Groundwater Potential Mapping Using SWAT and GIS-based Multi-Criteria Decision Analysis

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Introduction

- In arid and semiarid regions, groundwater is the most valuable freshwater resource that can be developed fairly economical and used for agricultural, domestic, and industrial purposes.
- Groundwater potential assessment is challenging in several parts of the world due to data scarcity and intricate geology and hydrogeological nature of the area.

Introduction

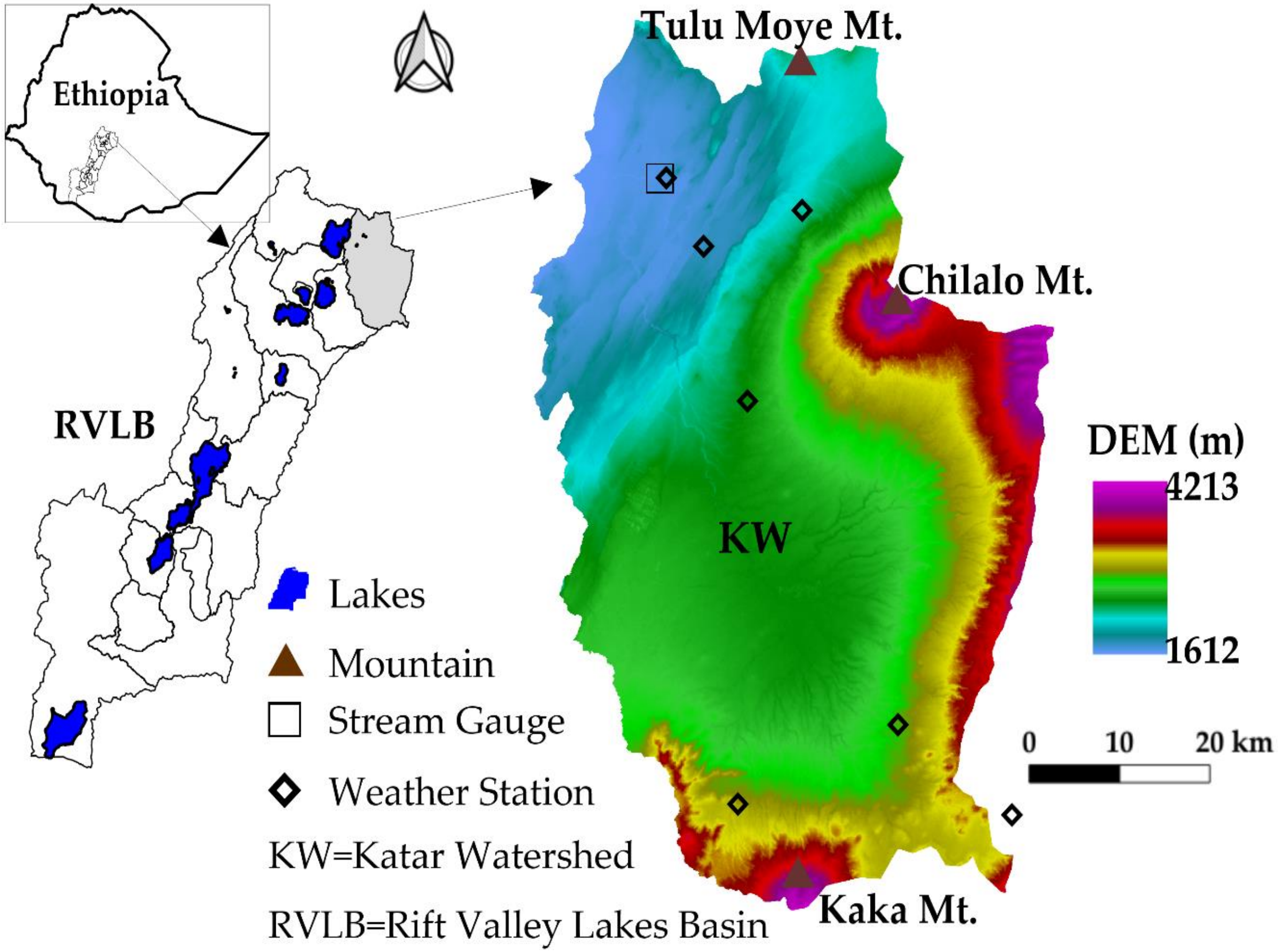
- In the absence of enough aquifer information or other reasons several researchers used remote sensing and GIS techniques to map groundwater potential zones.
- MCDA using GIS-techniques

Introduction

- In this study, SWAT and GIS-based MCDA were used to map the groundwater potential in a data-scarce region of Main Ethiopian Rift.
- MER is a region with tectonically active complex hydrogeological and discontinuous aquifers disrupted by faults founding the rift resulted in variable groundwater occurrence, discharge, depth, and flow patterns.

Materials and Methods

Study area



- Coverage area of around 3580 square kilometers.
- 21 small towns
- Countrywide geology, soil property,
- Climate data

