Mapping and GIS Analysis of Small Water Reservoirs in the Hills of the Halda River Watershed

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Abstract

The aim of this research is to the discovery of small water reservoirs in the Halda river watershed, analysing their geometric and geographic parameters like area, neighbourhood distance, elevation wise distribution, tortuosity, perimeter and also mapping these small water reservoirs. Through this research work, a total of 593 reservoirs is identified and mapped. The total area of those reservoirs is 6,124,117 m^2 (6.12 km^2) which cover almost 0.36% of total Halda watershed area and 0.56% of upland (>20 m elevation) area. The average area of these reservoirs found around 10327 m^2. The minimum and maximum area of these small reservoirs found around 180 m^2 and 115007 m^2 respectively. The neighbourhood distance also calculated. The highest occurring distance among reservoirs is around 830 m. The maximum and minimum distance is around 3391 and 44 m respectively. The total number of the neighbourhood is found 1595 under 3400 m cut off distance. The average elevation is found 30.74 m. Elevation wise distribution shows that most of the reservoirs are located in the hill tracts of Halda river watershed which commonly known as upland area. Tortuosity of reservoirs is calculated. From the descriptive statistics, the average tortuosity of studied reservoirs is around 7. Most of the small reservoirs have 250 m to 500 m perimeters. Their average perimeter is calculated as 696.17 m. For the first time, the reservoir map and their relative neighbourhood graph of Halda river watershed are generated through this research.

Keywords: Mapping, Small Reservoir, Watershed, Halda River, Relative Neighbourhood Graph (RNG), Area, Tortuosity, Elevation.

Introduction

Halda is a major tributary of Karnaphuli river and one of the main rivers of Chattogram district. It is the third main river of Chattogram after the Karnaphuli and the Sangu (Kabir

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et al. 2013). Halda River is originated from the Badnatali Hills range in Ramgarh Upazila in the Chattogram Hill Tracts and flows through Fatikchhari, Hathazari, Raozan Upazilla and Chattogram city, and finally falls into the Karnaphuli river (Akter and Ali, 2012). The main water source of this river is its tributaries. The length of the Halda river is 110 km with its headwaters and without headwaters, it is 100 km (Chowdhury, 2015). Halda river watershed lies within longitudes 91°48′–91°53′E and latitudes 22°24′–22°54′N. It consists of an area of 1,682.92 km^2 where land covers 1670.59 km^2 and water area covers 12.33 km^2.

The topography of Halda river watershed comprises of agricultural land, hills, upland, plain land, water areas (ponds, reservoirs, stream, tributaries), build-up area (towns and village) etc. Reservoirs are scattered in all of the watershed areas, especially in the upland area. These reservoirs are difficult to reach because of their location in the hilly area. There is no reliable and quality data on these reservoirs especially about their area, location, shapes etc. Source of water in these reservoirs is mainly rainfall especially the runoff water from hills. In the rainy season, the water level in these reservoirs rises with the increase of rainfall and they slightly expand their area horizontally. These small reservoirs can be classified as rain dominated system. The hilly region of Halda river watershed is well forested. The evaporation and transpiration rate in that area is also greatly depended on these small reservoirs. These small reservoirs increase the soil moisture and they are important for their aquatic resources. In this study, all the small water reservoirs existing in the Halda river watershed were mapped and their different geometric and geographic parameters were analysed. This study will also indirectly help in estimating the role of these small water reservoirs in the hydrologic cycle of Halda river watershed. Since the evaluation of watershed and to prepare a management strategy need quality measurement of land cover use parameters (Butt et al, 2015), so the study of these reservoirs was important.

Methodology

The major part of this research work was on-screen digitising of small reservoirs over a high resolution satellite image of Google Earth. Google earth application is used for on-screen digitising. A series of connected vertices (polygon geometry) is used for enclosing the shape of these small reservoirs. To create the exact curvy shape of these small reservoirs, vertices are dropped homogenously around the boundary of the reservoirs. A single polygon is created for every small reservoir. Then all polygons are saved in Keyhole Markup Language (KML) format. The watershed boundary was used from Halda river basin map (Chowdhury, 2015) and within this area, all the small reservoirs of the watershed were digitised. For better image quality during the digitisation of reservoirs, the image of different years and times were compared and the best image was used. To confirm some of the confusing small reservoirs, ground-truthing was done. After digitisation, QGIS 2.8.1 version software was used to analyse different parameters of these small reservoirs. The parameters that were calculated for these small reservoirs were area, neighbouring distance, elevation, tortuosity and perimeter. After that, exploratory data analysis was

done in Microsoft Excel and descriptive statistics were generated for every parameter. To generate a map of these small reservoirs and also for generating Relative Neighbourhood Graph (RNG), QGIS and Arc GIS 10.1 software version were used. In RNG map, the cut off distance were 3400 m that means reservoirs having distance more than 3400 m among them has no neighbouring relation.

