm over the entire study area. High percolation was simulated in the southern part of the R'Dom area, which corresponds to the high rainfall distribution and the main soil properties in this region of the basin, which allowed the important infiltration and recharge of aquifers. Water percolation decreases downstream as average precipitation decreases.

3.3.6. Water Yield

The R'Dom area is dominated by an average annual water yield ranging from 20 mm to 150 mm (Figure 6b). The water yield in a watershed is estimated using the following equation (Equation (4)), which includes surface runoff (Qsurf), lateral flow (Qlat), groundwater contribution to streamflow (Qgw) and transmission losses (Tloss) [48].

$$\text{Wyield} = \text{Qsurf} + \text{Qlat} + \text{Qgw} - \text{Tloss} \tag{4}$$

where:

Qsurf is the surface runoff;
Qlat is the lateral flow;
Qgw is the groundwater contribution to streamflow;
Tloss is the transmission loss.

3.3.7. Water Balance

The assessment of watershed hydrology, both calibrated models and validated water balance ratios (Table 4) and Figure 7c,d were used, and the results revealed a small difference between the two models. The water balance results at the R'Dom watershed during the simulation period (2002–2016) show that the catchment receives an average of 459.50 mm and the potential ET (PET) is about 1619.1 mm, which is calculated using the Penman–Monteith Equation by SWAT. ET accounts for more than 70% of the total input, surface flow accounts for 12.04% of the total precipitation, whereas 11.90% contributes to the lateral flow, and total aquifer recharge accounts for 4.14%.

