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Hydro-Geomorphological Modeling of Kani-Pan Sub Basin in Sulaimani City Using Spatial Information Technology

Azhar Kh. S. Bety[1], Abdulhaq N. Mahmoud[2]

[1] *Department of Geology, Collage of Science, Sulaimani University, Sulaimani, Iraq*

[2] *NRRC Natural Resource Research Center. Tikrit University, Tikrit, Iraq*

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Corresponding Author:

Name: Azhar Kh. S. Bety

E-mail:

azher.suliman@univsul.edu.iq

dr.abid@tu.edu.iq

Tel:

ABSTRACT

This study is based on multiple data including satellite image, DEM, climate data, geological map, soil map, basin drainage map, land use and land cover map to estimate the volume of water and sediment yield that can Kani Ban basin to convey Tanjero basin. The Soil Water Assessment Tool (SWAT) was used to achieve the aims of the study. The results showed that the rainfall on the study area is estimated at about 380 mm, while rates of runoff ranged between (73.16-151.18 mm). The percolation rates ranged between (117.48-195.94mm) and high values were concentrated in the northern and southern parts of the basin. Sediment yield was calculated using modified soil erosion equation, total amount of sediment ranged from (0.03-2.43 t / ha), at a rate of (1 t / km2). The water yield of the valleys ranged from (140.76 to 200.84) mm, where the water yield within secondary basins ranged from (120.25 to 214.95 mm).

Introduction

Kani-Pan basin from Sulaimani City, northeast Iraq was selected as ephemeral basins as a case study to find the modeling of hydro-geomorphologic by using Spatial Information Technology (SIT). The study aims to estimate the volume of water and sediment that can Kani-Ban basin to convey Tanjero basin, which is considered one of the important tributaries to reservoir water of Darbandikhan**.** The importance of the study also comes from the fact that the area under study is one of the important areas for future urban expansion of Sulaimani City; the study area is part of Sulaimani Master Plan area,[1].

The data adopted in this study varied between satellite image, DEM and climatic data. The study also relied on a map of the land cover and a soil map for the study area. AGWA (Automated Geospatial Watershed Assessment) is mean automated spatial assessment of water basins; it includes two tools (SWAT & KINEROS).The SWAT was chosen for this case study because it includes many useful components and functions for simulating the water balance, sediment loss, climate change, crop growth, and land management practices. SWAT is a continuous time, physically based hydrological model developed by the United States Department of Agriculture–Agricultural Research Service (USDA–ARS) [2] to predict the impact of land management practices on water, sediment, and agricultural chemical yields in large complex watersheds. ERDAS and GIS are also applied within this research to accomplish the goal of research.

The importance of this study is in the field of treating water scarcity in arid and semi-arid areas. It is one of the studies of the spatial analysis of modern technologies to apply the Soil and Water Assessment Tool (SWAT) model to predict surface runoff generation patterns and soil erosion hazard, and to prioritize most degraded sub-catchment in order to adopt the appropriate management intervention. Water and sediment yield contribute to the management of storm water storms and methods of exploitation, which has become a challenge of this area, [3] and [4].

Physiographic of the study area

Geographically, Kani-Pan basin is enclosed area between longitudes 45°10′ 00″E and 45°23′ 20″E and latitudes 35°27′ 00″N and 35°43′ 00″ N covering an area of 226 sq. km. The total length is equal to 14.6 km within the area of Sulaimani, (fig.1). Kani-Pan

basin together with Chaq-Chaq basin formed Tanjero stream which is the main part of Shahrazor basin.
Geologically, the study represents part of the unstable platform of the Arabian plate, it is situated near the eastern margin of the High Folded Zone according to [5] and it lies between High Zagros Reverse Fault (HZRF) and Zagros Mountain Front Fault (ZMFF) which make most of the studied area form part of the Zagros High Folded Zone according to.[6] The trend of the folds and the strike of the strata are generally in NW-SE direction in accordance with the main trend of Zagros folds. Folding and faulting within study area was resulted from several phases of deformations during the Alpine Orogeny.
Many geological formations are distributed throughout the study area. The Quaternary deposits cover large areas while the formation of Balambo, Shiranish, Tanjero, Kolosh and Sinjar formation are distributed among the remaining parts, fig.2 [7] Alluvial fans with fluvial deposits represent most of the Quaternary deposits in the study area and the fans are varying considerably in morphology and extent.
Climatically, the study area is part of northern Iraq, which is characterized by clear seasonal differences, caused mainly by the change in the type of atmospheric circulation during the year, and by the intensity of the insulation .[8] Also, it is characterized by cold and rainy winter with prevailing precipitations of all types (rainfall, hail and snow), as well as long, hot and dry summers. Based on the classification of Thornthwaite, the studied area is classified under semi-arid climatic moisture type .[9]
Soils in general within study area are formed from the processes of weathering, erosion and sedimentation during the Quaternary period, and most parts of the area have soils with a brownish to yellow surface layers; this color is due to iron oxides and indicates somehow more moist soil climate than red colors .[9] Clay is a dominated soil type in the study area, according to textural properties of USDA triangle.

