Reducing Flood Risk and Planning for Water Harvesting using Geoinformatics : A case Study of the Torsa, WB

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1 Introduction

This lecture note demonstrates how the geoinformatic techniques can be used to monitor the river system through time, how this technology can be used to reduce the flood risk, how the runoff water movement and volume can be determined and controlled for water harvesting. This case study should be treated as a technology demonstration rather than a research. With the help of satellite images (of Cooch Behar district, West Bengal) and GIS, a comparative study on changes in the flow path of river Torsa has been conducted. It has been observed that river Torsa has changed its flow-path resulting in formation of oxbow lakes, eroded plains etc. In addition to this, certain analyses have also been made to detect runoff water flow direction, watersheds, catchment areas etc. Finally, an effort has been made to detect suitable areas for establishing a water harvesting tank in order to utilize excess runoff water for irrigation and other purposes.

2 Data

The following data have been used in this case study

1. Rainfall data (July 2000) of Cooch Behar district. The month of July has been chosen because maximum amount of rainfall can be observed in this month
2. Soil compaction sample data
3. District map of Cooch Behar district, used to subset the satellite imageries
4. Digital Elevation Model (DEM) (10 February 2000)
5. Near infrared band of Landsat-MSS (22 February 1978)
6. Near infrared band of Landsat-TM (14 November 1990)
7. Near infrared band of Landsat-ETM+ (20 November 2005)

Near infrared band of Landsat imageries have been chosen because bare ground, vegetation and water can be clearly discriminated in this band.

3 Technology Demonstration

3.1 Monitoring River Torsa

Remote sensing images have been co-registered and clipped to subset the Cooch Behar district from the whole scene. Then river Torsa has been vectorized and overlayed. The overlay (Figure 1) shows that the river moves like a pendulum. Ground verification confirmed that the course of river primarily changes during the monsoon by flooding a vast area along the river. This analysis can help us to plan appropriate location and extents for establishing embankments to reduce the risk factor. The areas that are at high risk can be identified and protected to minimize the loss of life and other resources.

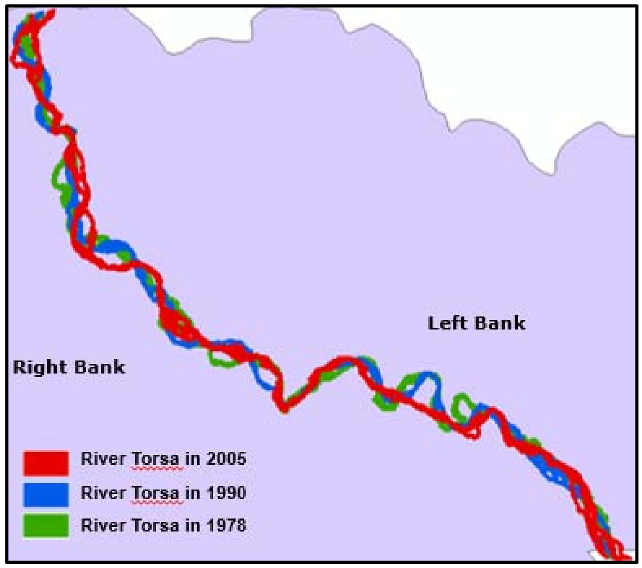


Figure 1 Overlay of multi-temporal river Torsa

3.2 Correction of DEM

The DEM has been clipped to subset the Cooch Behar area. The DEM generally contains some low altitude areas surrounded by high altitude areas. These small pockets will interfere in the hydrological analysis. Therefore, they must be filled to match the altitude of surrounding pixels. Figure 2 shows a cross section of the DEM before and after filling.

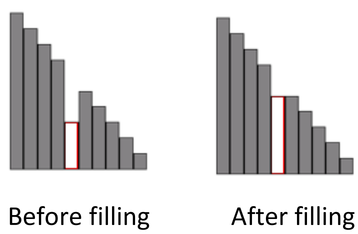


Figure 2 Correction of DEM

This filling can be achieved by using a 3x3 moving window. If the value of the central pixel of the moving window is smaller than the value of all surrounding pixels, it can be considered as a pocket. Then this central pixel value will be replaced by the lowest value of the surrounding pixels. In Figure 3, one can see that the central value of the moving window is 13 (lower than the values of all surrounding pixels). This value has been replaced by 14 (lowest of all surrounding pixels).

