ESTIMATION OF SEDIMENTATION RATE OF MALAMPUZHA RESERVOIR USING GEOINFORMATICS

1 INTRODUCTION

The world population is increasing drastically and the need for various commodities is also increasing. People compete themselves to reach their needs. The world nations are trying to maintain the needs of their citizens. In this regard the most important commodity to be preserved is none other than water. The life on earth without water cannot be thought. So, the preservation and clear utilisation of the water seem to be most important. To reach these needs water is preserved in reservoirs.

Reservoirs are constructed across the rivers for various purposes such as irrigation, power generation, discharge regulation, flood control and water supply. Various geological processes are carried out while water in a river flows downward. In this downward flow, water carries loads along with it in the form of suspended load. When this water reaches the reservoir, the velocity of it decreases and as a result these sediments get deposited in the banks and floor of reservoirs. This deposition of sediments is termed as reservoir sedimentation. Due to huge sedimentation, the purpose for which the reservoir was built will be depleted (Jain *et al*., 2002).

Reservoirs are generally located towards the end of a large watershed. Rainfall, runoff and snowmelt provide water to the reservoirs. Reservoirs mainly have two capacity namely dead storage and live storage (Munthali *et al*., 2011). The water stored in dead storage doesn't have any purpose. So if siltation takes place there, it does not affect the reservoir. But if sedimentation is carried out in the live storage, then the performance of the reservoir gets reduced. There are many reservoirs around the world that can no longer perform their design functions because much of their original live storage volume has been filled up by sediments (Ijam and Al-Mahamid., 2012).

There are almost 800000 reservoirs around the world. In which 300 are considered as major dams. The global area can be flooded by all the dams are greater than 400000 Km². Almost 30 to 60 million people were evicted due to reservoir construction (source: https://www.internationalrivers.org/damming-statistics). In India, there are 243 reservoirs.

Central Water Commission (CWC) is monitoring live storage status of 91 reservoirs in India on weekly basis. On the basis of the state, the 91 reservoirs in India are divided into 5 regions namely Northern Region, Eastern Region, Western Region, Central Region and Southern Region (source: http://www.cwc.gov.in/reservoir-monitoring).

In countries which are in a path of development, due to rapid population growth, uncontrolled and overgrazing, unsuitable land cultivation and deforestation, the soil erosion occurs in a great extent (Merina *et al*., 2016). These human accelerated soil erosion acts as a principal reason for sedimentation in reservoirs. Therefore, to utilize the reservoirs in an effective manner, proper monitoring and management of the capacity of the reservoir should be done. Periodic monitoring of reservoir sedimentation rate and taking needful measure to reduce it can only help to retain the reservoir. There are various methods by which the reservoir sediment yield can be computed. Various traditional techniques such as inflow-outflow technique, hydrographic survey method and integrated bathymetric survey etc. used for analyzing reservoir sedimentation are time consuming, clumsy and cumbersome, which may even leads to loss of money. So, as an alternative for these conventional methods, modern techniques such as GIS and Remote Sensing Technique are used for computing the sedimentation (Dadoria *et al*., 2017). Remote sensing is very much helpful in the periodic estimation of sedimentation rate than any other method. By remote sensing technique water spread area of every date can be inferred correctly and computing this with elevation of the same date the reservoir capacity of the day can be calculated. By comparing with various dates, the reservoir sedimentation rate can be identified.

Conventional methods, such as inflow-outflow method, hydrographic survey method (Heidarnejad *et al*., 2006) and integrated bathymetric survey (Patil and Shetkar, 2015), give more accurate result than modern remote sensing method; even though more time is needed. Nowadays conventional methods are less used.

1.1 Advantages of using GIS and Remote Sensing in Sedimentation

The advantages of modern Remote Sensing and GIS over conventional methods such as bathymetric survey etc. are numerous. First of all, bathymetric survey is highly expensive as compared to Remote Sensing. Data acquisition can be obtained from various satellites in the case of Remote Sensing. But bathymetric survey consists of various equipments which are very expensive. Another one advantage is that bathymetric survey is very time consuming while Remote Sensing can be done within no time. Bathymetric survey can be applicable only to present condition while in Remote Sensing satellite images provide synoptic repetitive and timely information regarding water spread area. In Remote Sensing Technique the present condition can be compared with a range of other dates and the rate of sedimentation can be calculated (Merina *et al*., 2016).

1.2 Review of Literature

Sedimentation in reservoirs seems to be a great problem hence it leads to loss of water holding capacity of reservoirs and purpose for which it was constructed cannot be retained. In order to make maximum outcome from those reservoirs, the sedimentation should be periodically monitored and desiltation measures must be taken (Chaitata *et al*., 2014). In this regard, various works have taken place all over the world to estimate sedimentation rate, to identify the reason for its cause and to propose various measures and action plans to be taken.

Minear *et al*. (2009) developed a spreadsheet model for sediment trapping in California of distinct geomorphic area. They also applied those rates to other reservoirs and computed the sedimentation rate and reported that about 200 reservoirs have lost their capacity as half of its initial. Munthali *et al*. (2011) carried out a work based on reservoir sedimentation in Songwe River Watershed in Malawi using Satellite Remote Sensing technique and GIS. They estimated total amount of sediment that is transported to downstream as huge using Pan-European Soil Erosion Risk Assessment (PESERA). Chaitata *et al*. (2014) used conventional methods,such as hydrographic surveys, grab sampling and depth-capacity methods, and evaluated Area Specific Sediment Yield (ASY), and concluded that the dead storage of the reservoirs in Semi-arid regions of Southern Zimbabwe will be lost in next 8 years. They also proposed that various methods must be carried out to desilt the sediments as this place lack water for their daily needs. Todosi *et al*. (2016) evaluated sedimentation of Podu Iloiei reservoir, from Bahluiet catchment, Eastern Romania, by modeling soil erosion using RUSLE2 model and constructed sediment budget using WaTEM/SEDEM model. They also assessed that at the present rate of sedimentation the reservoir gets filled up by next 21 years. The result obtained was compared with various methods such as hydrographic surveys, grab sampling and depth-capacity methods and found that the results are comparable with remote sensing method.

In India also, a number of studies have taken place to study the reservoir sedimentation and these studies are considered with much importance as India is a developing country. As the hydrographic survey gives much accurate result than satellite remote sensing survey, the sedimentation rate of Bhakra Reservoir using both hydrographic method and remote sensing method is being analyzed and concluded that both approaches seems to be close in result (Jain *et al*.,2002).Roman *et al*. (2012) estimated the loss in capacity of Ujjani reservoir on Bhima River, in Solapur District of Maharashtra and concluded that due to sedimentation, the water spread area of the reservoir for various elevations goes on decreasing. Mane *et al*. (2015) estimated sedimentation rate of Ujjani Reservoir in Solapur District of Maharashtra, using two techniques namely Satellite Remote Sensing technique (SRST) and mathematical modeling using HEC RAS. Both the methods are greatly applicable in this regard. Merina *et al*. (2016) studied sedimentation rate of Vaigai reservoir in Tamil Nadu, and reported that the sedimentation rate is increasing by passage of time and the storage capacity has reduced hugely. The work concluded that Vaigai reservoir is situated in steep sloppy area and also receives high rain fall, resulted in high soil erosion and leads to sedimentation in the reservoir. Pandey *et al*. (2016) evaluated reservoir sedimentation of Patratu reservoirin Jharkhand, using Normalized Difference Water Index (NDWI). They also proposed to adopt manual and mechanical digging along with flushing for desiltation to increase the live capacity of the reservoir. Various traditional techniques such as hydrographic survey method (Heidarnejad *et al*., 2006) and integrated bathymetric survey(Patil and Shetkar, 2015)etc. used for analyzing reservoir sedimentation are time consuming, clumsy and awkward and even leads to loss of money. So, as an alternative for these conventional methods, modern techniques such as GIS and Satellite Remote Sensing technique are used for computing the sedimentation in Murrumsilli reservoir in Chhattisgarh (Dadoria *et al*., 2017). Froehlich *et al*. (2017) assessed the sedimentation rate of various reservoirs and analyzed that the eastward and westward flowing regions differ in sedimentation. The work carried out by them assessed that the reason for this difference may be due to meteorological and geological influences on land surface runoff.