Result andDiscussion

Descriptive statistics were generated on data of every parameter of small water reservoirs (Table 1). Total five parameters were analysed. Descriptive statistics revealed the mean, median, mode, sum, count, minimum and maximum value of selected parameters.

Table 1: descriptive statistics data for Reservoirs in Halda river watershed:

Statistical Parameters	Area(m2)	Neighbour's distance(m)	Elevation(m)	Tortuosity	Perimeter(m)
Mean	10327.34	1208.52	30.74	7.03	696.17
Median	5782.96	1048.98	26	6.22	472.39
Mode	N/A	829.67	20	4.65	254.30
Minimum	180.93	44.67	5	3.68	62.03
Maximum	115007.43	3391.59	95	20.92	4858.48
Sum	6124117.37	1927592	18229	4173.3	412831.32
Count	593	1595	593	593	593

Reservoir Area

From the descriptive statistics (Table 1) the mean area of reservoirs is estimated at around 10,328 m^2. The median most reservoirs are nearly 5,783 m^2. In the study area, the minimum area of studied reservoirs was 180.93 m^2 and the maximum was 115,007.43

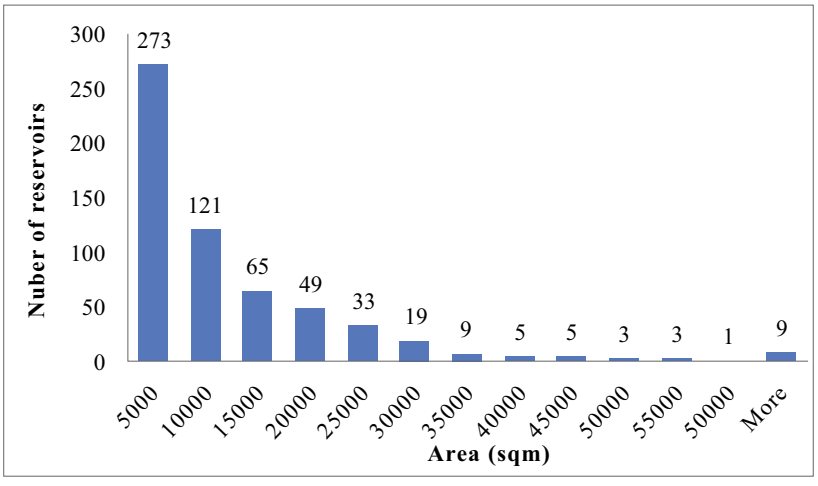

Fig. 1: Frequency of reservoirs according to their area.

m². The total area occupied by the studied reservoirs was 6,124,117.37 m². The total area of Halda watershed is 1,682.92 km². Reservoirs occupied 0.36% of total watershed area and 0.56% of upland (>20 m elevation) area. The total number of studied reservoirs is 593.

The bar diagram (Fig. 1) showing that the highest number of reservoirs cover 5000 m² and 9 reservoirs cover more than 60000 m².

The cumulative percentage graph (Fig. 2) is showing that 90% reservoirs are less than 30,000 m² and the median area is about 5,782 m².

