ATTACHMENT 4

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NSDI Pilot Project
Evaluation Report

September 2019

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Background/Preface of NSDI Pilot Project

1.0 Introduction

1.1 Spatial Data Infrastructure is an institutional concept in order to respond to needs for a wide range of spatially referenced data/information in various problem solving domains. This is being facilitated by the rapid growth of geographic information system (GIS) concepts and technologies for good management of infrastructure development, sustainable economic planning, environmental conservation and a variety of other challenges that we are presently facing in our society. National Spatial Data Infrastructure (NSDI) is therefore a national endeavor that has come to be seen as the technology, policies, criteria, standards and people necessary to promote geospatial data sharing throughout all levels of government, the private and non-profit sectors and academia. NSDI is an umbrella of policies, standards and procedures under which organizations interact to foster more efficient use, management and production of spatial data. It is a part e-governance strategy of many countries.

1.2 First surveying and mapping has been started by United States back in 1840. In the mid-1980s due to rapid growth of technology in terms of hardware and software, the use and sharing of geospatial data was felt by all decision makers. The term spatial data infrastructure was coined in 1993 and NSDI has been developed by USA in 1994. Since then different countries like Australia, New Zealand, Canada, Japan, South Korea, India, Indonesia, Pakistan and other countries have established NSDI for optimum use of their geospatial data. Cooperation, collaboration and harmonization of spatial data and technological development over the years made it technically possible for more people and organizations to be connected in NSDI.

1.3 Actually, geospatial data is an essential element that is used every day by government for policy development and execution, environmental management, disaster response, agriculture, health care, transportation planning, delivery of clean drinking water, land-records management, poverty eradication, sustainable economic development, defence as well as food security. Geospatial data is indispensable element of effective governance, including E-government, transparency in government, good science and better decision making. Geospatial resources of a country play a vital role in its economic development. Bangladesh, being a developing country, cannot fall behind in establishment of NSDI. Considering the importance of geospatial data and its varied applications in the present context, an International Seminar on “National Spatial Data Infrastructure (NSDI) for Bangladesh” was organized on 01 and 02 June 2016 by Survey of Bangladesh and JICA Bangladesh under the supervision of Ministry of Defence. Honorable Prime Minister of The Peoples Republic of Bangladesh Sheikh Hasina inaugurated the seminar. In her inauguration speech Honorable PM told:

‘**Various organizations are engaged in preparing geo-spatial data separately for their own purposes. By establishing NSDI all geo-spatial data will be**

preserved in a same platform. Geo-spatial data can be used effortlessly by different organizations and stakeholders according to their needs. To enhance the development and economic growth of the country, it is an appropriate initiative for establishing National Spatial Data Infrastructure (NSDI) for Bangladesh. As a result, it will bring a radical change for efficient sharing the accurate and updated geo-spatial data as well as avoid data duplicity.'

Considering the importance and necessity of NSDI, she gave following guidelines and suggestions, which will help in the successful implementation of NSDI for Bangladesh**:**

- Since most of the people in Bangladesh have inadequate knowledge and idea about NSDI and its benefit, therefore public awareness must be promoted about the benefits, importance and implications of NSDI.

- Bangladesh Government is going to formulate a national committee under the Ministry of Defence to make short, mid and long term strategic plan and provide necessary guidelines for establishing NSDI in Bangladesh.

- Necessary steps should be taken by MOD to formulate a law for the implementation of NSDI in Bangladesh. '

1.4 To find out the best fit NSDI for Bangladesh a Pilot Project on NSDI was launched on August 2017 with the overall supervision of MOD and financial support of JICA. SOB being the prime organization of NSDI coordinated the overall activities. Total 15 Government and trustee organizations participated actively in this Pilot project and worked persistently to make this project a success. The Pilot Project is developed on the basis of limited scale database taking only few parts of the country. NSDI pilot project is an experimental project aims to examine the function and performance of NSDI and to study on its benefits and issues prior to the introduction of the full scale NSDI of Bangladesh. The pilot project will end on July 2019.

Concept of NSDI Pilot project

2.1 Outline

At the “NSDI for Digital Bangladesh seminar” held in June 2016, Honorable PM Sheikh Hasina expressed her awareness about importance of NSDI (National Spatial Data Infrastructure) for this country and gave instruction to Ministry of Defence to urge the preparation of necessary legislation and organization for implementing actions.

There are variations of solutions to achieve the NSDI concept, however, the essential function of NSDI can be described as below: A common database system of geospatial information and maps of various organizations in which those information is stored in the manner of common geographical specifications (projection, geodetic datum, scale range, etc), together with clearly described characteristics such as quality and liabilities in order that all members can access and utilize all information in the database in a secured way for various kinds of public activities.

NSDI pilot project is an experimental project of such NSDI using a limited scale of database system (i.e. Prototype System). It aims to examine the function and performance of NSDI, and to study on its benefit and issues prior to the introduction of full scale NSDI for Bangladesh.

2.2 Purpose and target of the Pilot Project

2.2.1 Suggest the best specification of NSDI for Bangladesh.This Pilot Project targets to make good suggestion of required specifications such as system structure, software, function and security for Bangladesh NSDI.

2.2.2 Propose the rules of operations and roles of participated organizations This Pilot Projects targets to make a proposal of operational rules and roles of participants such as committee organization, system administration, authorization and monitoring.

2.3 Project members and roles

2.3.1 MOD Supervisor, Harmonizer of members

2.3.2 JICA Provider of fund to construct Prototype System, advisor on experimenting process

2.3.3 SOB Implementer of the project, coordinator of the Working Group

2.3.4 Working Group (at the point of report) MOD, SOB, BCC, LGED, DLRS, WASA, BUET, BMD, IWM, DSCC, DNCC, SPARSO, BBS, BWDB, BITWA, WARPO, DDM

2.4 Structure of Prototype System

2.4.1 Server System:
Base Map (SOB topographical maps)
Open layers (free access from users)
Partially open layers (free access to limited attributions)
Closed layers (authorized access only)

2.4.2 Geoportal:
WMS (viewer of selected layers)
Clearing House (search engine of registered information)
Web GIS (area search, buffer search, measuring etc)

2.4.3 Administration:
Register and unregister of maps and information
Update of layers and historical storage of datasets
Access control to layers and attributions by users
Access monitor and summary

2.4.4 Test data:
SOB topographical maps (Base map), map index, Geodetic Control point index

LGED Upazila Maps
DLRS Mouza Maps
WASA,BUET,BMD thematic information

2.5 Experimental Operation

2.5.1 Administration process
2.5.2 Authorization of information Check the quality and liability of requested maps and information and permit to register.
2.5.3 Registration Register maps and information layers according to the authorized request.
2.5.4 Access control Set the rules of access to the registered information
2.5.5 Unregister and update Unregister or replace the maps and information with regulated procedures.
2.5.6 Monitoring Monitor and summarize the accesses from clients.

2.5.7 Utilizing process:
- 2.5.7.1 Check and examine all functions of Geoportal.
- 2.5.7.2 Check security of closed and partially closed layers.
- 2.5.7.3 Check search and download operations of Clearing House

2.6 Evaluation

Collect suggestions and comments from members and summarize the result of experimental operations.

At the point of the intermediate report, test operation to check these items is still under going.

2.6.1 Data quality
- 2.6.1.1 Change of accuracy or completeness from source data
- 2.6.1.2 Workload and cost of conversion and registration
- 2.6.1.3 Consistency and integrity of different maps and information

2.6.2 System performance

2.6.2.1 Easiness and secureness of registration

2.6.2.2 Sufficiency of Function of Geoportal

2.6.2.3 System resource: capacity, speed

2.6.3 Operation bodies

2.6.3.1 Organization of NSDI operation

2.6.3.2 Process of operation

2.6.3.4 Summarization method of user activities

2.7 Final report

After completion of test operation, the final report should be compiled including following topics.

a) Benefits and issues in utilizing NSDI on activities of public organizations

b) Issues and necessity in preparation of base maps and geospatial information

c) Examples of activities and organizations in which NSDI is essential or efficient

d) Required specifications for full scale NSDI for Bangladesh

Development of NSDI Prototype

3.1 Project Objectives

Objectives of development is to create an NSDI (National Spatial Data Infrastructure) prototype system (NSDI-PS) to be used in the NSDI pilot project, an experimental project to evaluate the function and efficiency of NSDI. By designing, testing, and deploying the NSDI, JICA. common database system of geospatial information and maps of various organizations in which those information is stored in the manner of common geographical specifications (projection, geodetic datum, scale range, etc.), together with clearly described characteristics such as quality and liabilities in order that all members can access and utilize all information in the database in a secured way for various kinds of public activities. This document and the technical specifications listed herein comply with prototype system, technical standards and infrastructure.

3.2 System Overview

The NSDI PS is designed as an enterprise software tool which is compatible with and leverages existing BCC hardware and infrastructure. The NSDI PS tool will provide various user interfaces which will allow data entry, updates, tracking, and report generation. It will also allow users to export data to various formats.

One of the primary benefits of the NSDI PS tool over the GeoDASH system is its ability to consolidate maintenance data, managerial capabilities, data security, data standardization and accessibility.

The NSDI PS will provide the following capabilities:

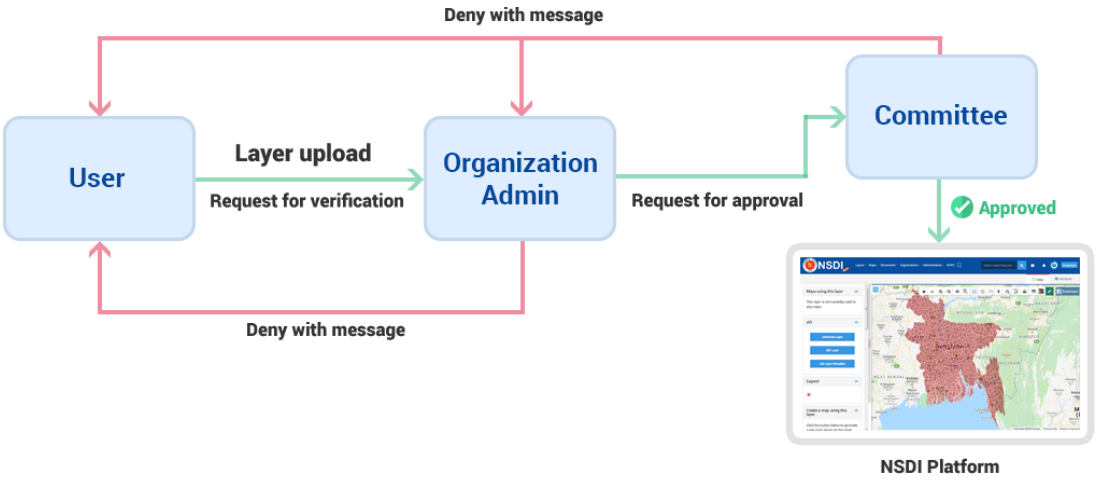
- A functional WMS for end user
- Own base map
- Data management
- Data administration
- Access control
- Layer search
- Cross layer buffer search
- Access history
- User, organization and working group management

3.3 Outcomes

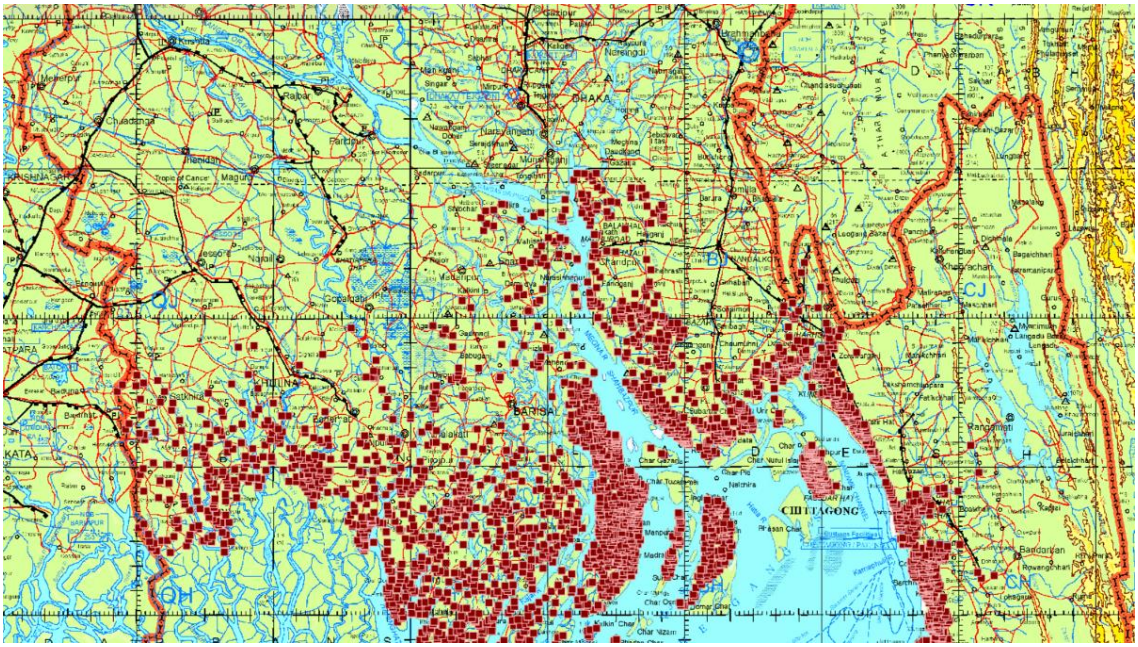
- Branded UI
  A new UI was proposed to represent the NSDI-PS. Currently running beta version as a prototype system. It has provision to change the slider images at later time

- NSDI Specific Features
  - Approval process
    Organization user will upload layer in the platform and an admin from that organization must verify that layer and request for approval of the NSDI

committee. If committee approve, only than the layer will be visible to the organization.



