DEM Processing for Watershed Delineation using QSWAT

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Abstract: The study of water resources at watershed scale is widely adopted as approach to manage, assess and simulate these important natural resources. The development of remote sensing and GIS techniques has allowed the use of spatially and physically based hydrologic models to simulate as simply and realistically as possible the functioning of watershed systems. Indeed, the major constraint that has hindered the expansion use of these tools was the unavailability or scarcity of data especially in the developing countries. Soil and Water Assessment Tool is widely used to support water quantity and quality studies. SWAT and digital elevation models (DEM) can be used to perform watershed delineation to a point, a reach, or an area of interest, which is usually one of the first steps in such studies. This paper presents the methodology that preprocesses the DEM in order to facilitate interactive watershed delineation. As a result, watersheds can be delineated quickly and with consistent time response, regardless of the DEM size, or the size of the resulting watershed. In present study area Kaddam watershed of Godavari river basin has been selected. With the help of DEM file generated, Soil and Water Assessment Tool is used for delineation of Kaddam watershed. The stream line generation, number of subbasins and subbasins area has been established.

Keywords: SWAT, Digital Elevation Model, Watershed, Hydrologic models.

Introduction: Watershed delineation is one of the most commonly performed activities in hydrologic and environmental analyses. Digital elevation models (DEM) provide good terrain representation from which the watersheds can be derived automatically using GIS technology. The techniques for automated watershed delineation have been available since mid-eighties and have been implemented in various GIS systems and custom applications (Garbrecht and Martz, 1999). In general, the traditional approach in automated watershed delineation required high-end GIS and often resulted in long processing times (hours) and times that varied with respect to the location of the point of interest (Perez, 1999). For example, if the point of interest was close to the overall watershed boundary, the processing time would be faster than if that point was close to the watershed outlet. This was not conducive to interactive use of the methodology and limited its use to GIS shops. It also limited overall use of the methodology since the end users (people needing the watershed boundaries) were not willing to wait sometimes for days to get results from the GIS group (and then realize that some other points would be of interest and then have to wait for few more days for the results). This paper presents the methodology for DEM preprocessing that provides the basis for fast (sub-minute) and consistent watershed delineation on DEMs of any resolution and size using Quantum Soil and Water Assessment Tool of Kaddam Watershed.

Study Area: The Godavari basin is situated between East longitudes 73˚ 21′ to 81˚ 09′ and North latitudes 16˚ 07′ to 22˚ 50′ in the Deccan plateau covering large areas in the states of Maharashtra, Madhya Pradesh, Chhattisgarh, Orissa, Karnataka, and Andhra Pradesh. Godavari catchment is divided into eight sub basins. The study area is a part of 'Middle Godavari' (G-5) sub basin of River Godavari which lies between latitudes 17˚ 04′ and 18˚ 30′

north and longitudes 77˚ 43′ and 79˚ 53′ east. The watershed spreads over twelve mandals which fall under Adilabad district. The total basin area and entirely lies in the state of Andhra Pradesh.

Review of Literature: SWAT is a basin scale, continuous time model that operates on a daily time step and is designed to predict the impact of management on water, sediment, and agricultural chemical yields in ungauged basins. The model is physically based, computationally efficient, and capable of continuous simulation over long time periods. Major model components include weather, hydrology, soil temperature, plant growth, nutrients, pesticides, and land management. Previous applications of SWAT have compared favorably with measured data for a variety of watershed scales. Brief descriptions of some of the key model components are provided here. In SWAT, a watershed is divided into multiple sub watersheds, which are then further subdivided into HRUs that consist of homogeneous land use, management, and soil characteristics. The HRUs represent percentages of the sub watershed area and are not identified spatially within a SWAT simulation. The water balance of each HRU in the watershed is represented by four storage volumes: snow, soil profile (0 to 2 meters), shallow aquifer (typically 2 to 20 meters), and deep aquifer (more than 20 meters). Flow, sediment, nutrient, and pesticide loadings from each HRU in a sub watershed are summed, and the resulting loads are routed through channels, ponds, and/or reservoirs to the watershed outlet.

