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RESEARCH ARTICLE

MAPPING AND GIS ANALYSIS OF HOUSEHOLD PONDS IN THE HALDA RIVER WATERSHED

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ABSTRACT

A project was undertaken to create an inventory and generate relevant baseline information on household ponds in the Halda river watershed. This research is mostly belongs to Mapping and GIS analysis. At first all ponds are divided into two groups, large ponds (above 1000 m^2 area) and small ponds (below 1000 m^2 area). Then some important geometric and geographic parameters of large ponds are calculated. They are area, elevation and elevation wise distribution, neighbourhood distances, length, width, aspect ratio. Descriptive statistics are generated on these parameters and their mean, median, mode, sum, standard deviation, count, minimum, maximum etc. were calculated. Some informative charts are included in the result showing the findings. To calculate the area and total number of small ponds, intentional sampling is used. The average area of large ponds is about 2670 m^2. The average elevation of these ponds is found 11.75 m. The mean neighbouring distance among these ponds is about 237 m and these ponds are rectangular shape in average because their average aspect ratio is 1.46 where aspect ratio 1.00 means the perfect square shape. The total area occupied by all ponds (both large and small) is estimated as 44.2 km^2 and it is 2.63% of whole watershed area and 7.38 % of the valley area (here <20 m elevation and relatively plain). The total number of pond is estimated 43745 (large pond 6730 and small pond 37015) and almost all of them are in the valley area of Halda river watershed.

KEYWORDS

Digitization, Pond Map, Halda river watershed, Relative Neighbourhood Graph (RNG).

1. INTRODUCTION

The watershed of the Halda River is compacted with large number of water bodies. Many natural water bodies behind manmade water bodies also exist in the watershed. But here the research is mainly focused on ponds. Ponds are mainly dug by the local people for different purposes. The main purposes are aquatic food production, house hold water supply, agricultural water supply, retaining water for dry season etc. Large number of fresh water ponds in a particular area also contributes to the expansion of aquaculture in that area. The wild catch of fish is decreasing day by day. In the year of 1983-84 the contribution of inland capture fisheries to total fish production was 62.59% whereas in 2016-17 it is only 28.14% (DoF, 2017). So from the trend it can be assumed that, in future, probably the culture of fish will mainly depend on artificial water bodies like ponds.

So, proper management of these ponds has much importance and the management is greatly depended on the correct information about these ponds. An intensive study of these ponds like this research work can reveal the proper baseline information and will be able to suggest policy maker and other related organization to take the proper steps for the best outcomes from these ponds. The watershed of the Halda River considered between 22° 23' 44.16" N to 22° 56' 8.16" N latitude and 91° 36' 59.04" E to 92° 01' 10.56" E longitude in this research. The total area of the Halda River watershed is approximately 1683 km^2. It falls in three districts of Bangladesh named Chittagong, Rangamati & Khagrachhari (Chowdhury, 2015). In the south east region of Bangladesh, Halda is one of the major rivers. After originating in Ramgarh upazilla (sub district) and flowing through several upazilla, it finally falls into the Karnaphuli River (Akter and Ali, 2012). Watershed of Halda is comprised of many large and small ponds.

The hilly region of the Halda River watershed rarely has any pond but the valley area is densely packed with numerous ponds. Mapping and GIS analysis are very important tools for generating information on geographic feature. If the aerial view is unobstructed, the remote mapping is very much useful technology generating accurate and continuous maps of different objects across entire watersheds (Marcus and Fonstad, 2007). Water bodies can be mapped accurately by using satellite data viz. Landsat TM data (Frazier, 2003). In case of freely available high resolution satellite

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images, Google earth is providing quality image. By zooming into the target location on satellite images, shape and clear aerial view of ponds are available. By precise onscreen digitization of these ponds, their geometric and other spatial parameters can be analyzed in GIS software. Obtaining this information without remotely sensed image and GIS analysis would be expensive and somewhere impossible.

2. METHODOLOGY

2.1 Digitizing

High resolution satellite image of Google earth is used (Figure 1). All ponds have been digitized using "Google earth" application. As ponds are polygon, so polygon tool is used to digitize ponds one by one across the whole watershed.