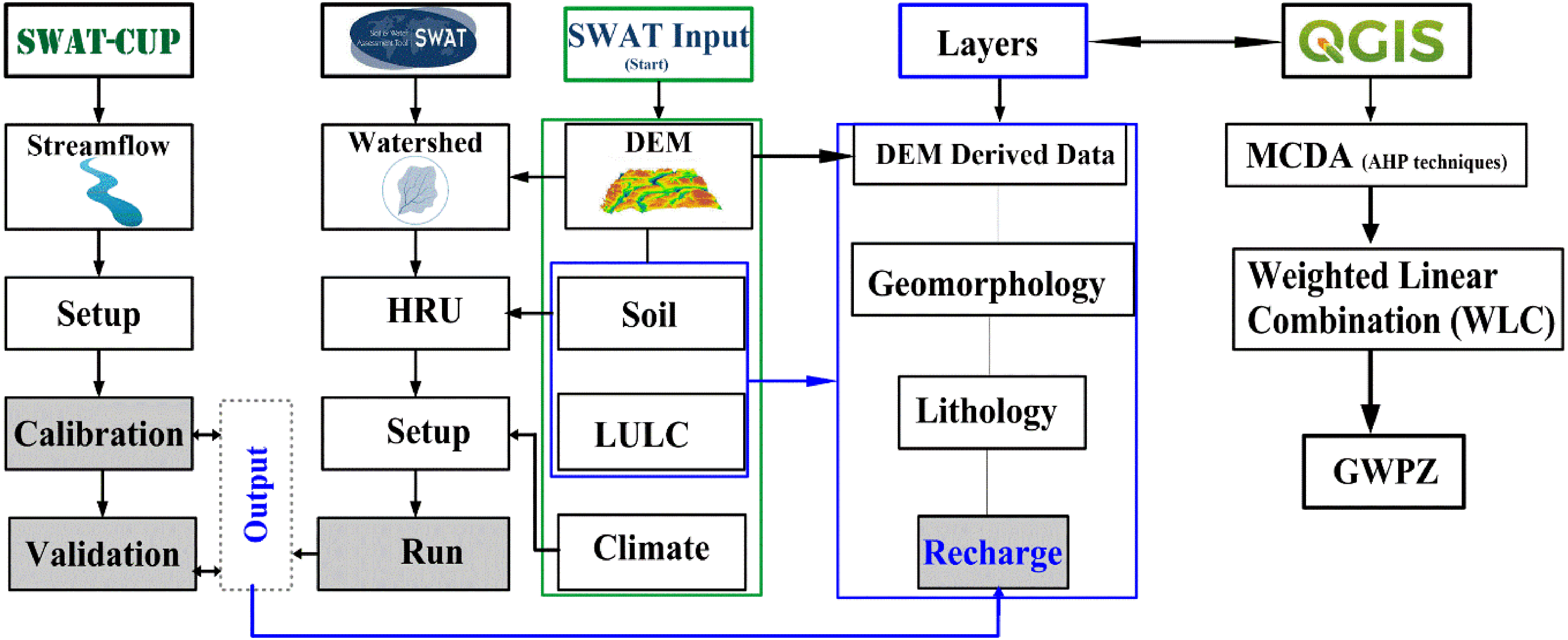
Materials and Methods

Study area

- Mainly the groundwater abstraction through springs and hand-dug wells and the development is in areas where shallow groundwater is available.
- There are a few machine-drilled boreholes, but most of them are controversial due to their low productivity and some of them are drying.

Materials and Methods

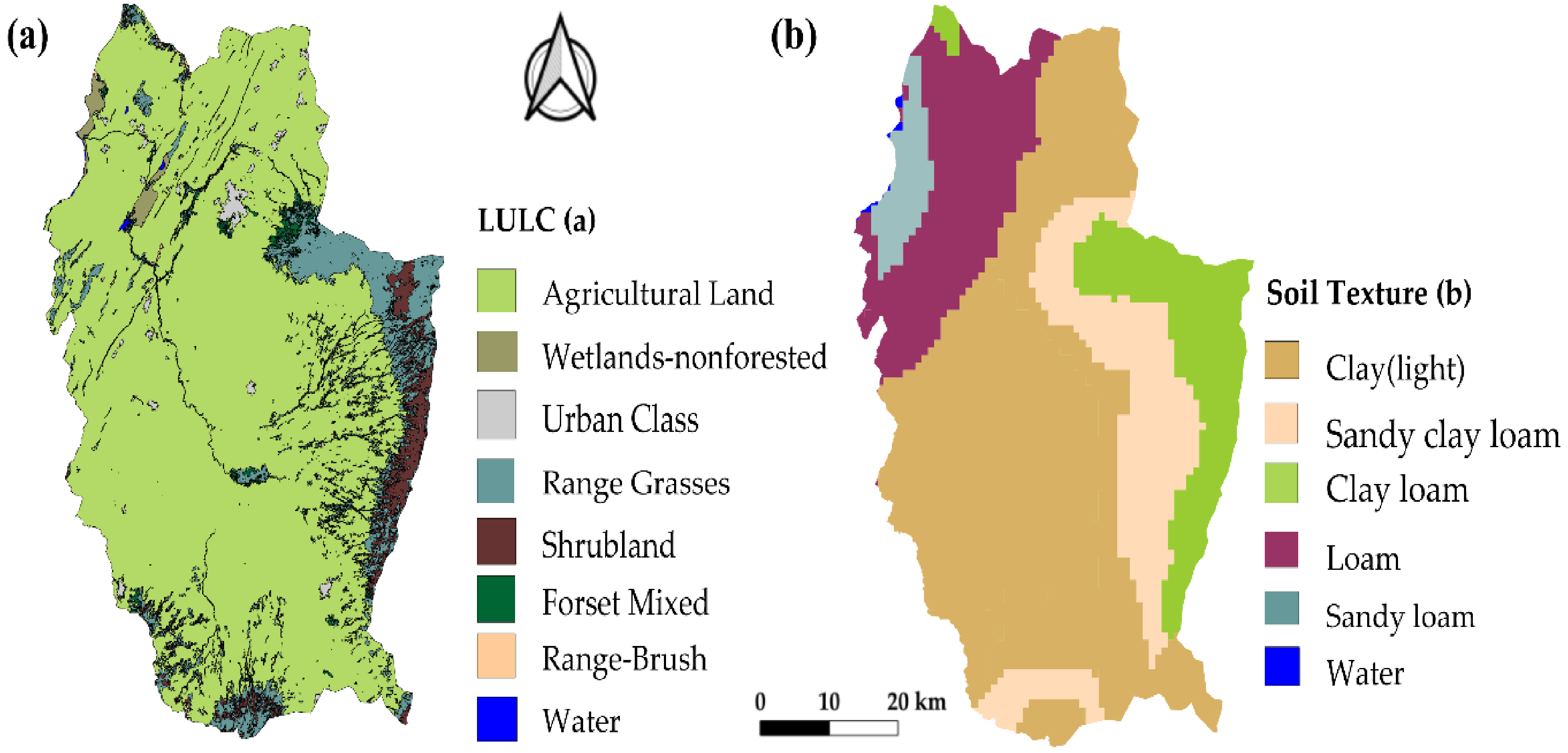
Recharge estimation and groundwater potential mapping