Materials and Methods

The data adopted in this study varied between satellite images, digital elevation model (DEM), and climatic data for 30 years. The study also relied on a map of the LCLU and a soil map; in general, the data used are:
- SIT (Spatial Information Technology)
Much software was used in this research including AGWA, GIS, Erdas and Excel. AGWA (The Automated Geospatial Watershed Assessment) tool is a multipurpose hydrologic analysis system for use by watershed, water resource, land use, and biological resource managers and scientists in performing watershed-and basin-scale studies. It was developed by the U.S. Agricultural Research Service's Southwest Watershed Resource Center and it includes two tools: SWAT & KINEROS.
-Satellite Image
TM Landsat satellite image from 2011dates with 30 m resolution were used in this study in the classification of land cover and land used (LCLU). The satellite images represent a valuable investigation tool for their spectral and geometric properties, especially over large areas, where a medium level of details is required.
-DEM (Digital Elevation Model)
DEM is a numerical representation of terrain elevation; it stores terrain data in a grid format for coordinates and corresponding elevation values .[10] DEM used to derive hydrological and geomorphologic aspect of the basin, especially water network and secondary basins. DEMs are composed of elevation data originally derived from land surveying, aerial photography or satellite images, or derived from contours on topographic maps. DEM with 30 m resolution was used in this study.
-Soil data
Soil is a specific geomorphologic factor for the strength and volume of water discharge of river floods. This role is demonstrated by the direct relationship between soil permeability and the volume of water flow in river tributaries, as well as the problems of drift processes, which are determined by their properties.[11] Soil type is one of the most important factors that significantly affect water transport in the soil.
Different soil types have different physicochemical properties such as soil texture, available water content, hydraulic conductivity, bulk density, and organic carbon content [12].

Results and Discussion

Computer modeling is a powerful and effective tool in supporting the decision to invest and develop water resources in multiple areas and provides the means to facilitate selecting the optimal solution to environmental problems. In this context, the research deals with the concept of hydrological modeling, which includes the extension used in the study AGWA and how it operates and its basic processes for the modeling of rain, runoff and sediments in unregulated water basins in arid and semi-arid zones with the possibility of future prediction through proposed scenarios and monitoring the response of water basins according to this change. The aquifer model consists of five basic components.[13] basin operations and hydrological characteristics, data entry, determination of equations, initial conditions surrounding the basin, and then the discharge phase.

Input Data

Preparing the data needed to accomplish this research is important. It includes the following processes:
-Drainage network
Stream network in the study area is a good substitute indicator of the landform organization and the density of the lowest order streams clearly delimits.[14] The drainage basin is recognized as a fundamental geomorphological unit and is frequently used as the primary landscape unit for hydrological, water supply and ecological investigations and for land management .[15] The drainage network of the Kani-

pan basin was derived from the DEM according to the Strahler, with 30m resolutions shown in (fig.3).

-Soil Map

Soil map of the study area was extracted from FAO, 2006 map with a scale of 1 / 5,000,000 which is one of the most modern soil classifications in the world. It contains soil type, depth, tissue, gradient, heredity of phases, chemical reactions and water discharge. It symbolizes special symbols as shown in (fig.4). According to .[9] most parts of the area have soils with a brownish to yellow surface layers; this color in soils comes from iron oxides and indicates to some extent more moist soil climate than do red colors.

-LULC map

TM Landsat image with 30m pixel size is used to obtain level (I) of USGS classification. The supervised classification in ERDAS IMAGING software is used to give the researcher a map of LULC. This map is produced with respect to USGS system, and the map shows that only four classes can be identified: Urban, Water, Agriculture and Barren land are (as shown in (fig.5).