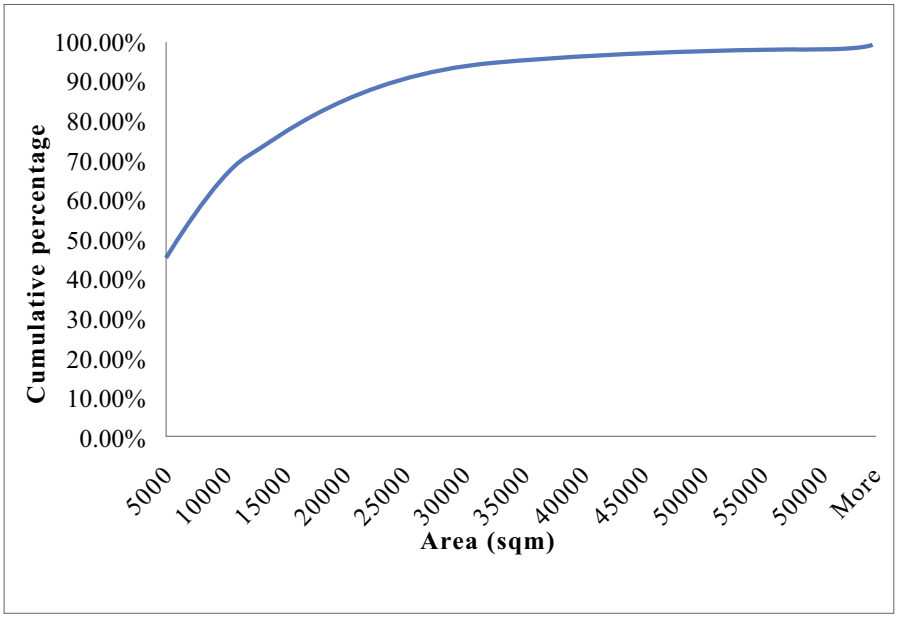

Fig. 2: Cumulative percentage of reservoirs according to their area.

The Neighbouring Distance Among Reservoirs

According to descriptive statistics (Table 1) the average distance among neighbouring reservoirs was around 1,209 m. The highest occurring distance among reservoirs was 830 m. The minimum distance among reservoirs was 44.67 m and the maximum was 3,391.59 m because 3,400 m were set as the cut off distance.

The frequency graph (Fig. 3) shows that the highest number of reservoirs (270) has around 700 m neighbourhood distance among them. The lowest number of reservoirs (10) has less than 100 m neighbourhood distance among them.

The cumulative percentage graph (Fig. 4) is showing that more than 75% reservoirs are in between 2,000 m neighbourhood distance and the median neighbourhood distance is around 1,048 m.

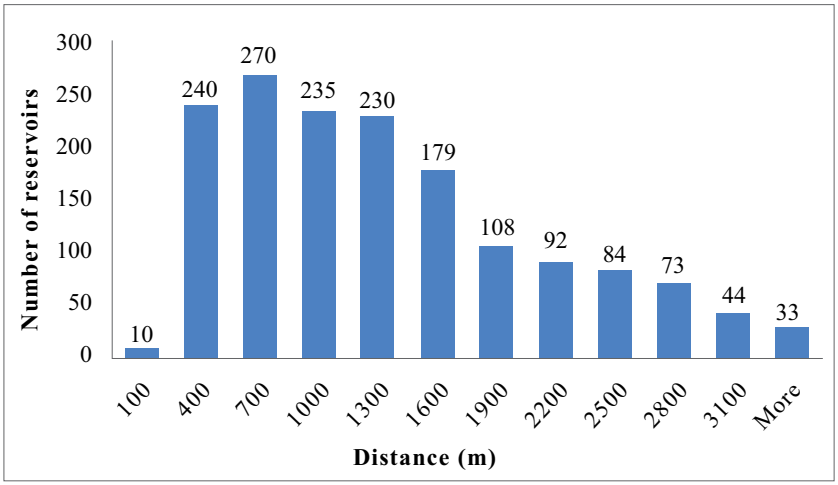

Fig. 3:Frequency of reservoirs according to their distance.

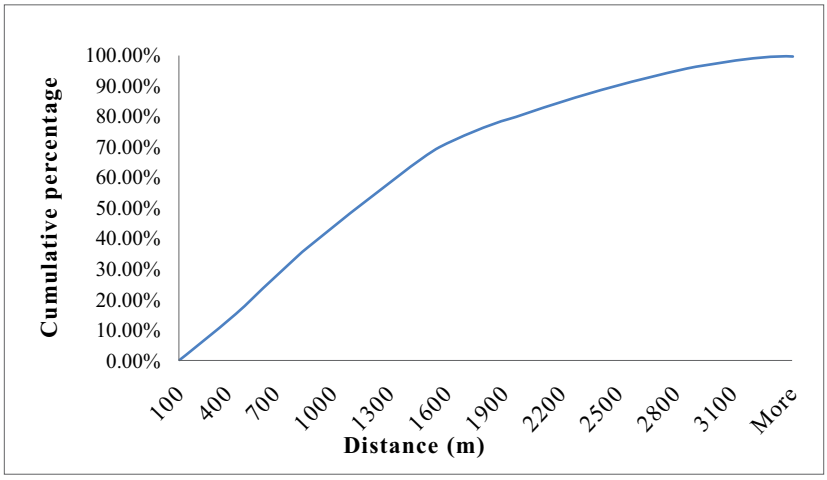

Fig. 4:Cumulative percentage of reservoirs according to their distance

Elevation Wise Distribution of Reservoirs

According to the descriptive statistics (Table 1), the average elevation (elevation from the sea level) of the reservoirs is around 31 m. The median most reservoirs are nearly 26 m elevation. The minimum elevation of reservoirs is 5 m and the maximum elevation is 95 m. Elevation wise distribution shows that most of the reservoirs located in the hill track which commonly known as non-valley area. Hilly region of the watershed is well forested while the plains are broad and fertile, suitable for cultivation.