Materials and Methods

Recharge Estimation using SWAT

- Temperature,
- Wind speed,
- Humidity,
- Solar radiation
- Precipitation
- Soil from MoW



A 30 m spatial resolution LULC and DEM

Materials and Methods

Recharge Estimation using SWAT

- The watershed was divided into 47 subbasins and the subbasins into 1651 HRUs; each HRU has unique LULC and soil property.
- The simulation was performed for 21 years starting from 1990
- Calibrated and validated using SWAT-CUP

Materials and Methods

Multi-Criteria Decision Analysis

- In this work, a GIS-based AHP is used to integrate thematic layers, which influence the natural storage and flow of water in the study area.
- Since the pairwise comparison is vital in the AHP application, the association of the thematic layers is weighted according to their contribution to groundwater existence based on Saaty's parameter scaling.

Materials and Methods

Multi-Criteria Decision Analysis

Saaty's parameter scaling varies from one to nine:

1—equal importance,

2—equal to moderate importance,

3—moderate importance,

4—moderate to strong importance,

5—strong importance,

6—strong to very strong importance,

7—very strong importance,

8—very to extremely strong importance,

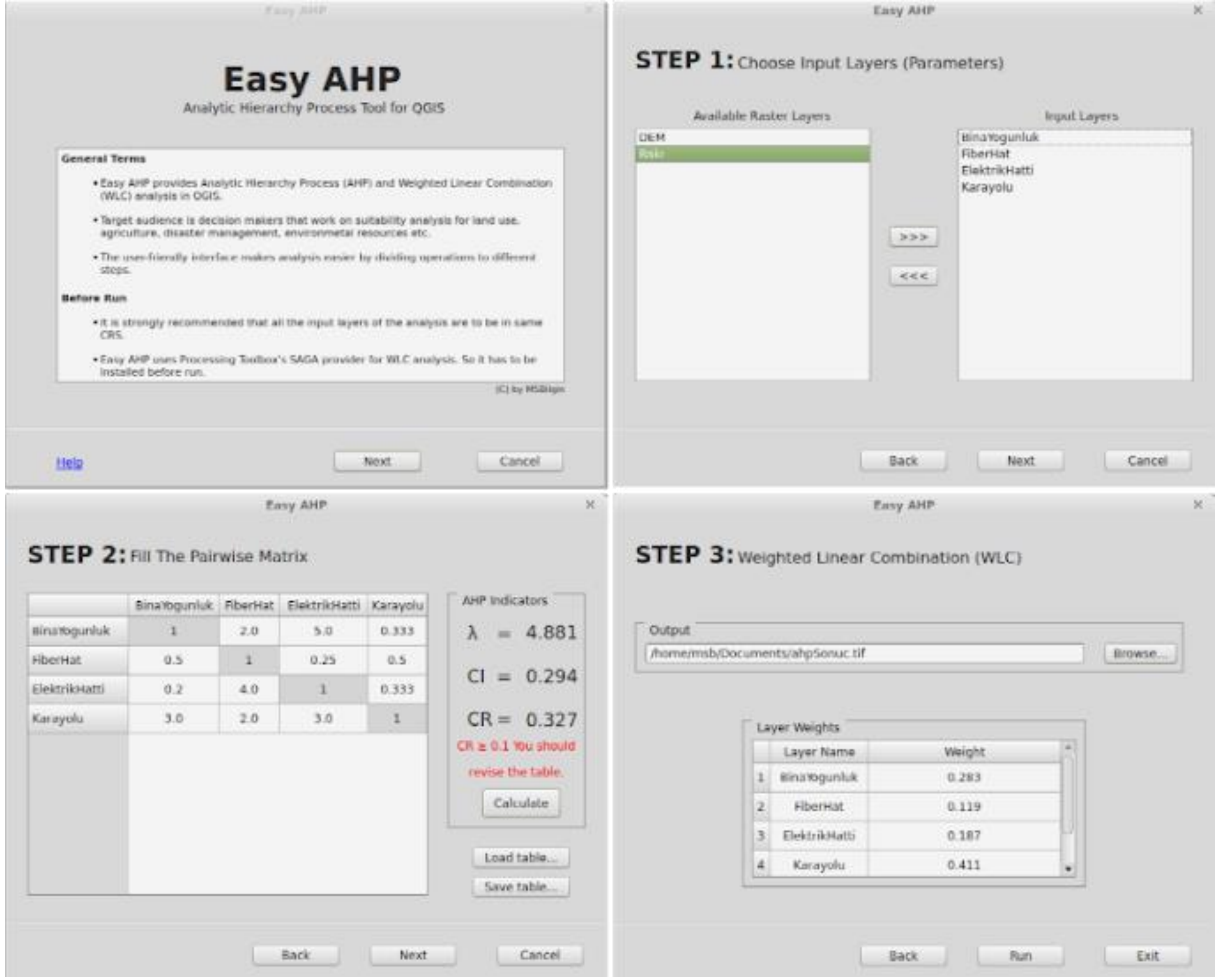
9—extreme importance.

Materials and Methods

- Consistency—a measurement of dependency within and between the sets of thematic layers of its structure—is important in AHP.
- The consistency ratio (CR), principal Eigenvalue (λ_{max}), and Consistency Index (CI) were calculated using a QGIS plugin so-called EASY AHP.