-Climate Data

Depending on the archives of Sulaimani Meteorological Station for the last 30 years, the maximum average of the monthly temperature was around 40 Celsius in July and August, while the lowest average degree was around 2 Celsius recorded in January and February. The maximum monthly rainfall recorded was 364 mm which was in December-1991 and the mean annual rainfall was 710 mm for the period from (1980 to 2010). The average wind velocity in the individual months of the year does not exceed 3 m/s. The average monthly relative humidity varies from 22.33% in July to 70.26% in January, while the average annual air humidity is around 45%, and it exhibits a high seasonal diversity according to .[16] The input data must be at the daily level for the possibility of designing simulation and forecasting at daily, monthly and annual levels. There was no daily rain and temperature data for Sulaimani station for 30 years, so the data was based on Kirkuk station, which is the nearest Meteorological station in the area.

Output Data

The results mainly depend on the output of the application within SWAT tool, and the accuracy of the output depends on the longer of the data; the following is an explanation of the most important outputs: the first is at the channel level, and the second is at the level of the surface.

-Rainfall

Daily rainfall data for 30 years was adopted, taking into account the expected fluctuation of the amounts of rainfall for the future in 30 years; it is clear from the (fig.6) the distribution of rainfall regularly on the basins, because of the existence of a climatic station while if there is more than one climatic station, there is a variation in the distribution of rainfall on the basin. The total rainfall was 380.09 mm/year.

The annual rainfall in the region is not much less than that in most European countries, rather its distribution [17] In general, according [8] the precipitation increases from SW to NE, reaching its maximum values at the highest mountainous around studied area. Watershed management strategies are necessary to efficiently use the natural resources [18]

-Surface Runoff

This outcome is one of the most important variables to control the possibility of establishing water harvesting projects. Surface runoff is generated when precipitation intensity exceeds the infiltration rate of the soil and moves down to channel stream [19]Runoff that occurs on surfaces before reaching a channel is also called overland flow. Where groundwater provides stream recharge during low flow periods, this can also be very helpful via the augmentation of the base flow in a river, which will improve the surface water quality, including cooler temperatures of the receiving water body, hence, it helps in maintaining terrestrial bio-diversity, [20] SCS curve number (Soil Conservation Service) method and Green Amptare used for calculating surface runoff in SWAT [21].Obtain more detail information about the status of rainfall runoff is very important. This information helps decision-makers for future programs about watershed managers of natural resources for sustainable development [22] Surface runoff is calculated according to the following equation:

$$Q_{surf} = \frac{(R_{day} - I_a)2}{(R_{day} - I_a + S)}$$

Where:

Qsurf: Accumulated water runoff or increased precipitation (mm).

Rday: Daily precipitation depth (mm)

Ia: surface storage and infiltration before precipitation re-fall (mm).

S: Maximum retention (mm).

The rates of surface runoff ranged between 73.16-151.18 mm, see (fig.7) High levels of surface runoff are concentrated in the middle of the study area, which receives water from adjacent areas which characterized by higher elevation and steeper slope with higher fracture rock. High area of surface runoff is mainly occupying quaternary deposit and the high ranks of the water network converge mostly in these areas, making it a higher surface runoff than other areas within the basin. In general, medium and high percentages of runoff are prevalent on the basin.

-Percolation

In general, it is intended to leak water from the surface of the soil to the lower layers, feeding the aquifer. The leak affects several factors, most importantly including the characteristics of the surface and the quality of the materials that cover it, its nature and cohesion, as well as the degree of permeability and porosity.

The percolation rates ranged between 117.48-195.94 mm; see (fig.8). High values were concentrated in the northern and southern parts of the basin. These parts of the basin are characterized by a slight slope allowing for increased leakage. Geological formations (Balambo in the north and Sinjar in the south) covering these parts are characterized by joints system that allow for increased percolation. Low dropout rates covered the center of the study area, which was characterized by high surface runoff.

-Sediment yield

Sediment is the product of the relationship between the types of rock on the one hand and the external modulation factors on the other. Sediments vary from rock masses to soft sediments and vary depending on the quality of the rocks and it affects through its size and type on the water basin environment. The sedimentations in the reservoir result from the sediment particles separated from their origin, then got deposited in the form of bed load and suspended a load [23]. Sediment yield refers to the amount of sediment exported at the basin outlet [24] Calculate sediment yield was done by using the modified soil erosion equation (universal soil equation modified), the model was relied on SWAT and the result is in (ton / haktar/ year). The annual erosion rate in the study area was predicted based on [25]equation, which is:

$$\mathbf{Sed} = 1.292 \cdot \mathbf{EI}_{USLE} \cdot \mathbf{K}_{USLE} \cdot \mathbf{C}_{USLE} \cdot \mathbf{P}_{USLE} \cdot \mathbf{CFRG}$$

EI: is the Rainfall intensity (Cm / m2 / h)

K: Soil erosion factor

C: Surface management coefficient

LS: The slope and length coefficient of inclination

CFRG: Coefficient of coarseness ratio

P: Soil maintenance laboratories

Distribution of stream channel and sub-watershed sediment yields shows similarity with the study area, the results of the equation are shown within (fig.9).