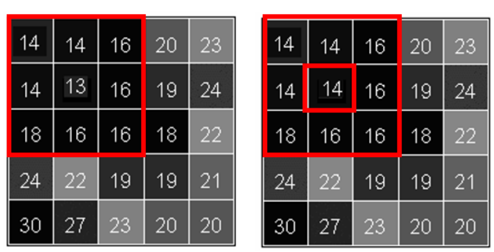
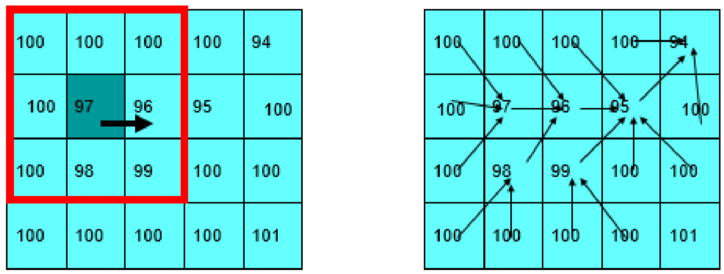


Figure 3 Replacing the value of central pixel

3.3 Determining the Direction of Water Flow

To determine the direction of runoff water flow the corrected DEM has been analysed. A 3x3 moving window was applied on the corrected DEM for each pixel. It was applied to find out the lowest pixel value among the surrounding pixels for each central pixel of the window. Figure 4(a) shows that the water from the central pixel (97) will flow towards the pixel having value 96. It is known to us that water flows towards lower elevation because of gravity. Figure 4(b) shows this water flow in a grid of 20 pixels for better understanding.



(a) (b)

Figure 4 (a) Moving window search to find out the lowest surrounding pixel value, (b) A grid shows water flow for all of the pixels in the grid

To represent the flow direction as a grid image different directions have been assigned with different integer values as shown in Figure 5. Therefore, a new grid will be created to represent the direction. For example, in Figure 4(a), pixel value 97 (central pixel of the marked window) will get value 1 in the new grid since the water is moving towards east (refer, Figure 5). Figure 6 clearly shows how this flow direction grid is generated from the DEM and Figure 7 shows flow direction map of Cooch Behar.

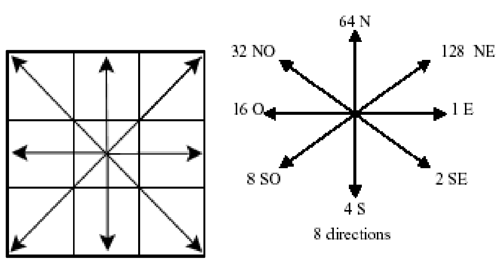


Figure 5 Values assigned for different directions

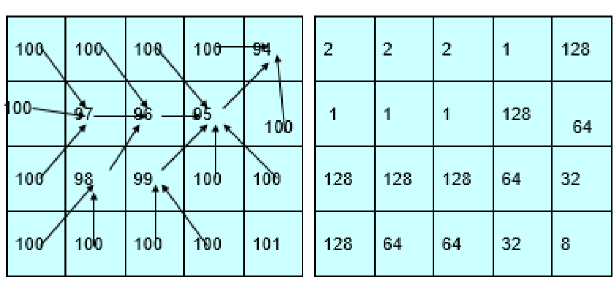


Figure 6 Flow direction grid (right) has been generated from the DEM (left)