In Kerala also, various studies have been reported on reservoir sedimentation using various methods including remotes sensing. Babu *et al.*(2000) worked on Neyyar reservoir of Thiruvananthapuram district and concluded that due to degradation of nearby evergreen forest, the catchment area got eroded and resulted in reservoir sedimentation. So, from this work it can be inferred that due to sedimentation not only the capacity decreases but it also results in various other impacts. Nallanathel *et al*.(2014) analyzed Malampuzha reservoir and assessed that reservoir sedimentation can even lead to various factors other than decrease in trap efficiency, such as increase in evaporation loss, increase in backwater flooding and also damages the powerhouse turbines. They also suggested that clear Catchment Area Treatment can only be possible to reduce the siltation since total stoppage of sedimentation is not possible. Therefore, estimation of sedimentation rate seems to be much important work.

Various studies on reservoir sedimentation have already taken place in all over the world. The works using remote sensing came to application by the end of twentieth century. In India too, various studies have been reported. Different studies reveal that the effects of reservoir sedimentation are not only the decrease in capacity, but also lead to various hazards. All the studies suggested that required measurements, such as desiltation, should be taken in order to retain the purpose of the reservoir. The studies using remote sensing are more useful in various regards such as time, expanse and labor.

2 METHODOLOGY

In the present study Remote Sensing technique was used to find out the water spread area of the reservoir. The sedimentation rate was found out with reservoir elevation data and the water spread area. The reservoir elevations of several of dates were collected (http://www.india-wris.nrsc.gov.in) and the cumulative capacity was calculated. These data were compared with the data of the time of its impoundment; with this the loss of capacity due to sedimentation was calculated. The study was conducted for the years 2009, 2015 and 2018.

2.1 Study Area

Malampuzha reservoir was constructed across the river Malampuzha which originates from the hills of northern Palakkad district. The river Malampuzha is a tributary of Kalpathipuzha which joins the river Bharathapuzha, the second largest river in Kerala. The Malampuzha dam is located about 8 km from the Palakkad town. Malampuzha catchment area receives an average rainfall of 1800mm and about 75% of the annual rainfall is received during south west monsoon that sets in the last week of May and continue up to September. The year of impoundment of Malampuzha Irrigation Project was carried out in year 1955. The proposal for its construction was in 1949.The catchment area of Malampuzha reservoir is of 147.63 Sq.km. The reservoir covers an area of 24.83 Sq.km during Full Reservoir Level (FRL). The Full Reservoir Level of Malampuzha is 115.06 m and Minimum Draw Down Level is 91.44 m. Malampuzha Dam is the second largest reservoir in Kerala after the Idukki reservoir and the largest irrigation project in Kerala. The reservoir has a canal system which serves to irrigate farms of Palakkad District and the reservoir serves as source for drinking water. The reservoir is located between 76° 29’ and 76° 42’ E and 10° 48’ and 10° 55’ N. The masonry dam harnessing the Malampuzha River forms a reservoir with a full storage capacity of 228.4 Mm^3. Various facts and hydrological details of Malampuzha reservoir are shown in below table (Nallanathel, M. and Santhanam,N.,2014).

Table 1 **Facts and other Hydrological details of Malampuzha Reservoir**

Sl.No.	Description	Details
01.	River Basin	Bharathapuzha
02.	Dammed Tributary	Malampuzha
03.	Catchment Area	147.63Km^2
04.	Reservoir Capacity	228.4 Mm^3
05.	Water spread at FRL	24.83 Km^2
06.	Dam Height	115.06 m
07.	Length	2069 m
08.	Dead Storage	2.4Mm^3

2.2Datasets Used

2.2.1 Satellite Images Used

The details of satellite images used for the study are given below (Table 2,3,4).

Table 2 **Details of Satellite Images used for 2009 Survey**

Sl. No:	Date	Satellite	Sensor	Path/Row	Bands
1	08 February 2007	LANDSAT 4-5	TM	144/52	2,4
2	12 March 2007	LANDSAT 4-5	TM	144/52	2,4
3	13 April 2007	LANDSAT 4-5	TM	144/52	2,4
4	27 December 2008	LANDSAT 4-5	TM	144/52	2,4
5	13 February 2009	LANDSAT 4-5	TM	144/52	2,4
6	01 March 2009	LANDSAT 4-5	TM	144/52	2,4

(Source https://earthexplorer.usgs.gov)

Table 3 **Details of Satellite Images used for 2015 Survey**

Sl. No:	Date	Satellite	Sensor	Path/Row	Bands
1	10 January 2014	LANDSAT 8	OLI	144/52	3,5
2	11 February 2014	LANDSAT 8	OLI	144/52	3,5
3	31 March 2014	LANDSAT 8	OLI	144/52	3,5
4	02 May 2014	LANDSAT 8	OLI	144/52	3,5
5	22 August 2014	LANDSAT 8	OLI	144/52	3,5
6	13 January 2015	LANDSAT 8	OLI	144/52	3,5
7	29 January 2015	LANDSAT 8	OLI	144/52	3,5
8	14 February 2015	LANDSAT 8	OLI	144/52	3,5
9	18 March 2015	LANDSAT 8	OLI	144/52	3,5
10	05 May 2015	LANDSAT 8	OLI	144/52	3,5

(Source https://earthexplorer.usgs.gov)

Table 4 **Details of Satellite Images used for 2018 Survey**

Sl. No.	Date	Satellite	Sensor	Path/Row	Bands
1	16 January 2016	LANDSAT 8	OLI	144/52	3,5
2	20 March 2016	LANDSAT 8	OLI	144/52	3,5
3	23 May 2016	LANDSAT 8	OLI	144/52	3,5
4	17 December 2016	LANDSAT 8	OLI	144/52	3,5
5	02 January 2017	LANDSAT 8	OLI	144/52	3,5
6	18 January 2017	LANDSAT 8	OLI	144/52	3,5
7	03 February 2017	LANDSAT 8	OLI	144/52	3,5
8	10 May 2017	LANDSAT 8	OLI	144/52	3,5
9	18 November 2017	LANDSAT 8	OLI	144/52	3,5
10	06 February 2018	LANDSAT 8	OLI	144/52	3,5
11	22 February 2018	LANDSAT 8	OLI	144/52	3,5
12	21 November 2018	LANDSAT 8	OLI	144/52	3,5

(Source https://earthexplorer.usgs.gov)

2.2.2 Reservoir Water Level Data

The reservoir water level or elevation was collected from authorities for various dates during the period from 2007 to 2018.

Table 5 **Water Level of corresponding Satellite pass for 2009 survey**

Sl. No.:	Date	Water Level/Elevation(m)
1	08 February 2007	107.20
2	12 March 2007	106.77
3	13 April 2007	105.51
4	27 December 2008	109.48
5	13 February 2009	102.63
6	01 March 2009	102.41

(Source http://www.india-wris.nrsc.gov.in)

Table 6 **Water Level of corresponding Satellite pass for 2015 survey**

Sl. No:	Date	Water Level/Elevation(m)
1	10 January 2014	110.19
2	11 February 2014	106.18
3	31 March 2014	103.39
4	02 May 2014	102.52
5	22 August 2014	113.05
6	13 January 2015	109.48
7	29 January 2015	107.44
8	14 February 2015	105.06
9	18 March 2015	104.65
10	05 May 2015	104.42

(Source http://www.india-wris.nrsc.gov.in)

Table 7 **Water Level of corresponding Satellite pass for 2018 survey**

Sl. No:	Date	Water Level/Elevation(m)
1	16 January 2016	106.47
2	20 March 2016	102.44
3	23 May 2016	99.94
4	17 December 2016	106.92
5	02 January 2017	106.01
6	18 January 2017	103.83
7	03 February 2017	103.63
8	10 May 2017	100.80
9	18 November 2017	111.67
10	06 February 2018	103.71
11	22 February 2018	103.16
12	21 November 2018	112.73

(Source http://www.india-wris.nrsc.gov.in)

2.3 Software Used

- Arc Map 10.5
- QGIS 2.18.18
- ERDAS IMAGINE 2015

3 ANALYSIS PERFORMED

- The bands (Green, Red and Near Infra-Red) of the satellite image were stacked using ERDAS IMAGINE.
- The subset images were again undergone an index namely the normalized difference water index (NDWI) to delineate open water features and to enhance their presence in imagery.