- Setup base map
  Custom base map with raster and vector layer. A web tile service can also be implemented as a static tile provider. Currently NSDI has 2.5 Lac scale map for zoom level 9 to 15



- Data management module
  We call layer as a data for NSDI-PS. Other than layer, NSDI does support uploading document (pdf, doc, xls etc.) and they can be linked to one or more layer. Data can be uploaded, altered, archived and shared. A user can create a map by using multiple layers from different organizations. In terms of map

permission, there is a catch. E.g. you created a map with the layer those are permitted for you. After that you gave permission to an organization who doesn't have the permission of any of the layer used while creating the map. In such cases, layer will be visible in the map but if they want to view the attribute, they wouldn't be able to see. Because that user doesn't have the permission of that layer.

Approval process remain same for Layer, map and document.

- Administration and user categories
  Administration and user are created under following model

  Sector > Department > Organization > Section.

  An organization needs to be created by the system administrator with an admin credentials. After that, organization must create their own section and user. System administrator has no right to do this. Though any or all account can be deleted, altered by the system administrator, if needed.

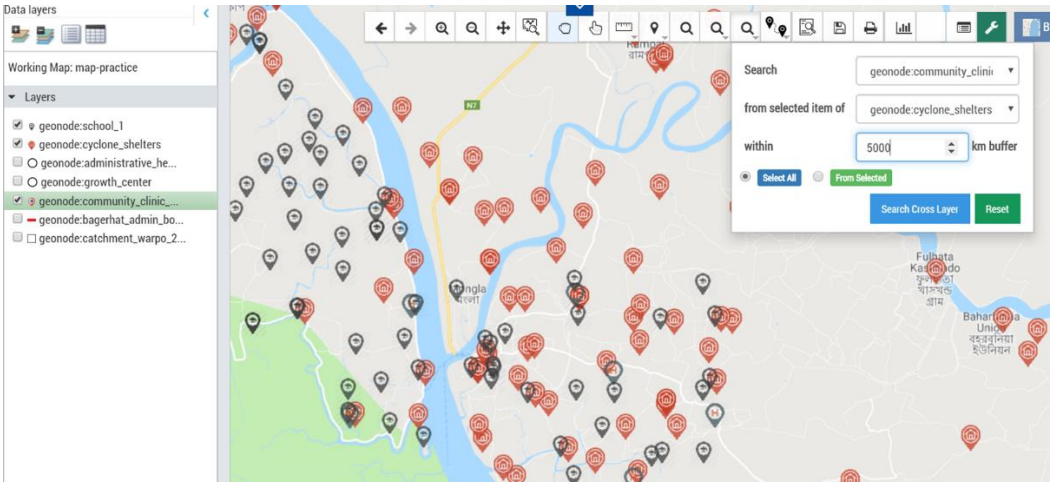
- Access control
  Layer attributes permission can be controlled by an organization. Only permitted attributes are visible to the users

- Functional web map service
  Full functional WMS service for the users. That means if has the following features out of the box

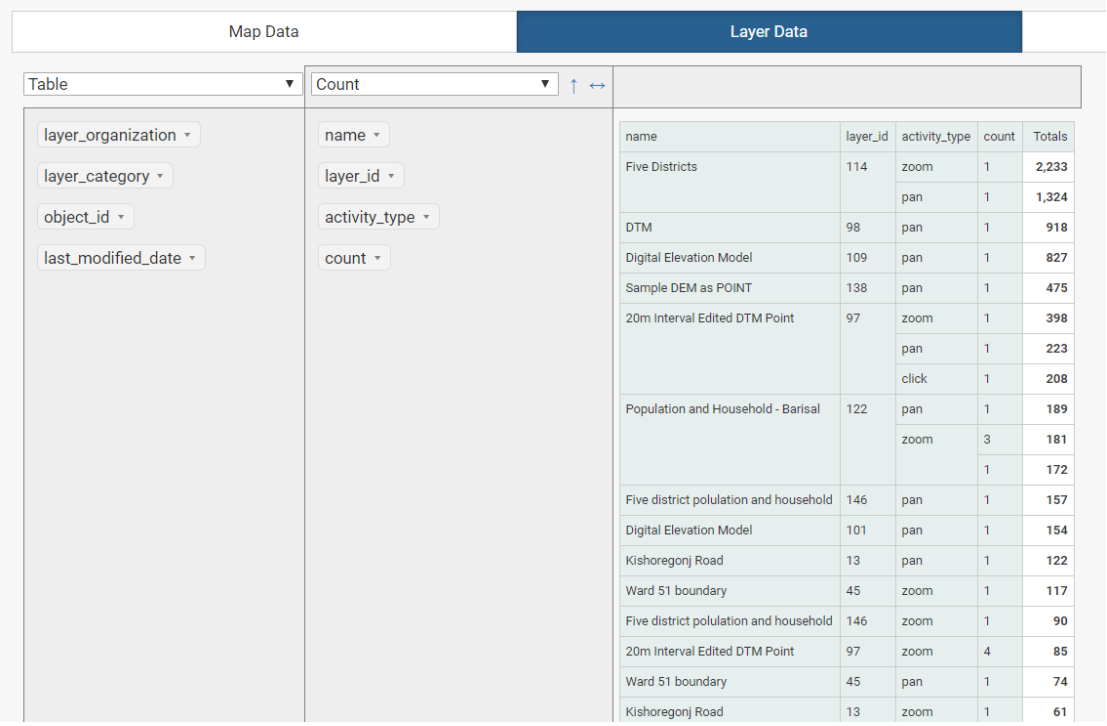
  - Upload shape formatted polyline, polygon, point layers.
  - Upload OSM formatted polyline, polygon, point, raster layers.
  - Upload CSV formatted polyline, polygon, point layers.
  - Upload TIF formatted layers.
  - Upload documents.
  - List/ Grid view of layers, maps and documents.
  - Dock favorite layers, maps, documents and organizations.
  - Create map using single/ multiple layers.
  - Centroids and centers.
  - Style layers.
  - Pan maps.
  - Get FeatureInfo.
  - Measure length.
  - Measure Area
  - Zoom in.

- zoom out.
- Print map.
- Download layer and metadata.
- Filter / select by attribute.
- Data classification.
- Data chart view.
- Buffer search.
- Radius search.
- Query on Map.
- Cross joining of different layer columns.

- Cross layer buffer search
  Searching in all layers within a certain distance. Currently fixed in 1KM. Example below



- Analytics
  NSDI gas built in GeoAnalytic in pivot reporting format. Currently this is only available for system admin. Can be found here https://nsdi.gov.bd/analytics/



name	layer_id	activity_type	count	Totals
Five Districts	114	zoom	1	2,233
		pan	1	1,324
DTM	98	pan	1	918
Digital Elevation Model	109	pan	1	827
Sample DEM as POINT	138	pan	1	475
20m Interval Edited DTM Point	97	zoom	1	398
		pan	1	223
		click	1	208
Population and Household - Barisal	122	pan	1	189
		zoom	3	181
			1	172
Five district polulation and household	146	pan	1	157
Digital Elevation Model	101	pan	1	154
Kishoregonj Road	13	pan	1	122
Ward 51 boundary	45	zoom	1	117
Five district polulation and household	146	zoom	1	90
20m Interval Edited DTM Point	97	zoom	4	85
Ward 51 boundary	45	pan	1	74
Kishoregonj Road	13	zoom	1	61

3.4 Change of Focus/Deliverables with Time

The project experienced a general change of focus and deliverables from the actual SoW over time. The following table summarizes this shift

Change Request	**Direct Beneficiary**	**Remarks**	**Implementation Status**
Should have some public layer/map to be accessed by any user other than NSDI WG organization	Anonymous user, who are not member of working group		Not implemented
Layer approval: a. A panel should approve b. Must have back and forth feedback session on what was wrong and what needs to be updated to get approval	Internal behaviour	A set of member from WG made as approving authority with accept and denied a layer/map/document	Fully implemented
List of metadata to be mandatory during layer approval	Internal behaviour	WG committee member decided the mandatory fields for metadata through discussion	Fully implemented

Restricted meta data, any other organization/user will not be able to see those metadata	Internal behaviour	NSDI PS has attribute level encapsulation but not metadata level encapsulation	Not implemented
Data standardization	All WG member	After several session, WG agreed on standard data parameters for NSDI	N/A
Decision support system through NSDI platform	End user		Not implemented
Each organization base map along with SOB base map	WG member	NSDI has the option to add custom base map (needs manual adding)	Partially implemented
Add extra feature like Earth Explorer, https://earthexplorer.usgs.gov/	WG member and GIS analyst/specialist		Not implemented
Map annotating: a) Annotation searching b) Styling c) Auto scaling d) Zoom level wise Symbology	WG member and GIS analyst/specialist	Like ArcGIS	Not implemented
Set map extend to Bangladesh only	Internal behaviour	Map will be loaded with Bangladesh map first	Fully implemented
Additional data type import facilities like: a. GDB b. AutoCAD/DXF file format	WG member and GIS analyst/specialist		Not implemented
NSDI-PS site theme based on followings: a) National interest b) Highlight WG's c) What/why NSDI d) Marked as prototype to beta	End user		Fully implemented

Metadata: a) Add data source field b) Add base projection and spatial references as three dropdown or text field c) Region to Division and District d) Mark following items mandatory I. Temporal II. Abstract III. Purpose IV. Keyword	Internal behaviour		Fully implemented
Spatial Search: Search all available layers in the current map extend	Internal behaviour		Not implemented
Two step verification for layer approval a) Organization admin will verify first b) Once verified, then push for approval of the WG's committee	Internal behaviour		Fully implemented
External tile API add from NSDI admin panel	End user	Currently it needs to be done by updating code	Partially implemented
Create raster layer/tile for different zoom level with different symbology and threshold	End user	Just like ArcGIS	Not implemented
Layer approval notification through SMS	Internal behaviour	Sending SMS has recurring cost	Not implemented

3.5 Limitations

Although NSDI PS is a big platform for online mapping solution, there are some limitations at this moment which can be implemented as feature to make NSDI richer. These limitations are listed here:

1. No other data source can be added to NSDI PS right now. Such as, if an organization wants to add their own data source to NSDI PS system to manipulate their inbuilt layers or maps then NSDI does not support this at this moment.
2. No layer editing option in NSDI PS. That means one cannot edit a layer to reposition any point on the map. It can be done only by changing on data and by replacing the layer itself.
3. No navigation support on the map. One cannot navigate from one place to another.
4. No analytical decision maker exists in the system. User cannot make any decision from his data to perform any further task from this NSDI system as no analytical tools in NSDI.
5. No option for time series data. User cannot upload or manage any time series data on NSDI.
6. There is no direct integration between ArcGIS to NSDI PS. A tool for ArcGIS which will publish a layer to NSDI PS will significantly reduce the overhead of publishing a layer in NSDI PS

3.6 Recommendations

NSDI PS will be able to handle quite a good number of layers and millions of users. But this will come with effort and time. It is built with a view to manage a huge amount of data and to manipulate these data in a digital way to easily co-operate each organization to others. As NSDI will deal with huge amount of data, there must have a performance concern to get better user experiences. Below are some steps that can be taken to enhance better performance of NSDI system.