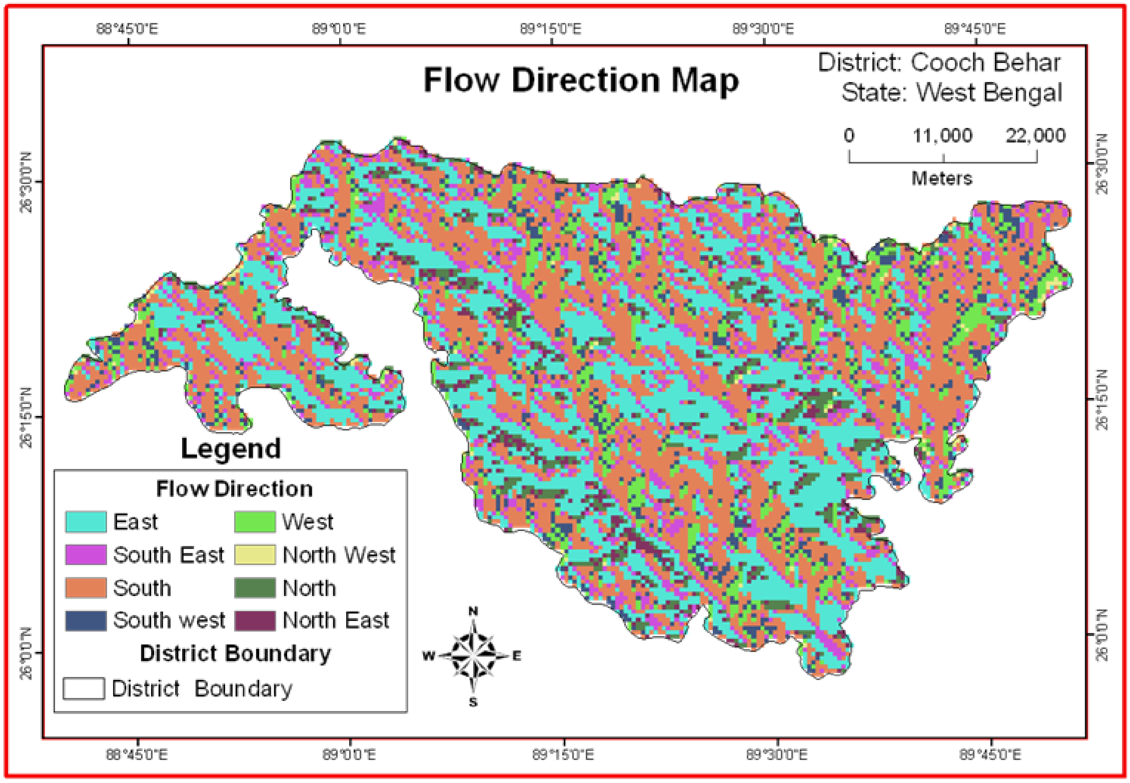


Figure 7 Runoff water flow direction map of district Cooch Behar

3.4 Determining Flow Accumulation

In the next step, flow accumulation grid has been generated from the flow direction grid. Flow accumulation grid is a grid in which a pixel value represents number of pixels from which water has been accumulated in the pixel. In Figure 8, the left-hand side grid shows the flow direction grid. The middle grid is the flow accumulation grid that has been generated from the flow direction grid. Now, by interpreting this new grid, we can identify the water streams as shown in the right-hand side grid. Section 3.5 demonstrates this stream definition technique.

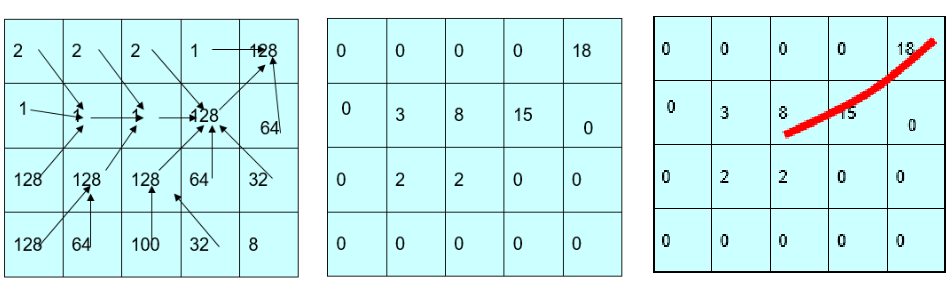


Figure 8 Determining flow accumulation grid from the flow direction grid

3.5 Determining Water Streams

To determine the water streams from the flow accumulation map a thresholding operation was necessary to perform. Determining this threchold is an iterative trial-and-error method. After several experimentations it was found that 20% of the maximum pixel value can be considered as a threshold. Pixel having values lower than this threshold have been converted into 0 and other pixels have been converted into 1 (as shown in Figure 9). Now, pixels having value 1 can be converted into vector generate a vector map of water streams as shown in Figure 10.