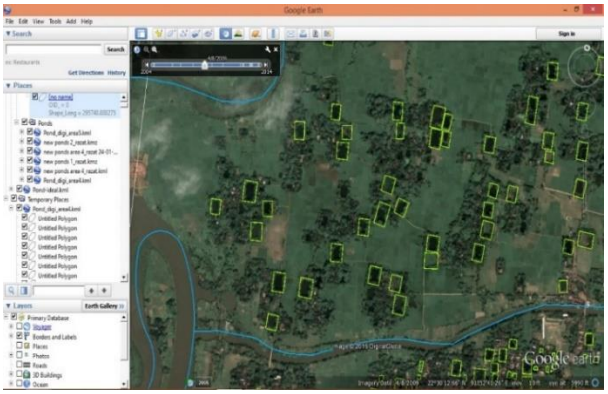

Figure 1: An overview of digitized ponds in the Halda River watershed

During digitization, only ponds above 40 m length were digitized, those ponds are approximately more than 1000 m^2. At the later stage, for GIS analysis, less than 1000 m^2 ponds were excluded and a separate statistic was generated for those small ponds based on intentional sampling of ponds by selecting 6 different sample areas in the whole watershed. In case of bad quality images, time slider was used to see the previous year's clear images. Among different year's images the best one was used. After completing digitization, the file of all digitized ponds was then saved as KML (key hole markup language) file. Keyhole Markup Language (KML) is a language which is based on XML and used to express geographical annotation and visualization (Samrat, 2012). Total 36 places were surveyed in the watershed for ground truthing.

2.2 Processing GIS data

For processing GIS data, QGIS 2.8 wien version was used, however it can be done in other GIS software also. Previously saved KML file of ponds was used to do further analysis. After loading the KML file in the GIS software the file is then saved as shape file (SHP file) which was then loaded in the GIS software as a vector layer. First of all the GIS software configured in a certain way such as the CRS (coordinate reference system) was set at WGS 84/UTM zone 46N and also all shape file was saved at CRS: WGS 84/UTM zone 46N. This was done because the study area is belongs to UTM zone 46N.

2.2.1 Calculating different geometric parameters of ponds in the attribute table of shape file (SHP file)

In the attribute table of shape file of digitized ponds, different geometric parameters of ponds like area, perimeter, length, width, aspect ratio etc. were calculated using different formulas.

2.2.2 Excluding small ponds (ponds less than 1000 m^2)

As we have only dealt with the large ponds (greater than 1000 m^2) in the first stage. We had to get rid of small ponds (less than 1000 m^2). To eliminate small ponds from the database, the rows of small ponds in attribute table was selected by expression and then deleted.

2.3 EDA (Exploratory Data Analysis)

Exploratory data analysis could be done in both QGIS and MS Excel applications. But for convenience MS Excel application was used. For doing EDA, the attribute table was exported from the GIS application as excel file with desired fields. After opening the exported excel file, descriptive statistics was generated based on desired column that is shown in the result.

2.4 Elevation statistics

Elevation data of ponds were extracted by ENVI software and then further analysed by excel file. The statistics based on the elevation of ponds are then included in the result.

2.5 Creating RNG (Relative Neighbourhood Graph) of ponds

Relative Neighbourhood Graph (RNG) of ponds shows the relationship of ponds with their neighbouring ponds. It shows the distance among neighbouring ponds and also identifies the isolated ponds which have no neighbour ponds around them. Here, for the RNG graph, the cut off distance 500 meters is used, that means if any ponds stay 500 meters away from a pond, there will be no relationship between those ponds.

2.6 Mapping

To create a map, at first the shape file of Halda river, It's basin polygon file, it's stream line file and other shape file such as shape file of ponds and Relative neighbourhood graph etc. (necessary files that will be shown in the map) was loaded in the GIS software. From the properties of those layers, the colour, border width, fill colour etc. were changed according to their categories as needed. After changing all the properties, the desired layers which were shown in a particular map were activated. Such as for pond map, the layer of ponds and Halda River basin, main stream and its tributaries were activated and shown in the map. Legends, map title, scale, direction, latitude and longitude were included in the map as map component.

2.7 Method of small pond analysis

Six sample places of 500 m x 500 m approx. were selected intentionally in the whole watershed and digitized all small ponds (less than 1000 square meters) existed in those sample areas. Then the KML file of small ponds was imported into the QGIS and then to the Excel for further analysis. Descriptive data analysis tool was used for analysing the attribute data of small ponds that was exported from QGIS.