The total amount of sediment yield with sub-watersheds is ranged from (0.03-2.43 t / ha/year), at a rate of (1 t/km^2). Sediment of water channels (streams), is ranged between 6.10- 17.4 t/km^2, was calculated as a large quantity concentrated within the main streams of the water network. This is a reflection of the importance of attention to water networks as well as the importance of choosing the best sites for water dams within study area. The nature of the regression and geological formations has a significant impact on the size of sediment transported by stream channels. Also, the quantification of soil loss is one of the greatest challenges in natural resources and environmental planning [26].

The results showed that high values with basin area were concentrated in the northern, western and southern parts of the basin, while the smaller percentages were concentrated in the central and eastern basin. The results also show that the high sediment values with the water streams are increasing downstream.The regions with the highest elevation and slope recorded a higher percentage of sediment transported. The regions with the lowest elevation recorded a small percentage in comparison with highest elevation. Rock units dominated by joint systems recorded high percentages of sediment transported compared to quaternary sediments.

-Water Yield:

The water yield in the basin is a function of the spatial distribution of rainfall and represents the amount of available water for runoff and soil/groundwater storage excluding water for evapotranspiration and transmission loos (Langat et al. 2018). Result is measured by (mm) for two level streams and sub-watershed. The water revenue of the streams ranged from (140.76 to 200.84 mm) and within sub-basins ranged from (120.25 to 214.95 mm) as shown in (fig.9). Obtaining more detailed information about the status of rainfall runoff is very important. This information helps decision-makers for future programs about watershed managers of natural resources for sustainable development [22]

Thepercentages of water revenues contributed to the activation and acceleration of the erosion process within the parts of the basin and led erosion to the stage of gully erosion. Rain from the surrounding areas due to the movement of air currents contributed significantly to these results, especially since the basin is surrounded by a range of mountain ranges. The secondary basins within the studied basin have varied rates of water revenue where the upper and lower secondary basins recorded higher rates than the rest of the parts within the pond area.

In general, Balambo, Shiranish and Tanjero Formation in the northern part and Kolosh and Sinjar Formation in the southern and western part of study area characterized by higher spatial distribution of rainfall especially within sub-watershed within the basin. These parts consist of hard rock's with higher slope and elevation compared to other parts within the basin. Higher streams water yield founded in the northern part, and the main reasons for this result is the water yield from surround area, especially mountain of Pira-Magron area, which characterized by high complex of tectonic and topography.

In addition, the LULC affected the distribution of water yield, higher water yields mainly occupy area within Barren land and lower water yield occupy area within agriculture and urban land.

Conclusions

This study demonstrated the efficiency of using modern techniques to calculate the amount of sediment and water received within the Kani-Pan basin in Sulaimani area.The study showed the obvious effect of the geological structure on the basin and the amount of sediment and water received within the main valleys as well as within the secondary basins in the main basin of Kani-Pan.

The study showed the effect of adjacent areas on the amount of sediment and water received through different geological formation as well as slopes played an important role in increasing these quantities into the basin.

In general, the study showed a high level of sediment and water carried inside the study area, which leads to attention and take advantage of the water received through the establishment of small dams to be used for agriculture, especially as the area is an important agricultural land for the city of Sulaimani.

Recommends

The study recommends using the allowed quantities of water through the construction of a dam in the study area. The study further recommends addressing the sediment accumulation issue, which has an impact on the future of the region.

