Regional Decomposition for Water Budget Purpose

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Background:

The current water accounting framework computes the water budget indices at the point level and then those indices are aggregated over zones. But this framework does not take into account the amount of water flowing into the village boundary and the respective flows associated with it. A considerable amount of runoff can be made available to the downstream villages from the upstream villages which can be used to tackle the crop water deficit more effectively. This issue can be addressed by mapping the administrative and watershed boundary and then establishing a relationship between the water available in each watershed and the drain points of the village boundary. If we are able to evaluate the amount of water available at drain points and also at the points within the village on stream network then we will be able to propose locations for water storage structures in order to achieve equal distribution and availability of water within the village. The runoff harvesting structures if built will be useful to farmers to use the impounded water in dry seasons. This work aims to build a water accounting framework which will roughly answer how much water was available to the village from external sources, how much was used and percolated within the village and how much water is flowing out of the village or is made available to other neighboring villages.

Motivation:

1. Regional or Village level Irrigation Planning
    a. Understanding stream flows and water availability
2. Integration of Administrative and Natural boundaries
    a. Establishing a relationship between Village and Watershed boundaries

Objective:

Given a DEM and village boundary, dividing the village into zones such that either each zone represents whole or part of the watershed for the drain point in the village or it represents a part of village boundary where water is flowing IN or OUT of the village.

Input:

- DEM (Digital Elevation Model)
    - Used for generating Stream Network
- Points
    - Intersection of Administrative Boundary & Stream Network called drain points
    - Other points representing Water Storage Structures on stream network

Output:

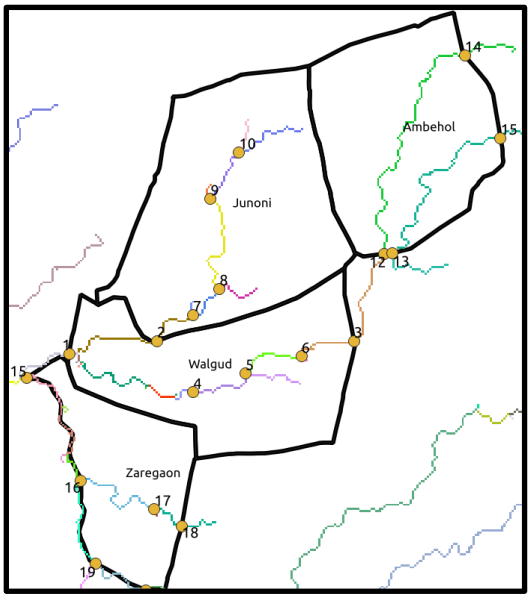
- Zones
    - Division of Administrative boundary into regions called as zones, based on a watershed basis
- Differential Watershed for each point
- IN or OUT notion representing the flow of the administrative boundary
    - Represents Water Flow within or OUT of the administrative boundary
    - IN and OUT notion of water flow is also applicable to points taken in input which is represented as a label in the output decomposition table

Concept of Differential Watershed:

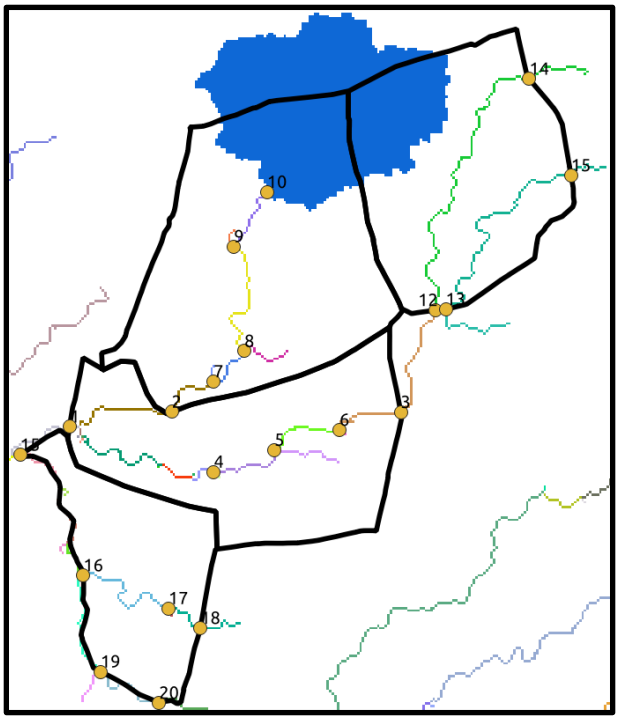
A watershed describes an area of land that contains a common set of streams and rivers that all drain into a single larger body of water, such as a larger river, a lake or an ocean. It is any surface area from which runoff resulting from rainfall is collected and drained through a common point. The differential of a watershed is that part of the watershed which is the new water accumulating at that point which may be the subset of the actual watershed of that point.
This gives us the idea of how much new water has arrived at that particular point which can be used to conceptualize a water accounting framework representing how much of water is coming IN the village and how much of water is going OUT of the village. The concept of differential water helps us to identify the amount of water which will be surely available even if no water is allowed to transcend from the surrounding points either through runoff or groundwater, etc.

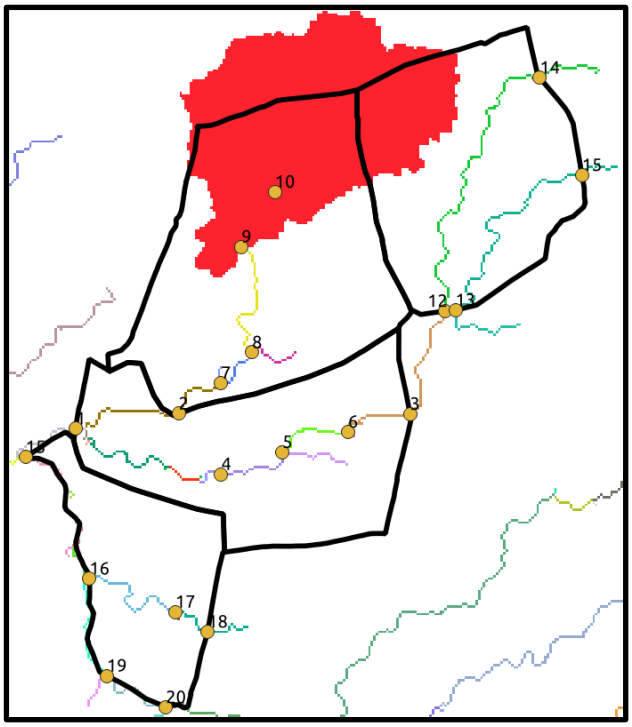
Example of Differential Watershed:

Let’s understand the concept of the differential watershed through example. Consider the below cluster boundary as administrative boundary and the respective stream segments generated from watershed which is a natural boundary. The points on the stream network represent the drain points and the potential water storage structure points.