3. RESULT AND DISCUSSION

After analyzing all GIS data, a descriptive statistics table was generated (Table 1)

Table 1: Descriptive statistics of all important geometric and spatial parameters of large ponds

Statistical Parameters	Area (m^2)	Aspect ratio	Neighbourhood distance (m)	Length (m)	Width (m)	Elevation (m)
Mean	2669.46	1.46	236.51	60.24	41.34	11.75
Median	2276.07	1.45	220.71	57.74	39.79	11
Mode	2309.63	1.42	167.48	50.89	43.10	7
Standard Deviation	2145.98	0.21	114.40	18.26	11.17	5.26
Minimum	1000.20	1.01	30.07	32.29	18.57	1
Maximum	54723.95	3.92	499.60	306.91	185.62	40
Sum	17965484.66	9760.55	3985384.86	402378.18	276135.52	79090
Count	6730	6680	16851	6680	6680	6730

3.1 Area statistics of large ponds

From the descriptive statistics the average area of large ponds is found around 2670 square meters. The median most ponds are nearly 2276 square meters and the most abundant ponds are of nearly 2310 square meters. As we only studied the ponds more than 1000 square meters in the first stage, the minimum area of ponds among the studied ponds is 1000.20 square meters and the maximum is 54723.95 square meters. The total area occupied by the large ponds is 17.97 km^2 that is 1.07% of the total watershed area and 3 % of the valley (here <20m elevation and relatively plain land that is 598.85 km^2). Total number of ponds those are

above 1000 square meters is 6730. A bar diagram (Figure 2) and a line diagram are given below showing the frequency and cumulative percentage of large ponds according to their area:

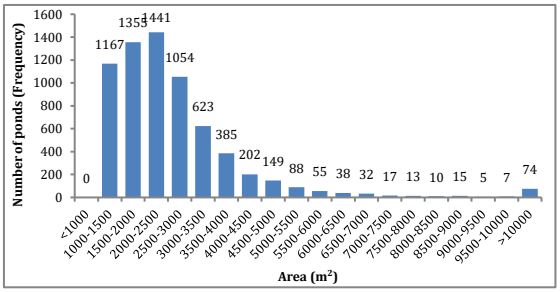

Figure 2: Frequency of large ponds according to their area

Here, the highest number of large ponds (1441) lie between 2000 to 2500 square meters. Combining top 4 bars in the bar diagram, it can be said that, most of the large ponds (above 1000 m²) are in between 1000 to 3000 m². The highest scale in the graph is 10000 m² and above this scale, there are only 74 ponds. That means extremely large ponds are very few in number.

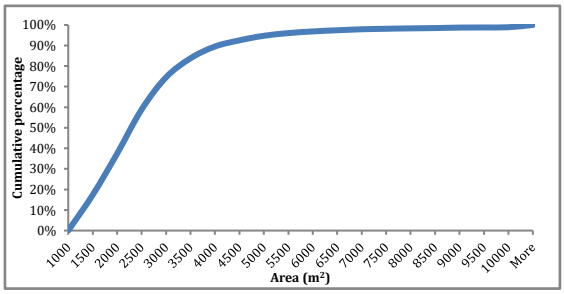

Figure 3: Cumulative percentage of large ponds according to their area

The cumulative percentage graph (Figure 3) is showing that, about 90% large pond is less than 4100 square meters and the median area is about 2300 square meters.

A map of all large ponds is given here. Here we can see almost all ponds are in the valley area of Halda River watershed.