1. **Splitting database:** As NSDI will deal with huge amount of data, the main database of this system can be split in multiple instances in multiple servers. This may enhance better performance of data access from the database server.
2. **Memory and storage:** More data needs more memory and storage. System needs more memory to deal with big data and to run NSDI system smoothly. Besides the system require more storage to store data and metadata, so by increasing the memory and storage this system can serve better performance.
3. **Tile caching server:** NSDI system is a web mapping solution system and GeoServer (map server here) plays a big role to serve layer tiles for the visualization of raw data. It is time consuming for GeoServer to serve tiles by creating it every time. Using tile caching server may reduce extra pressure of GeoServer which will result in better performance of the system.

4. **CPU performance:** Better CPU for the server machine can enhance performance of the system.
5. **Background Service**: Extensive use of background service for “user can wait” operation, such as, downloading a layer
6. **Implementing change request**: All or a subset of *not implemented* items can be implemented for the full scale NSDI
7. **Security**: NSDI PS only allows registered user to access the data and are able to see data of their own organization or the data shared with them.
   HTTPS is installed out of the box which will take care of the data security when transmitting.
   Rigorous security testing was not performed under this NSDI PS.

Working Group Activities

4.1 Introduction

NSDI Pilot Project started its journey in August 2017 with 5 working group organizations -

a. Survey of Bangladesh (SOB),

b. Bangladesh Computer Council (BCC),

c. Local Government Engineering Department (LGED),

d. Department of Land Record Survey (DLRS),

e. Dhaka Water Supply and Sewerage Authority (DWASA).

Later, feeling the necessity and considering other organizations huge data storage, handling and managing capacity, and for successful development of NSDI – PS, more 10 government organizations were gradually included in the working group committee. Those 10 government organizations were selected by the combined decision of working group members in the working group meeting. Those organizations are:

a. Dhaka South City Corporation (DSCC),

b. Dhaka North City Corporation (DNCC),

c. Bangladesh Bureau of Statistics (BBS),

d. Bangladesh Inland Water Transport Authority (BIWTA),

e. Bangladesh Water Development Board (BWDB),

f. Department of Disaster Management (DDM),

g. Water Resources Planning Organization (WARPO),

h. Bangladesh Telecommunication Regulatory Commission (BTRC),

i. Bangladesh Meteorological Department (BMD).

j. Bangladesh Space Research and Remote Sensing Organization (SPARSSO)

4.2 Mode of Operation

The working group members participated spontaneously and worked very hard in the development process of NSDI-PS. There was no approved Act or Law; neither there was any MOU among the working group organizations. Even though the working group organizations worked with good belief, remain focused and persistent on the development of NSDI –PS. Largely, all the organizations worked with the hope to start a new beginning, keeping the final destination in close view , especially for bringing all

government organizations under same umbrella and promote a common spatial data platform.

Survey of Bangladesh was in the pivotal role, coordinated activities of the working group members. JICA expert extended his cordial support and valuable guideline in coordinating all activities. Working group members used to sit together almost in each month in the form of meeting, conference, workshop, and training, helped in the gradual development/upgradation of the so far developed NSDI-PS.

4.3 System Design

Stream Tech Ltd was given with the contract of designing NSDI – PS web platform. Since the contract, Streams Tech worked effectively with close collaboration of the working group members.

The detail design and other technical know-how of the NSDI –PS has been elaborately discussed in Chapter 4 (Development of NSDI –PS).

4.4 Working Group Activities

The working group members sat for discussion almost 17 times in last 2 years in the form of meeting, conference, workshop and training.

Record of Working Group Activities:

	Date/venue	Topic	Chairperson / Participants	Achievement
1	15/05/2017	NSDI contributors meeting Concept of NSDI	Surveyor General 39 persons (14 org.)	Concept and requirement of NSDI for Bangladesh discussed.
2	09/08/2017	NSDI contributors meeting Roadmap for NSDI	Surveyor General	Draft of roadmap for establishing NSDI discussed Implement of pilot project for NSDI agreed
3	26/09/2017 SOB/Tejgaon	Pilot Project Kick-off Meeting Concept of NSDI Plan and schedule of Pilot Project	Surveyor General 22 persons (9 org.)	Concept of Pilot Project accepted. System specifications required for prototype system recognized.
4	16/11/2017	Pilot Project WG meeting Development of prototype system Census sheet of geospatial information	Surveyor General 20 persons (11 org.)	Structure of prototype NSDI introduced and discussed Purpose of Census sheet adopted, and distributed to members
5	15/02/2018	Pilot Project High Officials conference Agreement on provision of geospatial data	Secretary, MoD	Cooperation of all organizations for Pilot Project promised Provision of geospatial data to the prototype NSDI agreed
6	26/02/2018	Pilot Project WG meeting Development of prototype system Selection of project area	Joint Secretary, MoD 17 persons (9 orgs.)	3 sites are selected for Pilot Project and accepted
7	11/03/2018	Pilot Project WG meeting Preparation of data	Surveyor General	Feedback from members for development of prototype acquired and discussed
8	20/03/2018	Pilot Project WG meeting Preparation on outline of Prototype System Development	Surveyor General 22 Persons (11 orgs)	Some other organization can attend to get some ideas about NSDI for better output in future. One training program will arrange for WG by World Bank in December.

9	10/04/2018	Discussion on Pilot Project activities of NSDI Extension of NSDI Prototype Project time	Surveyor General 17 Persons (8 Orgs)	Focused on basic needs of NSDI. BBS person joined this meeting for the first time. To form a committee 5 persons have been selected from 5 organizations like SOB, IWM, LGED, BSGI, BBS.
10	14/05/2018	Discuss on Work Progress of NSDI Prototype Project focused on data storage of NSDI.	Joint Secretary 21 Persons (9 orgs)	Informed to develop the creditability of NSDI Pilot Project. Distributed one from among WG members to give feedback hoe to utilize the pilot project data.
11	26/06/2018	NSDI Prototype Project meeting Discussion on work progress and training	Surveyor General	Created one temporary web site for NSDI Prototype http://nsdi.gov.bd. All WG members have shared their data except 2/3 organization.
12	26/09/2018	• Discussion on uploading data by Working Group Members • Inclusion of 3 other department as Working Group Members • Utilization of Data in Sub-Project • Launching seminar on NSDI Pilot Project • Open Discussion	Surveyor General	Almost all WG members shared their data and ides for better development. LGED will share some data from NSDI platform for their own project.
13	28/11/2018	NSDI Prototype project WG meeting 1. Demarcation between GeoDASH and NSDI • We have understood that both systems	Surveyor General 18 Persons (14 Orgs)	3 new WG members joined in the meeting like DDM, BIWTA, WARPO The necessity of NSDI full scale has been defined nicely in this meeting.

		have advantages in the fields. At this moment, GeoDASH has much more data than NSDI. On the other hand, NSDI Prototype is more secured system and the data is geo-coordinated. Do you have any plan to make any legal framework to define the demarcation each other in the future? • What is your expectation to NSDI comparing to GeoDASH? 2. The basic idea on the component of new technical cooperation to establish full scale NSDI • It will provide technical support to prepare the technical requirement or specification of full scale NSDI. • It will not contain budgetary support to		

		establish and maintain the full scale NSDI system itself.		
14	11/02/2019	NSDI Pilot Project with WG to introduce New SG in SOB. Demonstration on project system and Discussion on Evaluation of NSDI Prototype System	Joint Secretary 24 Persons (13 Orgs)	One OJT (on job Training) will arrange on 20 February 2018 at Mirpur Office. Mr. Hatori Tomohiko will visit all WG organization.
15	20/03/2019	Discussion on Project Summary for Full Scale NSDI and updated status of data uploading	Surveyor General	Project Summary for Full Scale NSDI was finalized
16	29/04/2019	Proposal of Data Sharing for 2 more districts and presentation by WG on NSDI utilization	Surveyor General	Dhaka and Sylhet districts was selected for data sharing
17	12/06/2019	Discussion on Evaluation Report and data uploading status by WG Organizations	Surveyor General	Evaluation Report need to be completed before end of project

Data Uploading

5.0 **Data Uploading**

5.1 **SOB**

SOB has the database in various scales ranging 5k to 1000k for the entire country. The parameters used in preparing the database are as follows:

a. Geographic Coordinate System (GCS): WGS 1984.
b. Projected Coordinate System (PCS): BUTM 2010.
c. Datum: WGS 1984.
d. Prime Meridian: Greenwitch.
e. Central Meridian: 90^0.
f. False Easting: 500,000.
g. False Northing: 0.
h. Unit: Meter.
i. Scale Factor: 0.9996.

The database of SOB is in geodatabase (gdb) file format. NSDI PS allows uploading of following data format only; .shp, .osm, .csv, .geotiff. Therefore, SOB had to convert the data into .shp file format and upload in that format.

5.2 **BMD**

BMD has various weather data at different location of the country. The weather parameters are as follows:

a. Air pressure
b. Wind speed & wind direction
c. Temperature(Max. temp., min. temp, avg. temp,)
d. Relative humidity
e. Rainfall(3hrly,6hrly,daily)
f. Cloudiness
g. Visibility
h. Sunshine hour
i. Soil moisture

The weather data are point data. NSDI PS allows uploading of following data format only; .shp, .osm, .csv, .geotiff.Therefore, BMD had to prepare the data into .csv format and upload in that format.

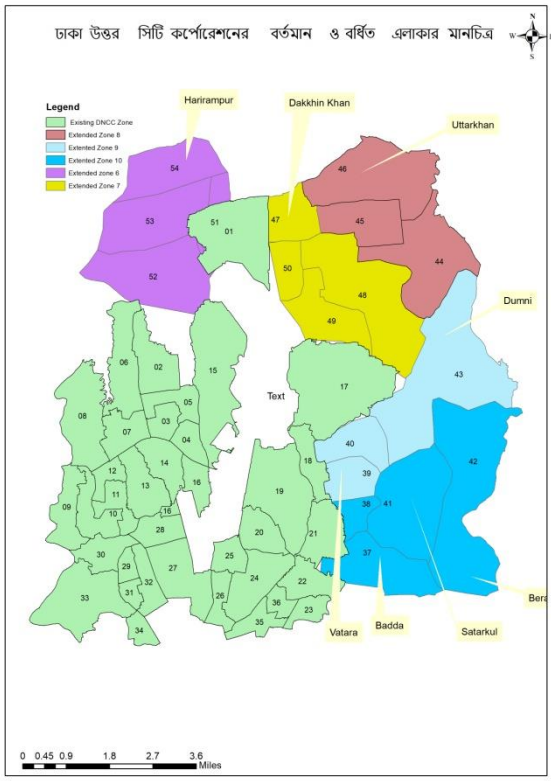
5.3 **Bangladesh Space Research and Remote Sensing Organization (SPARRSO)**

Bangladesh Space Research and Remote Sensing Organization (SPARRSO) is a research organization that deals with the peaceful application remote sensing techniques in various geo-disciplines. Since this organization is participating in NSDI Prototype Pilot Project, selected example data-sets have been uploaded to NSDI geo-portals. The data-sets are in UTM Projection (Datum: WGS 1984).

5.4 DSCC

5.4.1 Dhaka North City Corporation is one of the biggest city corporations in Bangladesh providing basic urban services of the citizens' like- construction and repair of road, footpath, median etc, street lighting, solid waste management, primary health, katcha market, graveyards, community centers etc.

