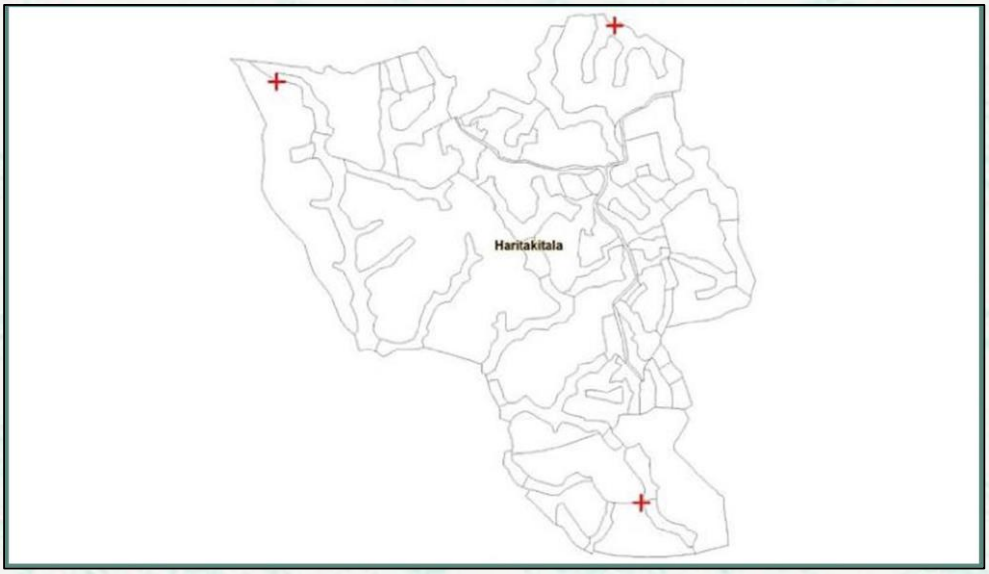
Pilot study for the development of methodology to support the Forest Land Boundary Digitization

Banstail Range, Tangail Forest Division



Bangladesh Forest Department

April 2016

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The Forest Department of Bangladesh leads actions to improve forest management and conservation, adopting forward thinking, innovative approaches in its management of approximately 1.55 million hectares of land across the country.

In 2015, the Forest Department began a process to establish a National Forest Inventory and Satellite Land Monitoring System for improved forest and natural resource management. The process addresses domestic information needs and supports national policy processes related to forests and the multitude of interconnected human and environmental systems that forests support. The process also supports climate change mitigation and implementation of REDD+.

The Bangladesh Forest inventory, led by the Forest Department, is a constant and comprehensive process that assesses, evaluates, interprets and reports on the status of trees and forest resources nationally. The activities implemented under the Bangladesh Forest Inventory process are implemented in collaboration between several national and international institutions and stakeholders. National partners from multiple government departments and agencies assist in providing a nationally coordinated approach to land management. International partners, including the United Stated Agency for International Development (USAID), the Food and Agriculture Organization of the United Nations (FAO) and SilvaCarbon are supporting the development of technical and financial resources that will assist in institutionalizing the process.

The results will allow the Forest Department to provide regular, updated information about the status of trees and forests for a multitude of purposes including for assessment of role of trees for firewood, medicines, timber, and climate change mitigation.

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Suggested Citation: **Islam, S. & Henry, M.** 2016. Pilot Study for the Development of Methodology to Support the Forest land Boundary Digitization. Dhaka, Centre for Environmental and Geographic Information Services, Bangladesh Forest Department, Food and Agricultural Organization of United Nations.

Disclaimer

Executive summery

The Bangladesh Forest Department (BFD) manages about 1.52 Mha (11% of the total land, FAO 2010) forest lands which includes Hill Forest, Sal Forest, Swamp Forest and Mangrove Forest (Natural and Plantation). The forest land boundary information is available in CS, RS and BS mouza sheet maps and gazette notified documents. Those information needs to be converted into GIS layers so that it can be integrated with other GIS layers to support decision making process. To develop a methodology for forest land boundary delineation, a pilot study was carried out in Banshtail Range, Tangail Forest Division.

The Banshtail Range of Tangail Forest Division comprises 90 CS Mouza sheets. Out of 90 CS Mouza sheet, 88 CS mouza sheets were collected from Directorate of land Record and Survey (DLRS) and Tangail Forest Division Office. The collected Mouza sheets were scanned in 300 dpi at a scale of 1:1 and saved in *.jpeg format. The plot boundaries were delineated from the scanned mouza sheets using head up digitization technique. After digitization, necessary attribute fields were added with each digitized mouza sheet. The critical part of the methodology was finding an option which will provide better positional accuracy than others. For this purpose two options: Option 1 - Edge Matching and Geo-referencing and Option 2- Geo-referencing and Edge matching were followed. The geo-referencing for option 1 was done using reference data: (a) BBS mouza, (b) randomly collected RTK point and (c) DGPS corrected IKONOS images and the same for option 2 was done using reference data: (a) randomly collected RTK point and (b) DGPS corrected IKONOS images. Finally, positional accuracy of geo-referenced data using 1a, 1b, 1c, 2a and 2b options was compared with each other.

The quality of georeferencing mostly depends on identification of reference ground control points on the ground accurately. It was observed that plot corners or plot boundaries which are visible in mouza sheets, are not visible on the ground due to land use land cover change and fragmentation of land plots. Some forest plots were also merged or encroached by settlements and agriculture. The best positional accuracy (6m) was found for option 2a (georeferencing using RTK reference data and edge matching). Though 2a option results high accuracy, it is very time consuming and costly. Another option 2b (georeferencing using DGPS corrected high resolution satellite image and edge matching) which results 38m accuracy. The positional accuracy obtained using this option can be improved if BRS or BS Mouza sheets are used. It will be cost effective and less time consuming.

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Acronyms

CS	Cadastral Survey
RS	Revised Survey
BS	Bangladesh Survey
RTK	Real Time Kinematic
DGPS	Differential Global Positioning System
GIS	Geographic Information System

1 Introduction

The Bangladesh Forest Department (BFD) manages about 1.52 Mha of forest land. Forest land includes Hill Forest, Sal Forest, Swamp Forest and Mangrove Forest (Natural and Plantation) and cover about 11% of the total land (FAO 2010). Though the GIS layer of the forest cover map has been prepared and updated using GIS and remote sensing technology under several projects, the GIS layer of forest land boundary is not updated. It is observed that a number of plots of land which had been allocated as forest land through gazette notification and demarked in the Cadastral Survey (CS) maps have been encroached by settlements and agricultural practices. Those forest land boundaries should be appended in the existing GIS layer for proper management and implementation of REDD+. It requires up to date forest land boundary and forest cover for the assessment of emission reduction and forest monitoring.

Several gazette notifications of the Government, CS, RS, BS sheet maps and some other base maps for the forest area are available in the head office, divisional offices, range offices and beat offices of FD. It is possible to develop a GIS layer of forest land boundary using the available maps and documents of the department.

2 Study Area

The Banshtail Range of Tangail Forest Division was selected for the pilot study. Geographically, it is located in the north-central part of Bangladesh. The Study Area includes Mirzapur and Sakhipur Upazila. The list of mouza, which includes 25 mouza under the Study Area, was collected from Project office. Figure-1 shows the location of Study Area.

3 Objectives of this study

This pilot study was designed to develop and test a methodology for preparation of GIS layer of the forest land boundary. This will also help identify the problems related to forest land boundary delineation from available sources.

4 Deliverables

The deliverables are:

- A Report presenting the methodology for the preparation of GIS forest land boundary
- GIS layer of forest land boundary and metadata for the Banshtail Range of the Tangail Forest Division
- A final Report presenting the results and documenting the GIS layers.