3.2 Pond map

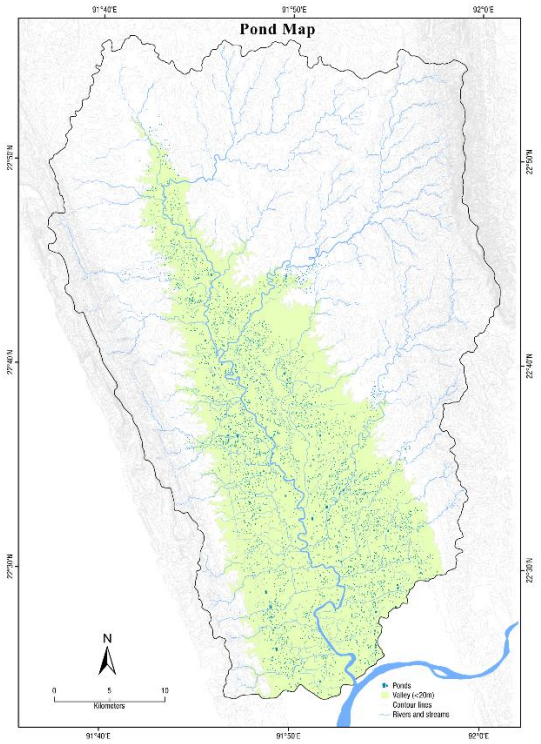

Figure 4: The map of all large ponds in the Halda River watershed

3.3 Aspect ratio statistics of large ponds

Here aspect ratio is the ratio of length and width. High aspect ratio denotes the less square shape of a pond. If the aspect ratio is 1 then that pond will be a perfect square size pond. The average aspect ratio is found 1.46 and the median most aspect ratio is 1.45. The highest number of large ponds has 1.42 aspect ratio. The minimum aspect ratio is 1.01 that means it is the squarest pond among the studied ponds. And the maximum is 3.92. As it is a ratio of same dimension so it has no unit. A bar diagram (Figure 5) and a line diagram (Figure 6) are showing the frequency and cumulative percentage of large ponds according to their aspect ratio.

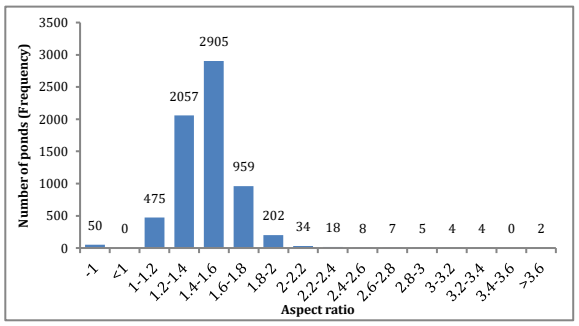

Figure 5: Frequency of large ponds according to their aspect ratio.

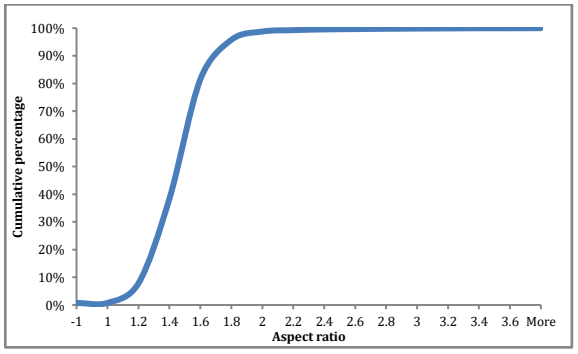

Figure 6: Cumulative percentage of large ponds according to their aspect ratio

In the bar diagram, the Highest number of large ponds (2905) lies between 1.4 and 1.6. Ponds having more than 3.6 aspect ratio is 2. Another important thing is that, number of ponds with aspect ratio "-1" is 50. This is because of nan values. These ponds had more than 4 sides. So their length and width were incalculable and ultimately their aspect ratio became nan values, that means "-1".The cumulative percentage graph is showing that, 95% large ponds have aspect ratio less than 1.9 and the median aspect ratio is 1.45.

3.4 Neighbourhood distance statistics of large ponds

The average distance among neighbouring large ponds was around 237 meters. The highest occurring distance among those ponds was 168 meter. The minimum distance among them was 30.07 meters and the highest (as 500 meters is used for cut off distance) was 499.60 meters. The total number of neighbourhood under 500 meters distance was found 16851