From frequency distribution (Fig. 5), the highest number of reservoirs (168) falls in elevation class of 20-30 m. Most of the reservoirs lie between elevation-class of 10-40 m. Only one reservoir lies between 90-100 m elevation class.

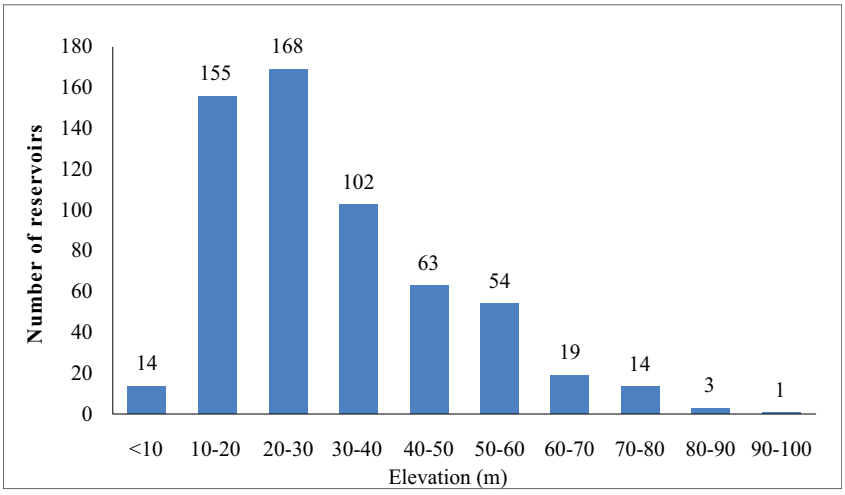

Fig. 5:Distribution of reservoirs at different elevation

The cumulative graph (Fig. 6) shows that about 80% of reservoirs are located between 10-40 m elevation classes. The median elevation of the reservoir is 26 m.

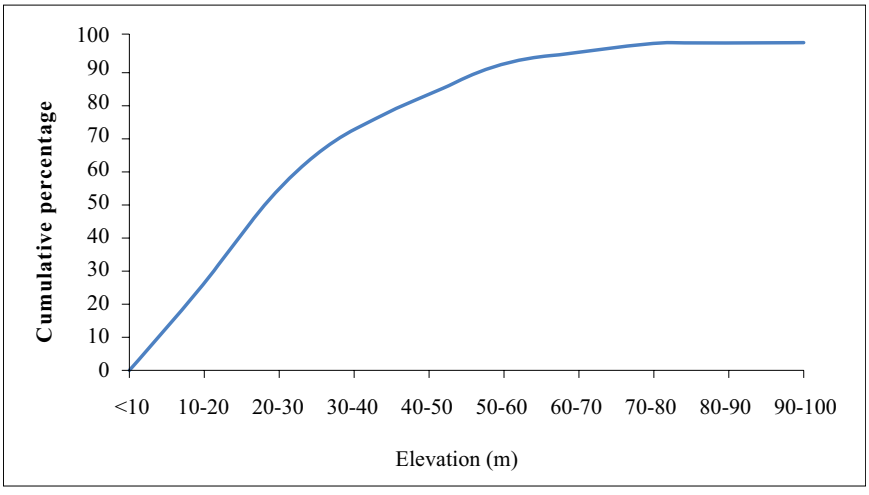

Fig. 6:Cumulative percentage of reservoirs according to their elevation

Tortuosity of Reservoirs

Tortuosity of a reservoir denotes that how much curvy the boundary of the reservoir is. From the descriptive statistics, the mean tortuosity of studied reservoirs is around 7 per unit area. The median tortuosity of the reservoir is 6.22 per unit area. The dominant tortuosity of reservoirs is around 5 unit per area. The minimum tortuosity of the studied reservoirs is about 4 and the maximum is around 21 unit per area.