5 Scopes of Work

The specific activities defining the scope of work under the study are:

a. Collection of hardcopy CS sheet maps from the Directorate of Land Records and Survey (DLRS)

b. Digitization of CS Mouza sheet maps
c. Geo-referencing of the CS sheet maps
d. Validation of the CS sheet map
e. Preparation of the final report

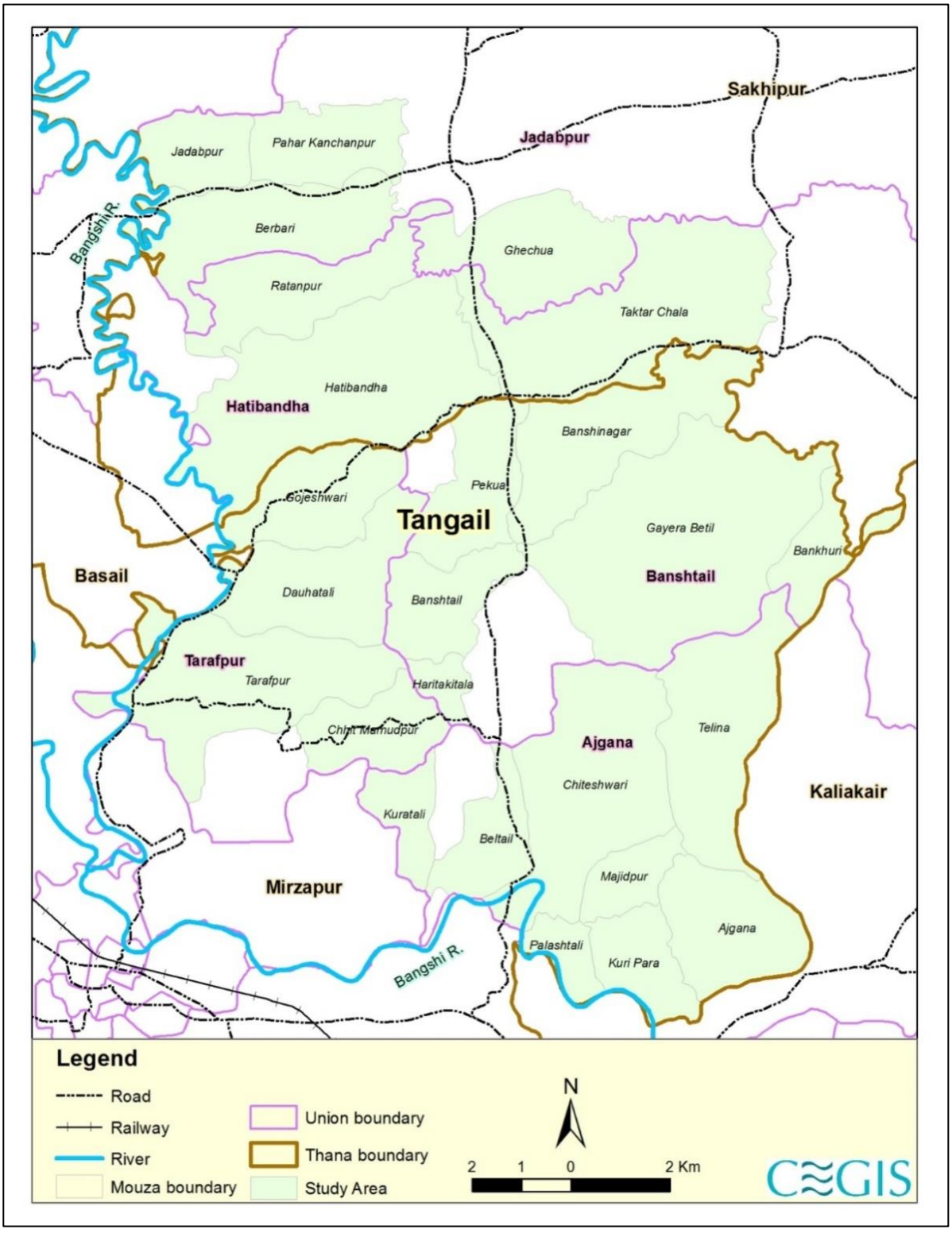


Figure-1: Location Map of Banshtail Range, Tangail Forest Division, Tangail

6 Literature Review

Under this study the hardcopy Cadastral Survey (CS) maps of the study area will be converted into digital maps using GIS technique. The critical part of this process is georeferencing. A georeferencing with higher positional accuracy requires a number of ground control points which are visible in the image and those points can be located on the ground accurately. The CS maps were prepared between 1888 and 1940. Due to change of land use and land cover, it is very difficult and time consuming to identify a plot corner in the mouza map on the ground. To understand how others are doing georeferencing of mauza maps, a literature review was done. In Bangladesh, many organizations are working with mauza sheets and georeferencing but no documentation was found related to the positional accuracy of geo-referenced mauza maps. However, some published documents on assessment of positional accuracy of georeferenced mauza maps carried out in India were found in the internet. One of the study named "Updating of Cadastral Maps Using High Resolution Remotely Sensed Data" by V. V.Govind Kumar, K. Venkata Reddy, Deva Pratap was published in International Journal of Engineering and Advanced Technology (IJEAT) [ISSN: 2249 – 8958, Volume-2, Issue-4, April 2013]. The study area was Venkatapuram village, Thorrurmandal of Warangal district, Andhra Pradesh, India. The mauza maps of the study area were converted into digital GIS files and geo-referenced using reference image of high resolution Google earth images. In this process, the Google earth images were geo-referenced with topographic map of this study area and after that digital CS maps were geo-referenced using the geo-referenced Google earth images. Finally, the accuracy of geo-referenced mauza sheets were assessed using randomly collected handheld GPS points. The positional accuracy of the mauza sheets was found about 157.84m to 185.64m. Finally it was suggested that the positional accuracy may be improved by comparing with the ground points collected using DGPS or RTK GPS system.

7 Methodology of Forest Boundary Digitization

The forest land boundary was delineated from Cadastral Survey (CS Maps) and converted into GIS layer following a step by step procedure (Figure-2). The collected CS Mouza sheets of Banshtail Range were scanned into digital image files. The plot boundaries were digitized from each scanned digital image using head up digitization technique and attributes of each plot were added with digitized data. The digitized data were geo-referenced in different options and the positional accuracy was compared with reference points collected from field using RTK. The detailed description of the methodology of this study is given below.