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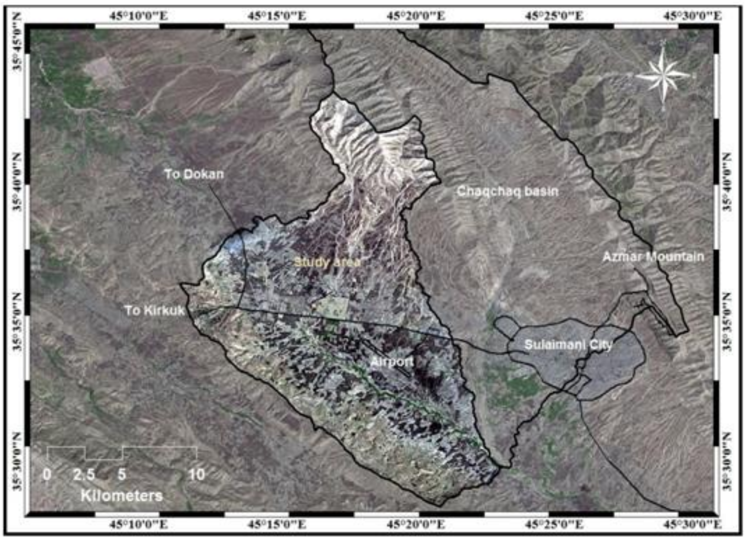
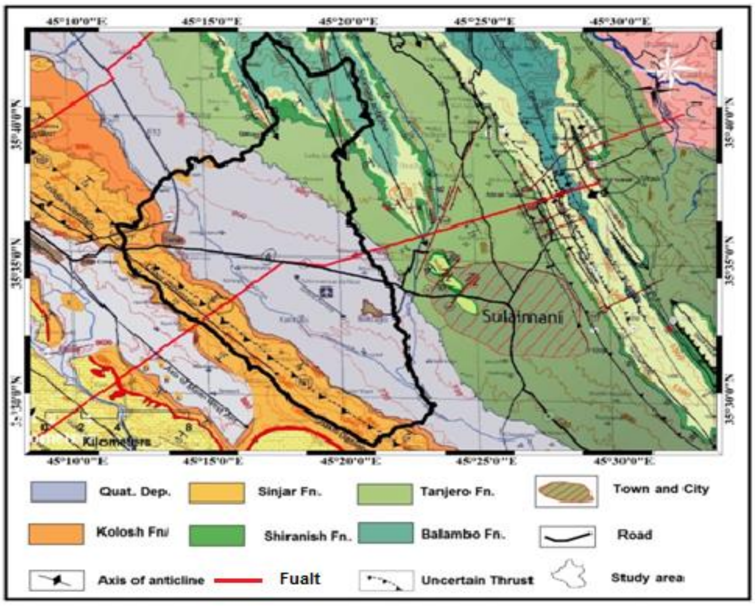
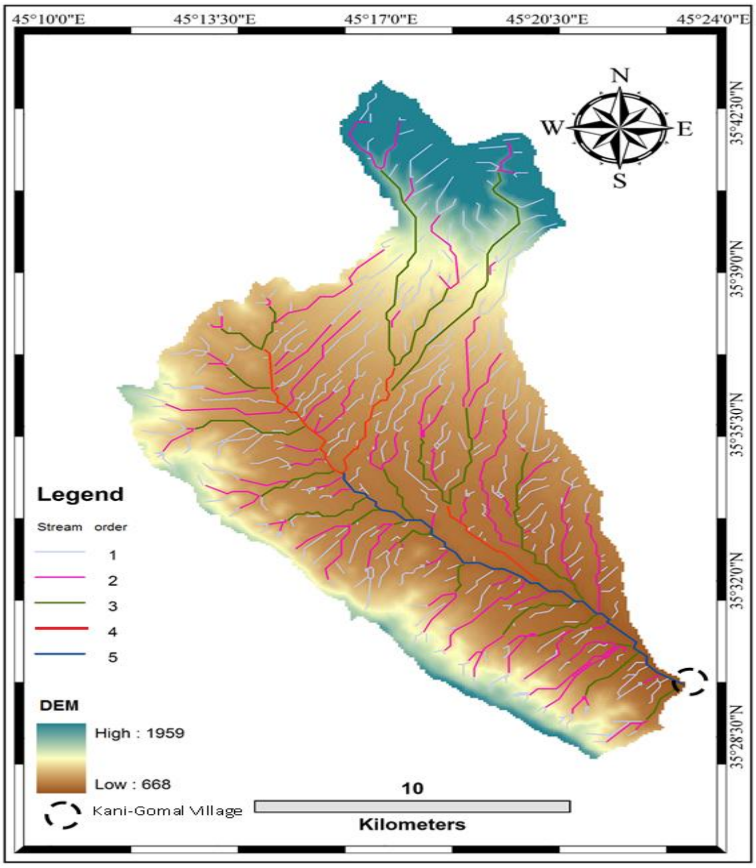
Figure (5) shows LULC map within study area.
Figure (6) shows the total rainfall within study area.
Figure (7) shows the surface runoff within study area.
Figure (8) shows the percolation rates within the study area.
Figure (9) Shows the Sediment yield and the water yield within study area.