As part of efforts to provide better civic amenities to the people of adjacent Union Parishads, eight UPs are included in the DNCC in 8thMay, 2016. The eight unions included in the DNCC are Beraid, Badda, Vatara, Satarkul, Harirampur, Uttarkhan, Dakshinkhan and Dumni. The inclusion has increased the DNCC's area from the previous 82.63 square kilometersby113.59 square kilometers. Now Dhaka North City Corporation area is 196.22sqkm and divided by 54 ward and 10 administrative zones. (Map : DNCC Administrative Map (including extended area)



5.4.2 **Data uploading**

DNCC has limited special data. but this data is not updated and not properly projected. So, within this limitation DNCC uploading data as possible and this will continue.

5.5 Water Resources Planning Organization (WARPO)

WARPO uploaded two data layers into NSDI portal, namely Hydrological Regions of Bangladesh and Catchment_WARPO_2016. These are WARPO's own data archived in the National Water Resources Database (NWRD) system.

5.5.1 Hydrological Regions of Bangladesh

A spatial data layer of extended hydrological planning area of Bangladesh along with other attribute information. WARPO developed this data layer during the formulation of "National Water Management Plan" in 2001. This data layer is useful to present and delineate the hydrological region boundaries and to use this data in hydrological and other kind of planning purposes at national or regional level.

5.5.2 Catchment_WARPO_2016

A spatial data layer containing the catchments boundaries of the river systems identified and delineated by Water Resources Planning Organization (WARPO). WARPO has developed this data layer in 2016 as an output of the project "Assessment of the States of Water Resources". This data layer is useful for the purpose of hydrological planning and design at national or regional level

5.5.3 WARPO preserved all data layers in NWRD in BTM coordinate system, but as per requirement of NSDI system the above data layers has been converted into BUTM 2010 coordinate system.

5.6 **BCC**

BCC is playing some specific roles for NSDI piloting project. For example, hosting of NSDI portal, provide online GIS data collaboration platform (i.e GeoDASH) for development of NSDI portal and so on.

Test Operation of NSDI

6.0 **Test Operation of NSDI**

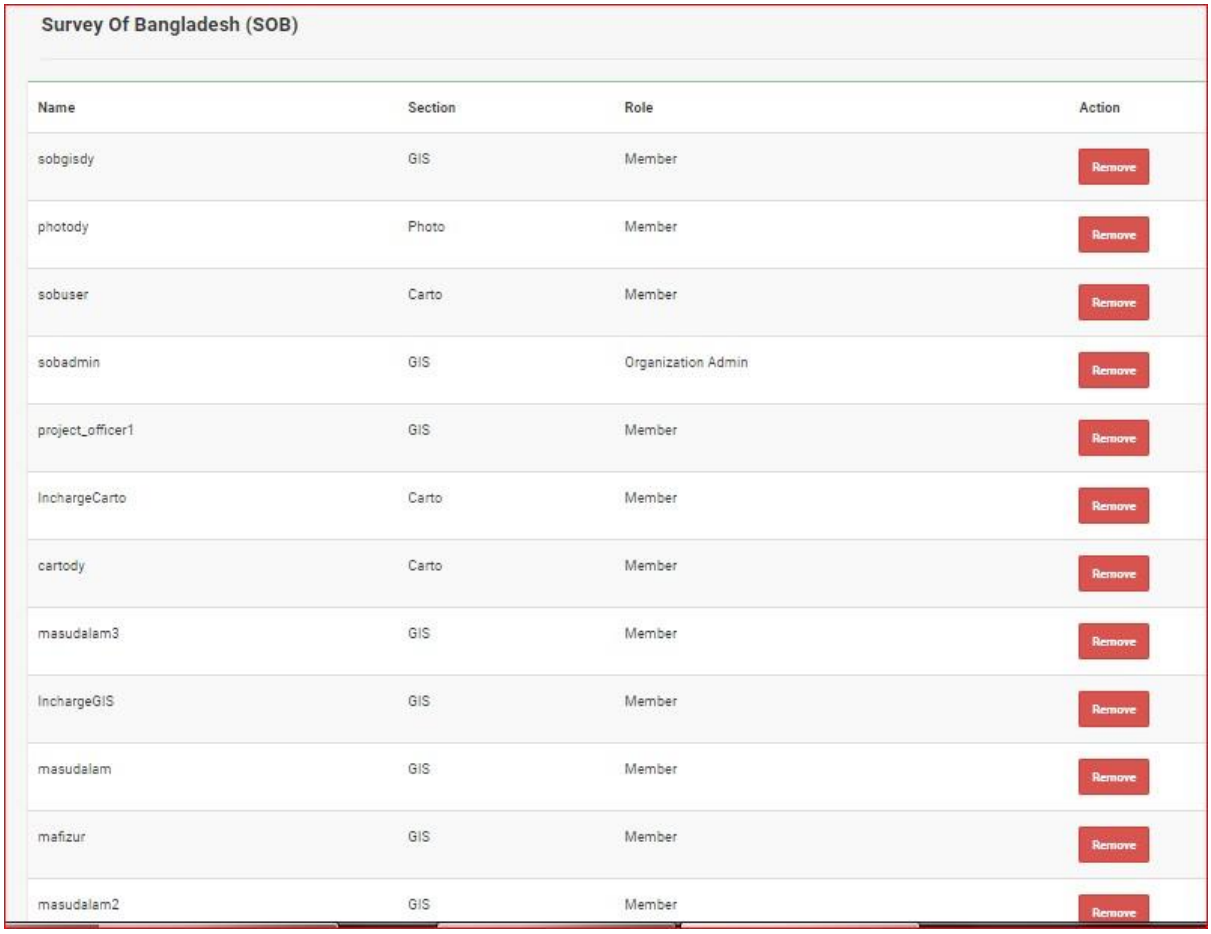
6.1 **SOB**

6.1.1 Management of Organizations

Survey of Bangladesh (SOB) is the national mapping organization of the country produces digital maps and database of various scales for the entire country. Overall digitization work is normally carried out through Digital Mapping Center (DMC) of SOB. Digital photogrammetry, GIS and Digital Cartography sections of DMC are the main organs for preparing digital maps and database.

6.1.2 User Registration

In this system, user has been registered under the photogrammetry, GIS and Cartography sections. Total 11 users have been created, among which 7 users are in GIS section, 1 user in photogrammetry section and 3 users in digital cartography section.



Survey Of Bangladesh (SOB)

Name	Section	Role	Action
sobgisdy	GIS	Member	Remove
photody	Photo	Member	Remove
sobuser	Carto	Member	Remove
sobadmin	GIS	Organization Admin	Remove
project_officer1	GIS	Member	Remove
InchargeCarto	Carto	Member	Remove
cartody	Carto	Member	Remove
masudalam3	GIS	Member	Remove
InchargeGIS	GIS	Member	Remove
masudalam	GIS	Member	Remove
mafizur	GIS	Member	Remove
masudalam2	GIS	Member	Remove

6.1.3 Access Control Management

Access to NSDI PS web is done through authenticated user ID and password. Organization admin is empowered for creating sections and users. Organization admin has created 3 sections for SOB and user ID has been made under these sections. The users of these sections uploaded data and pushed forward to organization admin for approval. Organization admin checked the data quality, metadata standard and finally pushed forward to committee for final approval if everything was found within the desirable standard, or else, it was

pushed backward to the user who uploaded the data with related remarks mentioning why the data couldn't be uploaded.

6.1.4 Setting Specification and Standard

The available maps and database of SOB along with specification and standard are as follows:

Title	Format	No. of Layers	Coordinate system	Projection	2D/3D (with height)	Suitable scale for display	Area covered	Year of preparation /revision
Topographic Map of 1:M	ESRI geodatabase, pdf	Almost 50	BUTM 2010	TM	3D	1:M	Whole Bangladesh	2016
Topographic Map of 1:500,000	ESRI geodatabase, pdf	Almost 50	BUTM 2010	TM	3D	1:500,000	Whole Bangladesh	2016
Topographic Map of 1:250,000	GCM/GCR, pdf	Almost 100	BUTM	TM	3D	1:250,000	Whole Bangladesh	2014
Topographic Map of 1:50,00	ESRI geodatabase, pdf, TIF	Almost 200	BUTM 2010	TM	3D	1:50,000	Whole Bangladesh	2014
Topographic Map of 1:25,00	ESRI geodatabase, pdf	Almost 300	BUTM 2010	TM	3D	1:25,000	Whole Bangladesh	2017
Topographic Map of 1:5000	ESRI geodatabase, pdf	Almost 200	BUTM	TM	3D	1:5,000	Dhaka	2005
Guide Maps	pdf	Almost 50	BUTM 2010	TM	3D	different	Different Important City	Different Year
Divisional Maps	ESRI geodatabase, pdf	Almost 50	BUTM 2010	TM	3D	different	Whole Bangladesh	2016

6.2 **BMD**

6.2.1 Management of Organizations

Bangladesh Meteorological Department(BMD) is the national organization of the country for issuing all sorts of weather forecast as well as warnings. Storm Warning Centre(SWC) of BMD is responsible for issuing all sorts of weather forecast as well as warnings.

6.2.2 User Registration

In this system, an user has been registered under the SWC.

6.2.2 Access Control Management

Access to NSDI prototype system is done through authenticated user ID and password. Organization admin is empowered for creating sections and users. Organization admin has created 1 section for BMD and user ID has been made under this section.The user of this section uploaded data and pushed forward to organization admin for approval. Organization admin checked the data quality, metadata standard and finally pushed forward to committee for final approval if everything was found within the desirable standard, or else, it was pushed backward to the user who uploaded the data with related remarks mentioning why the data couldn't be uploaded.

6.3 **DSCC**

6.3.1 NSDI is a very good platform with lot of good quality data and information. The JICA, consultants, working groups and specially SOB works hard to prepare the sample project. DNCC is proud as working group member of this platform. This is one of the successful initiatives of Bangladesh specially for special data. DNCC will use this platform like-

- For preparation of risk reduction and hazard map under Urban Resilience Project, funded by The World Bank, we have a plan to use NSDI Platform.
- At the same time, DNCC is going to prepare master plan for the new extended area, here NSDI projection system and platform will help DNCC.
- DNCC is authorized body to issues road cutting permission for various organizations within DNCC area. But unfortunately we don't have any sub surface map (below ground surface) specially for utility lines. Utility organizations also have no suitable map. Here, NSDI can also prepare suitable sub surface map with help of the different utility organizations like- wasa, titas, T&T, DESCO etc.

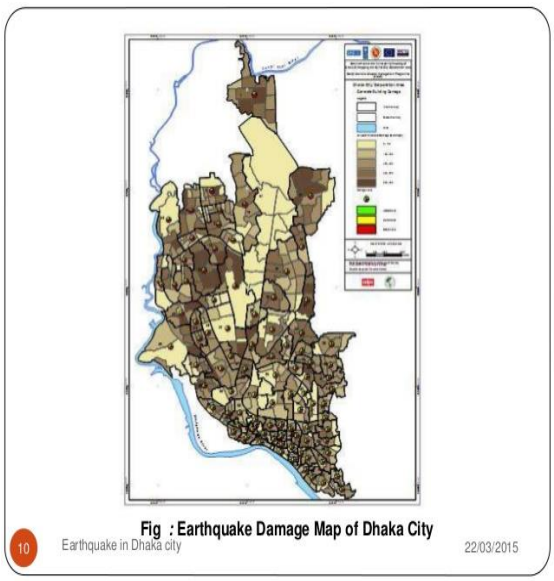


Fig : Earthquake Damage Map of Dhaka City



- Infrastructure development activities of DNCC are related to physical spaces. But at the present moments DNCC has no special database for its own land/property. Here NSDI information can helps us to

provide special data. It should be more helpful if DNSI is to prepare special database particularly in Dhaka North city (Ward map-19, part, DNCC).

- For development work, DNCC has prepared DPP for getting fund from govt. or development partners. Each and every time we have to prepare special location map and features individually. It misuse resources. if we have detail map with database then it helps us to misuse (reduce) of resources & time. here, NSDI also can play an important role.
- finally, NSDI is a good platform, DNCC authority/officials is trying to understand about NSDI platform as well as try to use this platform for project preparation, project evaluation and other purposes.