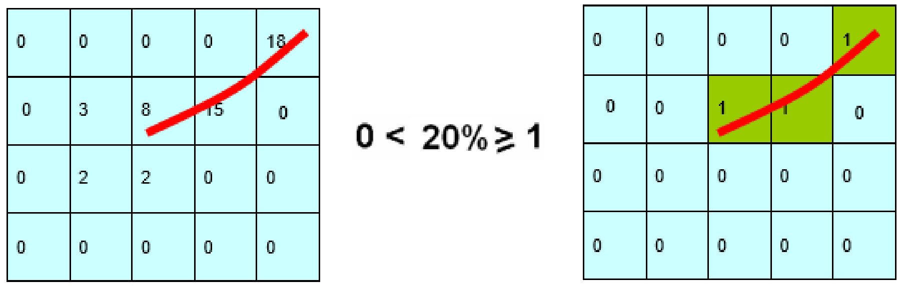


Figure 9 Water streams (right) were determined from flow accumulation grid (left)

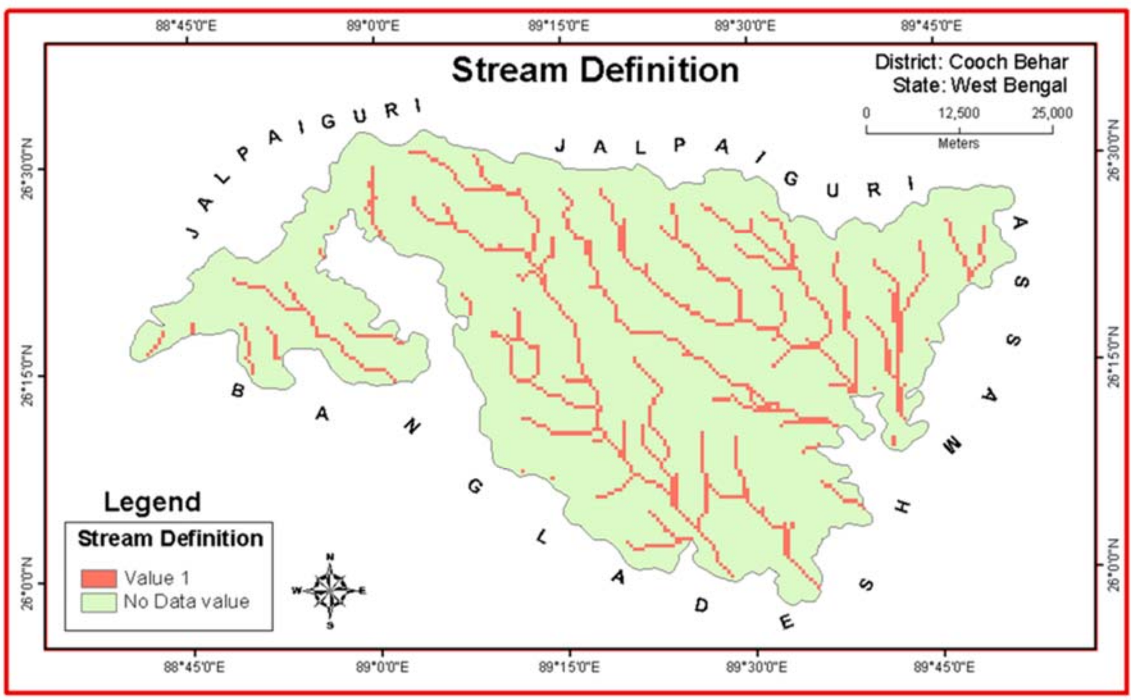


Figure 10 Water streams determined for the district of Cooch Behar

3.6 Identifying Flow Direction for each Vector Stream

Determining the streams is not adequate in hydrological analysis. Knowing the flow direction for each vector stream is equally important. Therefore, the vector map was overlaid onto the flow accumulation map and pixels at the ends of each vector stream were identified as shown in Figure 11. Each vector stream will have two associated pixels at two ends. Among these two pixels one will have lower value and one will have higher value. Low-value pixel is the starting point and high-value pixel is the ending point. Thus we can get the flow direction map of water streams as shown in Figure 12.