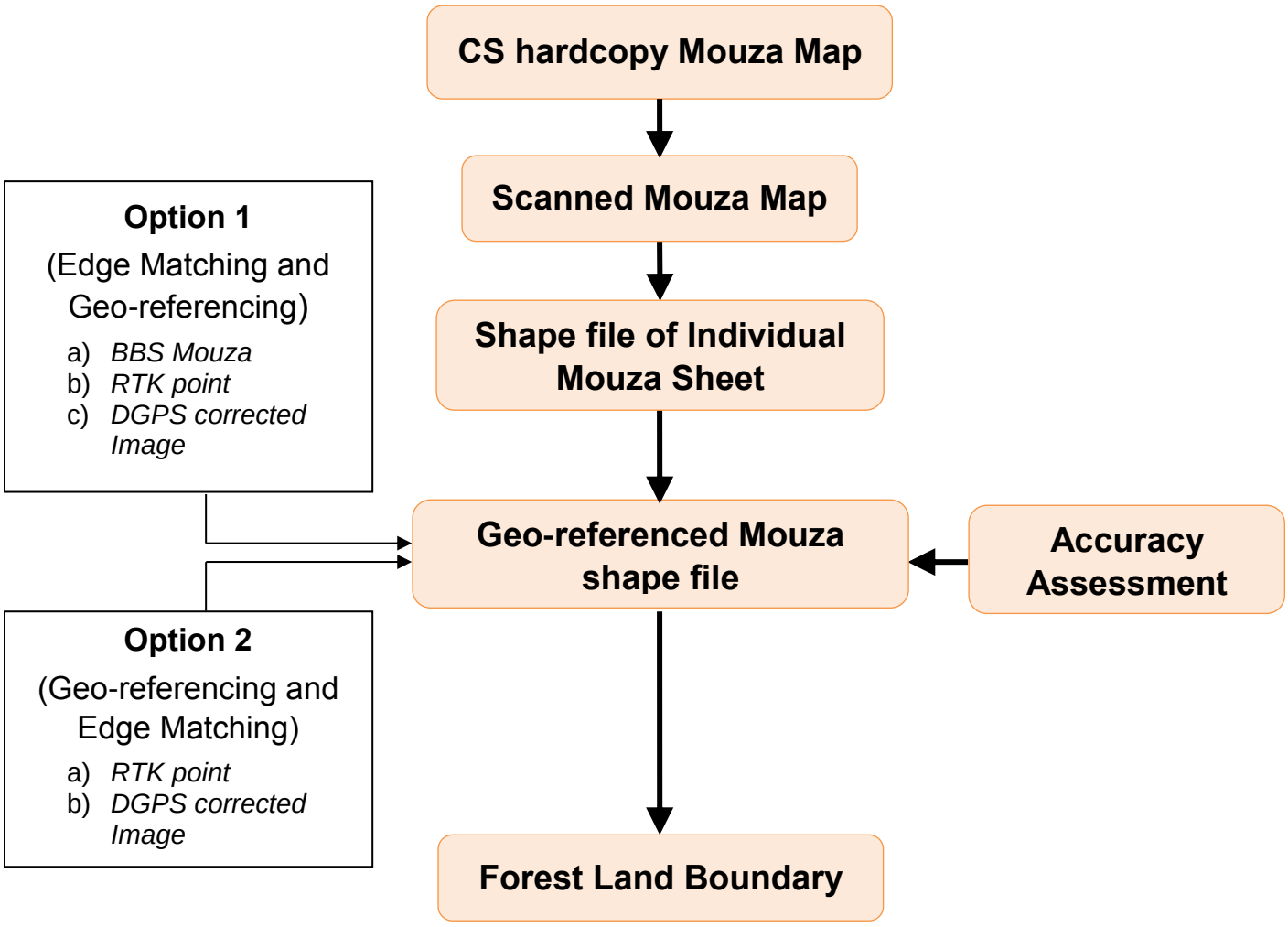


Figure-2: Flow chart of methodology of forest land boundary delineation

7.1 Collection of CS Mouza Sheets

The Cadastral Survey (CS) maps were selected for forest land plot boundary delineation because the forest land plots number were notified in the CS maps through gazette notification. It is the first land survey program in Indian Sub-Continent which was started in 1887 and ended in 1940. The CS Mouza sheets of Banshtail Range of Tangail Forest Division were prepared during the years 1914 to 1915.

Banshtail Range comprises of 25 Mouza and 90 CS mouza sheets. Out of 90 CS Mouza sheets, 88 sheets were available. Among the 88 Mouza sheets, 84 Mouza sheets were collected from DLRS (Directorate of land Record and Survey) and four (4) mouza sheets were collected from Tangail Forest Division Office. The two (2) Mouza sheets were not traceable either the DLRS or with the Tangail Forest Division Office. The list of collected CS Mouza sheets is given in Table-1.

Table-1: List of Collected Mouza Sheet

Upazila	Range	Sl.No	Mouza	J.L. No	Total Sheet	Collected Sheet
Mirzapur	Banshtail	1	Dauhatali	186	4	4
		2	Tarafpur	185	6	5
		3	Banshtail	190	3	2
		4	Gayera Betil	204	10	10
		5	Bankhuri	206	2	2
		6	Gojeshwari	187	3	3
		7	Kuri Para	197	3	3
		8	Chiteshwari	200	5	5
		9	Majidpur	199	2	2
		10	Banshinagar	205	4	4
		11	Pekua	189	2	2
		12	Ajgana	198	3	3
		13	Chhit Mamudpur	192	2	2
		14	Haritakitala	191	1	1
		15	Telina	207	5	5
		16	Palashtali	196	1	1
		17	Beltail	195	3	3
		18	Kuratali	193	2	2
Sakhipur	Banshtail	19	Hatibandha	84	7	7
		20	Ghechua	115	4	4
		21	Taktar Chala	117	7	7
		22	Berbari	86	4	4
		23	Jadabpur	98	1	1
		24	Pahar Kanchanpur	99	2	2
		25	Ratanpur	85	4	4
Total					**90**	**88**

7.2 Scanning of CS Mouza Sheets

All CS Mouza sheets were scanned in 300 dpi at a scale of 1:1. After scanning, the digital files were saved in *.jpeg format. **Figure-3** shows an example of a scanned CS Hardcopy Mouza Sheet (Sheet No.4 of Banshinagar Mouza of Mirzapur Upazila of Tangail District).

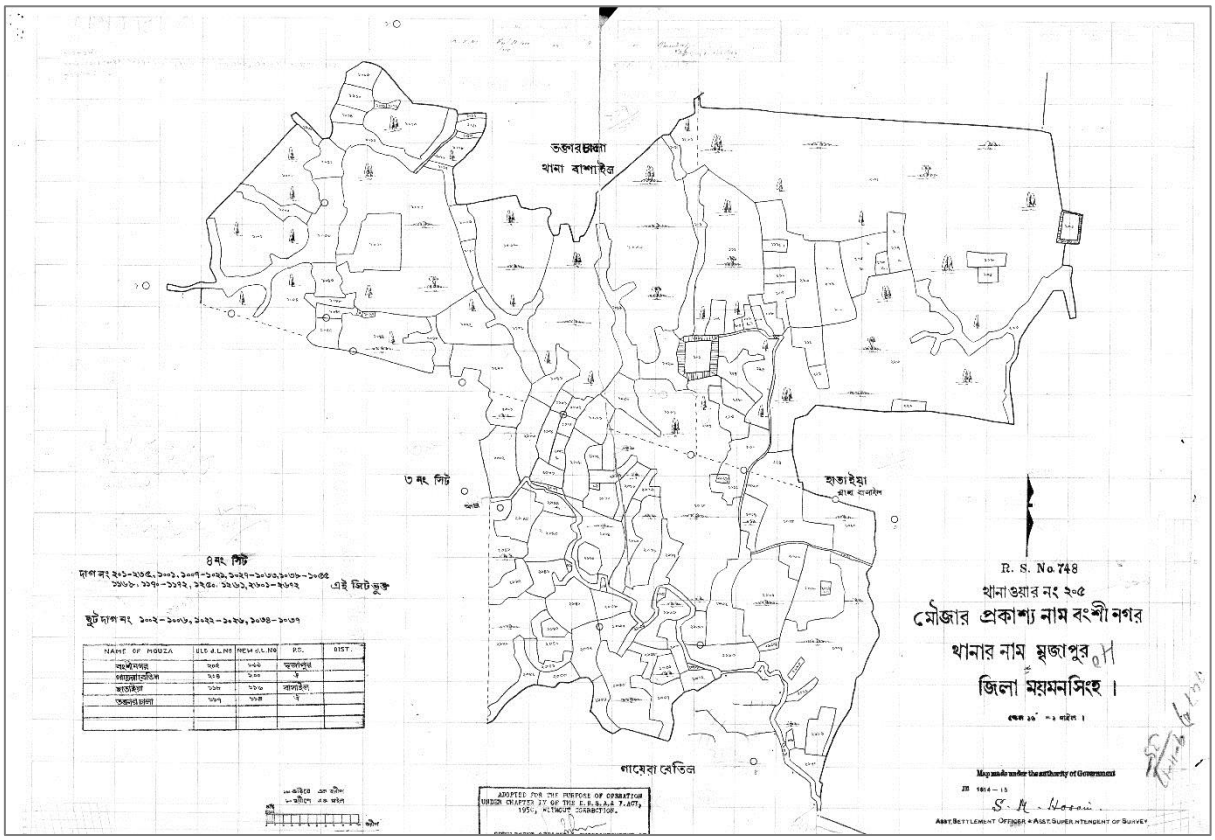


Figure-3: A scanned CS Hardcopy Mouza Sheet (Sheet No 4 of Banshinagar Mouza, Mirzapur Upazila; Tangail District)

7.3 Digitization of CS Mouza Sheets

All the digital scanned mouza sheets were digitized using editing tools of ArcGIS 10.1 software. As per the contract agreement, boundary of all the plots were digitized from each Mouza sheet. After digitization attribute fields were added with each digitized Mouza sheet. Table-2 shows the name of the fields, field type and field length which were added with the attribute table of each mouza sheet.