6.4 Water Resources Planning Organization (WARPO)

6.4.1 Management of Organizations

Water Resources Planning Organization (WARPO) is mandated for maintaining, updating and dissemination of 'National Water Resources Database' (NWRD) and 'Integrated Coastal Resources Database' (ICRD). Computer and Information Section WARPO has been assigned to perform the mandated duties of NWRD and ICRD. Other sections of WARPO use NWRD and ICRD for formulation of plans, policies, studies, researches and other different activities of WARPO.

6.4.2 User Registration

Users of NSDI from WARPO So far, there are 7 (seven) users of NSDI from WARPO including the admin. 3 (three) from Computer and Information section, 2 (two) users from Water Resources Section, 2 (two) users from Environment, Forest and Fisheries Section and 1 (one) from Engineering Section of WARPO.

Water Resources Section	Member
Water Resources Section	Member
Computer and Information Section	Member
Enviroment, Forests and Fisheries	Member
Enviroment, Forests and Fisheries	Member
Engineering Section	Member

WARPO expects to extend its users to enhance the use of NSDI among all sections of WARPO.

Evaluation on Sample Project

7.1 Background

LGED has got a rich GIS database. We have 19 layers of information in our GIS database. We update our database regularly, especially the infrastructure related database. Still there is lot of other GIS data owned and updated by other organizations. We would be happy to have these data with a view to taking the advantages of integrated analysis and use this as an effective tool for decision making, monitoring and evaluation of infrastructure development activities. That is how we can ensure optimum utilization of our invaluable national resources.

Data Requested from NSDI:

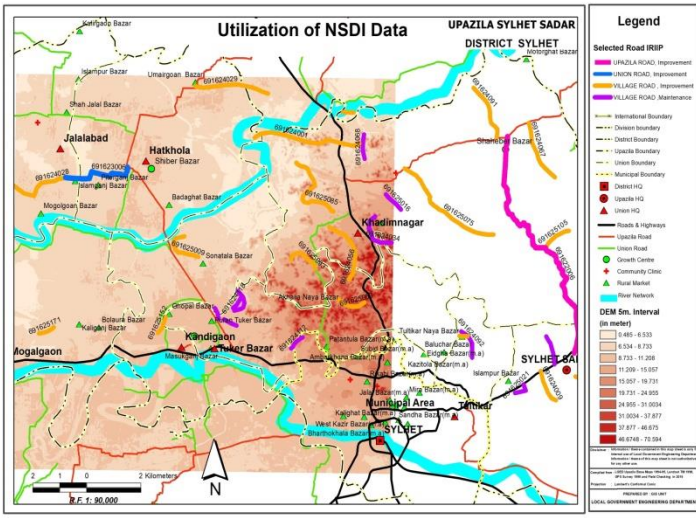
LGED has number of projects ongoing in the Sylhet and Bagerhat area, a small portion of which has been taken as pilot area. Consequently, LGED requested for the following data

- DEM
- Flood/ Tidal Surge Data
- Hazard Data
- Population Data
- Settlement Data

Out of the five requested data, we received DEM data from Survey of Bangladesh (SoB) and Population data from Bangladesh Bureau of Statistics (BBS).

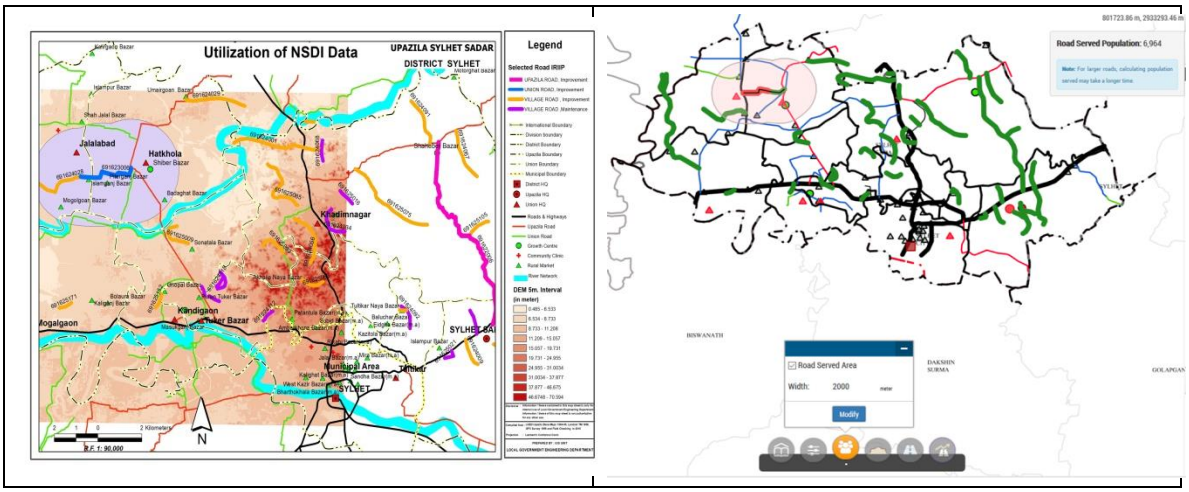
7.2 Utilization of DEM Data:

We have an ongoing project named SDIRIIP (Important Rural Infrastructure Improvement Project in Sylhet Division) in the pilot area. We imposed the proposed road (under this project) layer over the DEM data, and that shows the difference of elevation among the selected roads. If we get the DEM of allover Bangladesh it can be utilized in a more significant way.



7.3 Utilization of Settlement Data:

In the same project area as mentioned above, we imposed the population data as provided by BBS, and we made a 2 km buffer around the road. From that buffer we have calculated the number of people living in the buffer zone. We have found that the number of population living in 2 km buffer of the road is 6964. It means the road serves a total of 6964 people. As we know, one of the most important criteria to select a road for improvement, maintenance or reconstruction/rehabilitation is “how many people are served by the road”, this data will help us prioritizing road infrastructure for the same. That will consequently help us in optimum utilization of scarce national resource.


Utilization of NSDI Data
UPAZILA SYLHET SADAR
DISTRICT SYLHET
Legend
Selected Road IRIP
Jalalabad
Hatkhola
Kadimnagar
Kandigaon
Osmani Nagar
Jaintiapur
Companigonj
Fenchuganj
Golapganj
Beanibazar
Gowainghat
Jaintiapur
Kanaighat
Zakiganj
Dakshin Surma
Biswanath
Road Served Area
Width: 2000
Modify
Road Served Population: 6,964

Comments and Recommendation

8.0 **Comments**

8.1 **SOB**

8.1.1 NSDI – PS allows uploading of data only in the following four data format ie. .shp, .osm, .csv, .geotiff.Databaseof SOB is in geodatabase (.gdb) file format.A shape file (.shp) is a one-table-storage format ie.a feature class in this context. So, a shapefile generally contains just one feature type with a set of attributes or fields.A file geodatabase also contains feature classes, but it allows multiple feature classes or tables with relational characteristics to it as well. Therefore, geodatabase is considered as relational database. Full scale platform of NSDI should consider this issue and have the facility to upload geodatabase file format as well.

8.1.2 In NSDI –PS working group members uploaded own organization data after getting letter from Ministry of Defence. Every time when there is decision of uploading data in working group meeting, working group members used to ask letter from MOD. Since, working group members need legal authority to upload data in the NSDI platform and NSDI Act is yet to be enacted and may take some time; therefore, an MOU may be signed among all working group organizations for uploading data before launching full scale NSDI of Bangladesh.

8.1.3 It was observed in NSDI – PS; data uploading status, total no of view count of any data, total no of download for any data is not satisfactory. Working group organizations need to be encouraged more for utilization of the NSDI platform. At the same time, the interface and overall NSDI platform should be made more interactive, user friendly and capable of handling frequent needs of the user.

8.1.4 It was seen in NSDI – PS, normally focal point officer of respective organizations used to attend in working group meeting. In some cases, it was felt difficult for them to take instant decision on behalf of their organizations. Quarterly co-ordination meeting should be arranged among working group organizations chief/head for smooth flow of working group activities. Again, few working group organizations used to send different focal point officer in the meeting. Therefore, it was difficult to maintain the continuity. WG organizations should select permanent focal point for his organizations for smooth flow of WG activities.

8.1.5 NSDI is basically spatial data based web platform. Few WG organizations don’t have structured GIS cell and lack in GIS knowledge. Organizations should enhance their capacity in this sector. Side by side, a small package of GIS training can be incorporated within the project for organizations weak in GIS knowledge.

8.2 **SPARRSO**

8.2.1 Some image files are larger in size. Because of the internet speed it is difficult to upload the image files of more than few hundred MB in size.

8.2.2 Some earlier maps are available only in hardcopy. Projection systems of earlier thematic maps and layers are different than UTM/WGS84. Time and efforts are necessary to convert those files into digital format and desired projection system.

8.3 **DSCC**

8.3.1 DSCC have a small GIS unit with limited personnel's. So, DSCC is trying to recruit more GIS personnels with logistics.

8.3.2 NSDI can continue support DSCC for capacity building of GIS personnels.

8.3.3 NDSI can provide special data to DSCC for different development works.

8.4 **Water Resources Planning Organization (WARPO)**

8.4.1 “NSDI for Bangladesh” is a common platform to get a clear picture of GIS Data availability of different agencies. It will be helpful for reduction of time, cost, visit due to the GIS data collection and creation processes of different agencies, minimization of laps and gaps for GIS data of the country and development of Common Standards to improve and maintain GIS data quality for the country.

8.4.2 NSDI portal could be used by WARPO as well as other organizations to display their valuable, organized and quality data

8.4.3 WARPO expects to use NSDI portal for collection and creation of these GIS data layers like River Area Encroachment, Flood Plain Area, DEM (high resolution), Charland, SW-GW scarcity area, SW-GW Quality Map, Erosion and Accretion by River, Areas Prone Flood, Drought and Erosion etc.

8.4.4 There are need of the development of data management policies or guidelines of NSDI portal for maintaining data security, data quality, data back up and data purging

8.4.5 “NSDI Standard” containing common standards for NSDI to improve and maintain GIS data quality for the country, may be included in the NSDI web portal. Quality of the uploaded data has already been improved by maintaining the common coordinate system i.e.BUTM 2010 at the NSDI portal. This could be included in the “NSDI Standard” as common standard for coordinate system of GIS data layers

8.4.6 A ‘coordinate system conversion tool’ may be inserted in NSDI portal for easy conversion of different coordinate systems used in different organizations into the common coordinate system of NSDI portal

8.4.7 If NSDI will have provision to share the RS data and images among the govt. agencies, then RS image related data creation cost and time for different agencies, could be reduced

8.4.8 If tools to improve the GIS data quality and Tools for processing and conversion of RS images into user-friendly format, could be included in NSDI portal, then the relevant time and man-month will be saved in different govt. agencies

8.4.9 WARPO expects to use NSDI, for Updating of National Water Resources Database (NWRD) and Integrated Coastal Resources database (ICRD) and for the formulation of different Plans, Policies, Study, Research, Project activities

8.5 **BCC**

8.5.1 **BCC Expects** the piloting will be a successful one. BCC will continue support for GeoDASH platform by it's own capacity. In this regard, more valuable and lucrative features will be incorporated in GeoDASH platform. So GeoDASH will be more feature rich and more mature SDI. As a result, We hope that SOB will continue to use GeoDASH portal as the base of NSDI platform. Apart from this, INSPIRE Directives can be adhered for NSDI Bangladesh for better user experience and to make it world class.

8.6 **LGED**

8.6.1 With the data provided, we have done the partial analysis. Still the analysis was handful to us. With fully functional NSDI, we will be able to do precise planning for future interventions, which will ensure the value for money. As we know, to develop a concrete outcome using geospatial technology various data like Flood/ Tidal Surge Data, Hazard Data, Population Data, Settlement Data are required.

8.6.2 We have the following recommendation regarding up scaling of prototype:

- Approval of draft NSDI act;
- Prepare a DPP for up scaling;
- Capacity building of the organizations to standardize data;
- Technical cooperation & financial assistance;
- Inclusion of GIS professional in the organogram of all organization, and make sure the presence of representatives from concern Ministries;
- Technical documentation along with source code in an understandable way has to be submitted.