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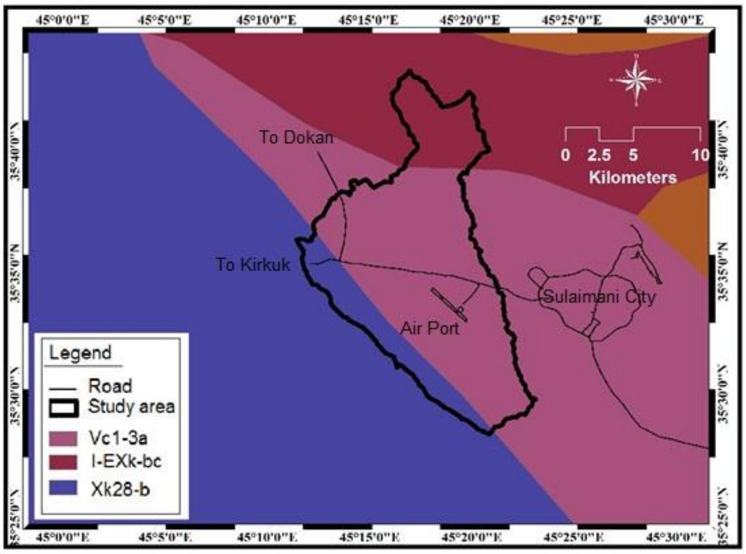
45°13'30"E
45°17'0"E
45°20'30"E
45°24'0"E
35°42'30"N
35°39'0"N
35°35'30"N
35°32'0"N
35°28'30"N
N
W
E
S
Legend
Stream order
1
2
3
4
5
DEM
High : 1959
Low : 668
Kani-Gomal Village
10
Kilometers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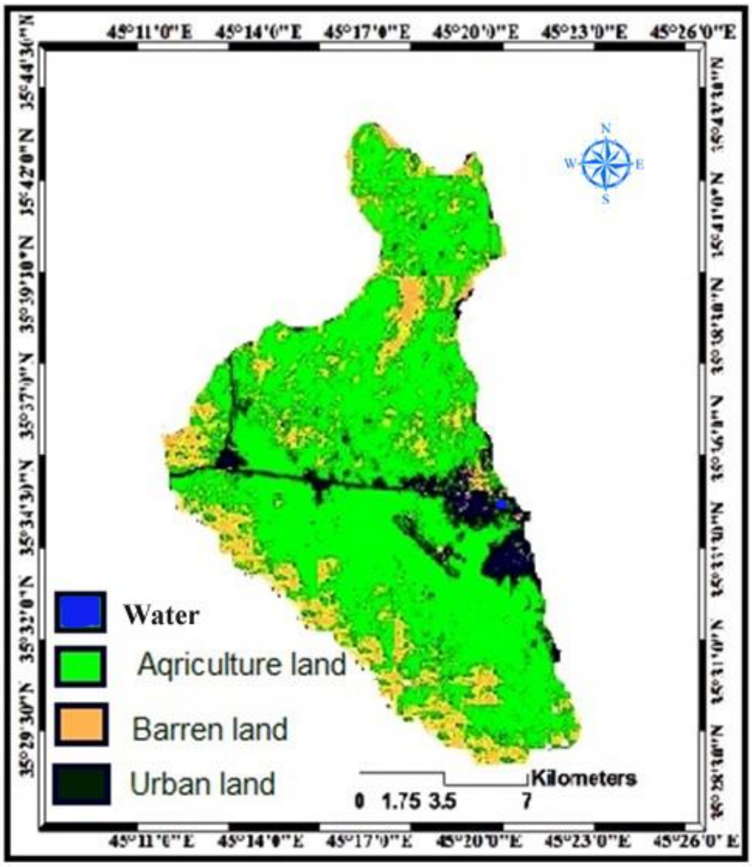
35°40'0"N
35°35'0"N
35°30'0"N
35°25'0"N
To Dokan
To Kirkuk
Air Port
Sulaimani City
0 2.5 5 10
Kilometers