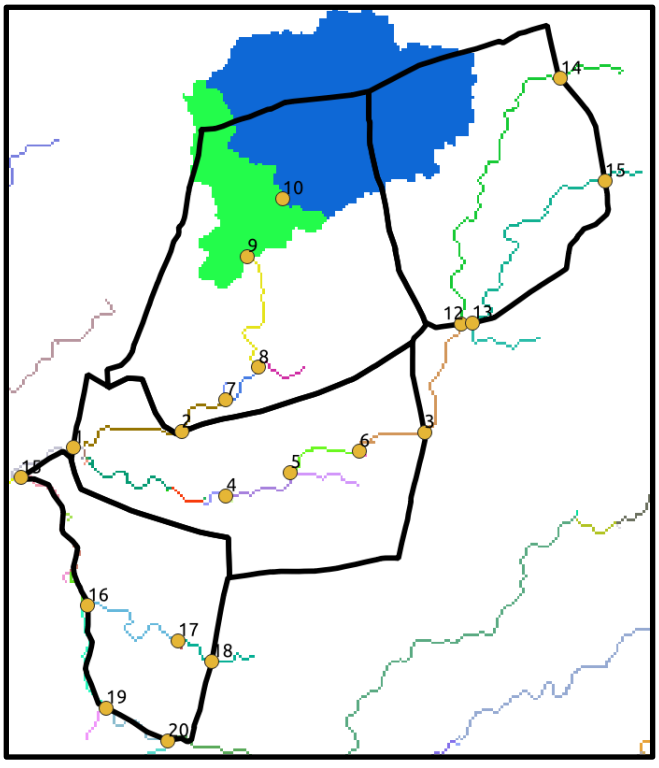


Below is the watershed for point 9 and 10 respectively.





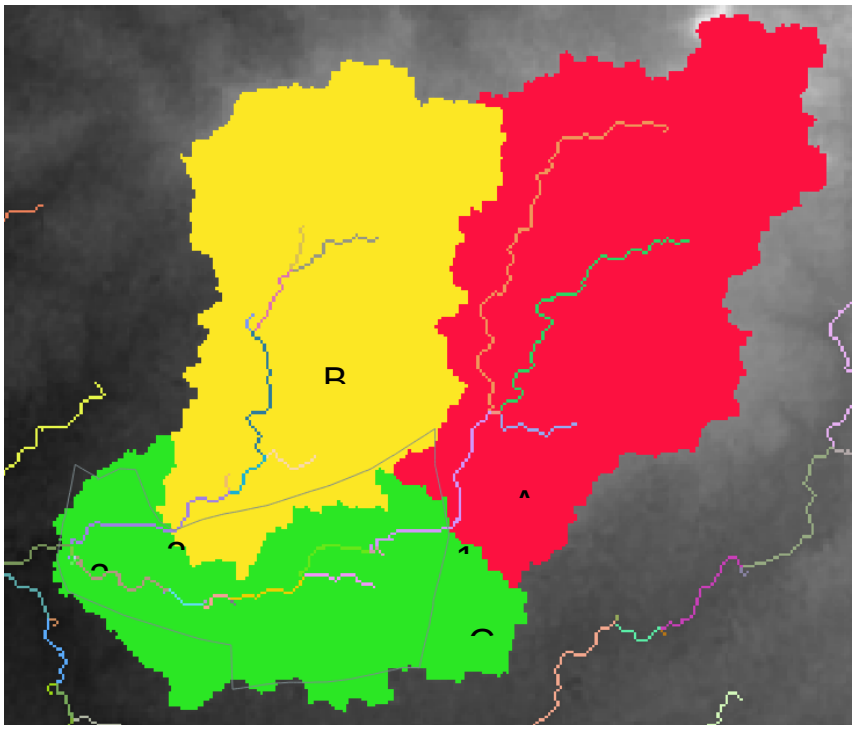
Now, the differential watershed for point 9 is the amount of water accumulating at point 9 and is not part of the watershed for point 10. The below area marked in green represents the differential watershed for point 9. Say “X” amount of water is available in the watershed for point 10 and “Y” amount of water is available in the watershed for point 9, then the differential watershed for point 9 will comprise of “Y-X” amount of water.



Regional Decomposition Procedure In Brief:

1. Derive Stream Network from DEM (Extended DEM)
2. Intersect Stream network and Village boundary for drain points
3. Find differential watershed for each point
4. Allocate zone to differential watershed areas
5. Identify and assign zones to areas not covered in any watershed boundary

Sample Outputs:

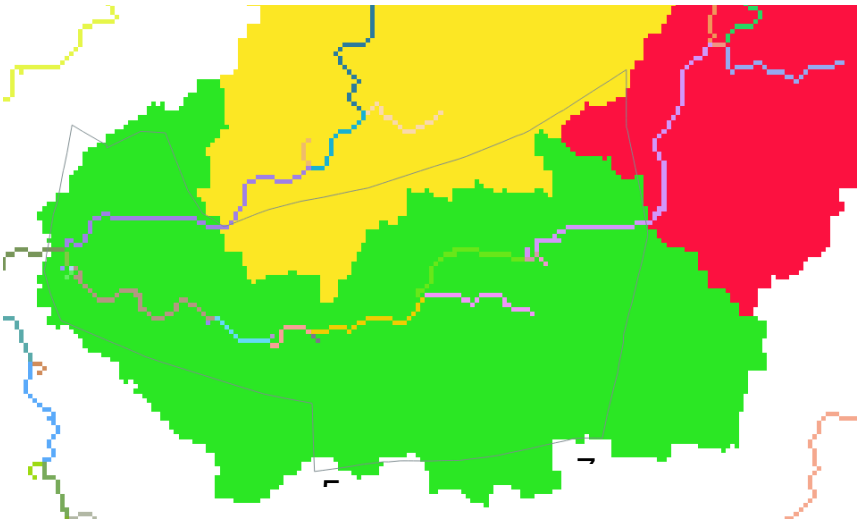


Zones for each drain point for the village:

Point No.	Zones	Outside Zones
1	A	A1
2	B	B1
3	C	C1

Issues:

- The decision needs to be taken on merging of zones having a comparatively smaller area than that of the village area
  Here zones E, F, G, D have a comparatively smaller area than total village area