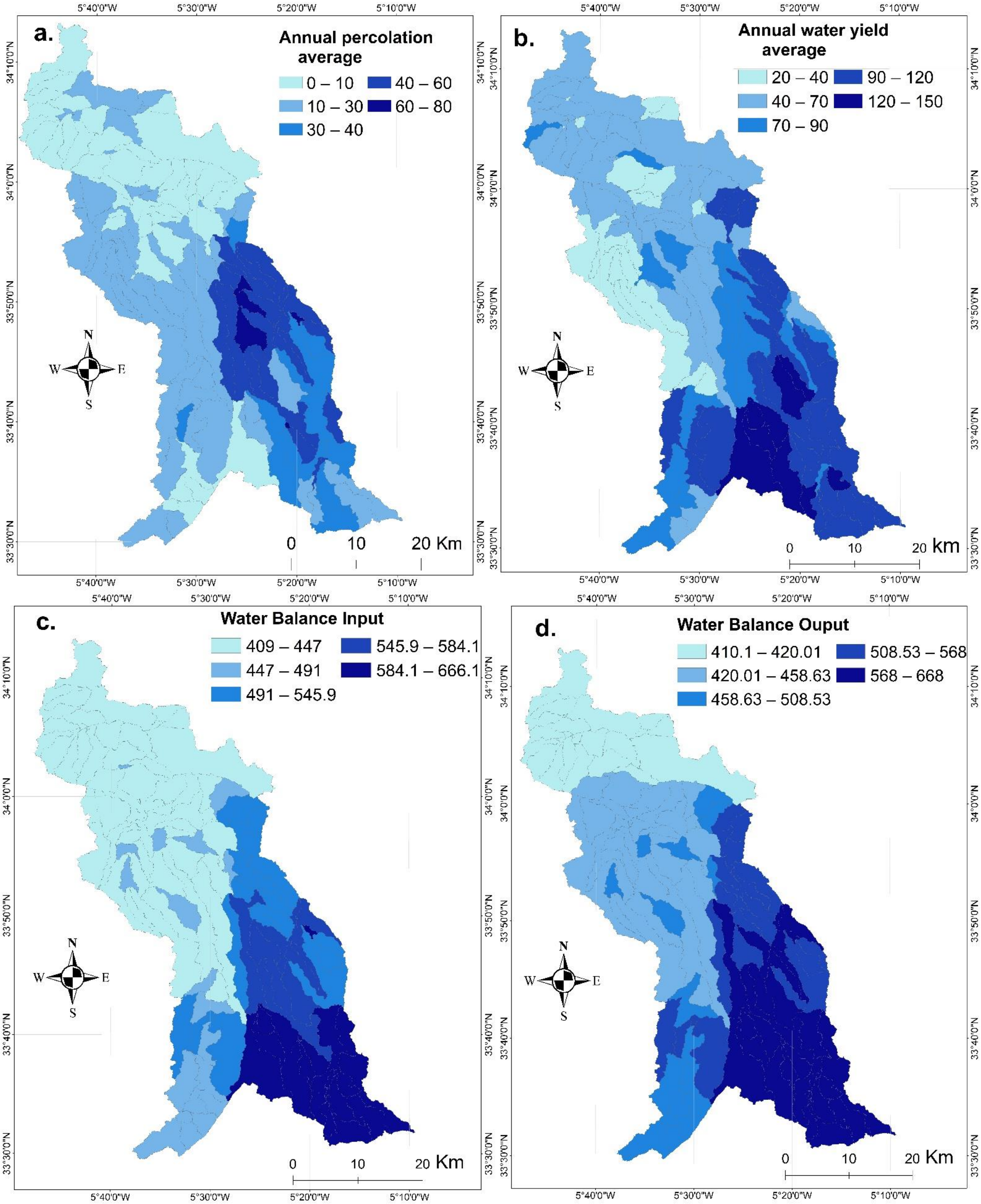

Figure 7. Spatial distribution of water balance components (mm) per landscape (2000/2016): (**a**) Annual percolation average, (**b**) Annual water yield average, (**c**) Water balance input, and (**d**) Water balance output.

Table 4. Water balance components.

	Parameter	Mean Values for Calibration (mm)	%	Mean Values for Validation (mm)	%	Average	%
Input	Precipitation Irrigation	435 5.94	100	484 5.75	100	459.5 5.85	100
Output	Surface runoff	56.43	12.70	59.7	12.04	58.02	12.73
	Lateral flow	37.2	8.46	58.3	11.90	47.75	10.26
	Percolation	10.6	2.40	20.3	4.14	15.45	3.32
	Evapotranspiration	331	75.06	354	72.28	342.5	73.60
Balance	Input–Output	5.71	1.28	−5.55	−1.12	0.08	0.03

Water demand is increasing considerably, while the supply remains fixed with considerable losses, both in agriculture, industry, and domestic activity. The water problem is therefore topical, with the general observation that Morocco has gone beyond the period of abundant water availability to enter a new era characterized by water scarcity and irregular supply [49]. Water management and planning, particularly in the medium- and long-term, are therefore critical to ensuring the country's water and food security. Water balance is the numerical result of comparing the total water inputs to a watershed with the water outputs. Water balance plays an interesting role in determining the amount of water available for use in a region. The physicochemical characteristics of the watershed, including land use, topography, and soil, influence the components of water balance. The landscape unit (LSU) is the sub-unit in the SWAT model and is used to simulate water balance processes. The water balance components simulated by SWAT+ allowed for basic comprehension of hydrological processes to be established to address water management issues in the basin. The research suggests that the SWAT+ model shows promise as a tool for predicting water balance and water yield to support policy and decision-making for sustainable water management at the basin level.

Previously, [50] studied the impacts of climate change on water balance in the Guajoyo River Basin (El Salvador) based on the SWAT model. Their results show a decreasing trend in the amount of water available during the base period (1975–2004). [51] applied SWAT to simulate hydrological processes in a mountainous watershed in northwest China. They found rising trends at the watershed scale, and the total runoff increased by 30.5% during the period 1964 to 2013.

In our case, the results of the water balance showed that the watershed was largely affected by water loss through evapotranspiration and represented 68% of the water input to the watershed. Other authors in other areas with similar contexts in Morocco confirmed these results. The results of a study conducted by [52] showed that the evapotranspiration rate was 453.2 mm, representing 65% of rainfall. Similarly, SWAT results showed that the estimated evapotranspiration loss rate is around 77% of the total annual rainfall in the Sebou watershed, and high water yields are found in the irrigation area east of Meknes. This is due to the lower AWC of the soils in this area, which causes more water stress in the crops. As a result, there will be more irrigation demand in this area with an increase in the water yield [53]. In addition, according to the study of M'Barek et al. [54] the El Grou watershed's hydrological system is dominated by evapotranspiration, which represents 75% of the total precipitation.