Methodology: The step by step procedure followed in delineating watershed is as follows:

Watershed Delineation:

To start automatic watershed delineation, click the Delineate Watershed button in QSWAT project. When the prompt box is opened browse to the data source in the dialogue box next to select DEM. The selected DEM will be copied to the projects source folder and if necessary converted to GeoTIFF format.

Creating stream networks:

The threshold size for creating Subbasins is set next. It can be set by area, in various units such as sq km or hectares, or by number of cells. Click on Create Streams: the number of cells will be adjusted to the corresponding value.

We can add outlets, reservoirs, inlets, and point sources by selecting the Draw Inlets/Outlets option. Points need to be placed on the stream network, and may need to zoom in to place them precisely.

Only points within the snap threshold of a stream reach will be counted as points. Click OK to confirm and exit.

Adding Inlets/Outlets:

If we have several points in inlets/outlets file we can use just a selection of them. To do this, choose the Select Inlet/Outlet option. Selected points will turn yellow, and a count will be shown at the bottom left of the main window.

Clicking Review snapped shows the snapped inlets/outlets, i.e. those within the defined threshold distance. Clicking on Create Watershed will create the watersheds after a few minutes.

Merging Subbasins:

In QSWAT we can select and merge subbasins. This is especially important in avoiding small Subbasins.

To merge Subbasins, select Subbasins under Merge sub basins. Selected Subbasins will turn yellow. When finished click on save. Click on Merge to perform the action. After merging of Subbasins, click on OK. This causes Subbasins to be numbered. This step ends watershed delineation.

Results and Discussions: Using Digital Elevation Model and Soil and Water Assessment Tool, delineation of Kaddam watershed is generated. Watershed, Number of subbasins and subbasins areas has been established. The following figures show Digital Elevation Model of Kaddam Watershed, Stream Lines of Watershed, and Subbasins of Watershed.

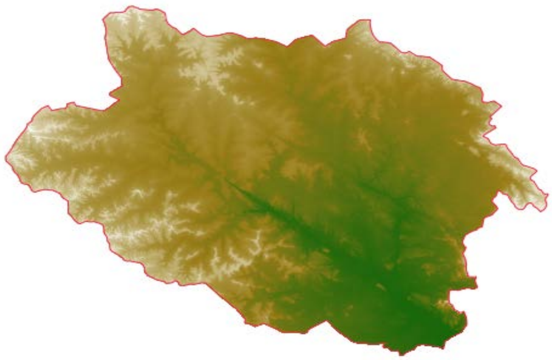

Fig 1: Digital Elevation Model of Kaddam Watershed in QSWAT

In creating stream networks, the threshold size should be set before creating streams; it can be set by area, in various units such as sq km or hectares, or number of cells. In properties of digital elevation model, the horizontal and vertical units of the DEM file should be in meters.