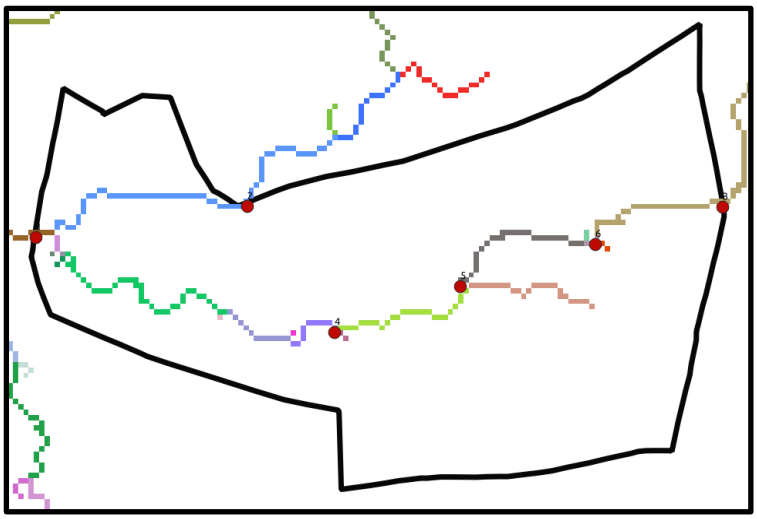
Application:

- Stream Flow Simulation
- Water Accounting Framework
- Integration with existing Water Balance plugin

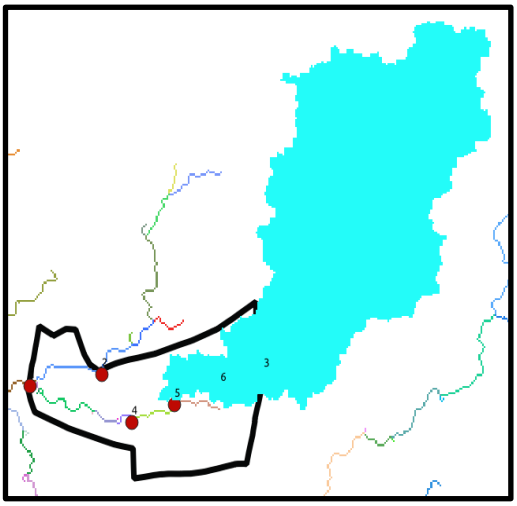
Points within the Village:

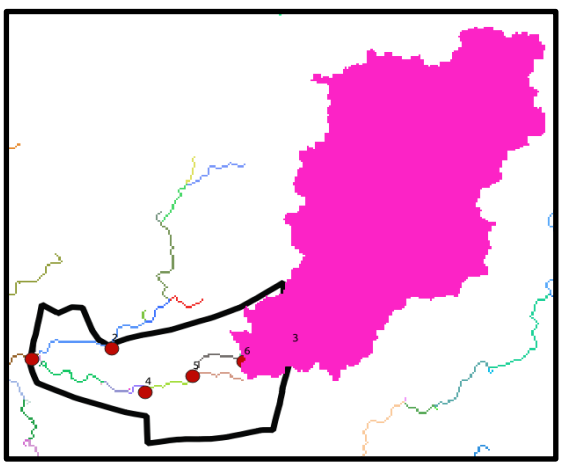
We can have additional points within the village i.e the points which are not in the intersection set of village boundary and stream network. This points may represent the location of current or proposed water storage structures and hence the analysis of such points will be useful. Let’s take a sample set of points. In the below-given image, we have

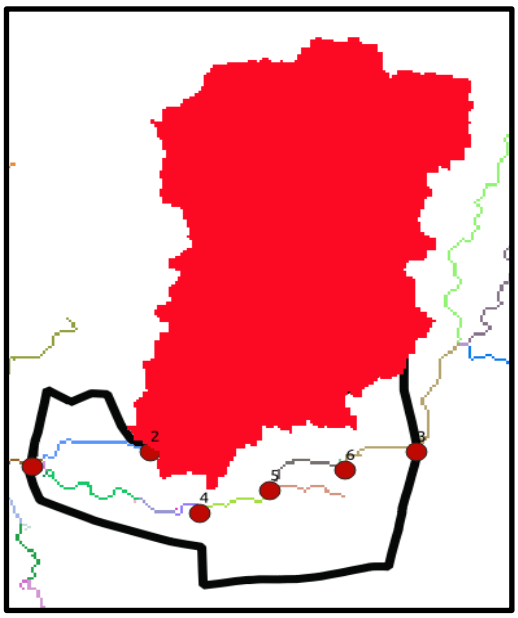
taken a total 7 points out of which 3 are on the village boundary and 3 points are within the village on stream network.

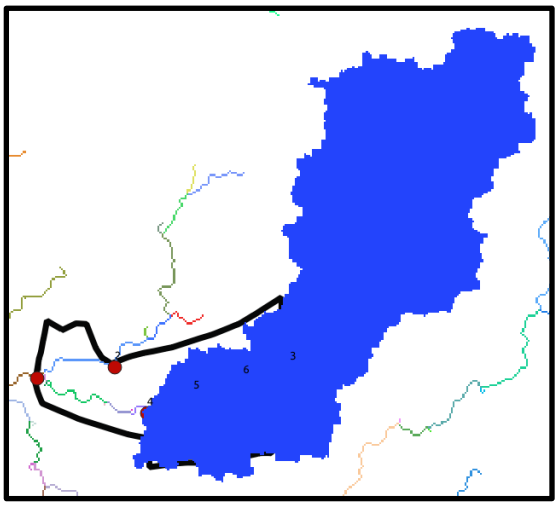


The watershed for each point is as below:






2
3
6
5
4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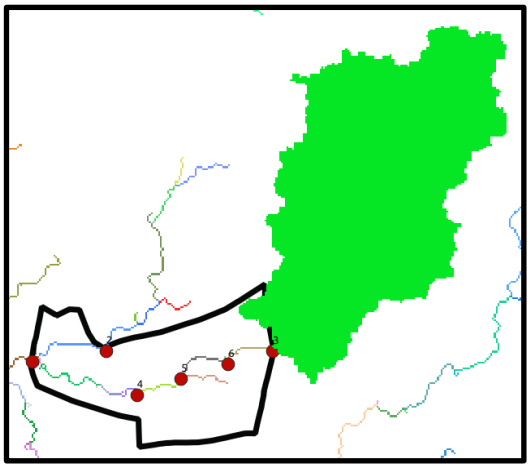
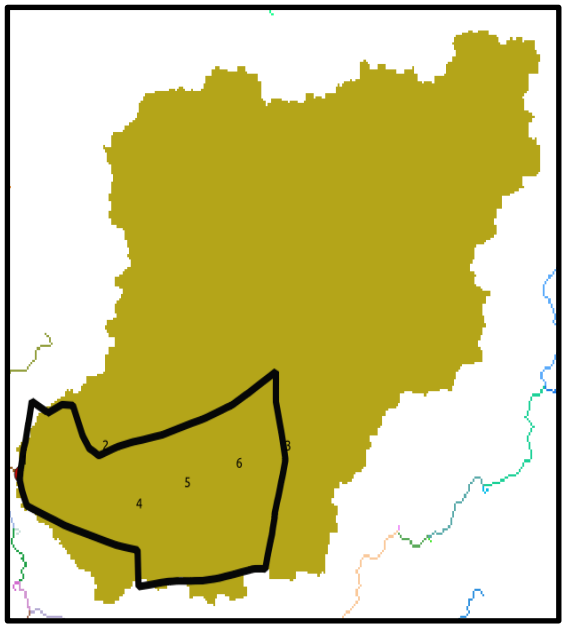
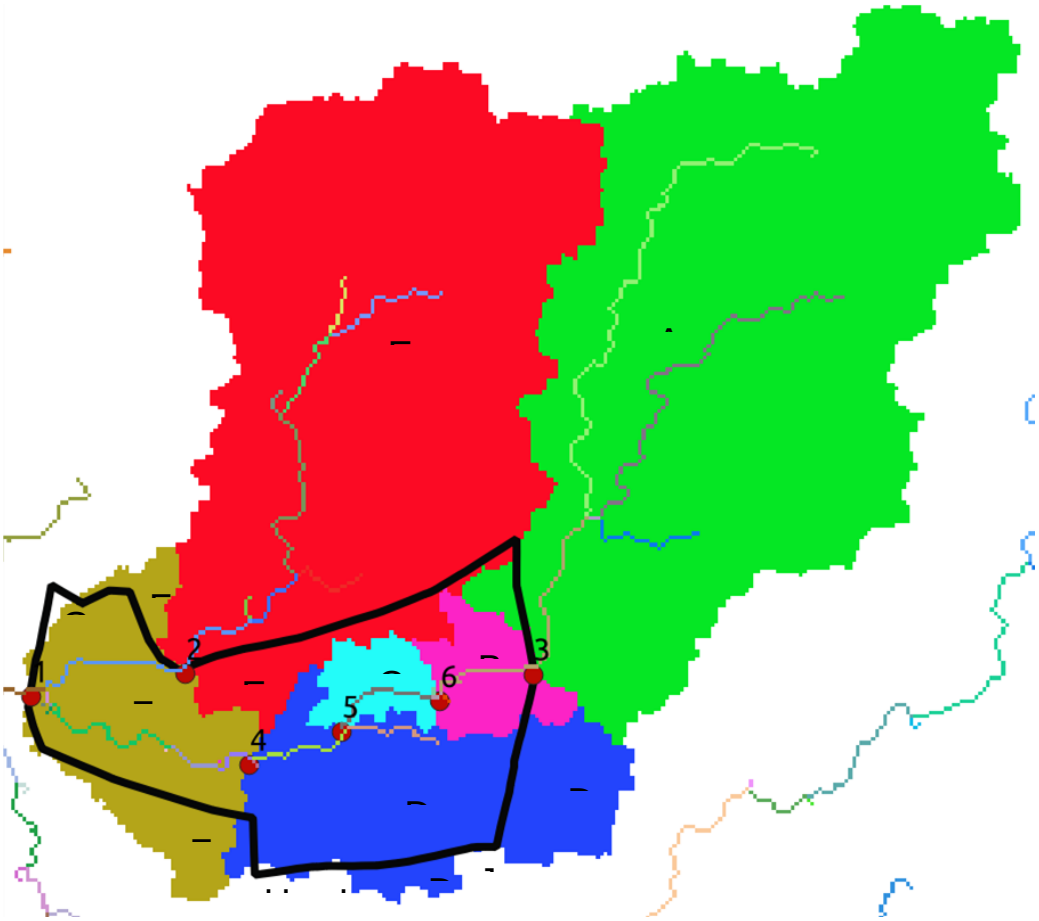




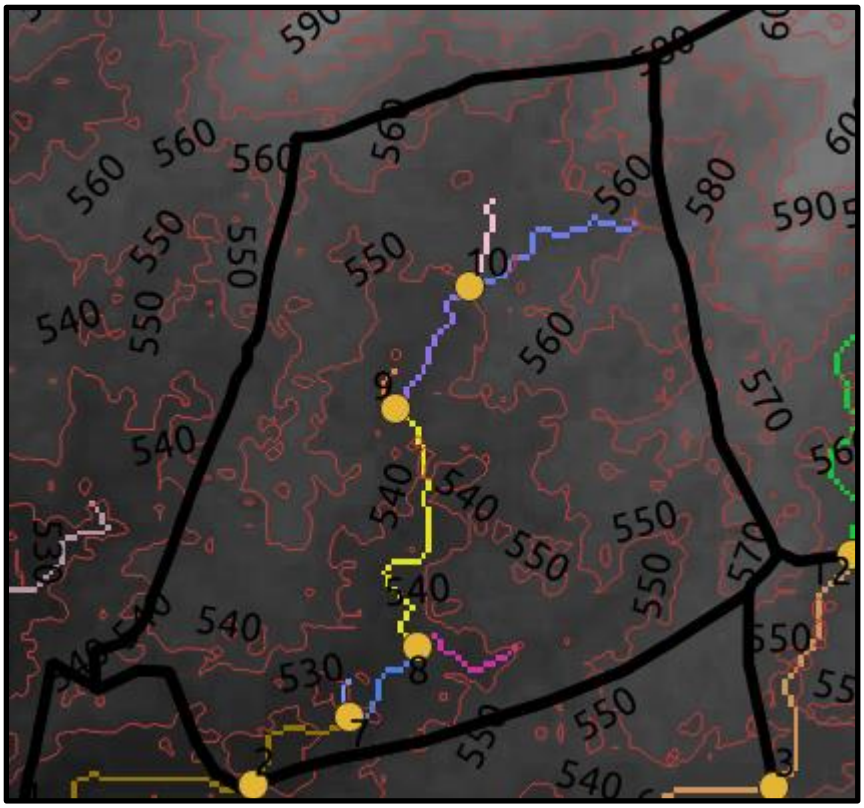
Zonal Decomposition for Water Accumulation of Walgud Village:



Point No.	Contributing Inner Zones	Contributing Outer Zones	Label
1	F	F1,F2	-1
2	E	E1	+1
3	A	A1	+1
4	D	D1, D2	0
5	C	-	0
6	B	-	0