According to the bar diagram (Fig. 7), the highest number of reservoirs tortuosity has 6 per unit area and the lowest number of reservoirs tortuosity has 20 unit per area.

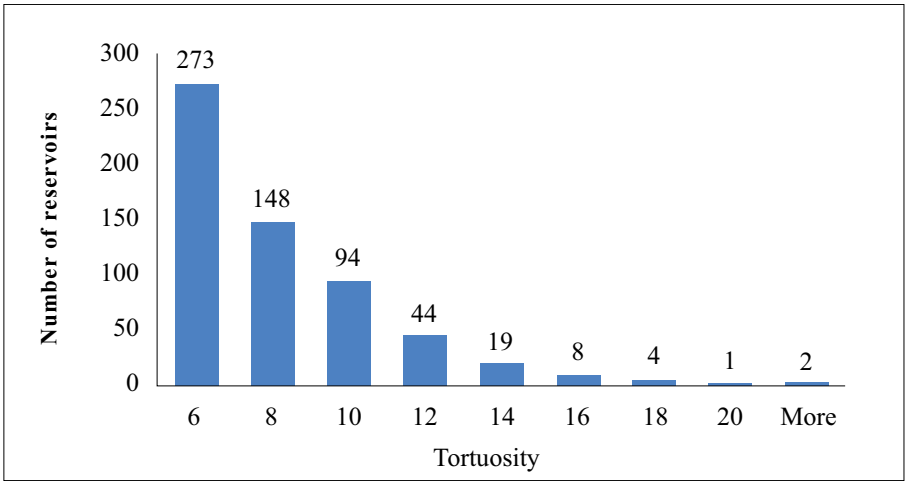

Fig. 7:Frequency of reservoirs according to their tortuosity.

The cumulative percentage graph (Fig. 8) showing that 90% of the reservoirs' tortuosity is less than 10 per unit area and the median tortuosity is about 6 per unit area.

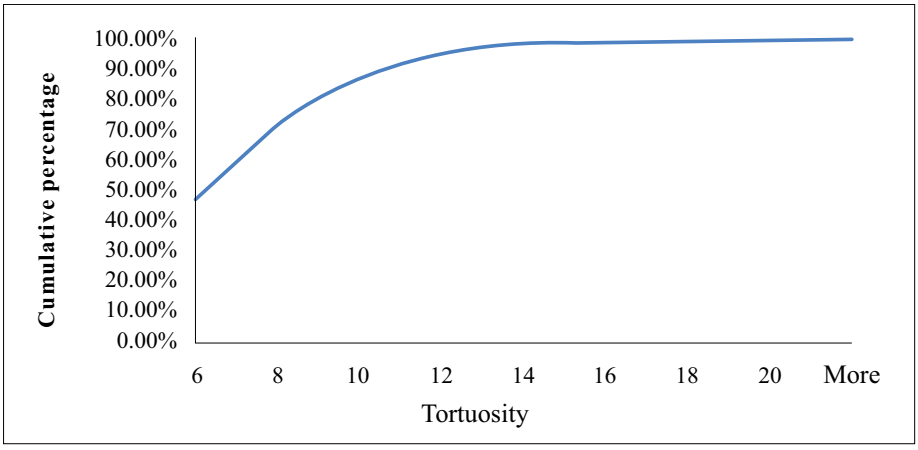

Fig. 8:Cumulative percentage of reservoirs according to their tortuosity

The Perimeter of Reservoirs

According to descriptive statistics (Table 1), the average perimeter of reservoirs is estimated at around 697 m. The middlemost perimeter of reservoirs is closely 473 m. From the descriptive statistics, the minimum perimeter of reservoirs was 62.03 m and the maximum was 4,858.48 m. These studied reservoirs have a total 412,831.325 m boundary line.

From the bar Diagram (Fig. 9), the highest number of reservoirs (211) cover 500 m perimeter and the 17 reservoirs' perimeters are more than 2500 m.