Materials and Methods

Multi-Criteria Decision Analysis



Materials and Methods

The plugin uses the following Saaty's CI equation:

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

$$CR = \frac{CI}{RCI}$$

Where n is the number of thematic layers considered and RCI is random consistency index value .

Materials and Methods

Multi-Criteria Decision Analysis

- A CR of 10% or less is acceptable to continue the analysis.
- If the consistency value is greater than 10 %, then there is a need to revise the judgment to locate causes of inconsistency and correct it accordingly.
- If the CR value is zero, it means that there is a perfect level of consistency in the pairwise comparison.

Materials and Methods

Multi-Criteria Decision Analysis

layer	Weight (%)	Layer	Weight (%)
Recharge	13.2	DD	5.9
Geomor	11.8	LD	10.3
LULC	10.3	TWI	8.8
Litho	8.8	Curvature	5.9
Soil	8.8	Roughness	4.4
Slope	7.4	TPI	4.4

Materials and Methods

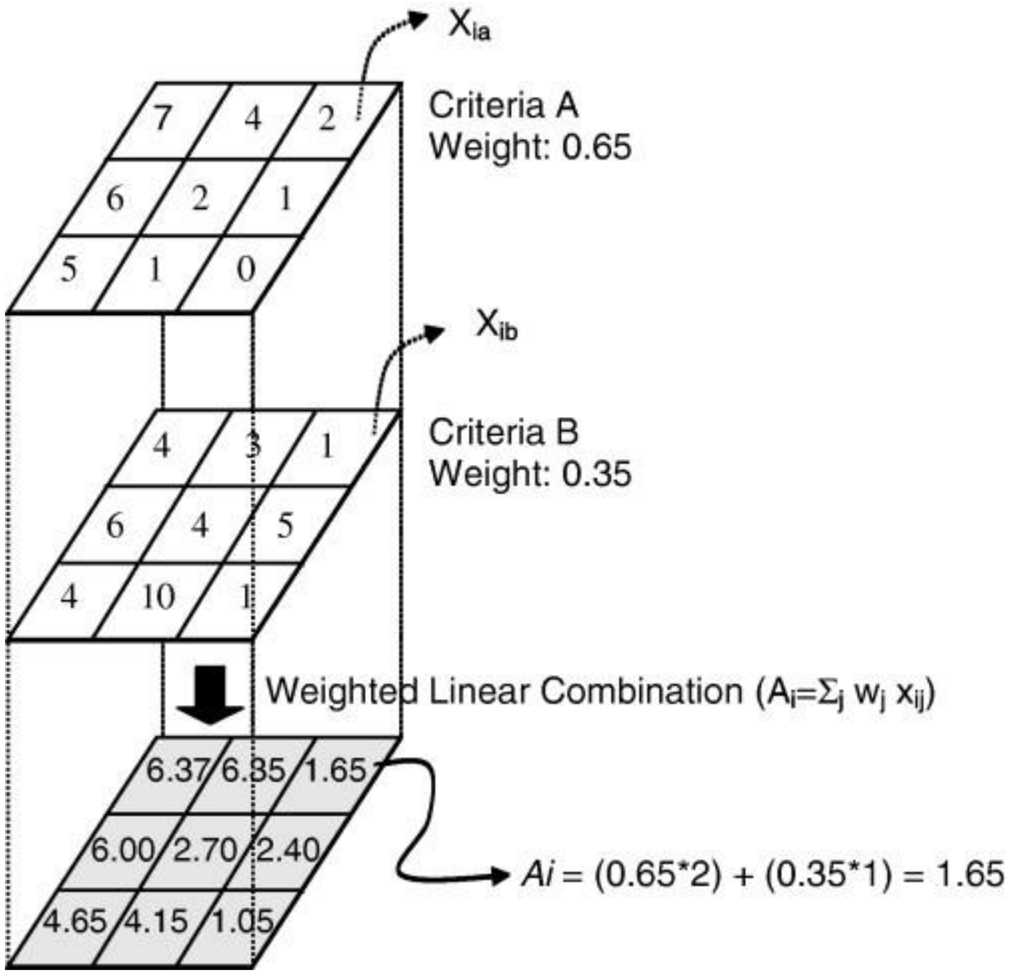
- From the pairwise comparison matrix, the normalized weight of each thematic layer was produced and the GWPZ map was produced using Weighted Linear Combination (WLC) technique.
- WLC is founded on the concept of a weighted average in which continuous criteria are standardized to a common numeric range.

Materials and Methods

Multi-Criteria Decision Analysis

The method can be executed using the GIS system; it is simple and it can be equated as follows:

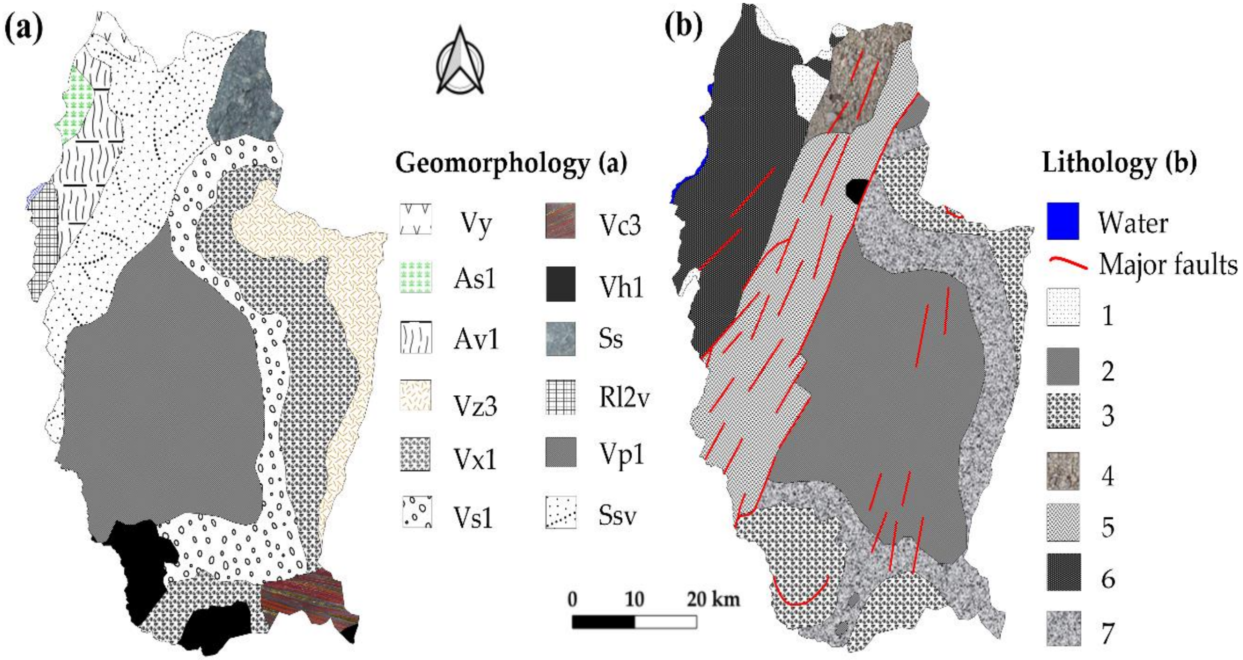
$$GWPZ = \sum_{i=1}^{n} (Weight_i \times Thematic\ Layer_i)$$

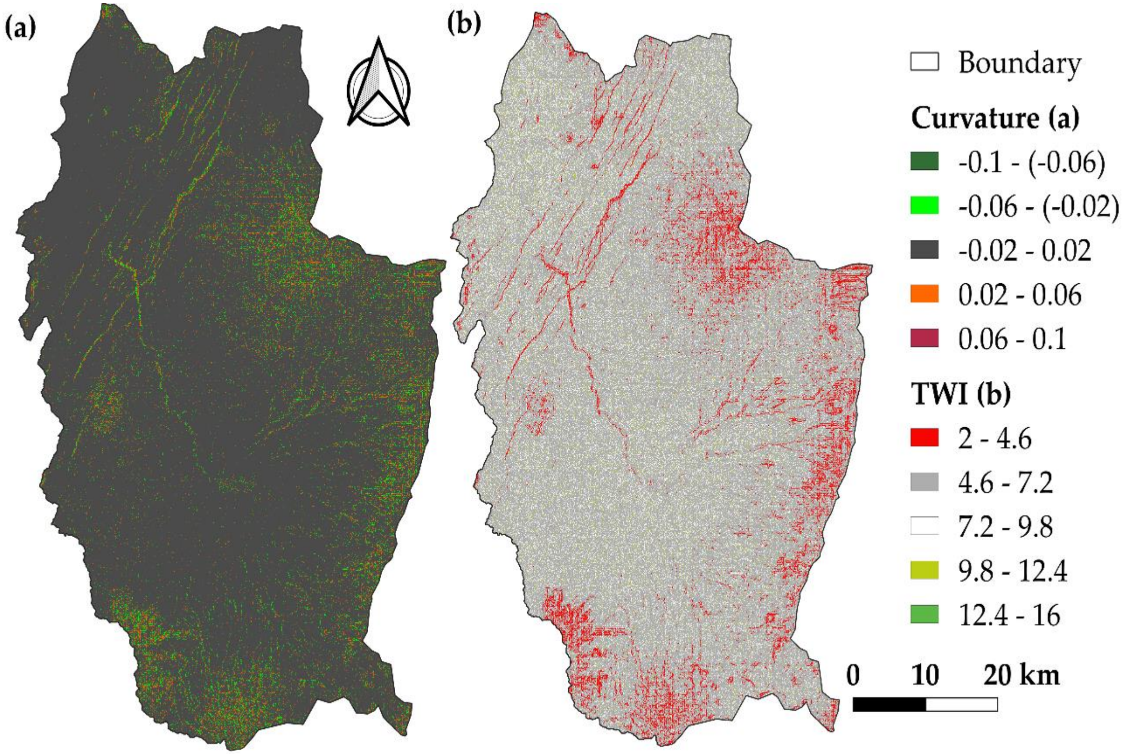


(Oscar M Pe¤rez, 2005)