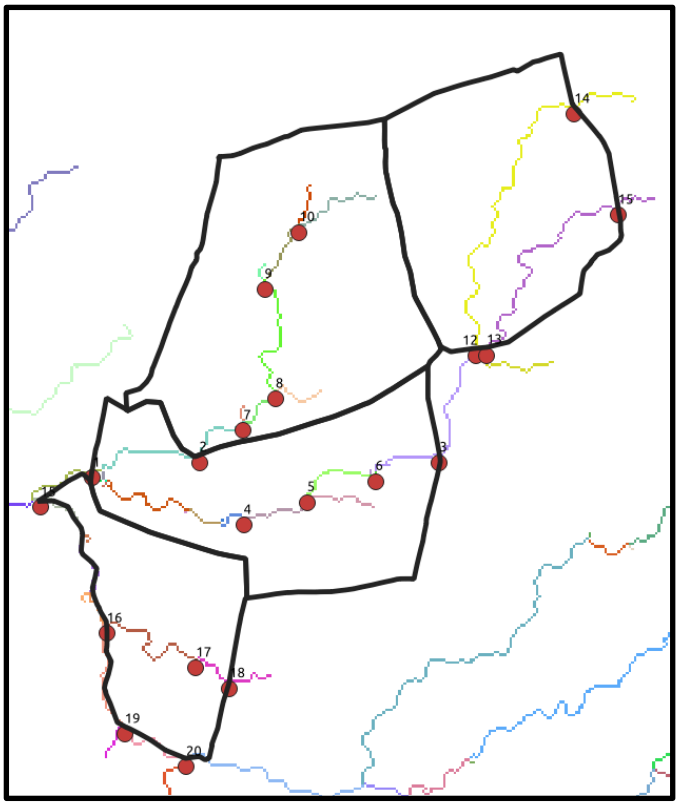
Label: "0" is for a point within the village, "+1" for water entering the village and "-1" for water leaving out of the village for that point.

The attribute “Contributing Inner Zones” represents the division of administrative boundary which is a village. The union of points F, E, A, D, C, B may not constitute a complete village area. It is because there is some part of the village which is not part of any watershed. The areas marked as H, I, J, G are such polygons which are not part of any watershed boundary. The attribute “Contributing Inner Zones” represents the differential watershed for respective point. The attribute “Contributing Outer Zones” represents the part of the watershed which outside the village boundary and is also differential for respective point of interest. The attribute “Label” indicates whether the water is flowing IN or OUT of that particular point. The identification of the flow direction of water can be either done through visualization of stream segments by checking if the stream segments are merging depicting the flow in the merging direction. The more concrete conclusion of direction flow can be done through contours generated from the DEM (Digital Elevation Model). The contours represent the elevation values for each point. The flow is generally considered to be flowing from point of higher elevation to a point of lower elevation. So, if the stream segments and points of intersection are overlapped with the contour layer then the direction flow can be verified as shown below.

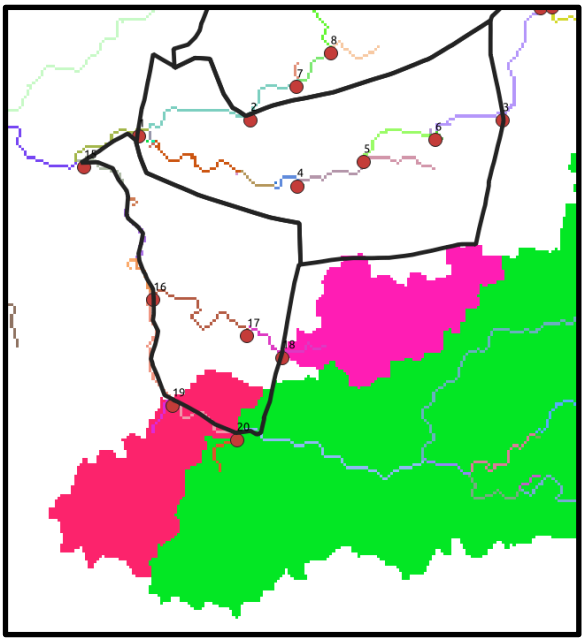


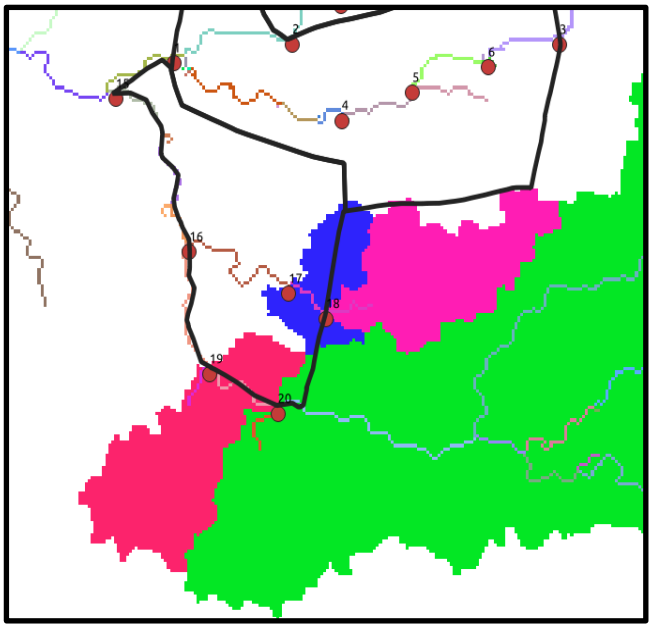
In the above figure, it can be seen that for point 7 the elevation value from contour is 530 and for point 10 it is 550 then it can be concluded that the water is flowing from point 10 to point 7. Similarly, for other points, the contour values will be useful to derive the flow.

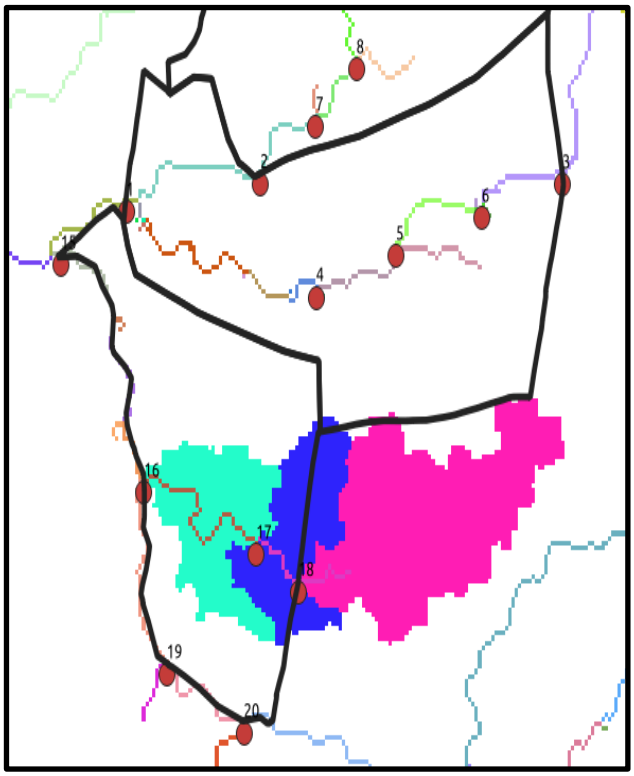
Zonal Decomposition of nearby villages (Cluster):