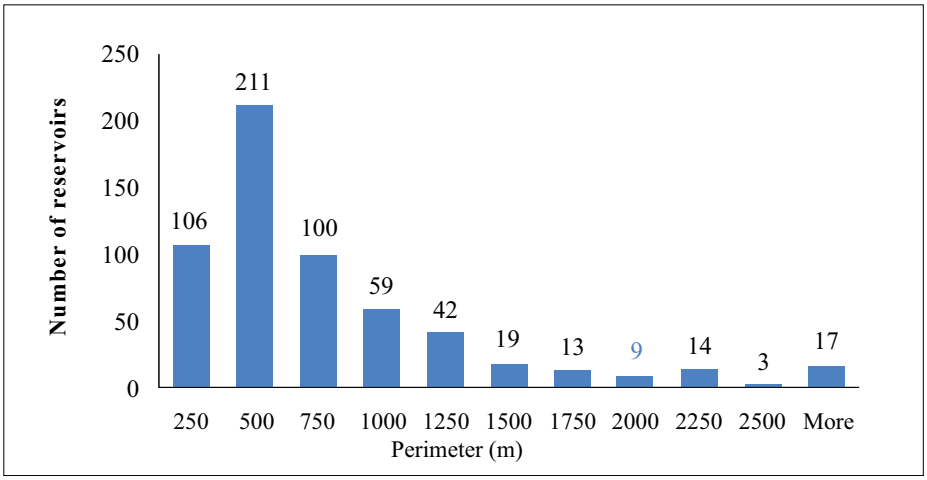

Fig. 9:Cumulative percentage of reservoirs according to their Perimeter

The cumulative percentage graph (Fig. 10) above is showing that 95% reservoirs are less than 1,300 meters and the median perimeter is about 473 meter.

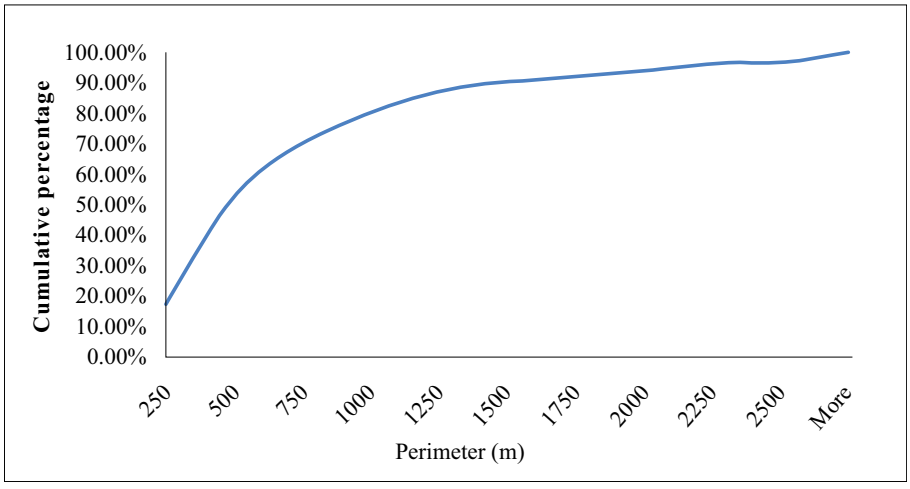

Fig. 10:Cumulative percentage of reservoirs according to their perimeter

Maps

Two maps of small water reservoirs are produced through this research work. First one is the small water reservoir map (Fig. 12) and the second one is the Relative Neighbourhood Graph (RNG) of reservoirs (Fig. 13). These two maps show the distribution of reservoirs in the Halda river watershed and their neighbouring distance.