8.7 **DDM**

8.7.1 DDM has the database of multi-hazard risk and vulnerability assessment for six (6) natural hazards (Flood, Cyclone, Drought, Earthquake, Tsunami and landslide) along with Technological and Health hazards for the entire country. We already have uploaded Cyclone Shelter database for the entire country.

The parameters used in preparing the database are as follows:

a. Geographic Coordinate System (GCS): WGS 1984.
b. Projected Coordinate System (PCS): BTM.
c. Datum: Gulshan303.

8.7.2 Test Operation of NSDI

8.7.3 Management of Organizations

Department of Disaster Management (DDM) is the national disaster management organization of the country producedmulti-hazard risk and vulnerability maps engaging an international firm and those maps are available in pdf and jpeg format. In few cases spatial datasets are available in .shp format. There is none operational level staff is available in the department.

8.7.4 User Registration

Users of NSDI from DDM, so far there is single user of NSDI from DDM only the admin. A few users will be created later.

8.7.5 **Suggestion**

- NSDI should maintain a common data standard and projection for the all members.
- Data quality and security issues need to be taken care of by NSDI for all stakeholders.
- NSDI would have the provision to make available DEM or RS data for the entire country. It will certainly avoid the duplication of data creation and reduce the cost for the country.
- NSDI could extend support to DDM for updating the multi-hazard risk and vulnerability assessment database.
- NSDI should include industrial and health sectorial stakeholders in full-scale NSDI implementation phase.

8.8 **Recommendation(summary)**

- Full scale platform of NSDI should also consider geodatabase(.gdb) file format along with .shp, .osm, .csv, .geotiff data format to upload data
- Legal authority to upload data- NSDI Act or MOU may be signed among all working group organizations for uploading data before launching full scale NSDI of Bangladesh
- Working group organizations need to be encouraged more for utilization of the NSDI platform
- The interface and overall NSDI platform should be made more interactive, user friendly and capable of handling frequent needs of the user.
- Quarterly co-ordination meeting should be arranged among working group organizations chief/head for smooth flow of working group activities
- WG organizations should select permanent focal point member of own organizations for smooth flow of WG activities
- A small package of GIS training can be incorporated within the project for organizations weak in GIS knowledge
- All WG organization must have GIS unit with adequate skilled personnel
- Formulation of policies or guidelines of NSDI portal for maintaining data security, data quality, data back up and data purging
- Common coordinate system i.e.BUTM 2010, at the NSDI portal could be included as“NSDI Standard” for coordinate system of GIS data layers
- A ‘coordinate system conversion tool’ may be inserted in NSDI portal for easy conversion of different coordinate systems used by different organizations into the common coordinate system of NSDI portal
- Tools for improvement of GIS data quality , processing and conversion of RS images could be included in NSDI portal
- Capacity building of the organizations to standardize data should continue
- NSDI should include industrial and health sector stakeholders in full-scale NSDI project
- BCC data center is recommended for hosting of full scale NSDI because of sustainability and reliability
- Promote utilization of NSDI PS by users

Procedure for generating orthoimages' map tiles using by QGIS + QMetaTiles plugin

1. System requirements

1.1. Software requirements

1) QGIS ver. 3.6 more

2) QMetaTiles

1.2. Hardware requirements (recommended)

1) CPU: Core i7-8650 or more

2) RAM: 16GB or more

3) HDD: SSD type and sufficient free space

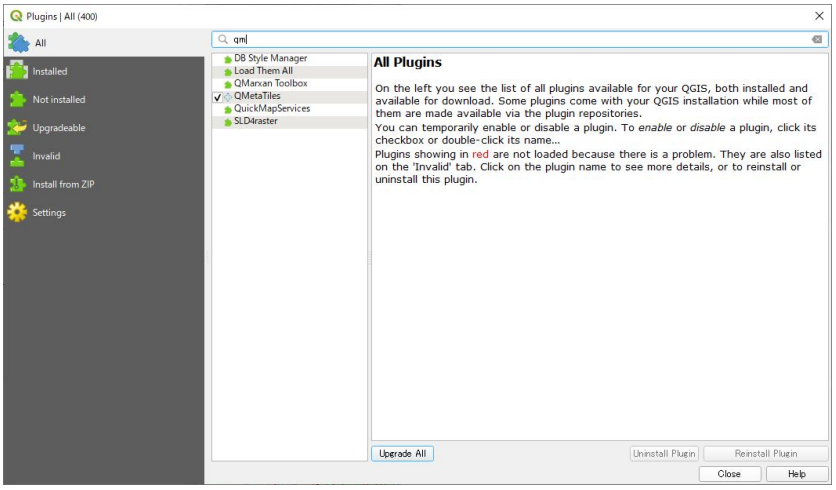
2. Procedure for generating map tiles

2.1. Install QGIS and QMetaTiles plugin

You can download setup for file for QGIS using following link: https://qgis.org/en/site/

After downloading the setup files, execute the file and the software simply clicking "Next" for all doing option.

After installing QGIS, select a menu of "Plugins" – "Manage and Install Plugins…" and search for "QMetaTiles" and install it.



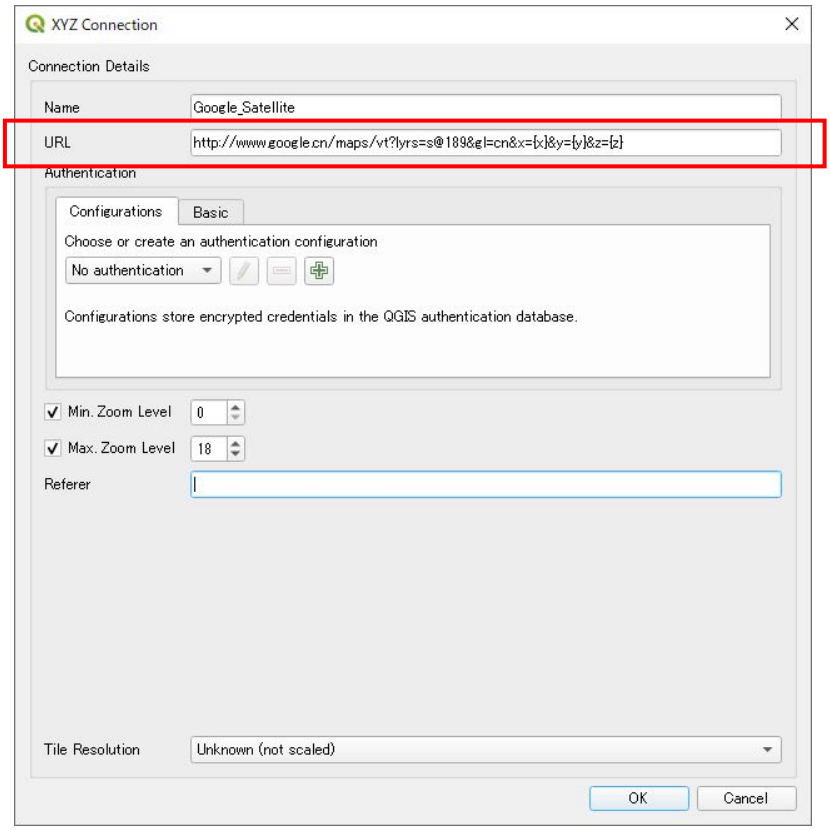
2.2. Connect XYZ tiles (Google Maps or Open Street Map or others)

1) Right click on “XYZ Tiles” from the Browser panel and select “New connection”.

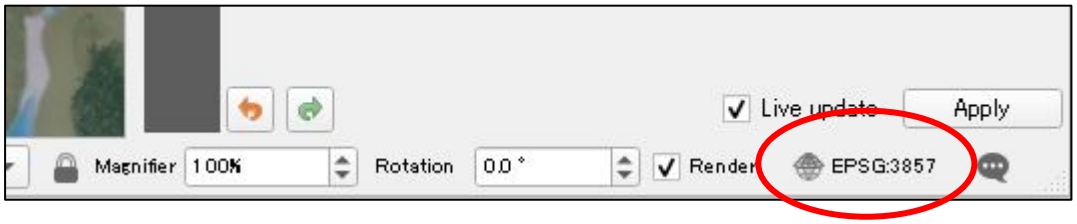
2) Set parameters in XYZ connection’s dialogue box.

<Case of Google Satellite>

- URL: http://www.google.cn/maps/vt?lyrs=s@189&gl=cn&x={x}&y={y}&z={z}



3) Add a layer of XYZ tiles and check that a value of projection coordinate reference system is 3857.

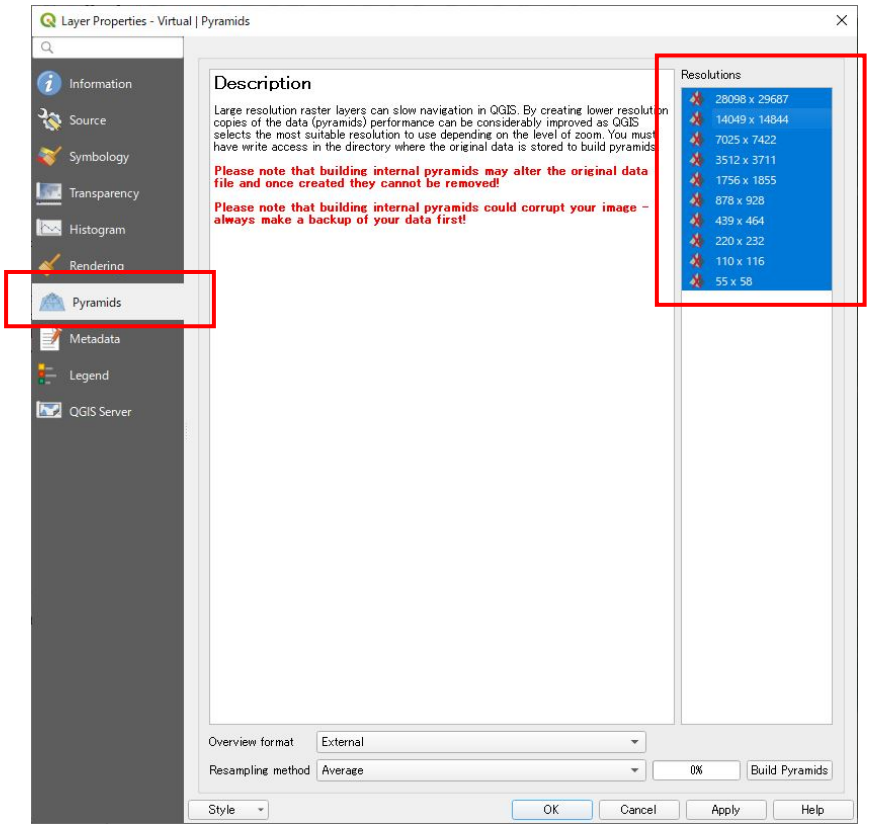


2.3. Add an orhtoimage and create pyramids.

1) Add an orhoimage to layers panel and check that it is displayed in the correct position.

2) Right click on the orthoimage layer, and select a menu of “Layer properties”.

3) Select “Pyramids” menu and highlight “Resolutions” and click on “OK” button.