Table-2: Name of Attribute Fields, Field Type and Field length

Name	Field Type	Field Length	Description	Example
GEOCODE11	Text	254	GEOCODE11	30936613033
DIV_CODE	Text	254	Division Code	30
DIST_CODE	Text	254	District Code	3093
UPZ_CODE	Text	254	Upazila Code	309366
UNI_CODE	Text	254	Union Code	30936613

Name	Field Type	Field Length	Description	Example
DIVNAME	Text	254	Division Name	Dhaka
DISTNAME	Text	254	District Name	Tangail
THANAME	Text	254	Thana Name	Mirzapur
UNINAME	Text	254	Union Name	Ajgana
MAUZNAME	Text	254	Mouza Name	Ajgana
JL_NO	Double	-	Jurisdiction Number	198
SHEET_NO	Double	-	Mouza Sheet Number	1
PLOT_NO	Double	-	Plot Number	1001
REMARKS	Text	254	Necessary Remarks	MTJ = Mix Tree Jungle BJ = Bushy Jungle P = Pond R = River M = Mosque

Both digitization quality and error were checked and those were corrected accordingly. The topological errors of adjacent plots such as “must not overlap” and “must not have gaps” were also checked. Finally, all mouza sheets were saved in Shape file format. Figure-4 shows a part of digitized Mouza sheet of Banshinagar Mouza (Jurisdiction List_205, Sheet No 4) in Shape file format.

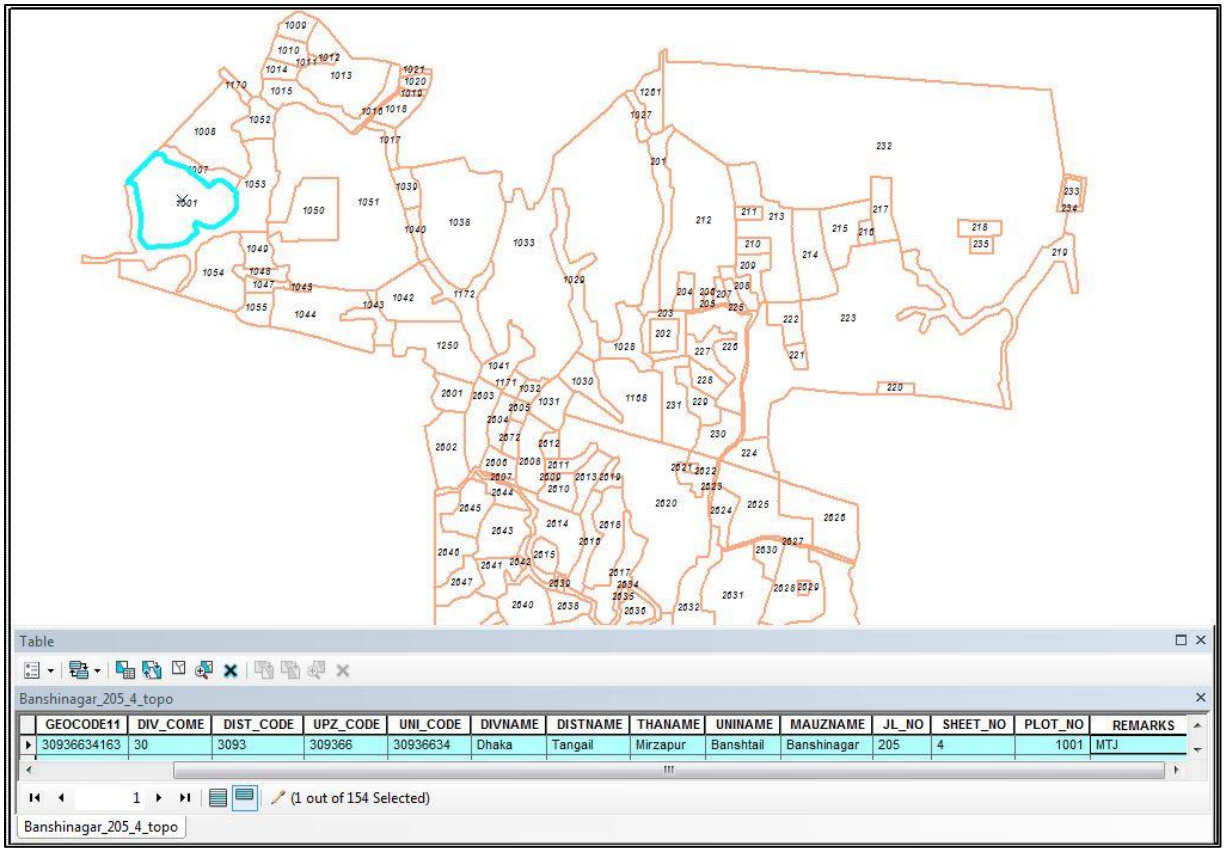


Figure-4: A part of digitized Mouza sheet of Banshinagar Mouza (Jurisdiction List 205, Sheet No 4) in shape file format

During digitization and editing it was found that some plots did not have any plot number, some plots shared the same plot number and some plot numbers mentioned in the mouza sheets were not found. A list of Mouza name having those problems is given in the Table-A.1.

7.4 Geo-referencing of Digitized Mouza Sheets

Considering cost and time constraint, it was proposed that edge matching of adjacent mouza sheets will be done before geo-referencing. Later, an alternative option of edge matching after geo-referencing individual mouza sheets was raised for testing. As there was budget limitation, CEGIS agreed to do the proposed test also for one mouza sheet.

7.4.1 Option 1: Edge Matching and Geo-referencing

Edge Matching

Edge matching of adjacent mouza sheets was performed to make a mosaic of all mouza sheets. It was performed using Spatial Adjustment tool of ArcGIS 10.1 software. During spatial adjustment process, Transformation-Similarity method was selected because the shape of the edge matched mouza sheets did not distort.

Figure-5 shows how edge of Sheet no 3 matched with edge of Sheet no 4 of Banshinagar Mouza are matched. The source and target points are linked and adjusted accordingly. Then topological errors of adjacent plots such as “must not overlap” and “must not have gaps” were also checked.