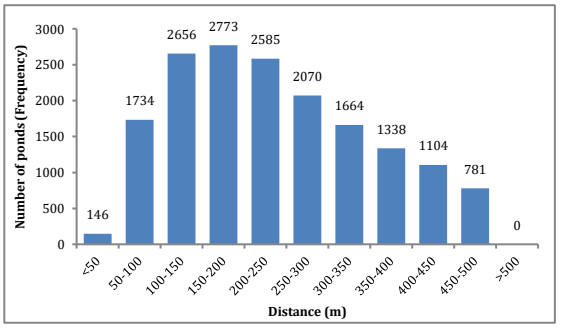

Figure 7: Frequency of large ponds according to their distances

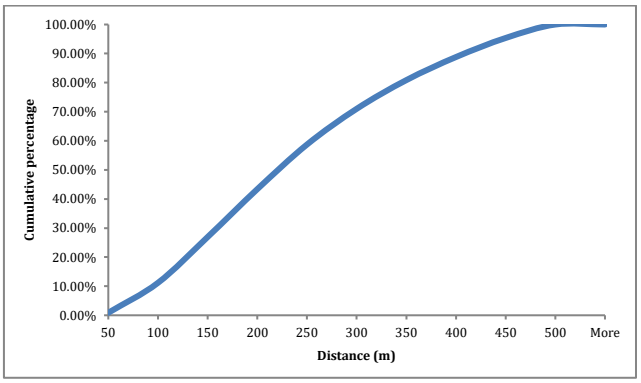

Figure 8: Cumulative % of large ponds according to their neighbourhood distance

Here, most of the large ponds (2773) have 150 to 200 meters neighbourhood distance. Lowest number of ponds (146) has less than 50 meters neighbourhood distance. The bar diagram (Figure 7) is showing that there is no significant difference in the number of ponds at 50 meters intervals. The cumulative percentage graph (Figure 8) is showing that, more than 90% large ponds are in between 400 meters neighbourhood distance and the median neighbourhood distance is around 220 meters. A relative neighbourhood graph (RNG) of all large ponds in the Halda River watershed is given here. This neighbourhood graph of all large ponds shows how close or far these ponds are situated and also show their density. Points are the representative of large ponds and connecting lines are the distances among them.

3.5 Relative Neighbourhood Graph (RNG)

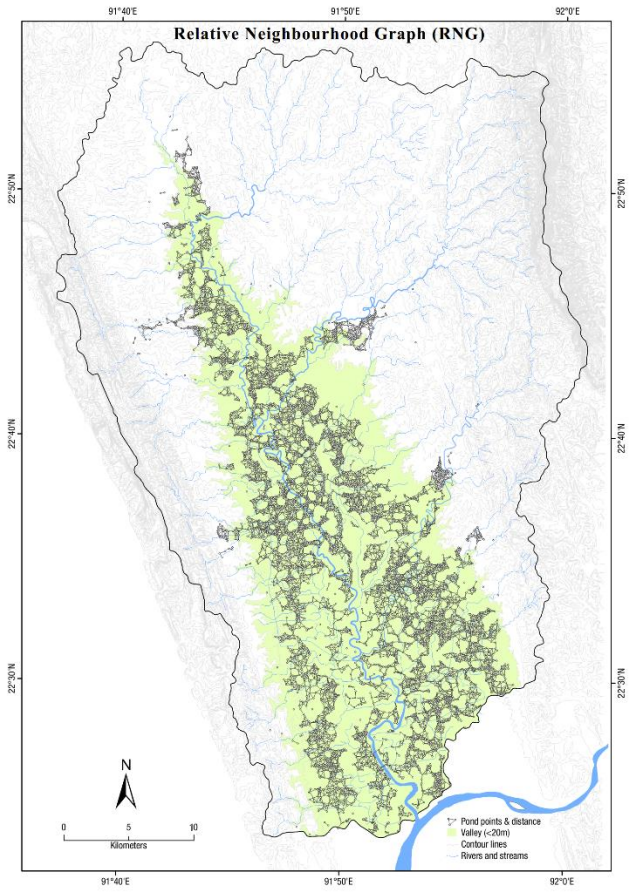

Figure 9: Relative Neighbourhood Graph (RNG) of all large ponds

If we zoom into the RNG map it will be looked like figure 10.

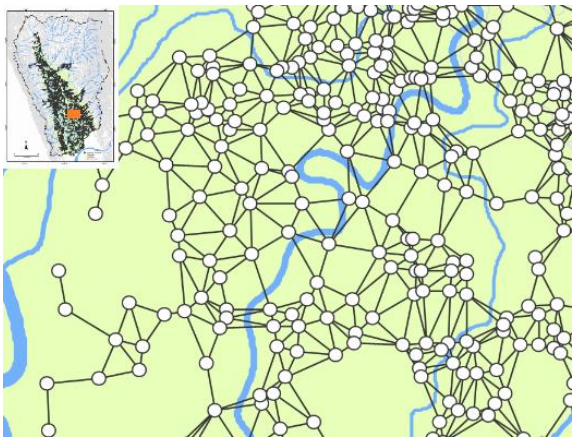

Figure 10: Zoomed view of the RNG (with the zoomed location in inset)