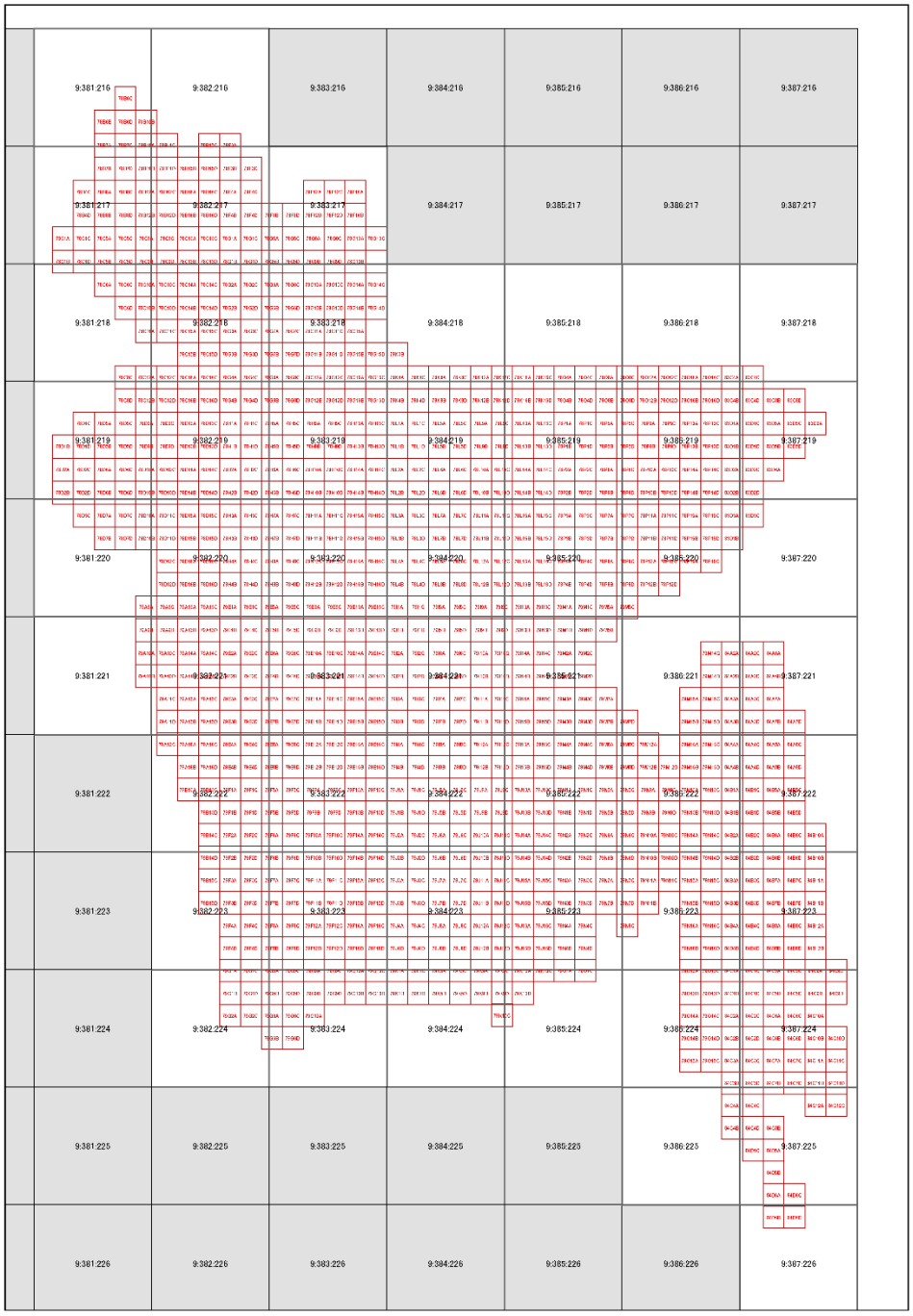
3) Create pyramids of all orthoimages that generate map tiles.

2.4. Add orthoimages included in one grid of Zoom level 9

1) Refer to an index map including Zoom level 9 grid and 1:25,000 topographic maps sheet grid.

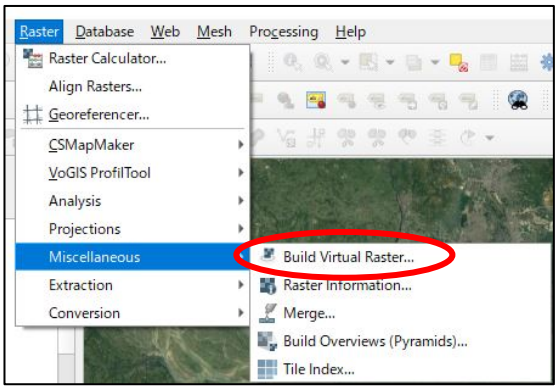
2) Add orthoimages included in one grid of Zoom level 9.

For example, in case of X=381 and Y=216, add 7 orthoimages, ‘78B6B’, ‘78B6C’, ‘78B6D’, ‘78B7A’, ‘78B7C’, ‘78B10B’ and ‘78B11A’.

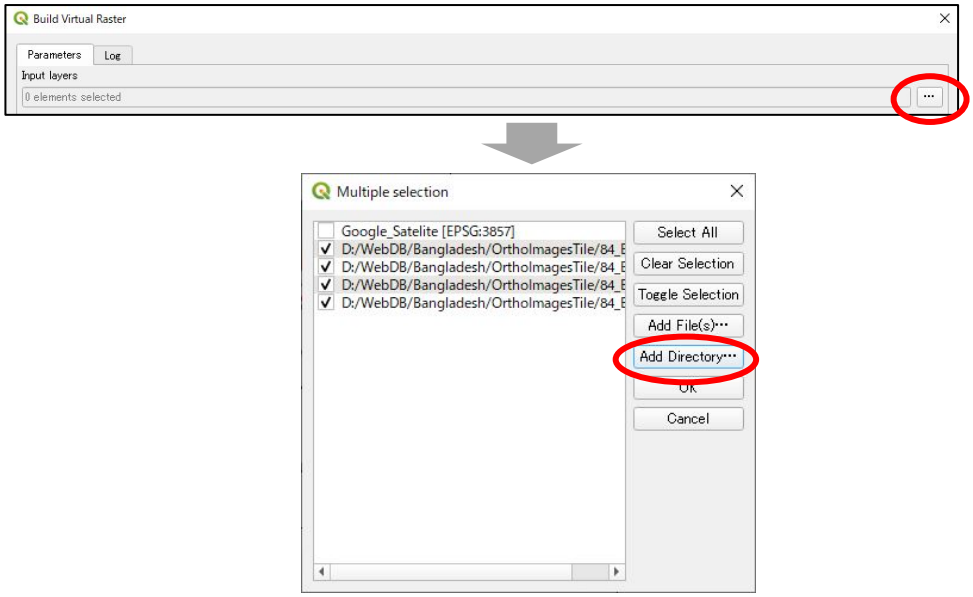


2.5. Build virtual raster

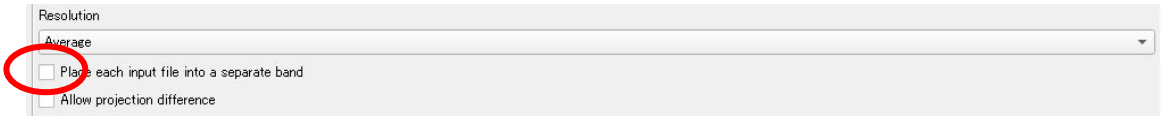
1) Select “Raster” – “Miscellaneous” – “Build Virtual Raster…” from menu bar.



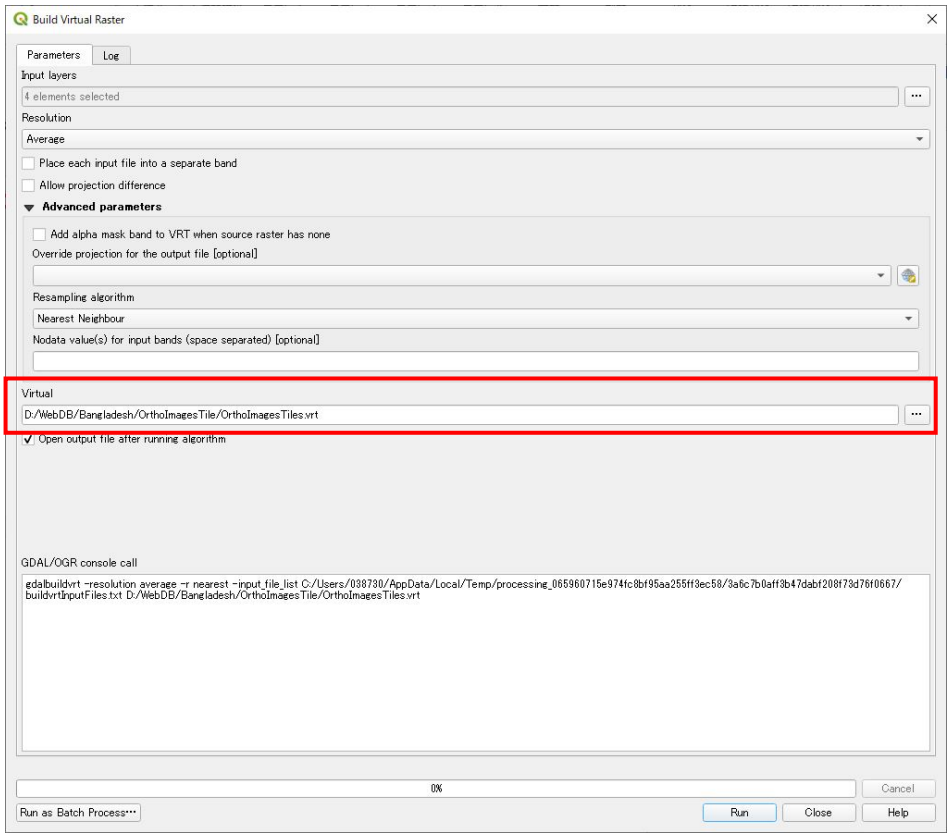
2) Set input layers. Click on “Input Layers” button and show “Multiple selection”. Then click on “Add Directory” and select folders which data source are stored.



3) Uncheck the checkbox of “Place each input file into a separate band”. (Important)



4) Set a “VRT” file name and click on “Run” button.



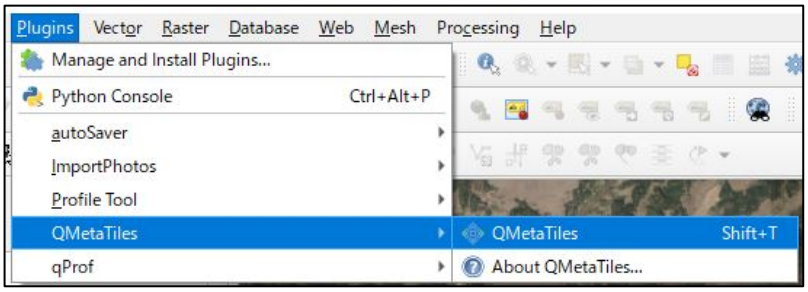
2.6. Create tiles.

1) Add grid data included one polygon of Zoom level 9.

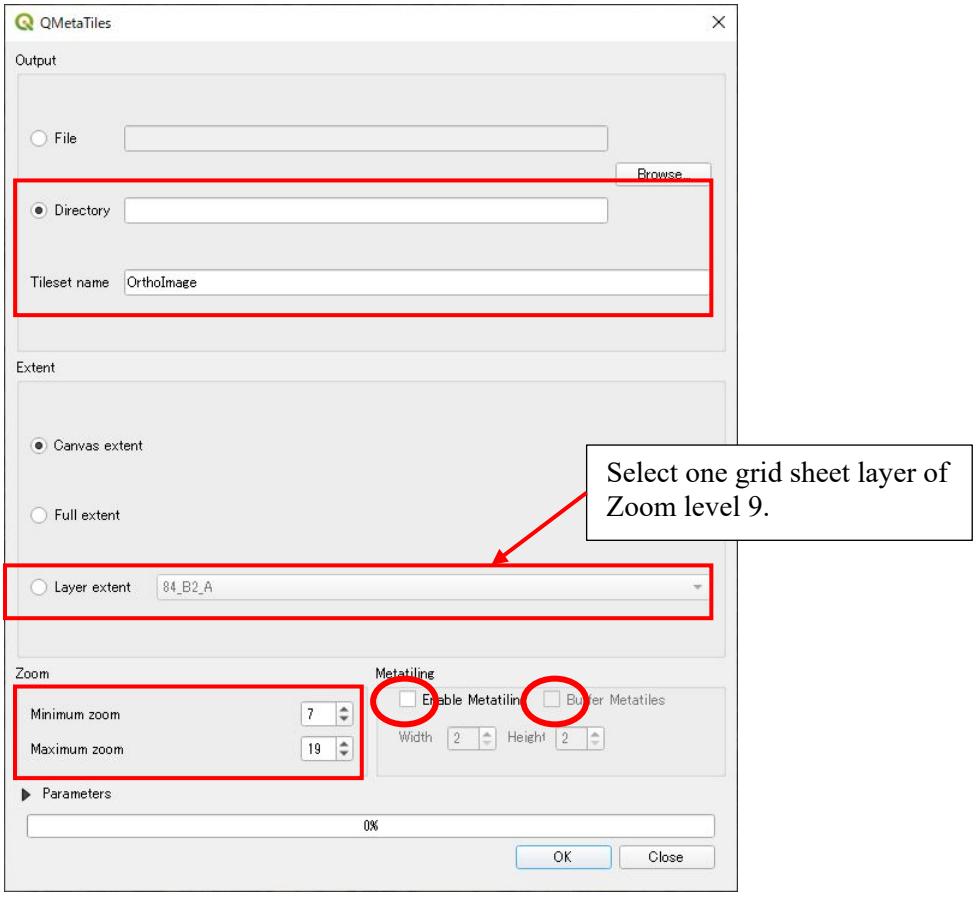
2) Check that orthoimages are covered in one grid of Zoom level 9 or not.