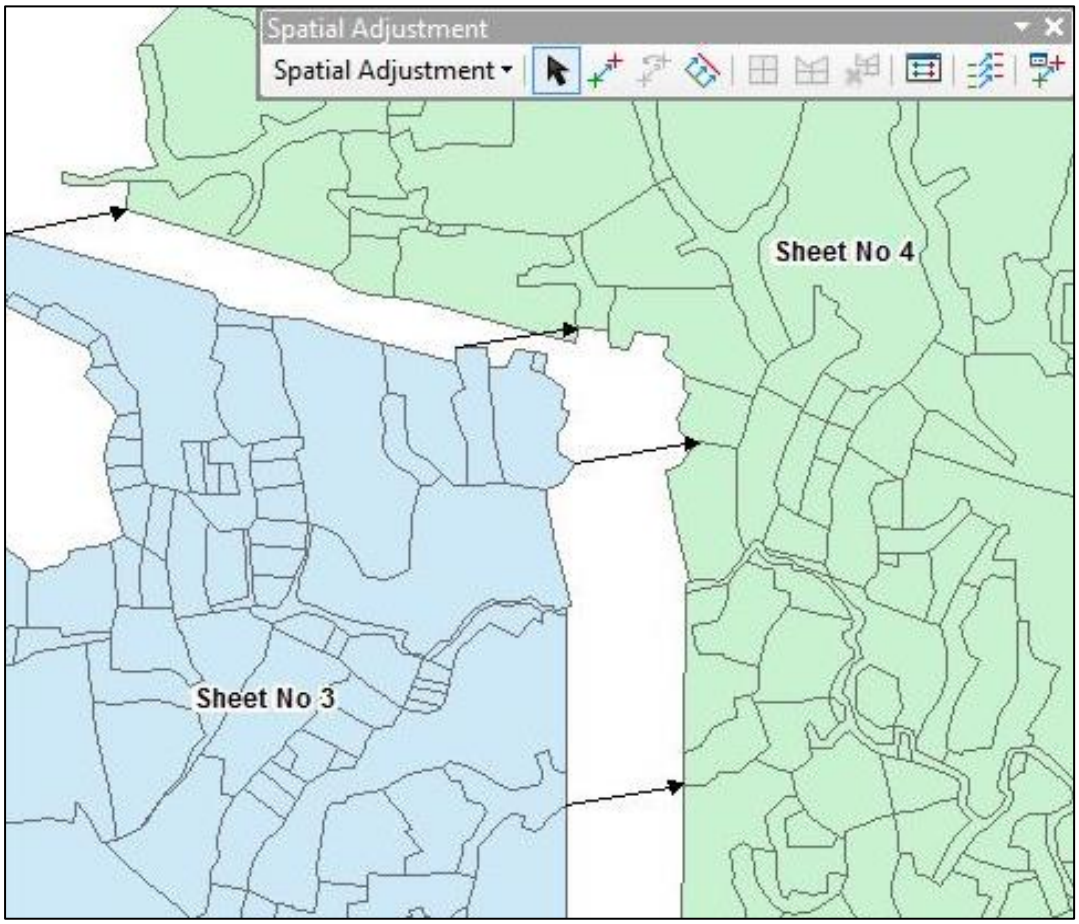
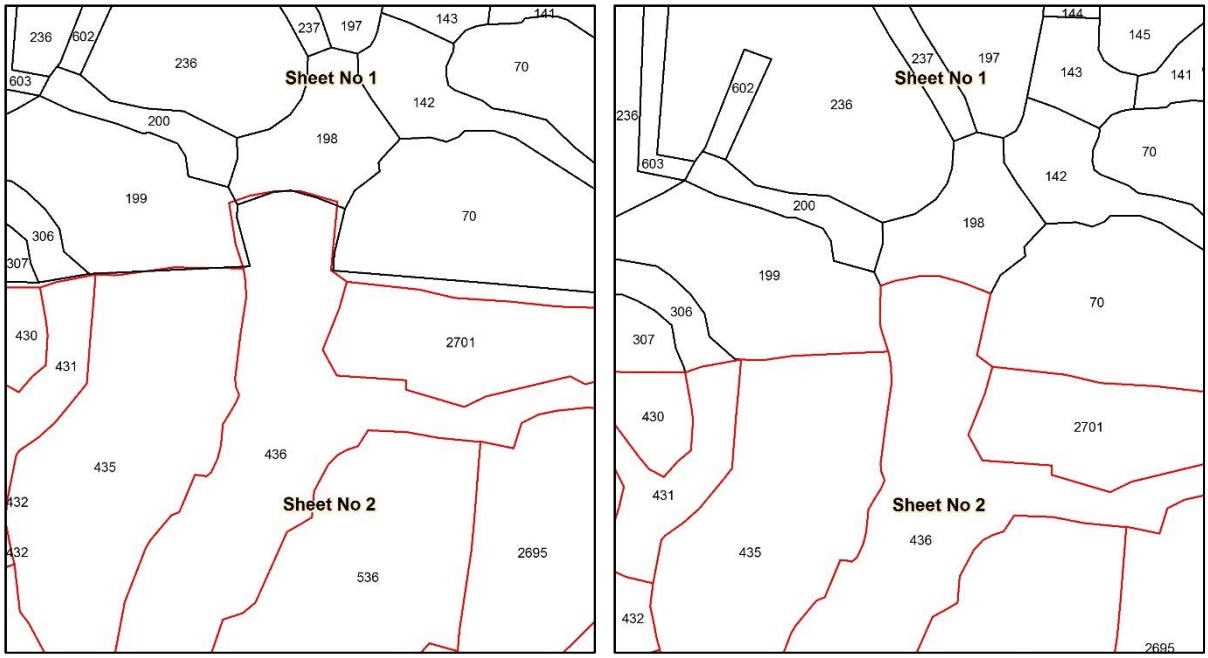


Figure-5: Edge matching process

After checking topological error, adjacent polygons within the edge matched zone may gain or lose area extent (**Figure-6**).Following this method all mouza sheets were edge matched and merged together.



a. Before topology correction b. After topology correction

Figure-6: Overview of adjacent plot boundary before and after the topology correction.

Geo-referencing

The edge matched mouza sheets were geo-referenced using reference coordinates collected from BBS mouza map, form Field using Real Time Kinematic GPS and from DGPS corrected high resolution satellite images.

a. Ground Control Points from BBS Mouza

After edge matching the mosaic mouza sheets were geo-referenced using geo-referenced BBS mouza data. Its coordinate system is in Bangladesh Transverse Mercator (BTM). The geo-referenced BBS mouza data contain mouza boundary. But it does not contain any plot boundary within the mouza. Finally geo-referencing was done using Transformation-Affine option of Spatial Adjustment tool of ArcGIS 10.1 software (Figure-7).

b. Real Time Kinematic Points

A total of 17 (Seventeen) Ground Control Points (GCPs) at Mouza plot corner were collected from the Study Area using Real Time Kinematic GPS system. Due to time difference, it was difficult to locate the plot corners in the Mouza sheet maps on the ground. In this case, a local land surveyor helped to identify those 17 Ground control points on the ground accurately. It is very important to involve local land surveyor in the process to identify GCP points on the ground accurately and to save time.

Figure-8 shows the spatial distribution of the collected GCPs. Of the 17 GCP points, 8 GCPs were used for geo-referencing the digitized edge matched mouza sheets into BTM coordinate system. The rest of the points were used for accuracy assessment.