Materials and Methods

Data processing

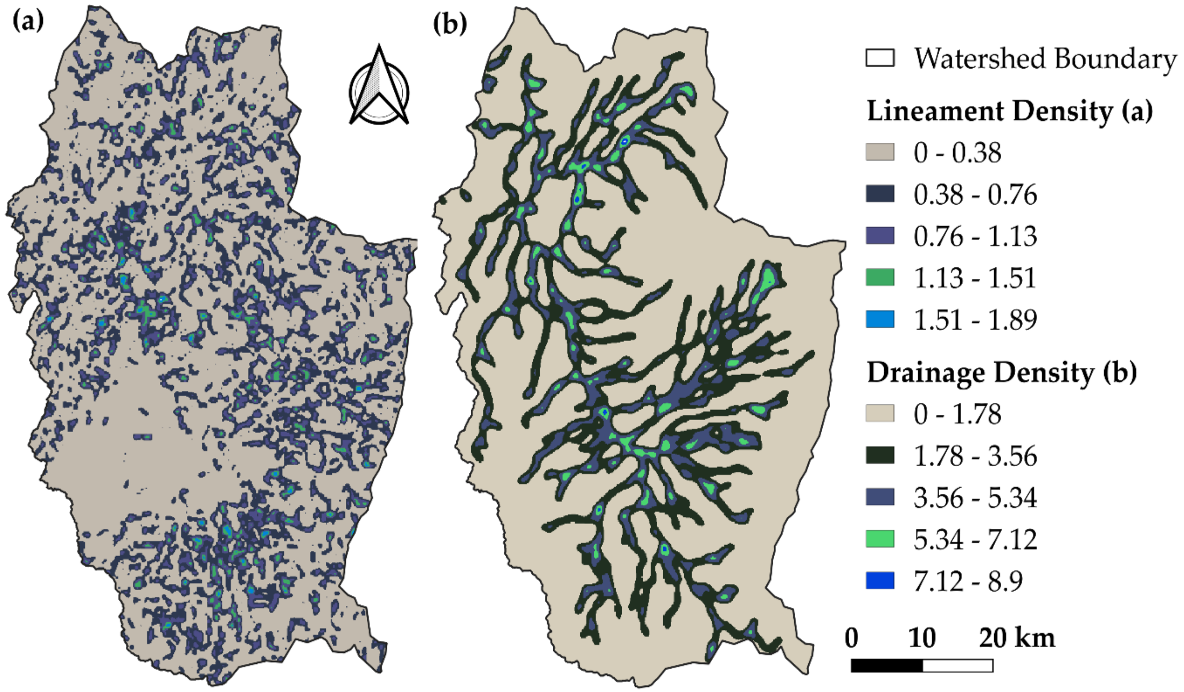




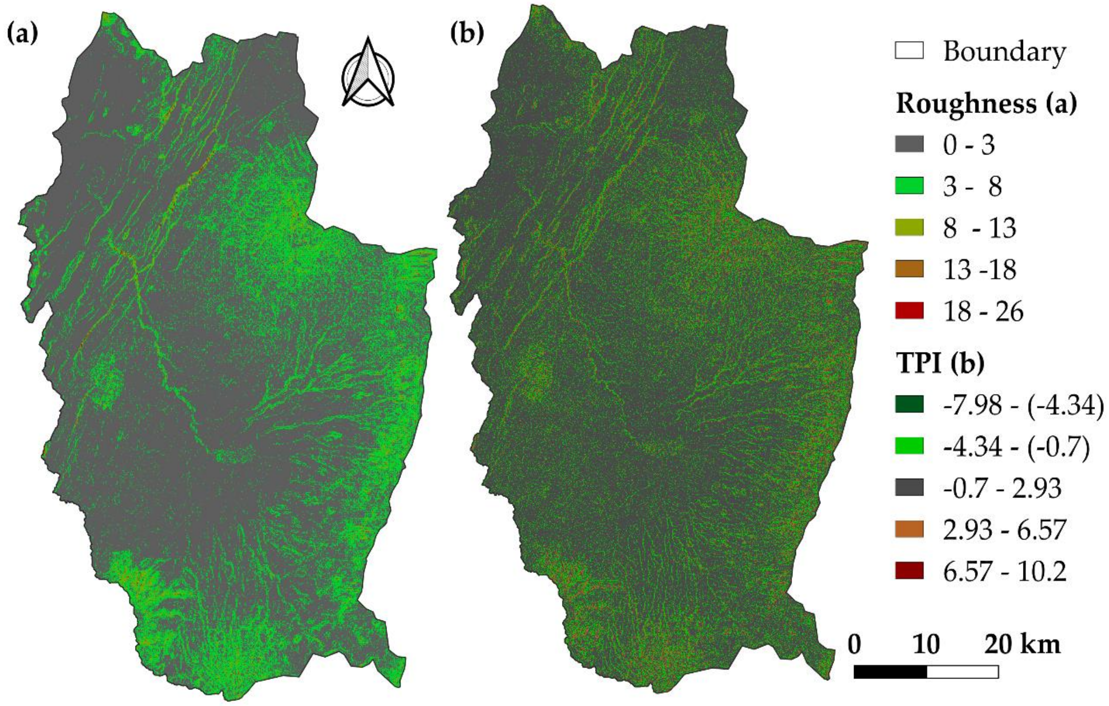
TWI quantifies how much the topography is favorable in facilitating the recharge process from precipitation

Materials and Methods

Data processing



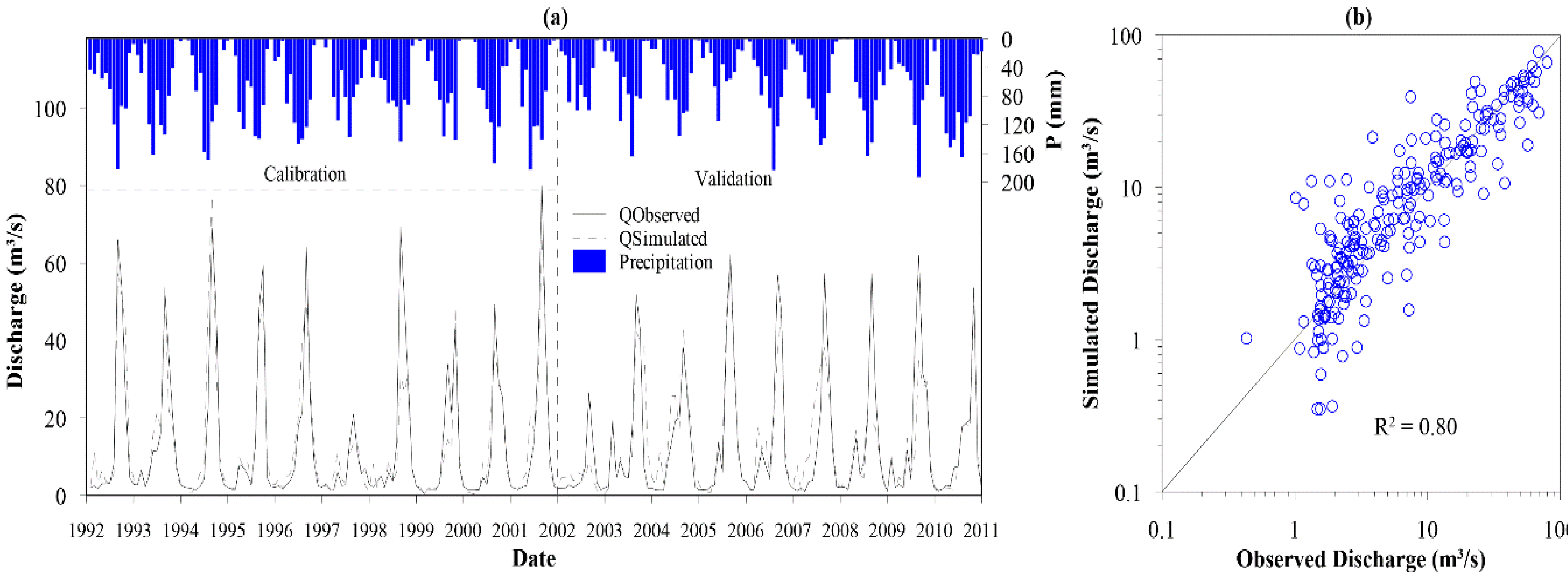
Lineaments are an expression of an underlying geological structure, including faults