3.6 Length statistics of large ponds

From the descriptive statistics of large ponds the average length is around 60 meters. The median most length is nearly 57 meters and the highest number of large pond is with around 50 meters length. The minimum length found around 32 meters and the maximum length found around 307 meters. And the total number of ponds of which length is measured is 6680. Because ponds with more than 4 sides are not accounted for measuring length and their number is 50. So (6680 + 50) = 6730, the total number of ponds. A bar diagram and a line diagram are given below showing the frequency and cumulative percentage of large ponds according to their length:

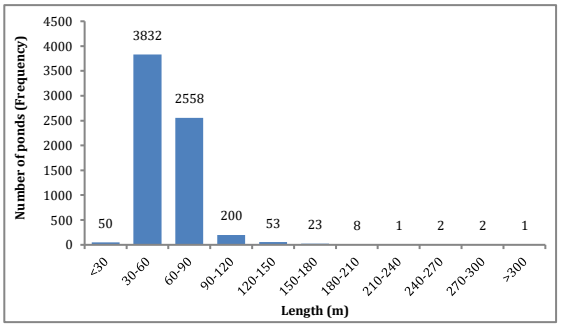

Figure 11: Frequency of large ponds according to their length

Here (Figure 11), most of the large ponds (6390) have length in between 30 to 90 meters and the lowest number of ponds (1) having length in between 210 to 240 meters.

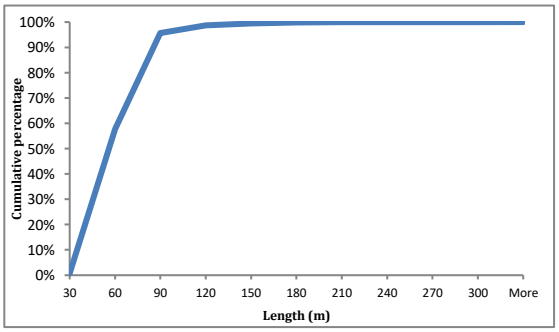

Figure 12: Cumulative percentage of large ponds according to their length

The cumulative percentage graph (Figure 12) above showing that about 90% large ponds have length less than 90 meters and median length is about 57 meters.

3.7 Width statistics of large ponds

From the descriptive statistics, the mean width of large ponds is about 41 meters. The median most width of these ponds is about 39 meters.

Maximum ponds occurred with 43 meters width. The minimum width found about 18 meters and maximum found nearly 186 meters. And the count of ponds is 6680 because of the reason as stated in length section. A Bar diagram showing the frequency of ponds according to their width is given below:

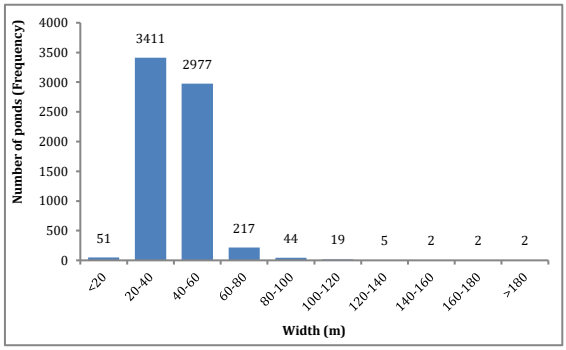

Figure 13: Frequency of large ponds according to their width

Here (Figure 13), most of the large ponds (6388) have width in between 20 to 60 meters and the lowest number of ponds (2) having width in between 160 to 180 meters.

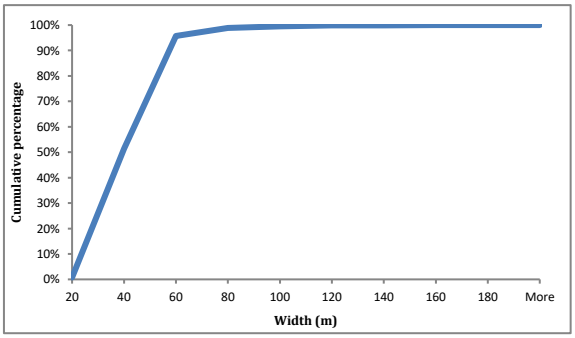

Figure 14: Cumulative percentage of large ponds according to their width

The line diagram (Figure 14) is showing that, 95% large ponds have length less than 60 meters and the median width is about 39 meters.