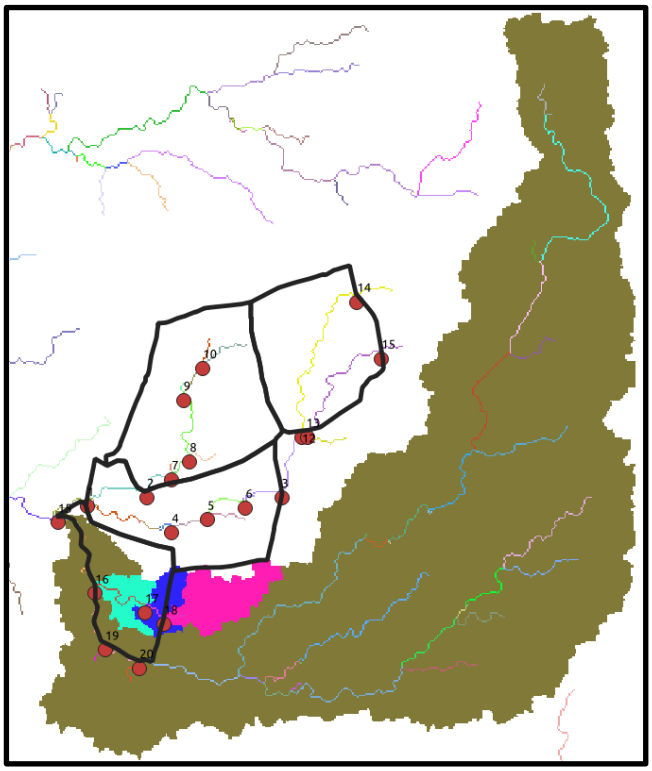


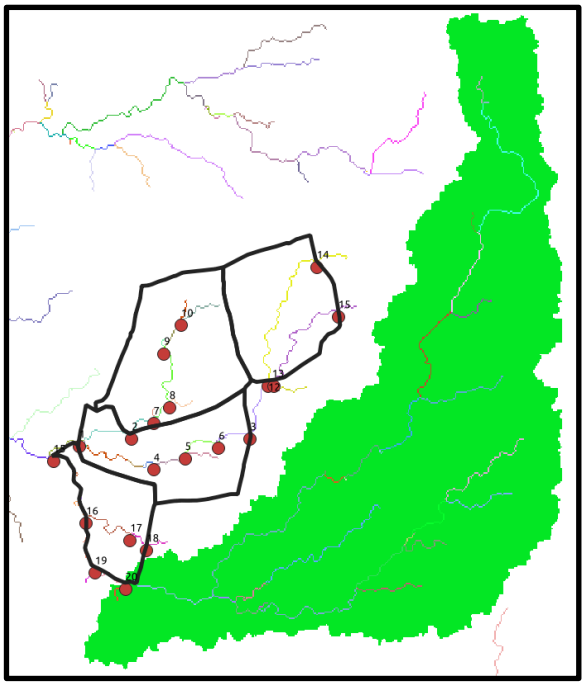
Watershed for each point in Zaregon village (Lowermost in Cluster):