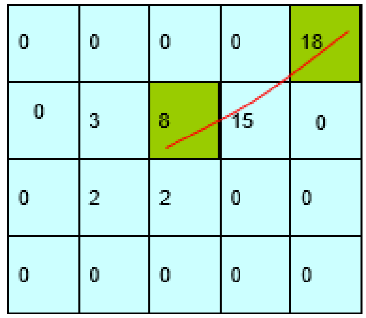


Figure 11 Identifying the starting and ending nodes

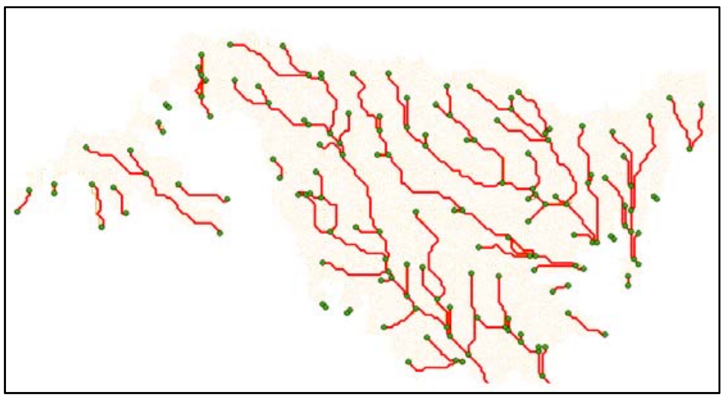


Figure 12 Water streams with starting and ending nodes

3.7 Determining Catchment Areas

Catchment area is the area from which rainfall flows into a river, lake, water drainage, or reservoir. To determine the catchment areas, flow direction grid and water stream map can be used. One can determine the pixels from which water flows into a specific water stream as shown in Figure 13. Different catchment areas (for different streams) have been assigned with different IDs and thus the vector boundary of catchment areas have also been determined as shown in Figure 14. Then the catchment area of river Torsa was separated as shown in Figure 15.