  The NDWI was derived from the index NDVI (normalized difference vegetation index) which enhances terrestrial vegetation and soil features and suppresses open water features. The NDVI index is calculated as follow:

  $$NDVI = \frac{(NIR - Red)}{(NIR + Red)}$$

  This gives values between -1 and +1. The equation for NDVI is reversed and red band is replaced by green band to get NDWI Index. Thus, water features will be enhanced and vegetation soil features will be suppressed. The equation for NDWI is given below:

  $$NDWI = \frac{Green - NIR}{Green + NIR}$$

  The value obtained from NDWI varies from -1 to +1 and here 0 is the threshold value (McFeeters, 1996). The pixel values above 0 are water bodies. Those pixels above 0 were extracted to get water body distinctly.
- From NDWI image, the pixels having value less than 0 were undergone set null operation in raster calculator of QGIS. Those isolated water pixels having no connection with

reservoir water were removed. Thus, pure reservoir water pixels were obtained.

- These raster images were converted to vector to calculate the absolute water spread area.
- The obtained areas were used to compute the volume between two consecutive elevations using Prismoidal formula.

$$\Delta V_{1-2} = \frac{\Delta h(A_1 + A_2 + \sqrt{A_1 * A_2})}{3}$$

Where,

ΔV = Volume between elevations E2 and E1

ΔH = E2 -E1 (difference between elevations)

A1, A2 = Water spread area at elevation E1 and E2

Thus, the cumulative capacity was calculated and hence the loss in live storage was also computed. The loss in capacity was obtained by subtracting the present capacity from the original live capacity at the time of impoundment. The maps for various dates were prepared using Arc Map. The complete methodology is represented in the flow chart given below:

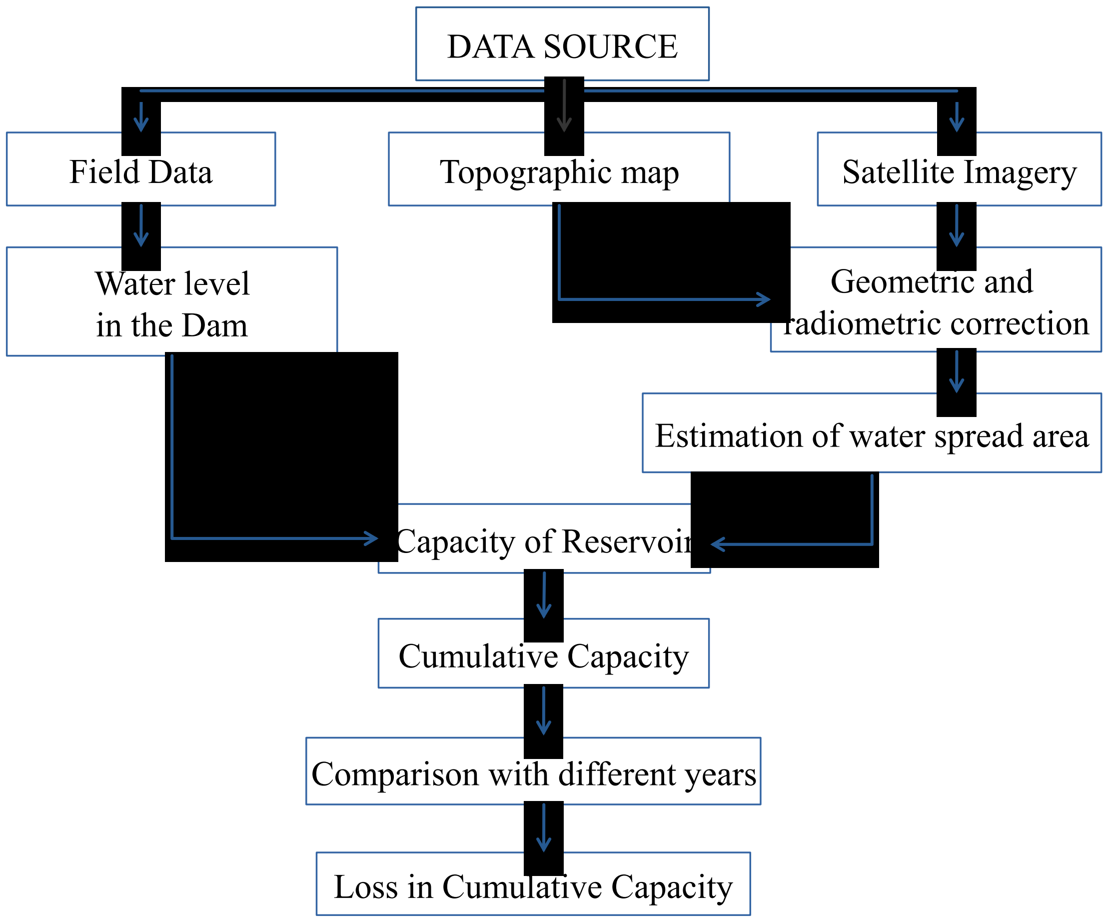

Fig.1**Flow chart of the methodology of the work**

4 RESULTS AND DISCUSSION

Avinash, G. and Chandramouli, P.N. (2018) states that the water spread area of the reservoir decrease for same elevation in different years due to sedimentation. This concept was taken as supreme in this project on sedimentation rate calculation. The study was conducted for the years 2009, 2015 and 2018. The water spread areas for various elevations ranging between MDDL (Minimum Draw Down Level) and FRL (Full Reservoir Level) were identified. The FRL of Malampuzha Reservoir is 115.06m and the MDDL is 91.44m.

The capacities between consecutive elevations were estimated using Prismoidal Formula. Hence the cumulative capacities for various elevations were calculated. The cumulative capacity during FRL for 2009, 2015 and 2018 surveys were 204.561 Mm^3, 195.871 Mm^3 and 195.425 Mm^3 respectively. These cumulative capacities were compared with the live capacity of 1955 (the year of impoundment) and the percentages of loss of capacity were estimated. The gross capacity of Malampuzha Reservoir of 1955 was 228.4 Mm^3. Thus, the loss of capacity of Malampuzha reservoir by the year 2009, 2015 and 2018 were 23.839 Mm^3, 32.529Mm^3 and 32.975Mm^3 respectively and the percentage loss in capacity were 10.437%, 14.242% and 14.437% respectively.

Various hydrographic surveys have also taken place in Malampuzha reservoir. The details of the surveys explain that by the year 1977 the capacity of the reservoir declined to 220.15 Mm^3 i.e., 8.25 Mm^3 volume of sediment had deposited there. This trend increased drastically, and by the year 1990, the loss in capacity of Malampuzha reservoir reached to 20.27 Mm^3. Again, the hydrographic survey was conducted in 2006 and the inference of the survey was that the percentage loss in capacity reached to 14.48% i.e. 33.072 Mm^3 capacity of reservoir was lost. Instead of hydrographic survey, a survey using Remote Sensing technique was conducted in the year 2005. The survey says that by the year the reservoir capacity had reached to 203.95 Mm^3. By 2006 survey, the observed rate of siltation since 1990 survey was 0.8 Mm^3/year. But if the rate was calculated based on the 2005 Remote Sensing survey, the rate of siltation would be observed to be 0.279 Mm^3/year. That is, 0.521 Mm^3/year difference in sedimentation rate was seen. Jain *et al*., (2002) estimated the rate of sedimentation in Bhakra reservoir using both hydrographic and Remote Sensing method, and concluded that there could be slight difference in sedimentation rate. This is also seen in the case of Malampuzha reservoir.