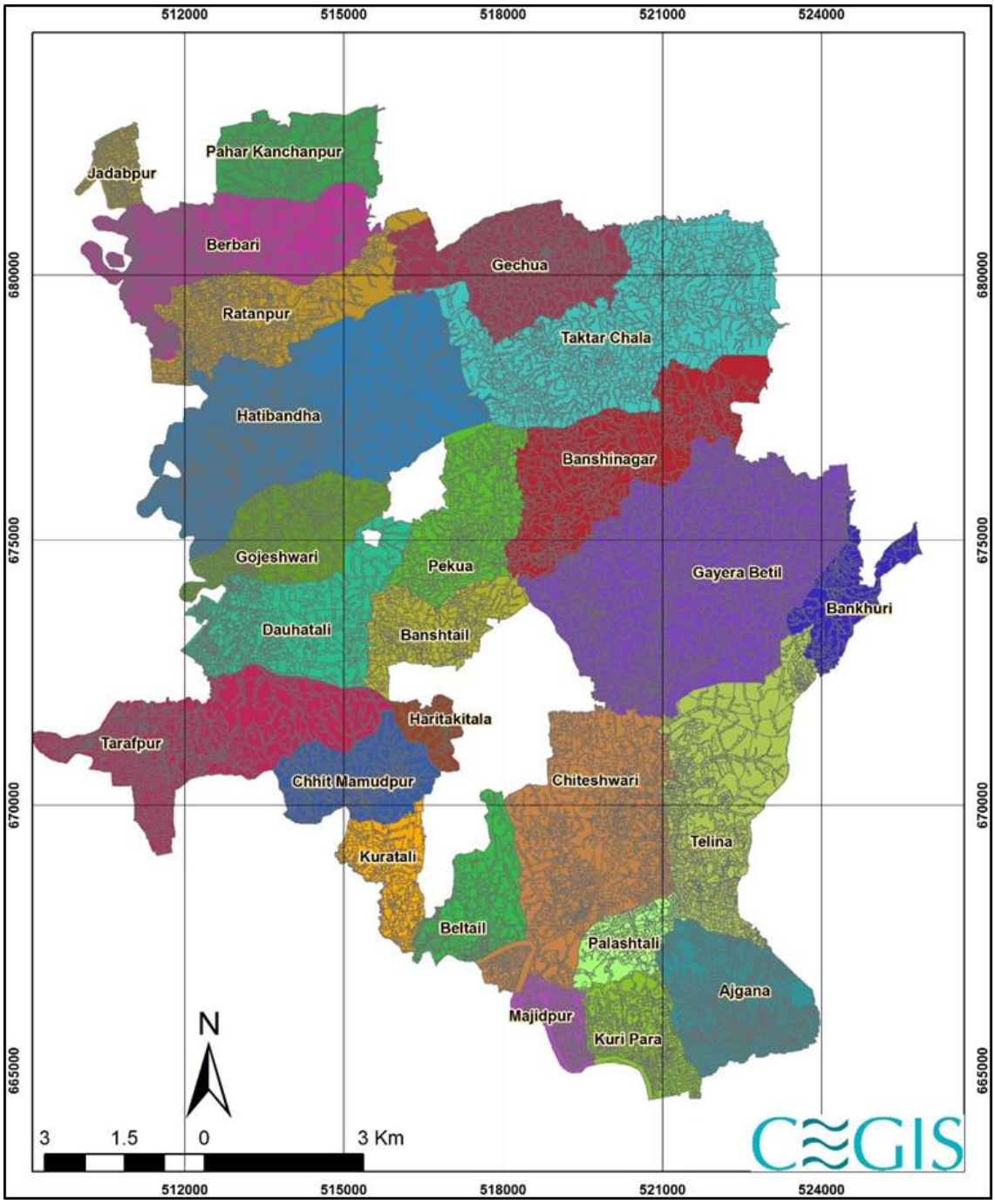


Figure-7: Geo-referenced Mouza of Banshtail Range, Tangail Forest Division

c. DGPS corrected high resolution satellite image

The digitized edge matched mouza sheets were also geo-referenced using DGPS corrected high resolution pan-sharpened IKONOS (Resolution: 1m) satellite images (Figure-9). A total of 20 GCPs were identified both in the digitized edge matched mouza sheets and DGPS

corrected IKONOS satellite image. The Transformation-Projective method of Spatial Adjustment tool of ArcGIS 10.1 was used for geo-referencing into BTM coordinate system.

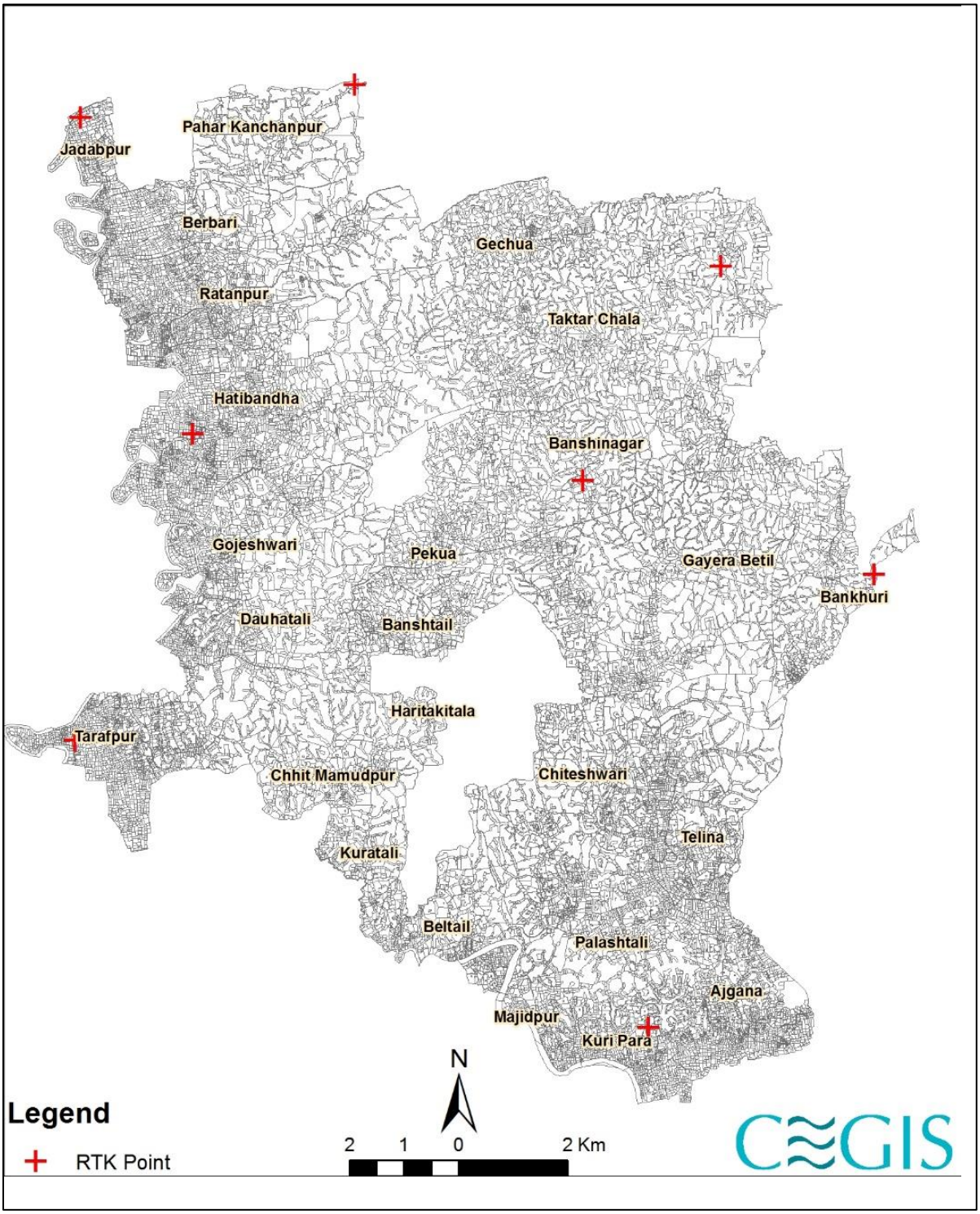


Figure-8:Distribution of RTK points.

7.4.2 Option 2: Geo-referencing and Edge Matching

It was proposed in the meeting held on 16th February, 2016 to carry out an alternative test of geo-referencing individual sheets before any edge matching. It requires minimum three GCPs for geo-referencing an individual mouza sheet and 75 GCPs for 25 Mouza sheets. The budget and time of the study were estimated for collecting 17 GCPs from the whole Study Area. Besides these, difficulties were experienced and found very time consuming of finding even one GCP on the ground for one individual sheet.

a. Real Time Kinematic Points

Only four GCPs were found for Haritakitala Mouza Sheet and it was geo-referenced using 3 RTK point (Figure-10)**.**One GCP was kept for accuracy assessment**.** The RTK points were collected from different plot boundary corners of the Haritakitala Mouza. Using the three GCPs, the Haritakitala Mouza Sheet was geo-referenced following same procedure described above (6.4.1.b section).

Figure-9: Overlay of Geo-referenced Mouza of Banshtail Range on IKONOS Images

b. DGPS corrected high resolution satellite image

The Haritakitala Mouza Sheet was also geo-referenced using DGPS corrected high resolution pan-sharpened IKONOS satellite images. Similar procedure of geo-referencing described above in 6.4.1.c section was used for geo-referencing Haritakitala Mouza Sheet. Figure-11 shows geo-referenced Haritakitala Mouza on IKONOS Images.