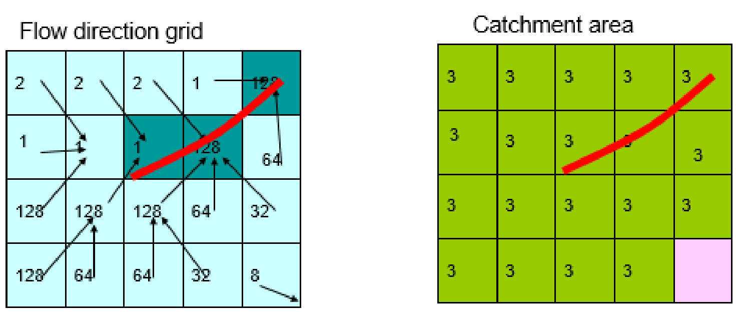


Figure 13 Determining catchment areas

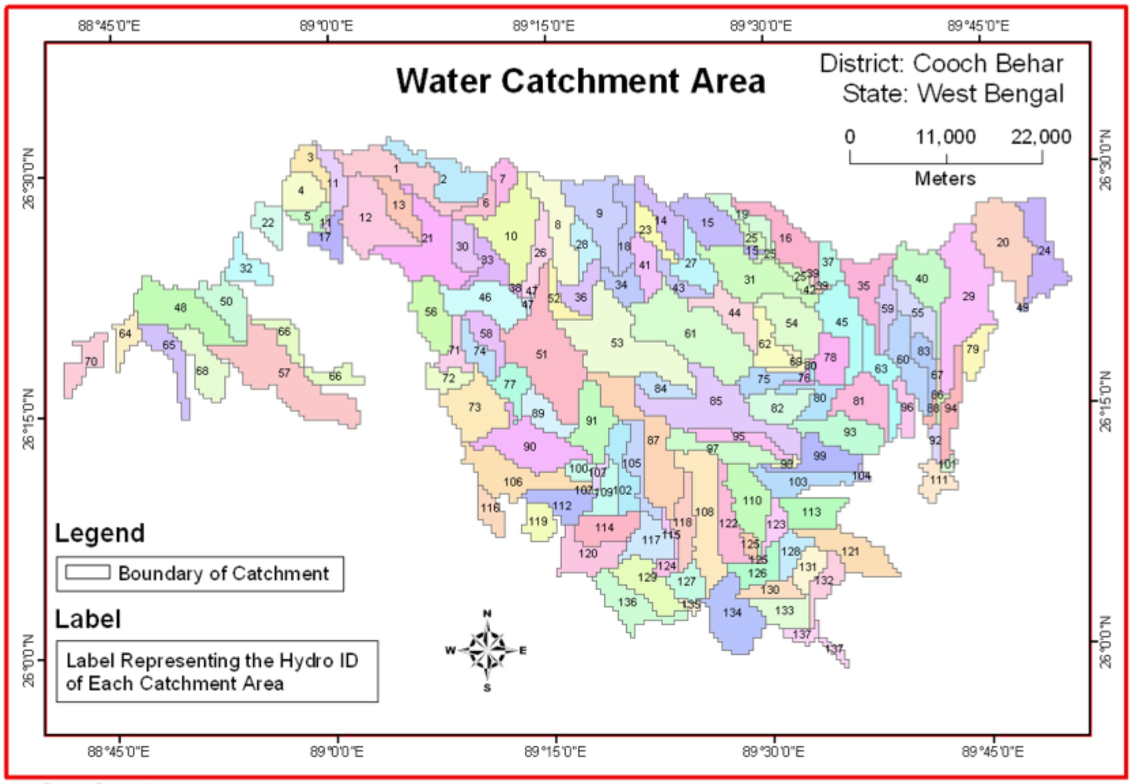


Figure 14 Water catchment areas of Cooch Behar district

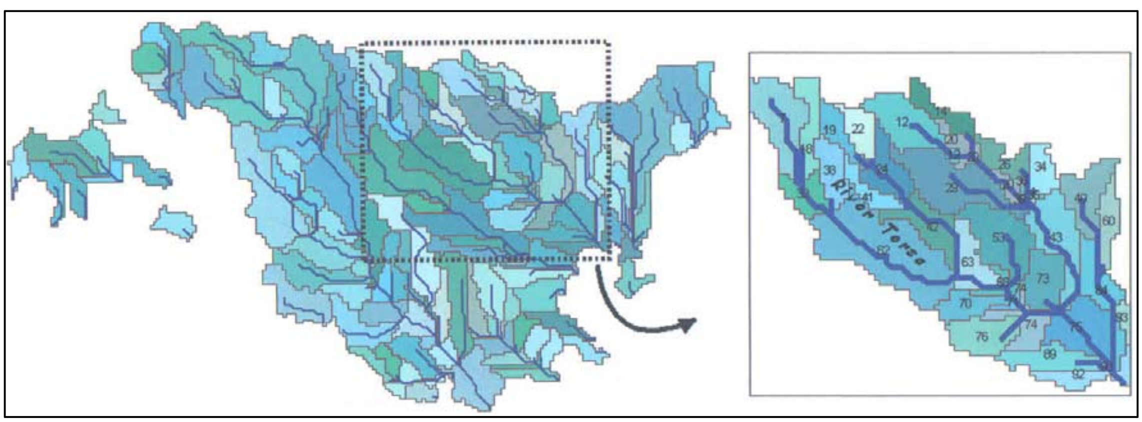


Figure 15 Catchment area of river Torsa

3.8 Determining Rain Water Volume

A rainfall map was created by interpolating the rainfall point data. Then this rainfall map was used to calculate the rain water volume for each catchment areas. To establish a water harvesting tank priorities have been assigned according to the rain water volume.