From the survey of 2006, it was concluded that if the reservoir sedimentation goes on same rate, in the nearest future the reservoir would be fully deposited by sediments and become useless. So, KERI (Kerala Engineering Research Institute) came up with the suggestion of desiltation in Malampuzha reservoir in order to retain the storage capacity of the reservoir. During the budget speech in 2009, the Finance Minister for the State of Kerala announced a program for desiltation of Malampuzha reservoir. The proposal said that about 8 Mm^3 sand could be excavated.

By 2009 survey, conducted using remote sensing, instead of decline in capacity of reservoir, it was observed that an increase by 0.611Mm^3 capacity since last survey (2005). By the year 2018, the reservoir lost its capacity by 32.975Mm^3. That is, by the passage of 63 years, since commissioning of the Malampuzha reservoir, the reservoir lost 14.437% of its capacity.

Table 8 **Details of the Previous Surveys**

Sl.No.	Year of Survey	Period (year)	Cumulative Capacity (Mm³)	Loss of Capacity (in %)	Observed Rate of Siltation Since Last Survey (Mm³/year)
Hydrographic Survey					
1	1955	0	228.400	0.000	
2	1977	22	220.150	3.610	0.375
3	1990	13	208.130	8.870	0.925
4	2006	16	195.328	14.480	0.800
Remote Sensing Technique					
1	2005		203.950	10.705	

(Source: CWC2015)

Table 9 **Elevation-Area Capacity chart of Malampuzha Reservoir of 2009**

Sl.No.	Elevation (m)	Area (km²)	Difference in Elevation (m)	Capacity (Mm³)	Cumulative Capacity (Mm³)
1	91.44	0.000	0.00	0.000	0.000
2	102.41	6.733	10.97	24.620	24.620
3	102.63	6.844	0.22	1.493	26.114
4	105.51	10.303	2.88	24.522	50.636
5	106.77	11.754	1.26	13.886	64.522
6	107.20	12.573	0.43	5.229	69.751
7	109.48	15.228	2.28	31.645	101.396
8	115.06	21.953	5.58	103.165	204.561

Table 10 **Elevation-Area Capacity chart of Malampuzha Reservoir of 2015**

Sl.No.	**Elevation (m)**	**Area (km^2)**	**Difference in Elevation (m)**	**Capacity (Mm^3)**	**Cumulative Capacity (Mm^3)**
1	91.44	0	0	0.000	0.000
2	102.52	6.420	11.08	23.711	23.711
3	103.39	7.471	0.87	6.037	29.748
4	104.42	8.185	1.03	8.060	37.808
5	104.65	8.923	0.23	1.967	39.775
6	105.06	9.499	0.41	3.776	43.551
7	106.18	10.954	1.12	11.444	54.995
8	107.44	12.470	1.26	14.747	69.742
9	109.48	15.012	2.04	27.992	97.733
10	110.19	15.764	0.71	10.924	108.658
11	113.05	17.933	2.86	48.153	156.811
12	115.06	20.972	2.01	39.060	195.871

Table 11 **Elevation-Area Capacity chart of Malampuzha Reservoir of 2018**

Sl.No.	Elevation (m)	Area (km²)	Difference in Elevation (m)	Capacity (Mm³)	Cumulative Capacity (Mm³)
1	91.44	0.000	0.00	0.000	0.000
2	99.94	3.920	8.50	11.107	11.107
3	100.80	4.414	0.86	3.582	14.688
4	102.44	6.376	1.64	8.799	23.487
5	103.16	7.356	0.72	4.939	28.426
6	103.63	7.870	0.47	3.577	32.004
7	103.71	7.929	0.08	0.632	32.636
8	103.83	8.100	0.12	0.962	33.597
9	106.01	10.645	2.18	20.369	53.966
10	106.47	11.389	0.46	5.067	59.033
11	106.92	11.597	0.45	5.172	64.205
12	111.67	16.891	4.75	67.266	131.471
13	112.73	18.188	1.06	18.588	150.059
14	115.06	20.782	2.33	45.366	195.425

Table 12 **Inference of the surveys**

Sl.No.	Year of Survey	Period (year)	Cumulative Capacity (Mm³)	Capacity loss (Mm³)	Loss of Capacity (in %)	Observed Rate of Siltation Since Last Survey (Mm³/year)
1	2009	54	204.561	23.839	10.437	
2	2015	6	195.871	32.529	14.242	1.448
3	2018	3	195.425	32.975	14.437	0.149