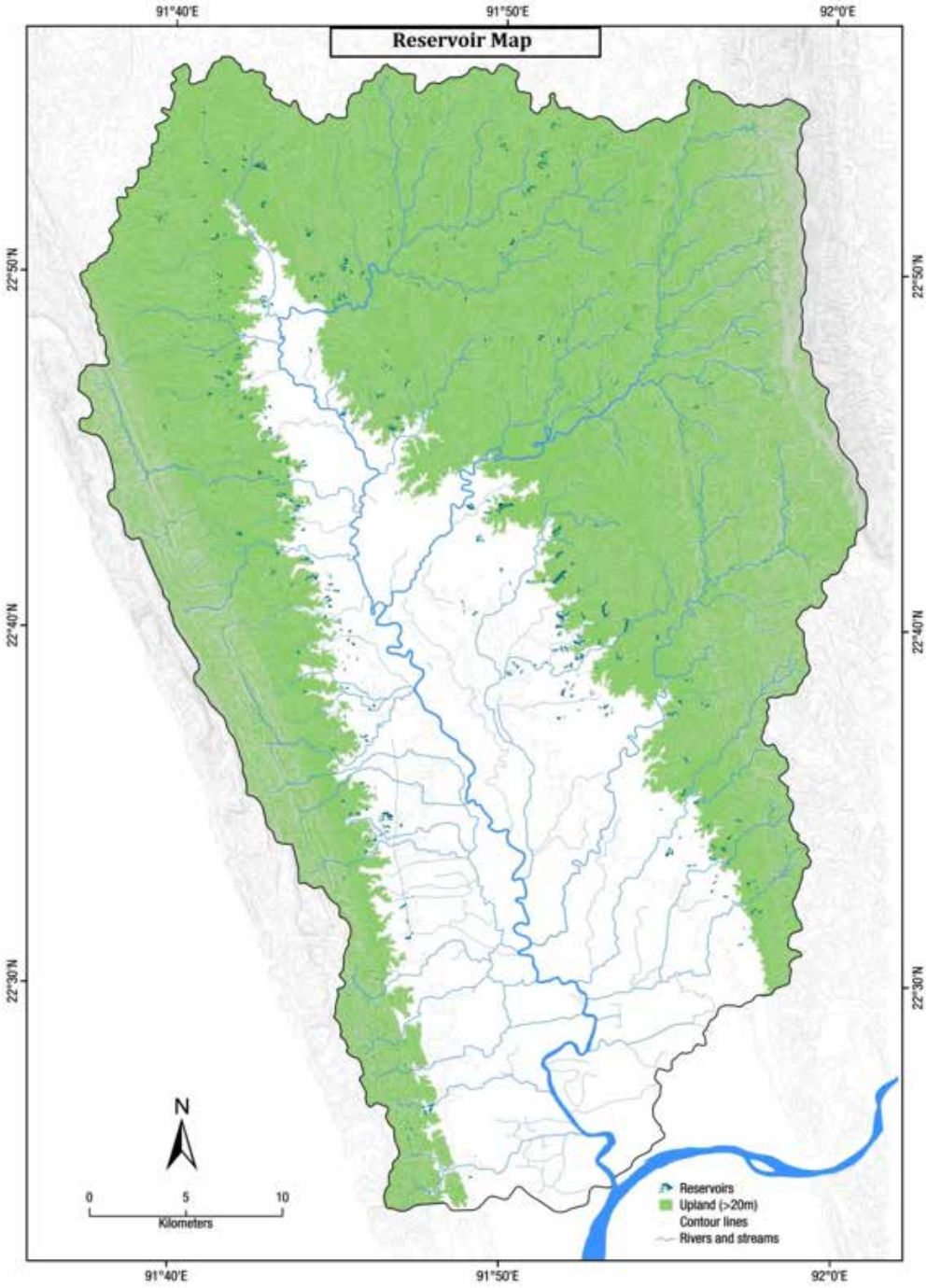

Fig. 11:Map of all reservoirs in the Halda river watershed

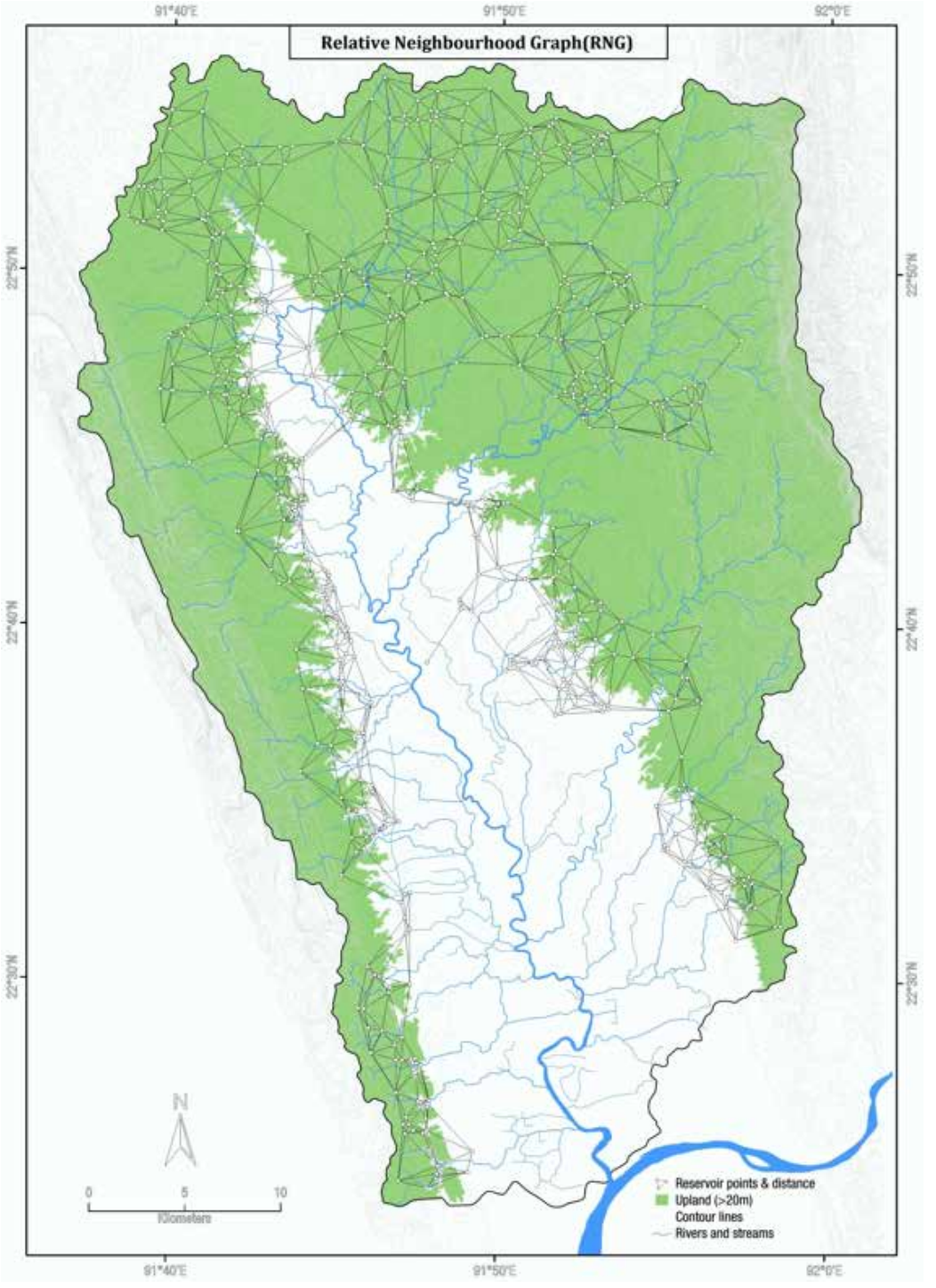

Fig. 12:RNG Map of reservoirs in the Halda river watershed

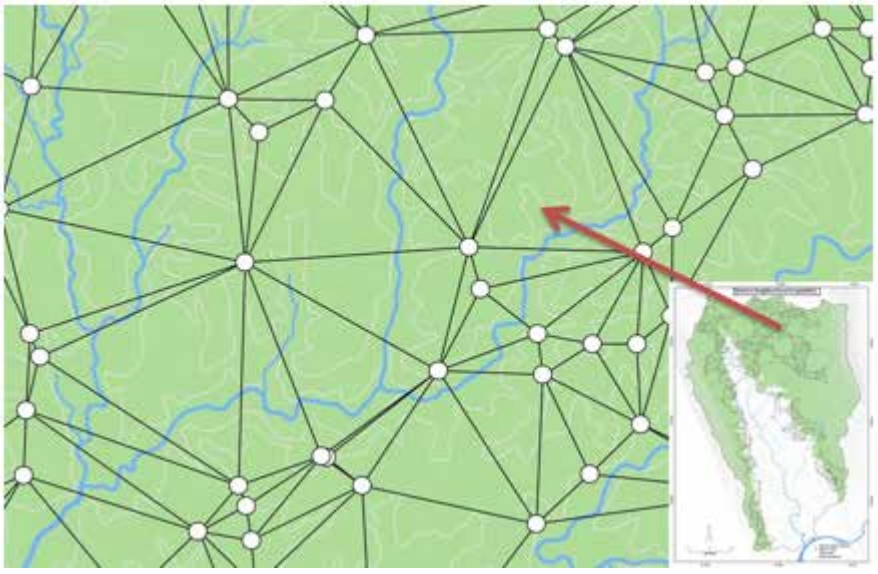

Fig. 13: Zoomed view of RNG graph

Conclusion

The result gathered from the study can be useful for management and planning for watershed and conservation of reservoirs. Total research work and data analysis have been done by using GIS and statistical software. Digitisation of small water reservoirs was done in the Oceanic and Atmospheric Data Analysis Laboratory (OADAL) of the Institute of Marine Sciences, University of Chittagong. Special thanks to Google for their freely available high-resolution satellite images. On behalf of all authors, the corresponding author states that there is no conflict of interest.

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