Additionally, the hypothesis of this study is focused only on whether the quantity of water loss from land returned as a vapor to the atmosphere is high. Therefore, the government and water managers must look for new technologies and methods to reduce evapotranspiration and use hydrological models to implement effective planning for water management policies in the area.

4. Conclusions

This research was conducted with the main aim of simulating streamflow and assessing water balance in the R'Dom watershed in Morocco. The model was calibrated and validated with monthly streamflow data. Furthermore, different water balance components were investigated and analyzed to infer appropriate conclusions for the sustainable management of the watershed. For the model output comparison, the Nash–Sutcliffe efficiency (NSE) was used. The SWAT+ model has been successfully implemented in the watershed, and this has provided comprehensive results on hydrological processes. This approach model has major advantages, such as: (a) the data used is mostly global and freely available from the internet; (b) the ungauged watersheds without monitoring data (e.g., flow data) can be successfully modeled; (c) it is a computational efficiency model which can be simulate very vast basins with a lot of management options without expending a lot of time or money; and (d) the SWAT+ model is a public domain model that is capable of integrating a modelled the climate change and its impacts on hydrology. On the other hand, the disadvantages of the SWAT model are that there are significant conceptual limitations in simulating groundwater flow and storage in the aquifer system, and they are not designed to simulate detailed single flood events.

The calibration and validation results suggested that the NSE is 0.70 and 0.65 for the monthly time step, respectively; the results should only serve as proof of how sensitive the streamflow is to climatic conditions, wherein each water balance component plays a major role in determining the outflow of the R'Dom watershed. According to the water balance, most precipitation (72.28%) returns to the atmosphere as water vapor evaporated from the soil and transpired by the plant, 12.04% of precipitation contributes to surface runoff, 11.90% contributes to lateral flow, and 4.14% contributes to total aquifer recharge. According to this study, the SWAT+ model is a viable model for predicting water balance and yields great results to support policies and decision-making for sustainable water management.

There are some natural solutions applied in the region to reduce evapotranspiration, including planting to capture rain and deliver it to the tree, growing crops under cover against insolation, using certain soil fertilizers, and planting olive trees around the farms. Not all trees and vegetation are transpiration efficient and can withstand periods of semi-arid conditions. Native species to the area are often recommended due to their long history of local weather adaptations. Many studies indicate that pines use an excessive amount of water because their stomata stay open or do not close contrary to some other plants. Some plants have waxy leaves that help retain water. Another way to reduce ET is to plant a "windbreak" of trees and shrubs. This is particularly effective in warm-dry climates that are windy. Note that the trees and shrubs will use water. Therefore, trees, and shrubs growing in a windbreak may offset any ET reduction in a field, and the reduction in the amount of air-water reduces evaporation in a reservoir. Keeping this in mind, the application of the SWAT+ model can provide water resources managers of the basins with indicators likely to feed the reflection around the impacts of climate changes and land use and promote decision-making at the scale of sub-basins of Moroccan territory.

Accordingly, the following suggestions are made for the study's advancement and for future research: (i) the input data used is partly responsible for the model's accuracy. It is highly advised to include the impact of irrigation across the study region, and it is crucial to obtain more precise data, particularly regarding climate. (ii) Since watershed outflow is mainly governed by climatic data, such as rainfall and temperature, a more simplified conceptual model could be done using a longer simulation period. (iii) Due to the effect of climate changes and land-use changes, the possible extension of this study is to use the SWAT+ model to assess the water quantity of the R'Dom area or for the entire Sebou basin.

This approach may therefore yield good results, which will serve as a guide for water management in this study. In addition, the developed approach could be applied in different study areas with similar backgrounds. Therefore, it may play a role as a powerful tool for management activities to follow by decision-makers in water studies.

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