3.8 Elevation statistics of large ponds

By generating descriptive statistics on elevation data of large ponds, the average elevation of these ponds is found 11.75 meters. The minimum and maximum elevation is 1 and 40 meters respectively. The highest number of large pond is found at 7 meters elevation. But in case of elevation range, the highest number of pond is found in the range of 10-15 meters. Another Range of elevation with 2nd highest number of ponds is 5-10 meters. Combining this two elevation ranges, it can be said that, most of the ponds are in between 5 to 15 meters of elevation from the sea surface. And if we see the pond map, we can see that almost all of the ponds are in the valley of the Halda River watershed. Here is a bar diagram (Figure 15) showing the number of large ponds according to their elevation.

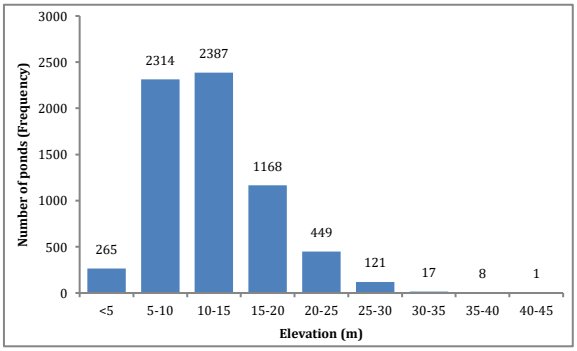

Figure 15: Frequency of large ponds according to their elevation.

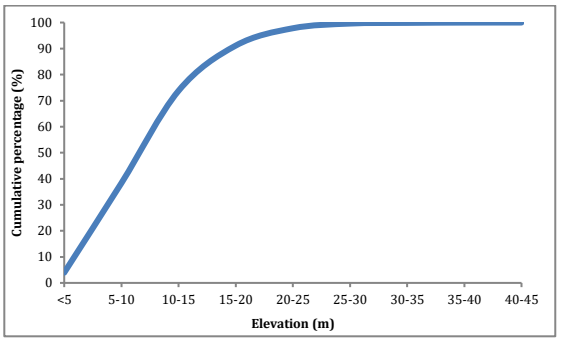

Figure 16: Cumulative percentage of large ponds according to their elevation

From the cumulative percentage graph (Figure 16) it can be said that, 90% of large ponds are below 20 meters elevation and the median most elevation is 11 meters.

3.9 Result of small pond analysis and combined estimation

Six areas were intentionally selected in the watershed area and digitized all ponds existing in those sample areas. Here small ponds means, ponds having less than 1000 m^2 area.

Table 2: Result of small pond analysis

Total sample area	6
Total ponds found in the sample areas	26
Total number of small pond found in the sample areas	22
Total number of large ponds found in the sample areas	4
Large ponds: Small ponds	1: 5.5
Total area of small ponds in the sample area (m^2)	8367.07
Total area of large ponds in the sample areas (m^2)	5722.65
Small pond (area): Large pond (area)	1: 1.46
Estimated total number of small ponds in the whole watershed	37015
Estimated total area occupied by small ponds (m^2)	26229607.66

Result in table 2 showing that the number of small ponds approximately 5.5 times than large ponds (as large ponds found 6730), That is 5.5 small ponds for one large pond. The estimated total area occupied by the small ponds 26.23 km^2 which is 1.46 times than large pond's area, where the total area of large ponds is 17.97 km^2. The area of small pond is about 1.56% of the whole watershed and 4.38% of the valley area (area <20 m elevation and relatively plain, which is 598.85 km^2 in total), where the area of large pond is about 1.07% of the whole watershed and 3% of the valley area. Collectively, these ponds occupy 44.19 km^2 and that is 2.63% of the whole watershed and 7.38% of the valley area, where the whole watershed is 1683 km^2. The total number of ponds (both small and large) was then estimated 43745.

4. Conclusion

Through this research work an informative GIS analysis has been done on the ponds in the Halda River watershed. This research revealed important Geometric and geographic characteristics of ponds in the Halda River watershed. Some of the parameters are excluded from the analysis like Vertices of pond's polygon, perimeter of ponds etc., because these are less important characteristics to be considered. The information generated through this research can raise other questions like the effect of this ponds and their density on local economy and ecology. How they are changing over the years and it can be a database for future comparison in case of land use changing trend. It can also be a good helping hand for generating an effective management plan.

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