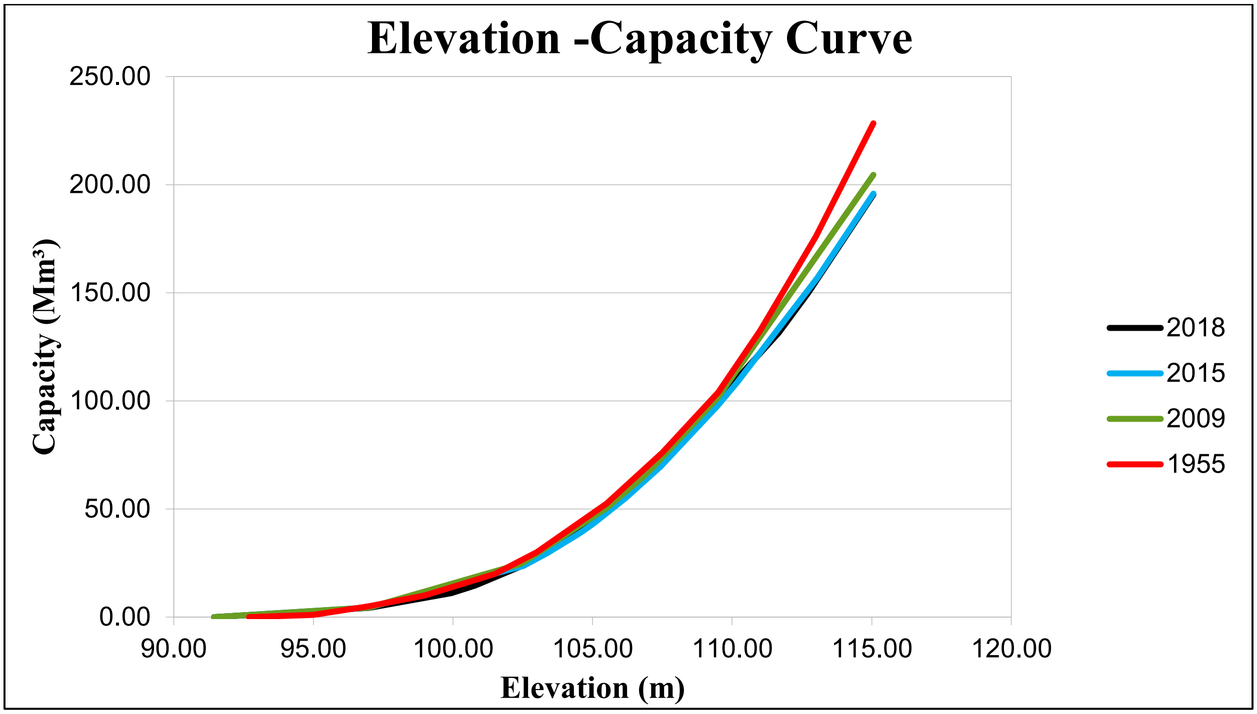

Fig.2 **Elevation Capacity Curve of 1955, 2009, 2015 and 2018**

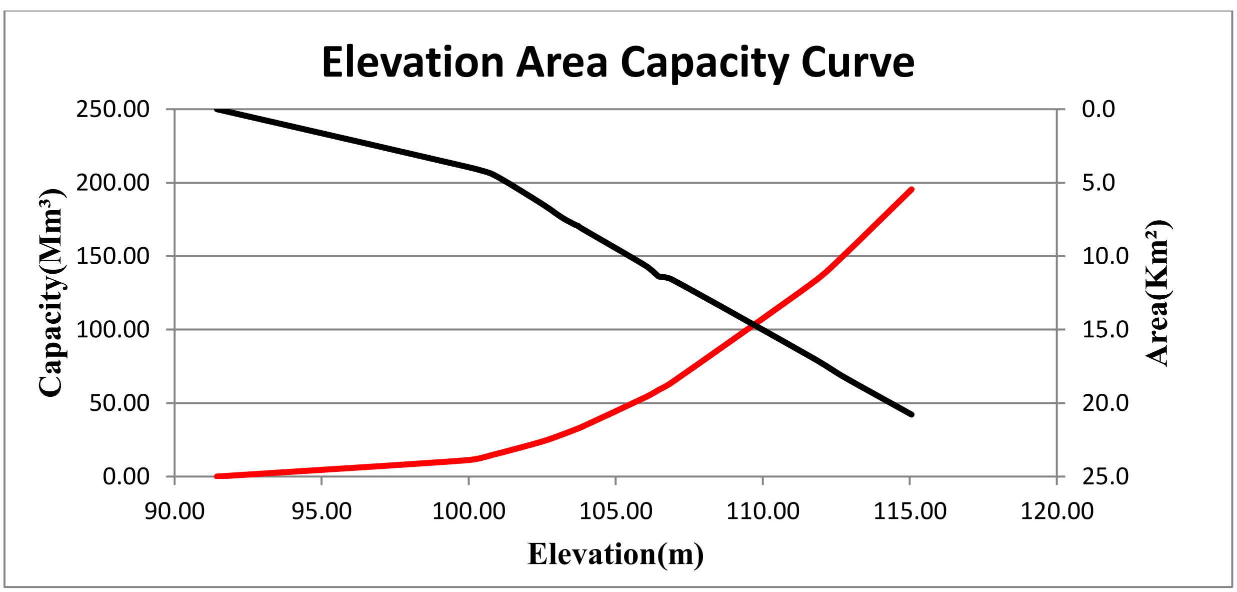

Fig.3 **Elevation Area Capacity Curve of 2018**

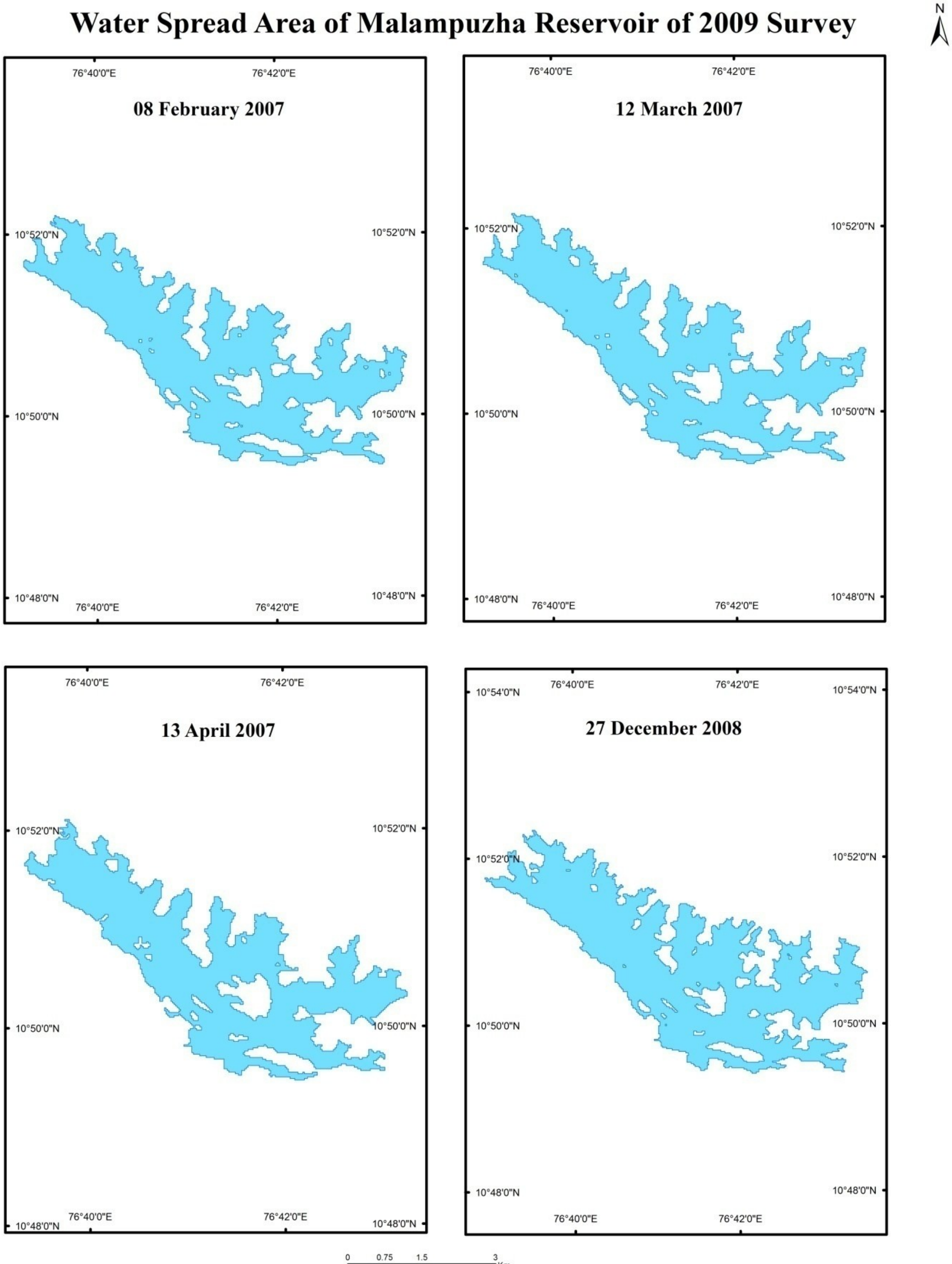

Fig.4 **Water spread area of Malampuzha reservoir**

Water Spread Area of Malampuzha Reservoir of 2009 Survey

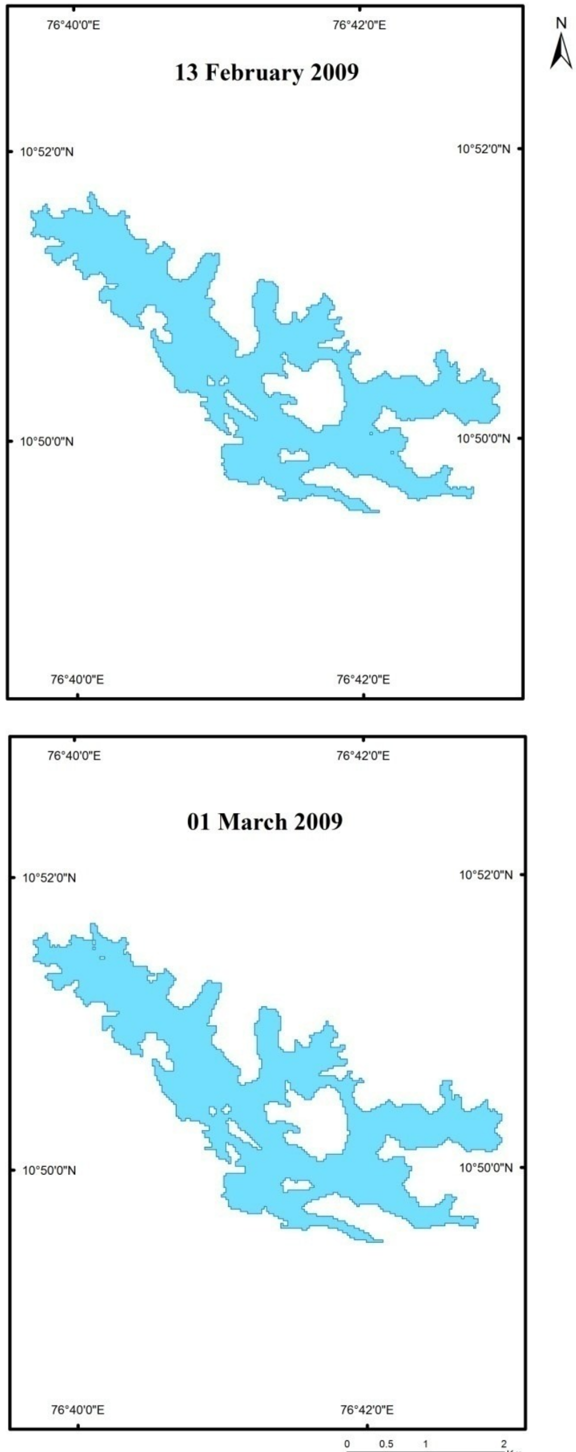

Fig.5 **Water spread area of Malampuzha reservoir**