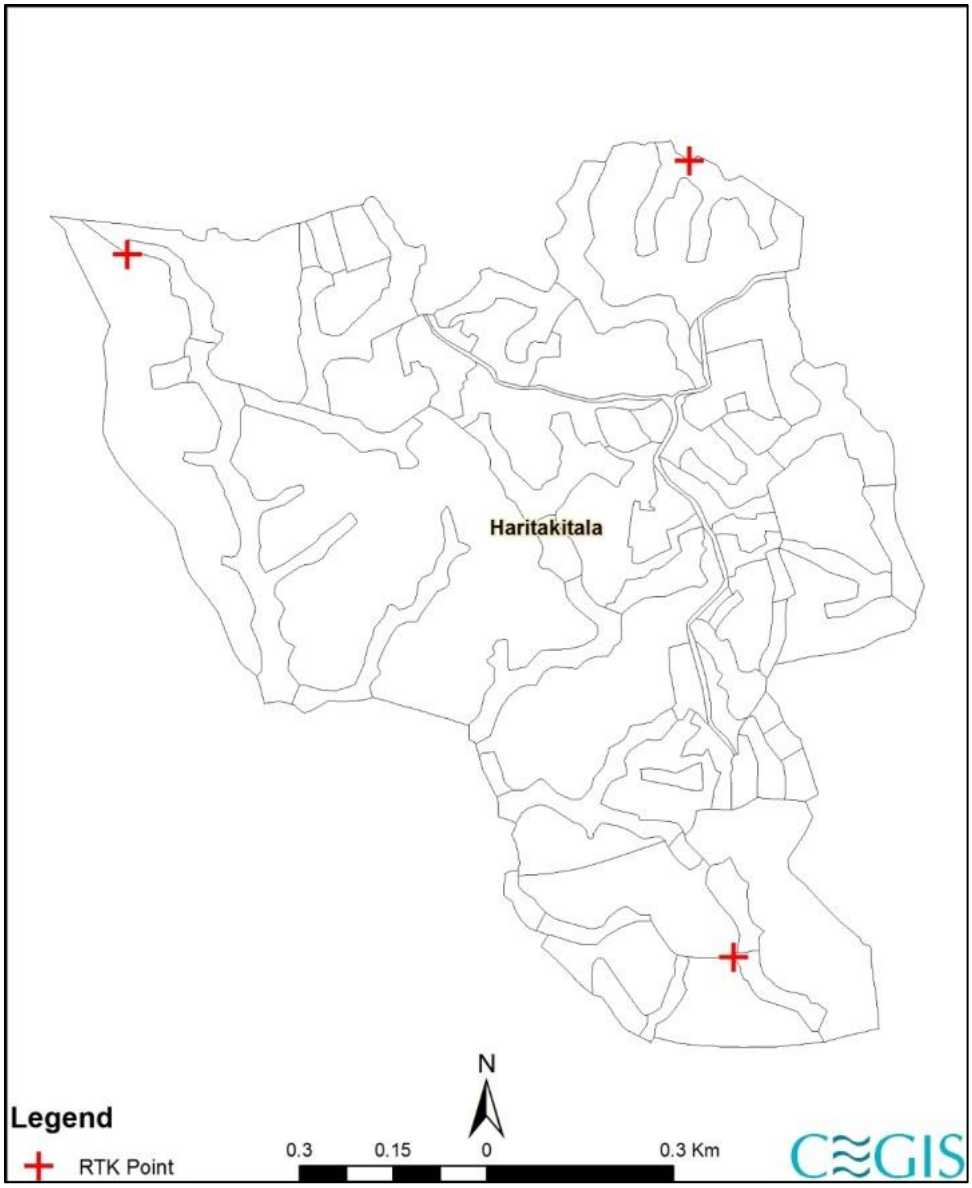


Figure -10: Distribution of RTK points in Haritakitala Mouza Sheet

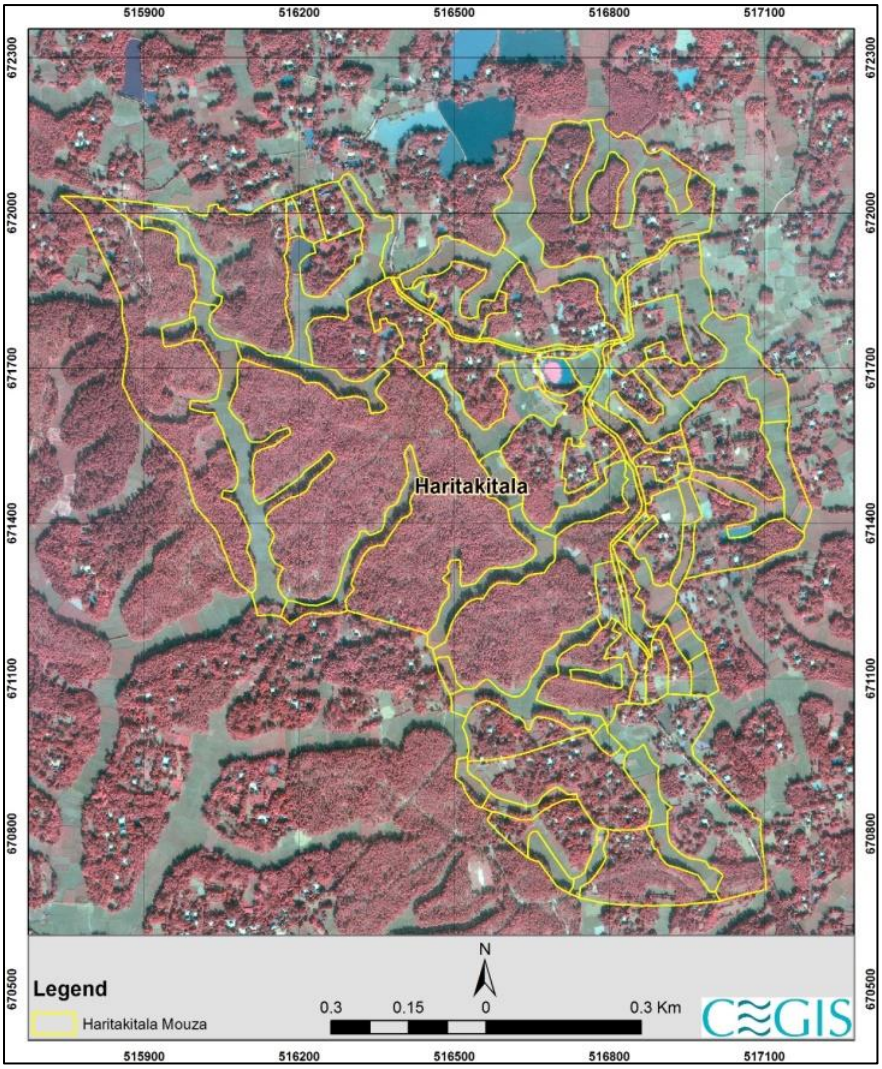


Figure-11: Overlay of Geo-referenced Haritakitala Mouza on IKONOS Images

8 Positional Accuracy Assessment

The GCPs collected from different reference sources were used for geo-referencing. Edge matching of adjacent mouza sheets was done before geo-referencing and after geo-referencing. A positional accuracy of different options which were used for geo-referencing mouza sheets were assessed. The summary of finding is given in the Table-3.

Table-3: Positional Accuracy Assessment of geo-referencing options

Options	Source of Ref. GCPs	Number of Accuracy Assessment points	Average RMS error (m)
1. Edge matching and Geo-referencing	a. BBS Mouza	17	117
	b. RTK GPS	5	59
	c. DGPS corrected high resolution Image	17	94

Options	Source of Ref. GCPs	Number of Accuracy Assessment points	Average RMS error (m)
2. Geo-referencing and Edge matching	a. RTK GPS	1	6
	b. DGPS corrected high resolution Image	4	38

The Table-3 shows that the average RMS errors for all options are very high except for option 2a. The high RMS error for other options may be due to following reasons:

The Study Area comprised about 165 sq.km. While matching the edges of all 88 Mouza sheets, some gaps and overlaps were generated within the edge matching area. Topological error checking resolves those problems but adjacent plot boundaries are displaced. In addition, each plot rotates in each individual edge matching sheet. That is why RMS error is of Option 1a, Option 1b, and Option 1c is high.

The forest land boundary delineated from CS Mouza maps were prepared during 1914-1915. Compared to current study period, it is about 100 years past. By this time, the land use and land cover have changed, dramatically. Also, forest plot lands were encroached by settlement or by agriculture land. It was difficult to identify the CS plot boundary corner by the local surveyor.Figure-12 shows one of the RTK points that were collected from pillar of the forest land. The picture shows the forest land is encroached by agriculture.

Figure-12: RTK point collected from pillar of forest land, Banshtail Range.

The RMS error of Option 2a (5.95 m) is better compared with other options. The accuracy of the option can be improved by collecting more RTK points within the Haritakitala Mouza.

RMS error of Option 2b is 38.89. The Mouza sheet of Haritakitala was geo-referenced using DGPS corrected 1 meter resolution IKONOS images of this study area. The IKONOS images were acquired between the years 2011-2012 years. It was difficult to spatially adjust the CS Haritakitala Mouza map with recent IKONOS images.