Legend
Road
Study area
Vc1-3a
I-EXk-bc
Xk28-b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Aqriculture land
Barren land
Urban land
Kilometers
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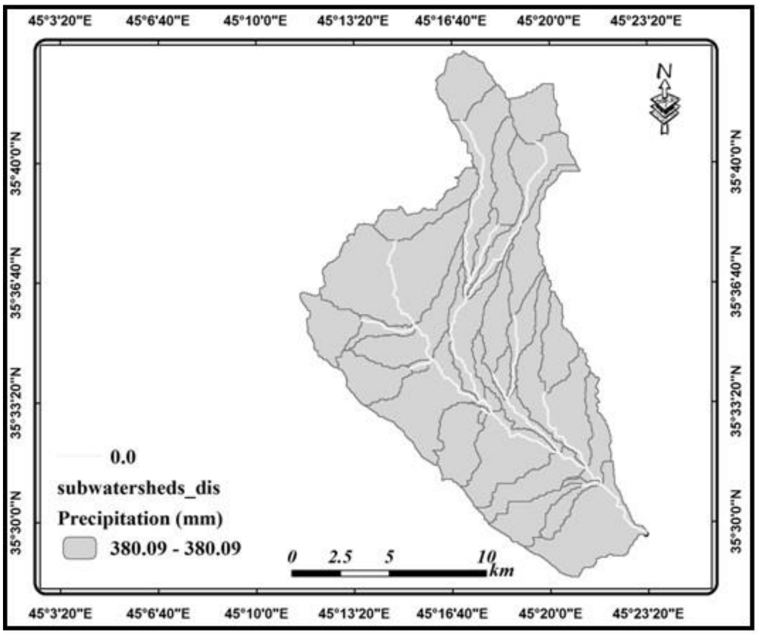
0.0
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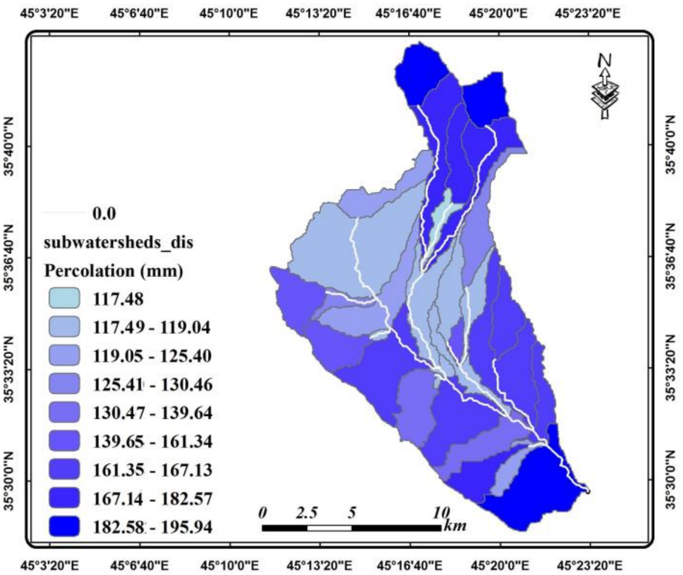
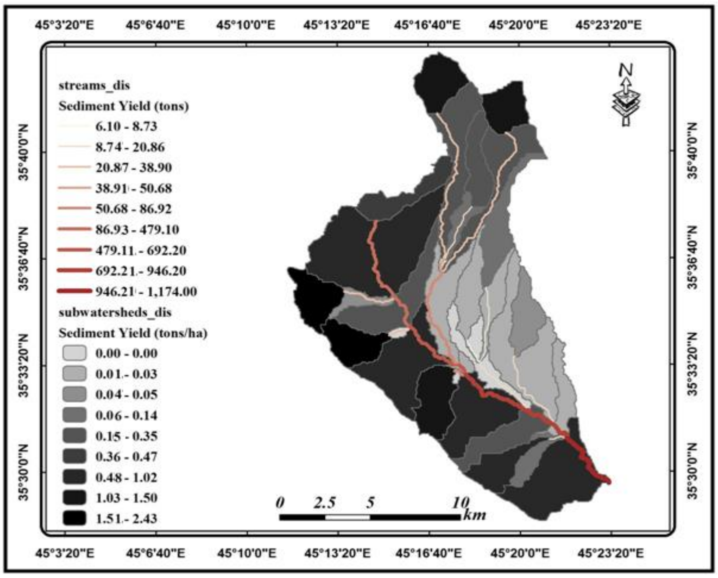
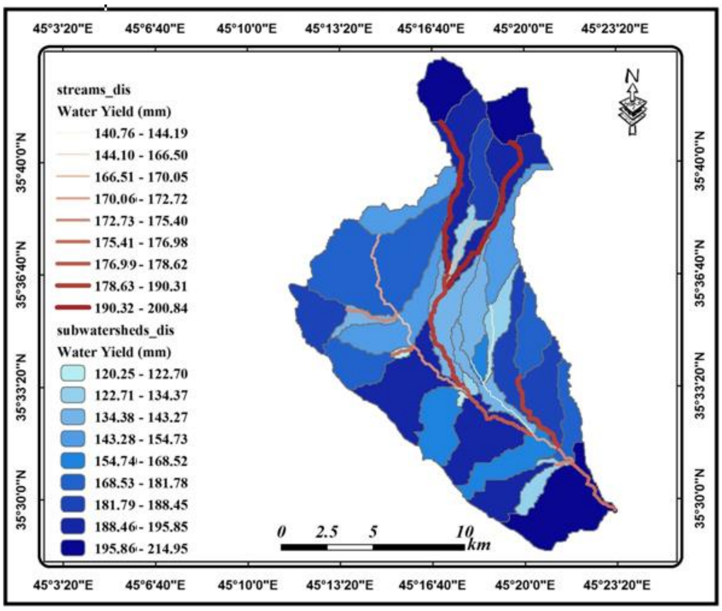
Precipitation (mm)
380.09 - 380.09
0 2.5 5 10
km