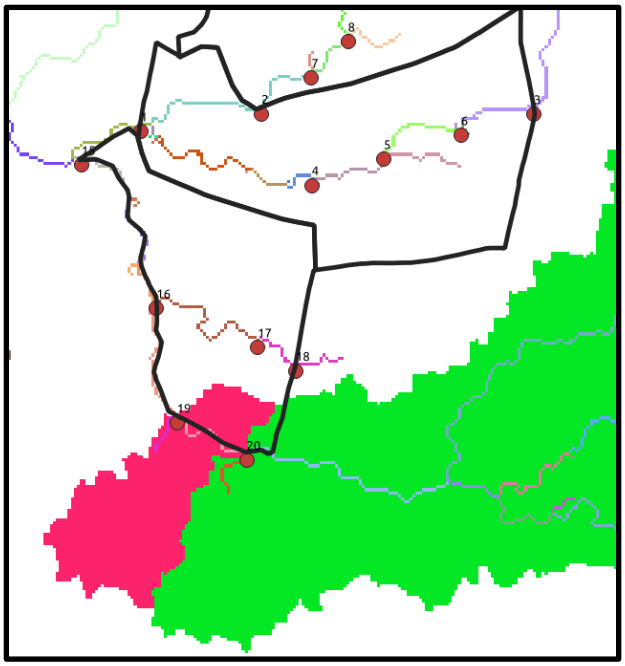




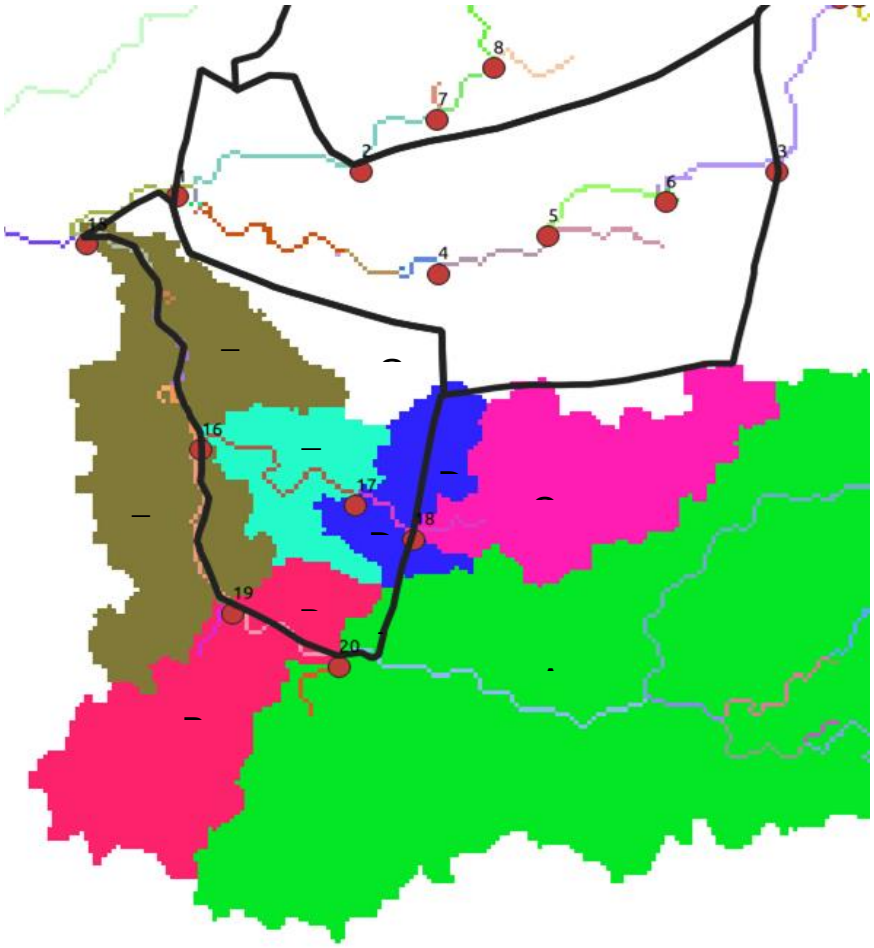








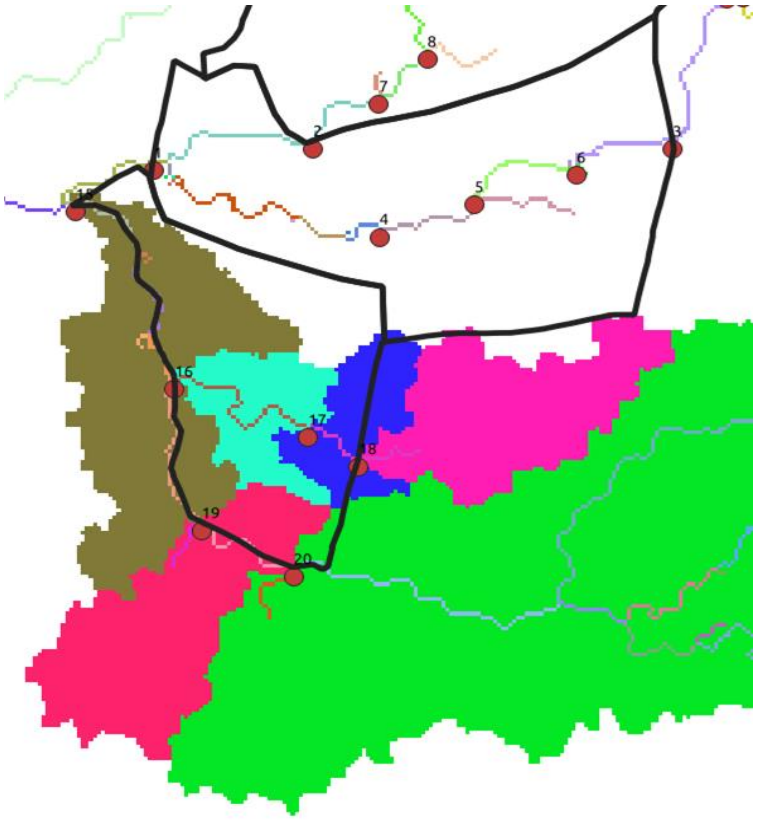
Final zonal Decomposition:

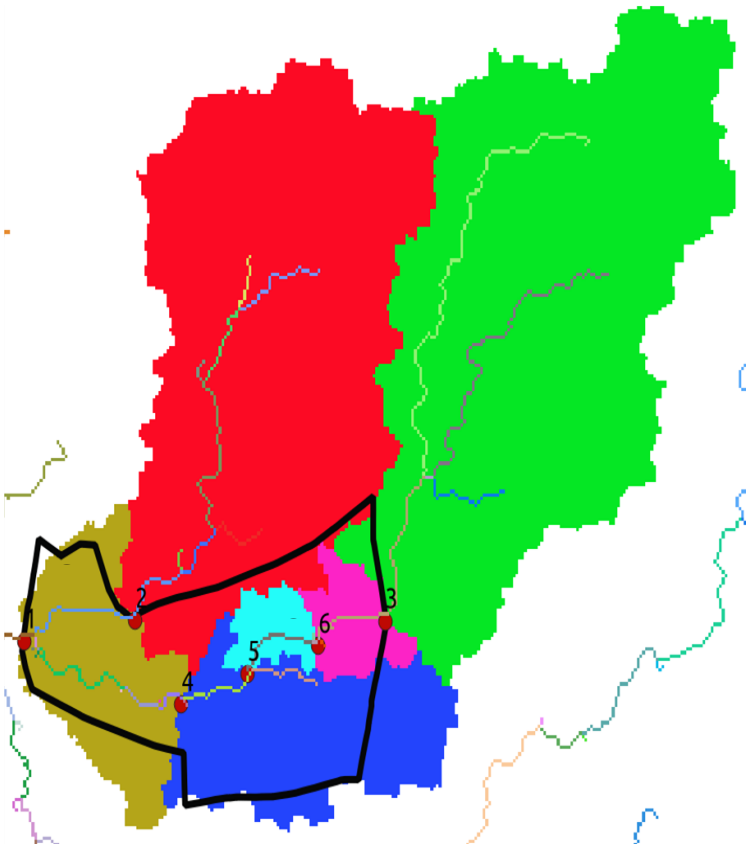


Point No.	Contributing Inner Zones	Contributing Outer Zones	Label
15	F	F1	-1
16	E	-	+1
17	D	D1	0
18	-	C1	+1
19	B	B1	+1
20	A	A1	+1

The F, E, D, B, A are the zones formed by watershed boundary and zone G is the part not in any watershed. All the inner and outer zones represent the respective differential watershed.