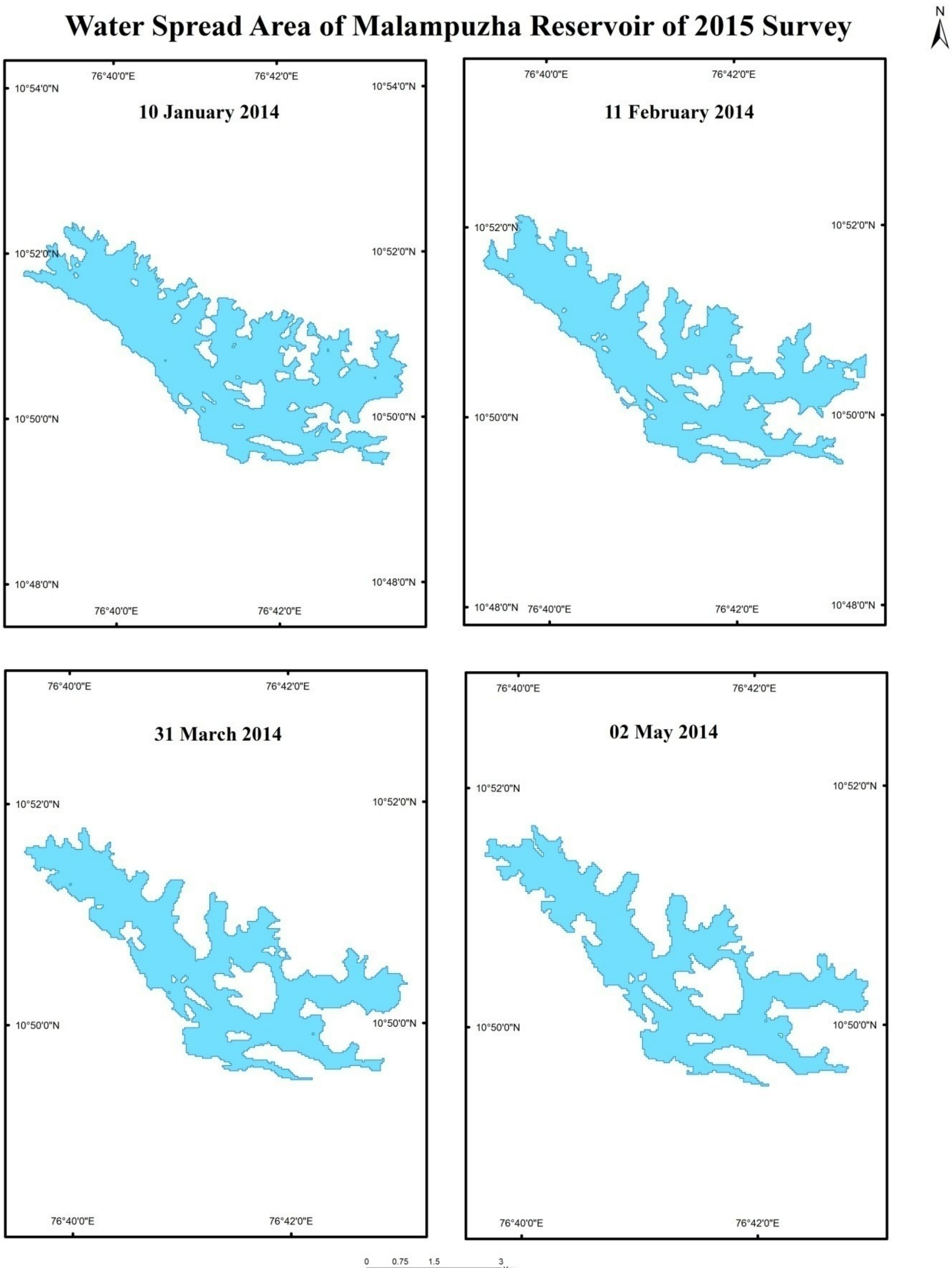

Fig.6 **Water spread area of Malampuzha reservoir**

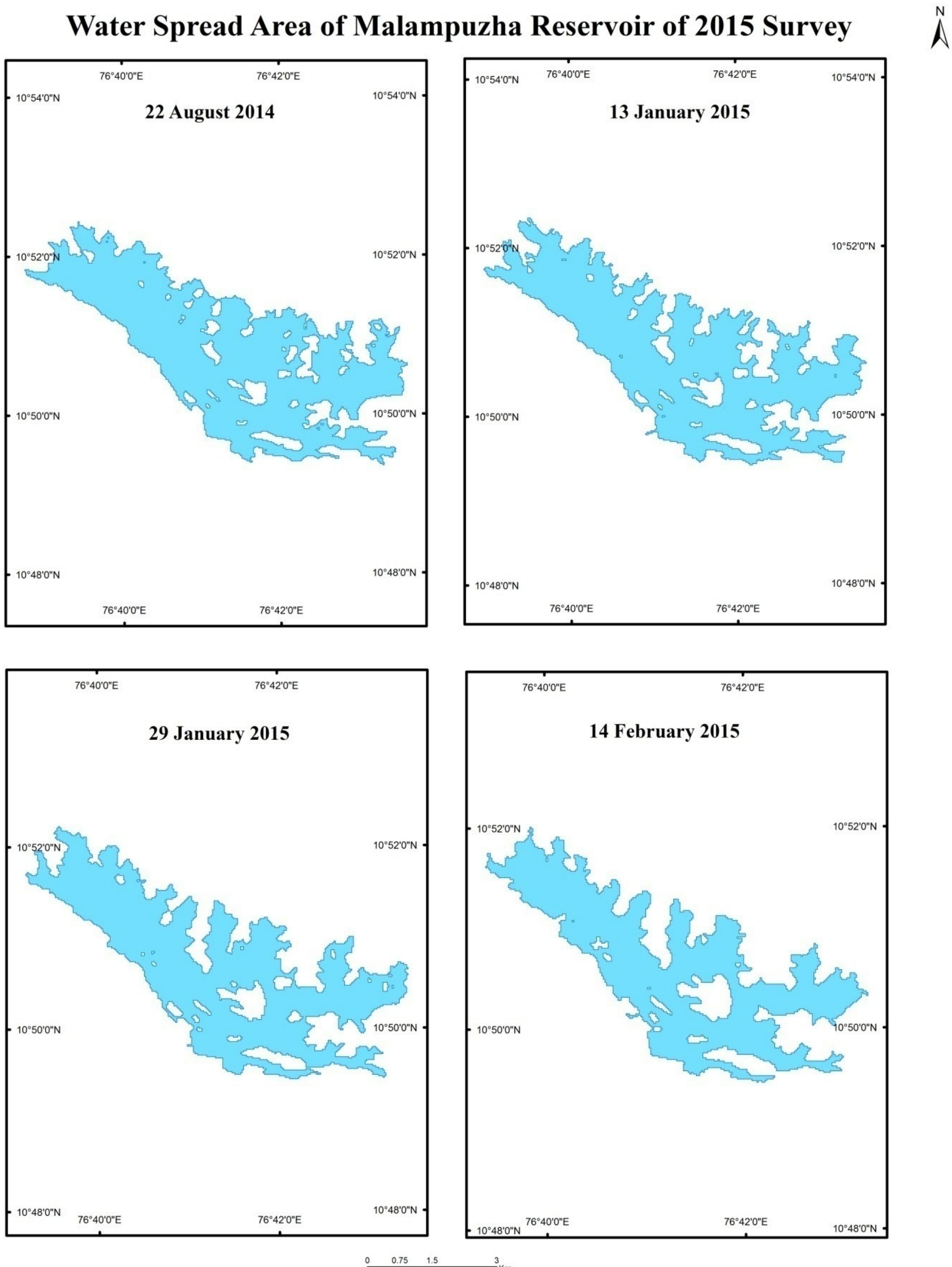

Fig.7 **Water spread area of Malampuzha reservoir**

Water Spread Area of Malampuzha Reservoir of 2015 Survey

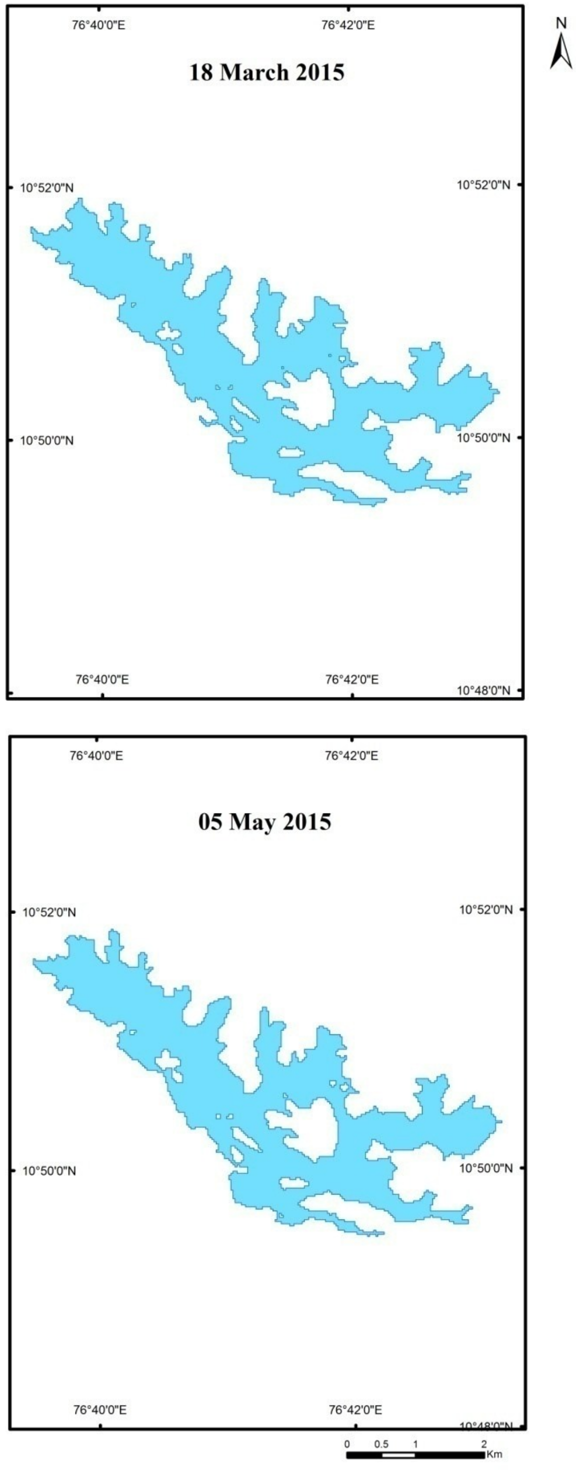

Fig 8 **Water spread area of Malampuzha reservoir**

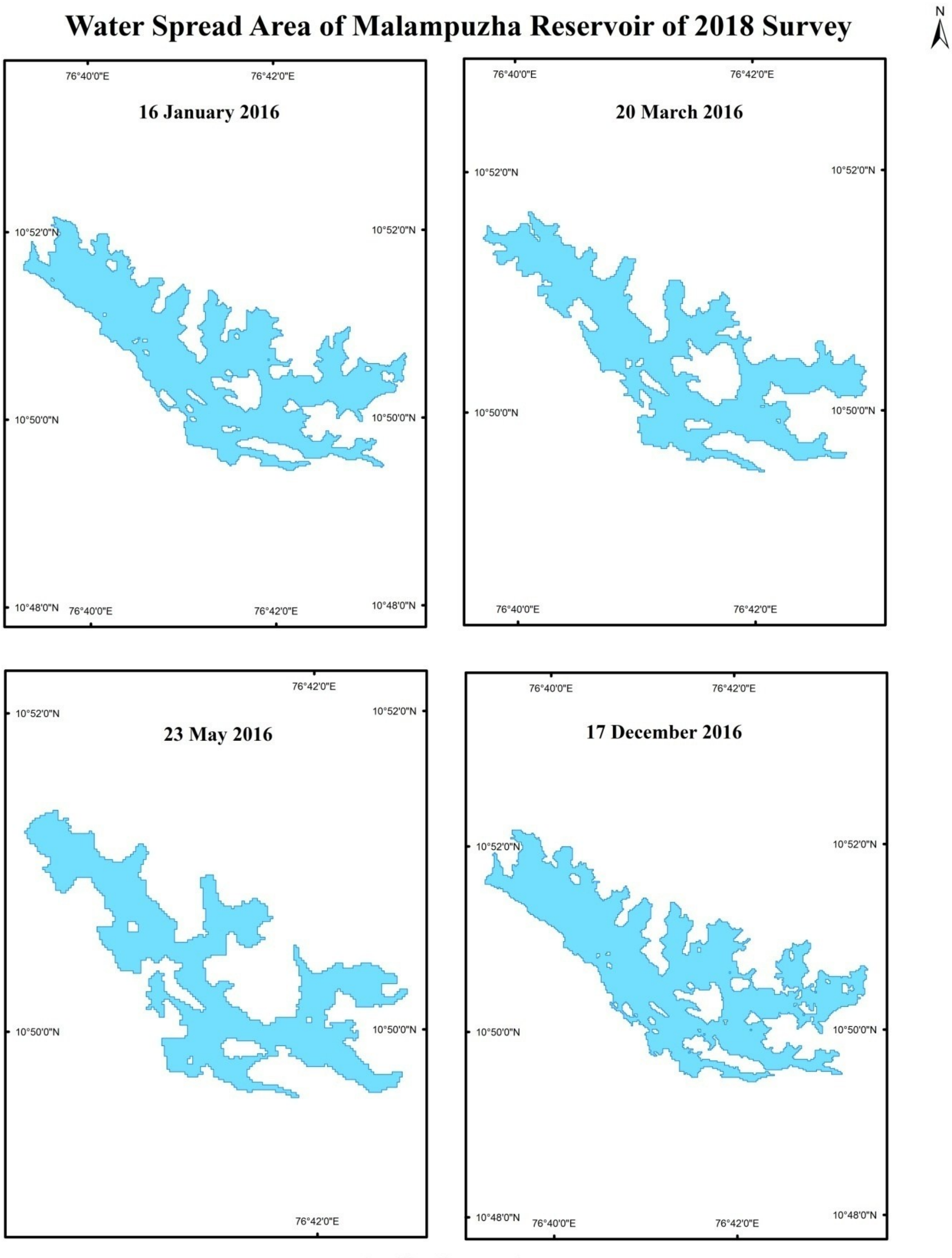