TPI shows how big is the inter-cell difference of a central pixel from its surrounding cells in a DEM

Results and discussion

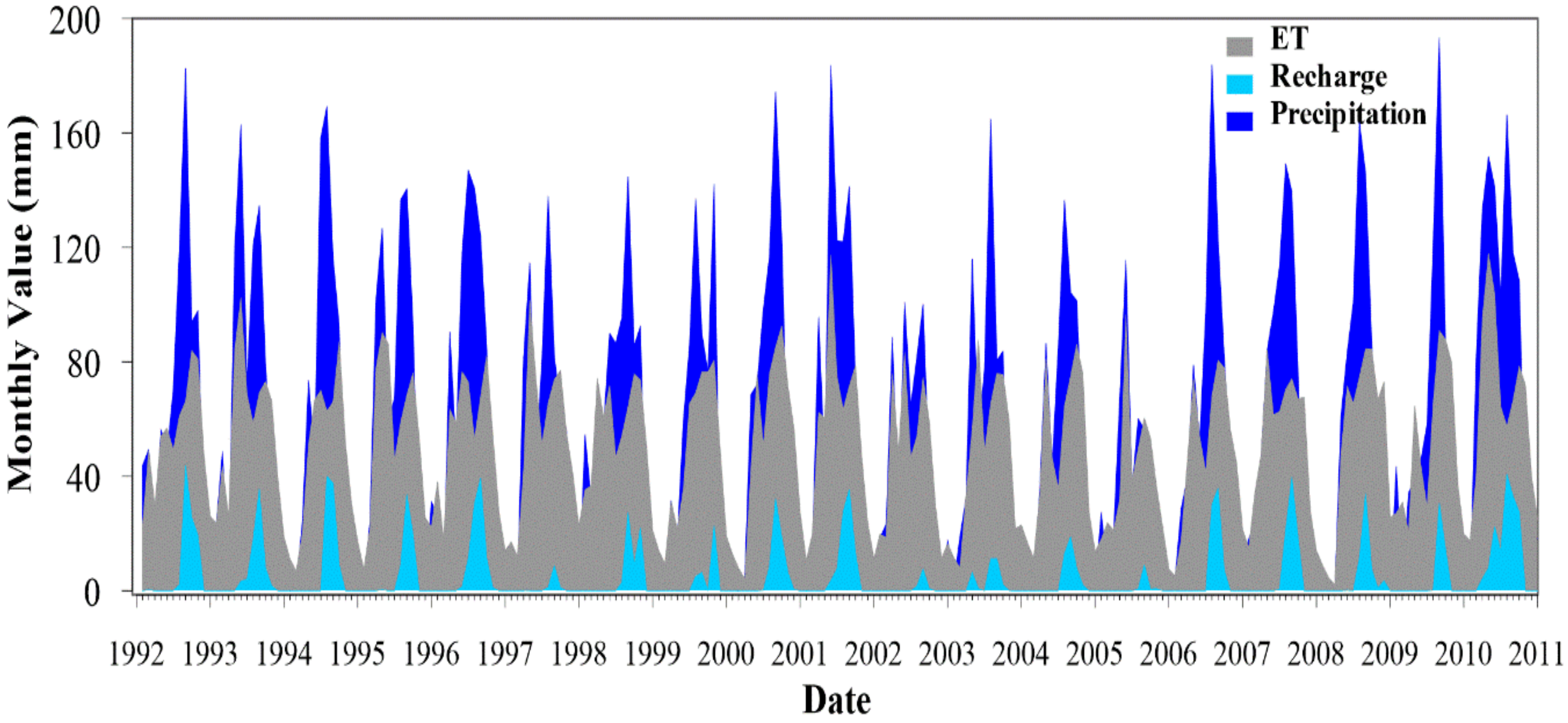
SWAT model results



Monthly observed and simulated streamflow over a period of 1992 to 2010

Results and discussion

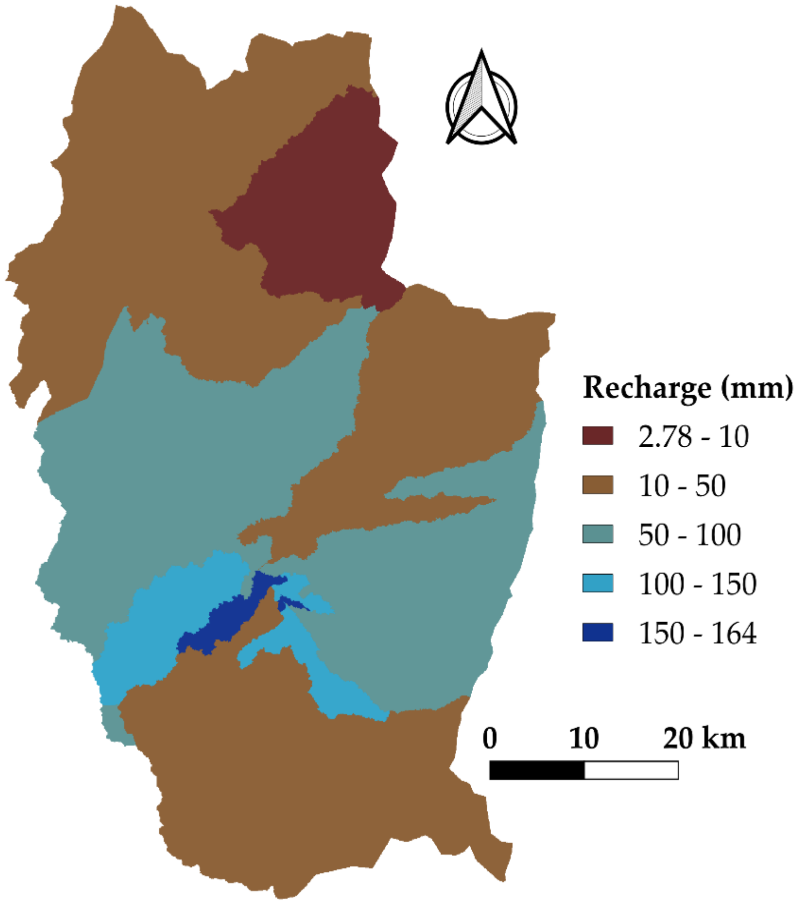
SWAT model results



Monthly average recharge, ET, and surface runoff over a period of 1992—2010

Results and discussion

SWAT model results



Yearly average recharge

- The maximum monthly average recharge is 27 mm and in December and January, the recharge is almost zero.
- Around 44 percent of the recharge occurs in Agust which counts around 21 percent of the areal precipitation in the watershed.
- More than 85 percent of the recharge occurs from July—September.

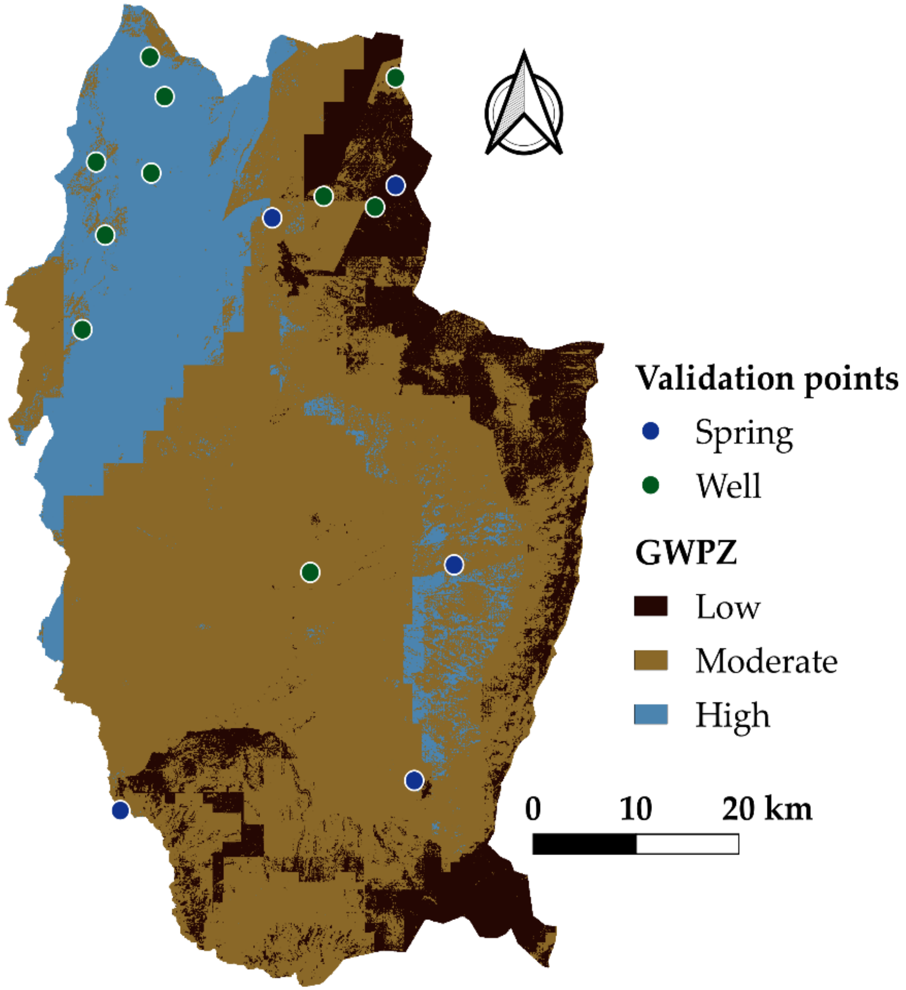
Results and discussion

SWAT model results

Parameter	Calibration	Validation
NSE	0.83	0.74
R^2	0.83	0.74
PBIAS	2.4	-1.2
RSR	0.41	0.51

Results and discussion

SWAT model results



- Less than 22 percent of the total area has high groundwater potential,
- more than 61 percent is moderate and
- 17 percent low groundwater potential.
- 93 percent of the production rate of the wells and springs match with the produced GWPZ map.

Conclusions

Groundwater potential zones were produced using GIS based MCDA. The result was classified into low, moderate, and high groundwater potential zones and validated using the wells and springs information available in the region.

However, the result should be used wisely by considering the limitations in this research.

Thank you for your attention!

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