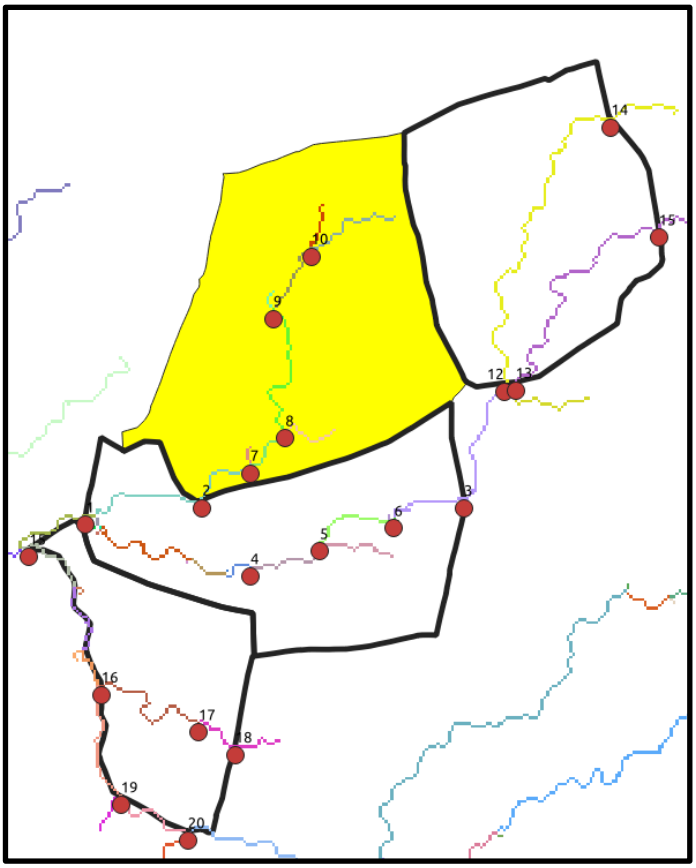
Comparative Analysis of Intra Cluster Water Accounting:

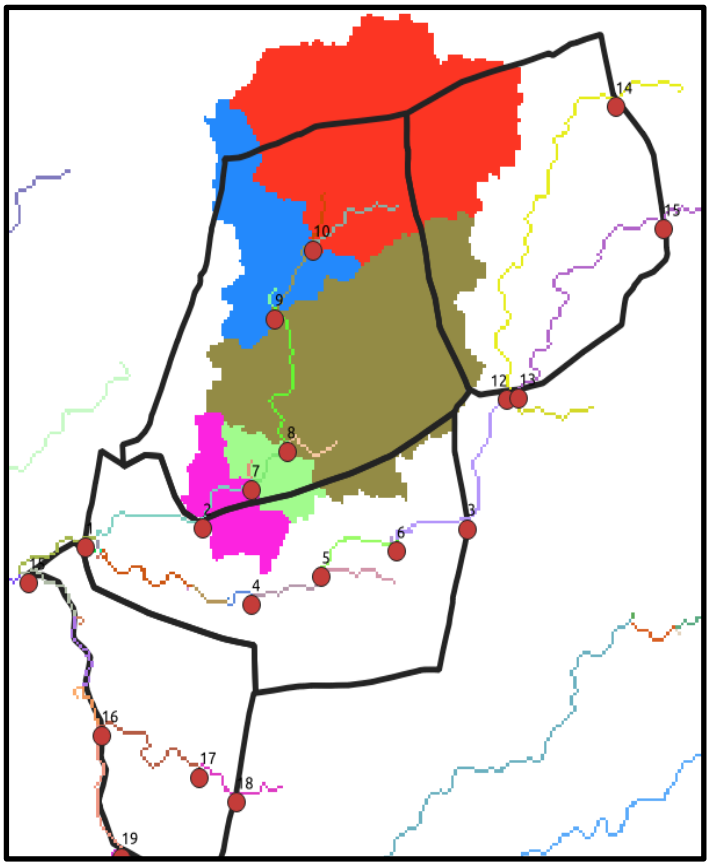




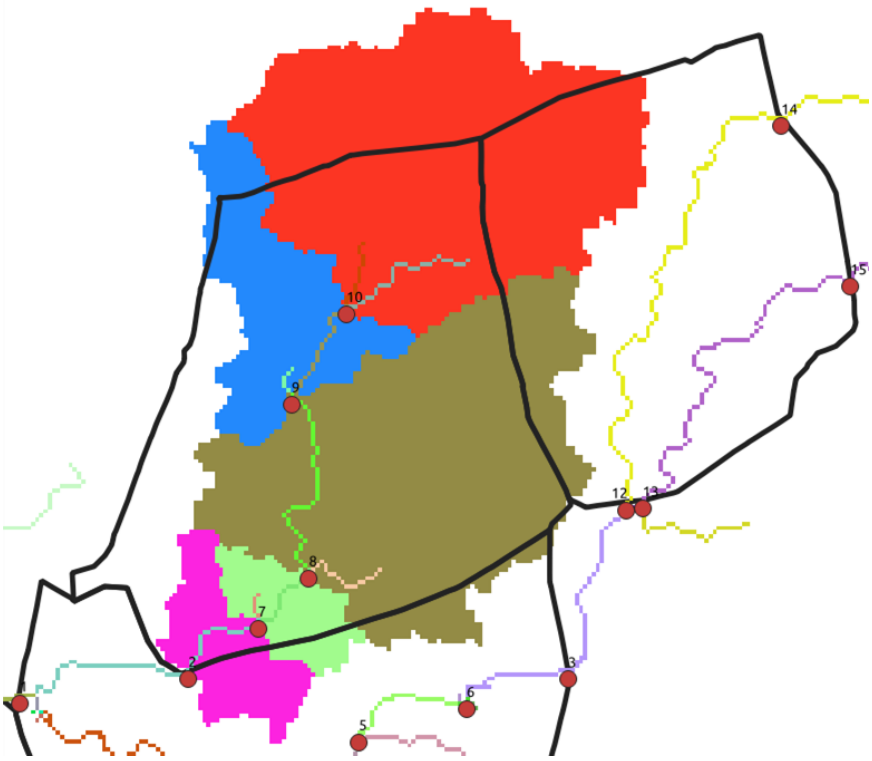
The zone G has no water coming IN from the points within its village boundary which can be seen in the left side figure. The water contributing to the zone G then has to come from one (or more) of the adjacent village. In the right side figure, it can be seen that F2 zone (and some part by H zone) is the watershed part which is contributing to the zone G from the left side. This type of water accounting brings more conceptual clarity of the contributing water based on watershed zones, the flow of water and the overall mapping of the natural and administrative boundaries. Similar accounting can be established for each part of the village with respect to its adjacent villages.

Zonal Decomposition and Watershed of Junoni village (Above Walgud):





Zonal Decomposition:



Final Zonal Decomposition of Junoni VIllage:

Point No.	Contributing Inner Zones	Contributing Outer Zones	Label
2	F	F1	-1
7	E	E1	0
8	C	C1,C2	0
9	B	B1	0
10	A	A1	0

Area Analysis for Junoni Village:

Village area:- 804.751 ha
Total Watershed Area (including watershed outside the village):- 1144.290 Ha
Total Watershed Area (excluding watershed outside the village): -701.379 Ha
Village area not in any Watershed:- 103.373 ha

Village Area = Total Watershed Area (excluding watershed outside the village) + Village area not in any Watershed