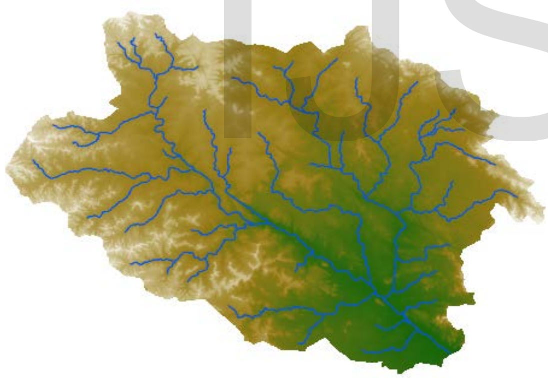

Fig 2: Stream Lines generation of Kaddam Watershed using QSWAT

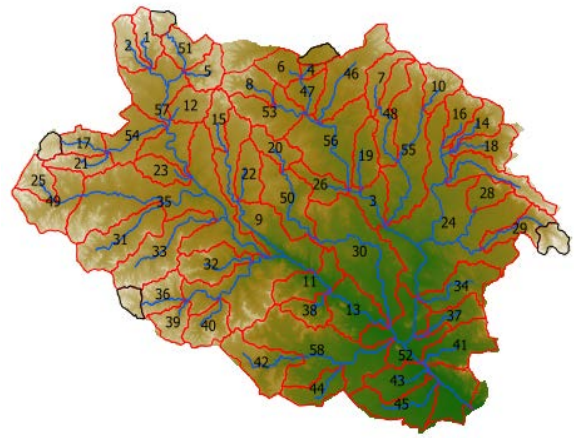

Fig 3: SWAT subbasins generation of Kaddam Watershed in QSWAT

Subbasin S.No.	Area in Hectares
1	20143277.1
2	22638713.43
3	23336284.97
4	5253360.916
5	21098842.24
6	21082661.46
7	21577074.27
8	25046953.32
9	168122831.2
10	22861648.67
11	35319952.73
12	23050424.47
13	43546982
14	20803992.41
15	20125298.46
16	23374939.06
17	19370195.24
18	25524286.42
19	27385076.48
20	20809386.01
21	19756736.17
22	25751716.32
23	19356711.26
24	203183891.3
25	20335648.64
26	20550493.48
27	35847626.04
28	19349519.8
29	24331403.13
30	109914261.8
31	57424700.32

32	35125783.33
33	62474003.58
34	37636501.51
35	178785967.2
36	25529680.01
37	22455331.22
38	19751342.58
39	19241647.91
40	27695208.15
41	40113959.19
42	45567782.03
43	29661173.3
44	24373652.95
45	41545059.56
46	59805972.23
47	19472673.54
48	36047189.03
49	46633915.85
50	52041893.14
51	25154825.21
52	95045021.04
53	39380430.35
54	34618785.46
55	87728610.28
56	74662627.92
57	79366741.14
58	111507170

Table 1: Areas of Subbasins

S.No.	Stream Lines Length in m
1	11191.7
2	6125.7
3	14832.2
4	4321.2
5	11013.4
S.No.	**Stream Lines Length in m**
6	5711
7	12325.7
8	11667.1
9	7470.9
10	6148.4
11	12862.1
12	9541.3
13	6035.7
14	2935.6
15	5911.4
16	9500.7
17	8314.8
18	0
19	11795.2
20	17489.9
21	9712.8
22	14217.2
23	13166.6
24	0
25	1202.7
26	16429.9
27	4006.9
28	4632.5
29	3442.3
30	5714
31	6629.3
32	4750.3
33	7522.7
34	7485.5
35	8514.4
36	0
37	5738.9
38	5630.4
39	7513.3
40	2575.8
41	4994.5
42	6562.1
43	4231.2
44	2445.6
45	5145.3
46	2503.4
47	0
48	5723.4
49	6178.3
50	0
51	7838.8
52	27675.8
53	17419.1
54	22572.8
55	9255.3
56	45261
57	51708.8
58	25502.1
59	11900.9
60	49000
61	17793.6
62	25588.5

Table 2: Lengths of Stream Lines in Kaddam Watershed

Table 1 shows the areas of subbasins in the watershed, and number of subbasins generated in the watershed, which is 58 in number. The areas of subbasins are in Hectare units. The units of areas are fixed in QSWAT model by default. Table 2 shows the lengths of stream lines in watershed.

Figure 3 shows the order and sub basins of Kaddam watershed. The order of stream lines will be displayed in SWAT attribute table after watershed delineation. In present study, the threshold size of 9 sq km is used in generating stream lines.

Conclusions: The methodology described in this paper allows efficient and consistent watershed delineation on DEM's of any size. The speed of delineation can be controlled by the user during the preprocessing stages. The required preprocessing needs to be done only once for a given DEM and can be done at a different location from the one where the actual delineation work will be performed. The study shows the finest delineation of watershed of particular area. The study had demonstrated the use of digital elevation models and soil and water assessment tool, which can easily provide us the data of elevations, stream flows, subbasins efficiently. Further from the watershed generated, the Hydraulic Response Units can be generated using land use and soil data. With this study on watersheds the model will have better predictive capabilities and the improved model can be used for nutrients calibration and best management practices (BMP) analysis for decision making.

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