Fig.9 **Water spread area of Malampuzha reservoir**

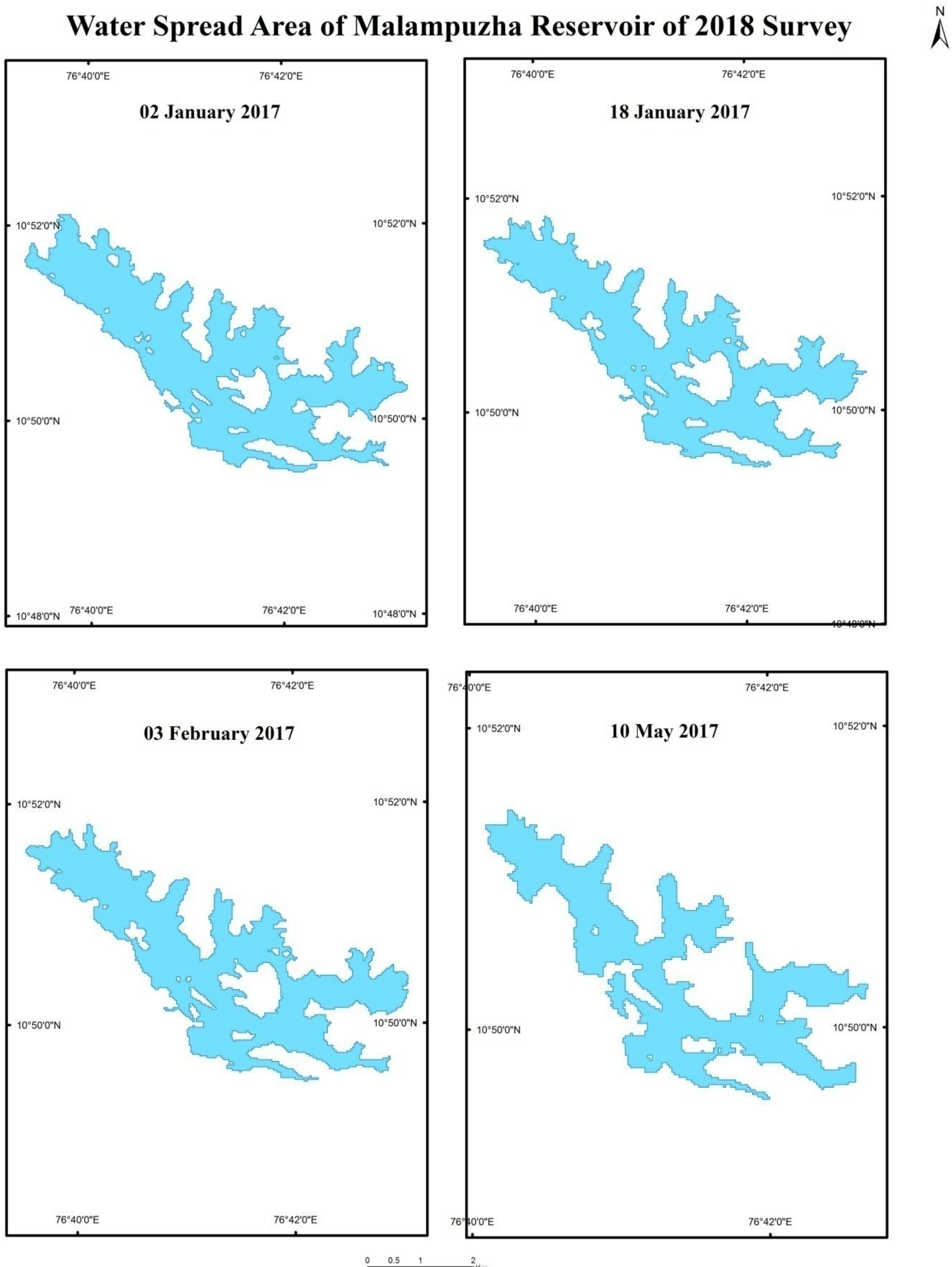

Fig.10 **Water spread area of Malampuzha reservoir**

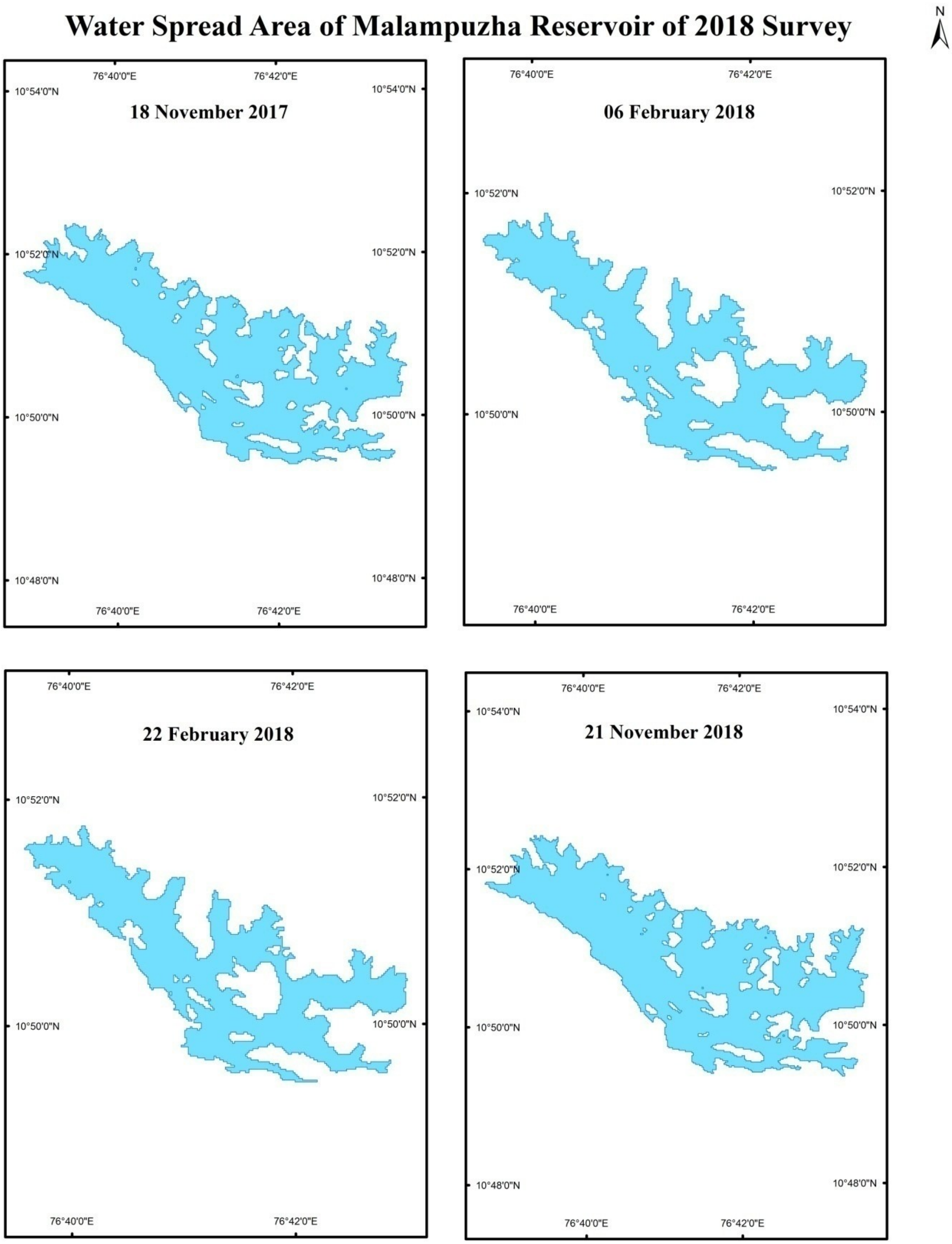

Fig.11 **Water spread area of Malampuzha reservoir**

5 CONCLUSION

The estimation of sedimentation rate using Remote Sensing technique is more effective when comparing with conventional methods in terms of labour and time. In this work, the loss in capacity of Malampuzha reservoir is calculated. The live storage capacity of Malampuzha Reservoir at the time of impoundment was 228.4Mm^3 and reduced to 195.425 Mm^3 by the year 2018. The percentage loss in capacity was calculated to be 14.437 % by the passage of 63 years. A sudden increase in sedimentation rate by 0.63% per year was observed during 2009-2015.

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