9 Forest Land Boundary Delineation

A data table of forest plot land was generated from the Gazette Notification. The table has two fields: PLOT_NO and TYPE. The PLOT_NO field contains the Mouza plot numbers which are declared as forest land in the gazette notification. The Figure-13 shows the forest land boundary in green color.

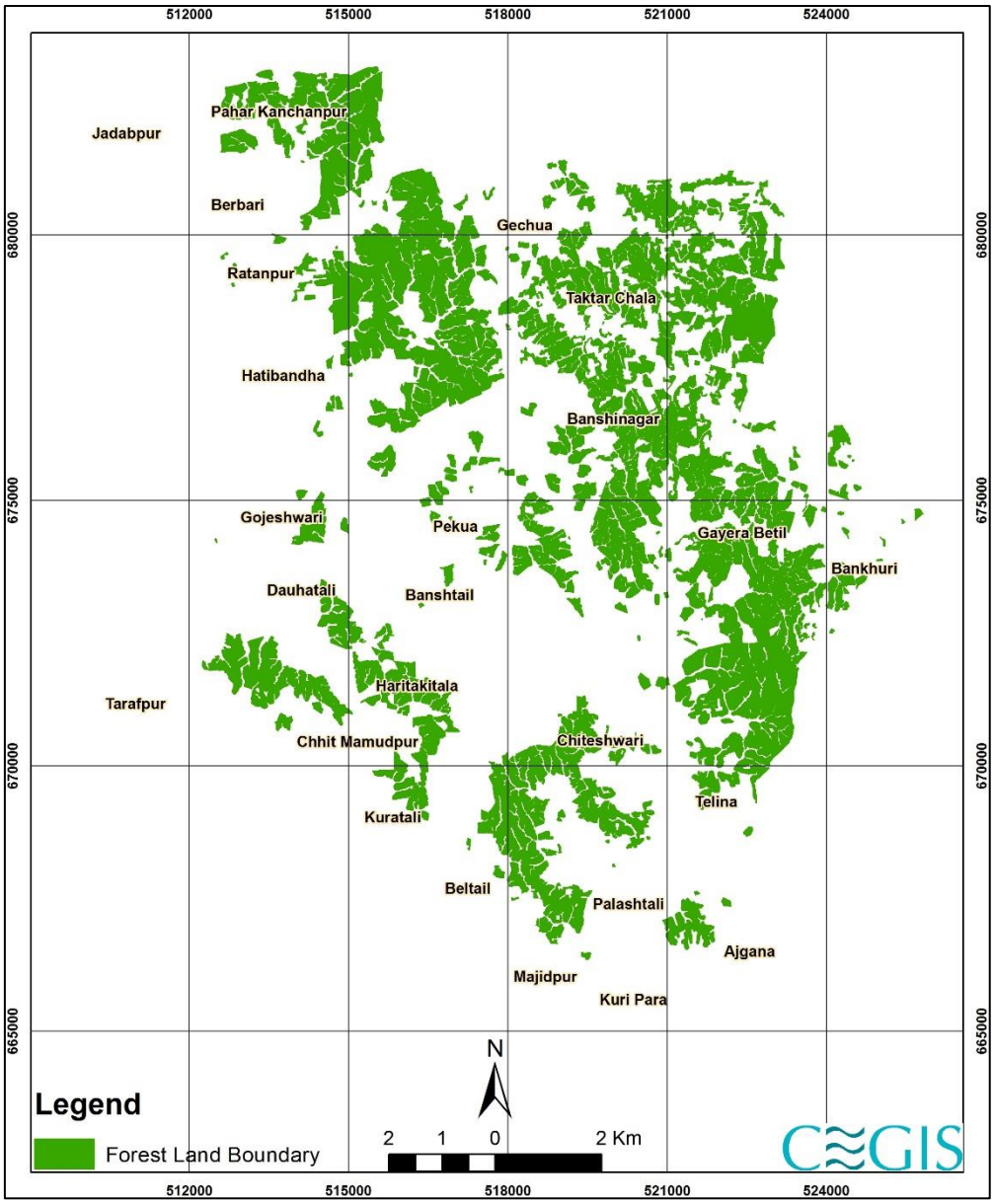


Figure-13: Forest land boundaries of Banshtail Range, Tangail Forest Division.

10 Conclusion and Recommendation

Conclusion

Forest land boundary of Banshtail Range, Tangail Forest Division, was delineated from available 88 CS Mouza sheets of 25 Mouza of Mirzapur and Shakhipur Upazila, Tangail. The main issue of delineating forest boundary from Mouza plot sheets is to find out an option which will provide the best positional accuracy of mouza plot boundaries. Five different options: 1a, 1b, 1c, 2a, and 2b were used for geo referencing the Mouza plot sheets. The positional accuracy of geo-referenced data was checked with GCPs collected using RTK GPS system. Average RMS error of Option 1a, 1b, 1c, 2a, and 2b are 117 m, 59 m, 94 m, 6 m and 38 m respectively. The positional accuracy of geo-referencing depends on well distributed and highly accurate GCPs. During field survey, it was found difficult to identify the plot boundaries or corners on the ground. Some forest land plots were also merged and encroached by settlements and agriculture. Plot corners which are visible in Mouza plot sheets, most of those were not found on the ground due to land use/cover changes and fragmentation of plots. Option 2a (individual Mouza plot sheet geo-referencing using RTK points and edge matching) may give high accuracy but it is very time consuming and costly.

Recommendation

The main objective of this study is to develop a methodology for forest land boundary delineation. Using available data such as gazette notification and Mouza sheet maps it is relatively easy to identify forest land boundary. The main critical issue of the methodology is to improve the positional accuracy of forest land boundary. It is found that of the options, Option 2a would provide high accuracy but it will be time consuming and costly.

Another Option may be 2b (Geo-referencing individual sheets using DGPS corrected high resolution satellite image and edge matching). It would provide 38 m accuracy. But it can be improved if BRS or BS Mouza sheets are used. It will be cost effective and less time consuming.

Appendix

Table A.1: List of Unavailable Mouza Sheet

Upazila	Range	Sl. No	J. L No	Mouza	Unavailable Sheet No
Mirzapur	Banshtail	1	185	Tarafpur	1
		2	190	Banshtail	3

Table A.2: List of Null Plot No, Missing Plot No and Duplicate Plot No of Collected 88 CS Mouza Maps, Banshtail Range, Tangail Forest Division

Upazila	Range	Sl. No	Mouza	J. L No	Null Plot No	Missing Plot	Duplicate Plot
Mirzapur	Banshtail	1	Ajgana	198	1	2612	
		2	Bankhuri	206	1		
		5	Beltail	195			
		7	Chiteshwari	200		328, 2555, 3331	
		8	Dauhatali	186	5	2516, 2517, 2519, 2522	1324
		9	Gayera Betil	204		3901-3950	
		10	Palashtali	196	1		
		11	Pekua	189	4	301, 1673, 1674	
		12	Tarafpur	185		2261, 2264, 2265	
		13	Telina	207	1	2682, 2686	
Sakhipur		14	Berbari	86		938	
		15	Pahar Kanchanpur	99		118	
		16	Ratanpur	85		350, 859, 2027, 2033	
		17	Taktar Chala	117	3	1803, 1806,	

Mouza: Haritakitala, Plot: 802

Mouza: Tarafpur, Plot: 1006

Mouza: Haritakitala, Plot: 135

Mouza: Haritakitala, Plot: 101

Mouza: Haritakitala, Plot: 118

Mouza: Gojeshwari, Plot: 256

Mouza: Hatibandha, Plot: 840

Mouza: Ratanpur, Plot: 1982

Mouza: Jadobpur, Plot: 24

Mouza: Pahar Kanchanpur, Plot: 683

Mouza: Takter Chala, Plot: 130

Mouza: Banshinagar, Plot: 62

Mouza: Gayera Betil, Plot: 5034

Mouza: Bankhuri, Plot: 167

Mouza: Telina, Plot: 1016

Mouza: Chiteshwari, Plot: 1968

Mouza: Kuri Para, Plot: 829

Figure A.1 RTK point of different plot corner of Banshtail Range, Tangail Forest Division.