0.0
subwatersheds_dis
Percolation (mm)
117.48
117.49 - 119.04
119.05 - 125.40
125.41 - 130.46
130.47 - 139.64
139.65 - 161.34
161.35 - 167.13
167.14 - 182.57
182.58 - 195.94
0 2.5 5 10 km
N


streams_dis
Sediment Yield (tons)
6.10 - 8.73
8.74 - 20.86
20.87 - 38.90
38.91 - 50.68
50.68 - 86.92
86.93 - 479.10
479.11 - 692.20
692.21 - 946.20
946.21 - 1,174.00
subwatersheds_dis
Sediment Yield (tons/ha)
0.00 - 0.00
0.01 - 0.03
0.04 - 0.05
0.06 - 0.14
0.15 - 0.35
0.36 - 0.47
0.48 - 1.02
1.03 - 1.50
1.51 - 2.43
0 2.5 5 10 km
N


streams_dis
Water Yield (mm)
140.76 - 144.19
144.10 - 166.50
166.51 - 170.05
170.06 - 172.72
172.73 - 175.40
175.41 - 176.98
176.99 - 178.62
178.63 - 190.31
190.32 - 200.84
subwatersheds_dis
Water Yield (mm)
120.25 - 122.70
122.71 - 134.37
134.38 - 143.27
143.28 - 154.73
154.74 - 168.52
168.53 - 181.78
181.79 - 188.45
188.46 - 195.85
195.86 - 214.95
0 2.5 5 10 km
N

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النمذجة الهيدروجيومورفولوجية لحوض كاني بان الفرعي في مدينة السليمانية باستخدام تقنيات المعلومات المكانية

أزهر خليل سليمان ، عبدالحق نايف محمود

[1]قسم الجيولوجيا ، كلية العلوم ، جامعة السليمانية ، السليمانية ، العراق

[2]مركز بحوث الموارد الطبيعية NRRC ، جامعة تكريت ، تكريت ، العراق

الملخص

اعتمدت الدراسة على بيانات متعددة بما في ذلك صور الأقمار الصناعية ، ونموذج الارتفاع الرقمي DEM ، والبيانات المناخية، والخريطة الجيولوجية، وخريطة التربة، وخريطة تصريف الحوض، واستخدام الأراضي ، وخريطة الغطاء الأرضي لتقدير حجم وإنتاجية المياه والرسوبيات والتي يمكن لحوض كاني بان ايصالها لحوض تانجيرو. تم استخدام أداة تقييم التربة والمياه (SWAT) لتحقيق أهداف الدراسة. أظهرت النتائج أن هطول الأمطار على منطقة الدراسة يقدر بحوالي 380 مم ، بينما تراوح الجريان السطحي بين (73.16–151.18 مم). كذلك تراوحت معدلات الرسوبيات بين (117.48–195.94 ملم) وتركزت القيم العالية في الأجزاء الشمالية والجنوبية من الحوض. تم حساب الناتج الرسوبي باستخدام معادلة تعرية التربة المعدلة حيث تراوحت الكمية الكلية للرواسب من (0.03–2.43 طن / هكتار) بمعدل (1 طن / كم 2). تراوح الإنتاج المائي للوديان من (140.76 إلى 200.84) ملم، حيث تراوح إنتاج المياه ضمن الأحواض الثانوية من (120.25 إلى 214.95 ملم).