3.9 Integrating Soil Properties

As a technology demonstration, level of soil compaction have been considered. Interpolated soil compaction grid has been generated based on sample locations. The priorities have been assigned according to the degree of compaction.

3.10 Integration of multi-priorities

Finally, the priority maps (generated from the rainfall data, soil compaction data, water stream map, flow accumulation map, and flow direction map) have been integrated to determine the most suitable locations for establishing water harvesting tank in the river Torsa watershed as shown in Figure 16. This integration can be achieved by multi-agent analysis in GIS environment.

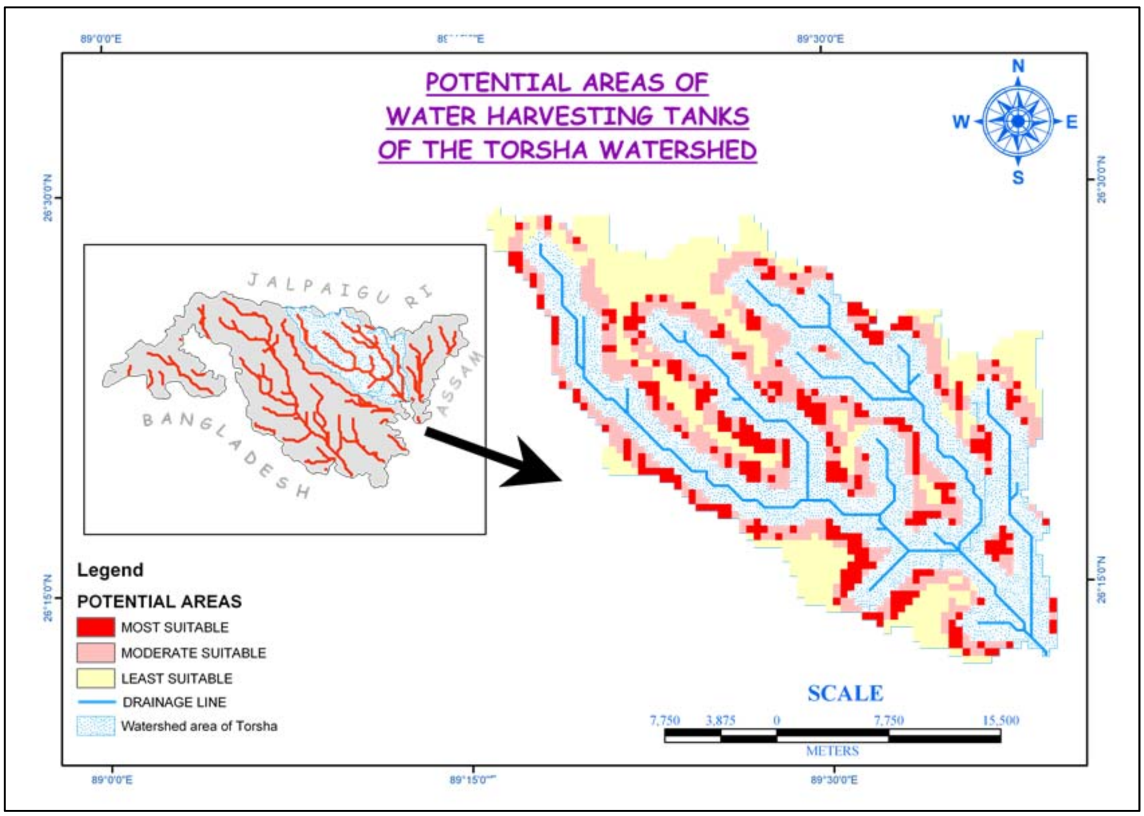


Figure 16 Map showing suitable areas for the establishment of water harvesting tank

4 Conclusions

The analysis shows that remote sensing and GIS can be used very efficiently to monitor the river system and several hydrological analysis to plan for water harvesting tanks. The runoff water can be stored in these tanks and thus we can reduce the risk of overflow of the river. Further, this stored water can be used for irrigation to reduce the risk of draught.