3) Uncheck the checkbox on layers panel except orthoimgaes.

4) Select a menu of “Plugins” – “QMetaTiles” – “QMetaTiles” from menu bar.



3) Set parameters of an output directory, extent and zoom level in the QMetaTiles dialogue box. Uncheck the checkbox of “Enable Metatiling” and “Buffer Metafiles” and click “OK” button.



2.7. Merge web map tile data.

1) After generating web map tiles data, you should copy and overwrite in order of Zoom level 9 grid number to one folder.

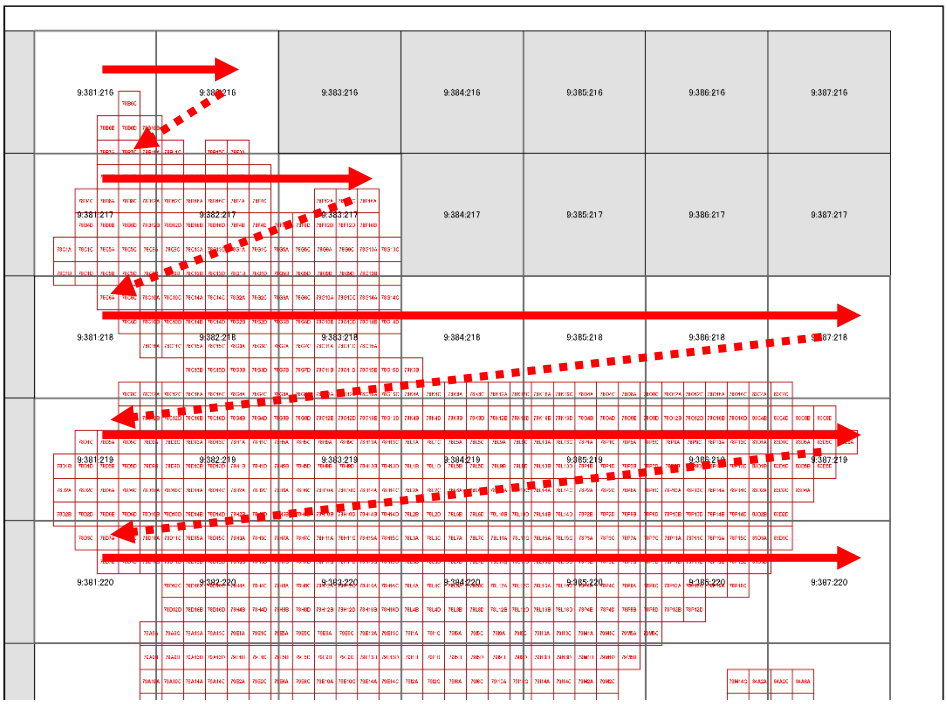
1st: X=381, Y=216

2nd: X=382, Y=216

3rd: X=381, Y=217

4th: X=382, Y=217

5th: X=383, Y=217 …



9:381:216
9:382:216
9:383:216
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9:387:226

Basic Operation of the new NSDI Portal

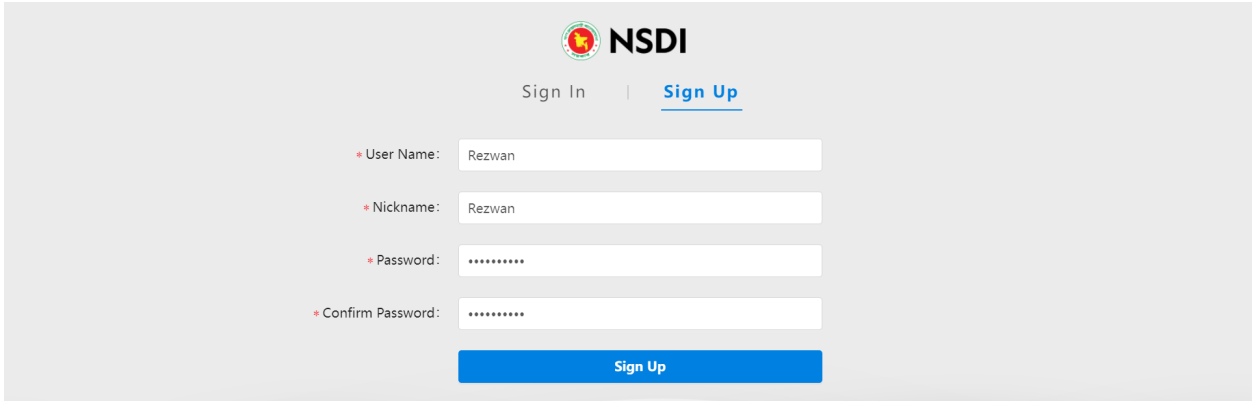
NSDI Portal has gone through massive changes over the last few months. The old portal that can be accessed through nsdi.gov.bd will be announced deprecated soon and all the files and maps will be shared through geoportal.nsdi.gov.bd. All the data and users have been migrated to geoportal and future operations will be held there. This session aims to disseminate the knowledge and uses of the newly developed portal to the working group members of NSDI.

Sign Up / Sign In / User Account Management

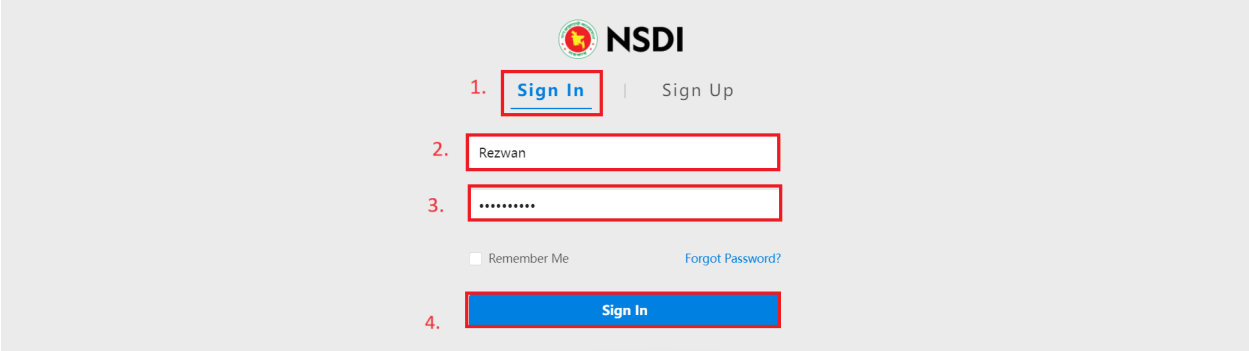
1. NSDI Geoportal is now available for sign up for the working group members who haven't done it already. If you don't have an account please go to geoportal.nsdi.gov.bd and click on the Sign Up button at the top right corner.



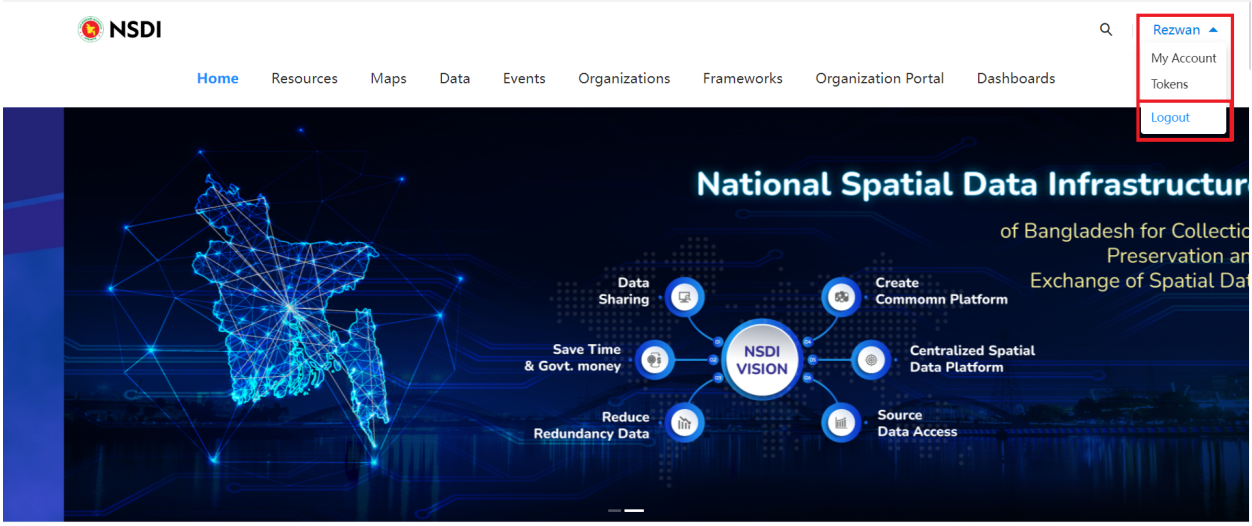
2. Once you get to the sign up page enter your Username, Nickname, Password and confirm the password to continue the signing up process. This should be mentioned that both username and password are case sensitive. So once you sign up make sure that you use your appropriate username and password to login to NSDI Geoportal.



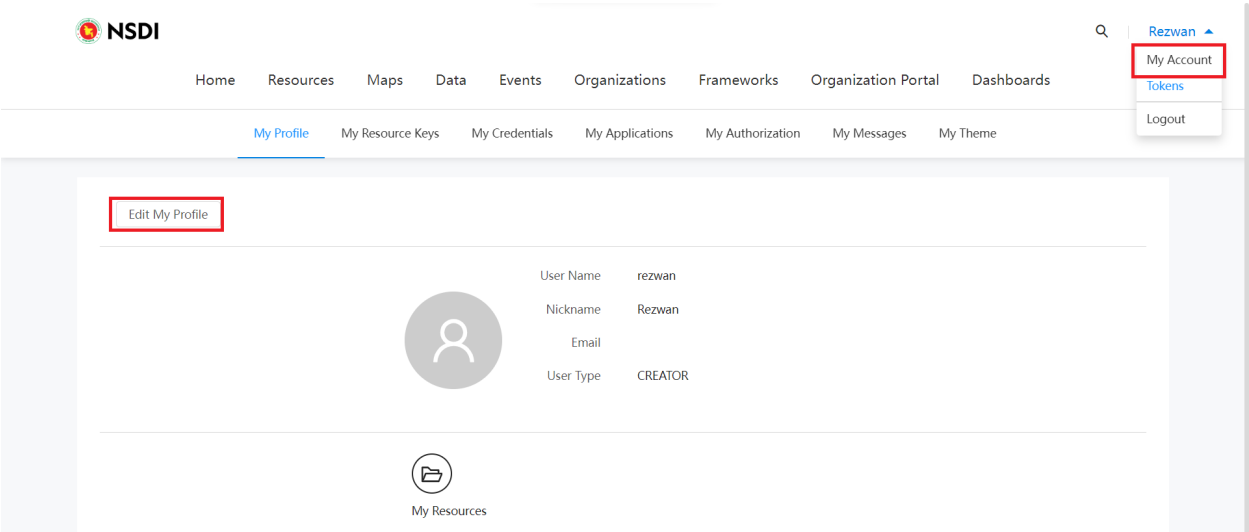
3. Once you have signed up, go to the Sign in Tab. And enter your username, password and click on Sign In to login to your account.



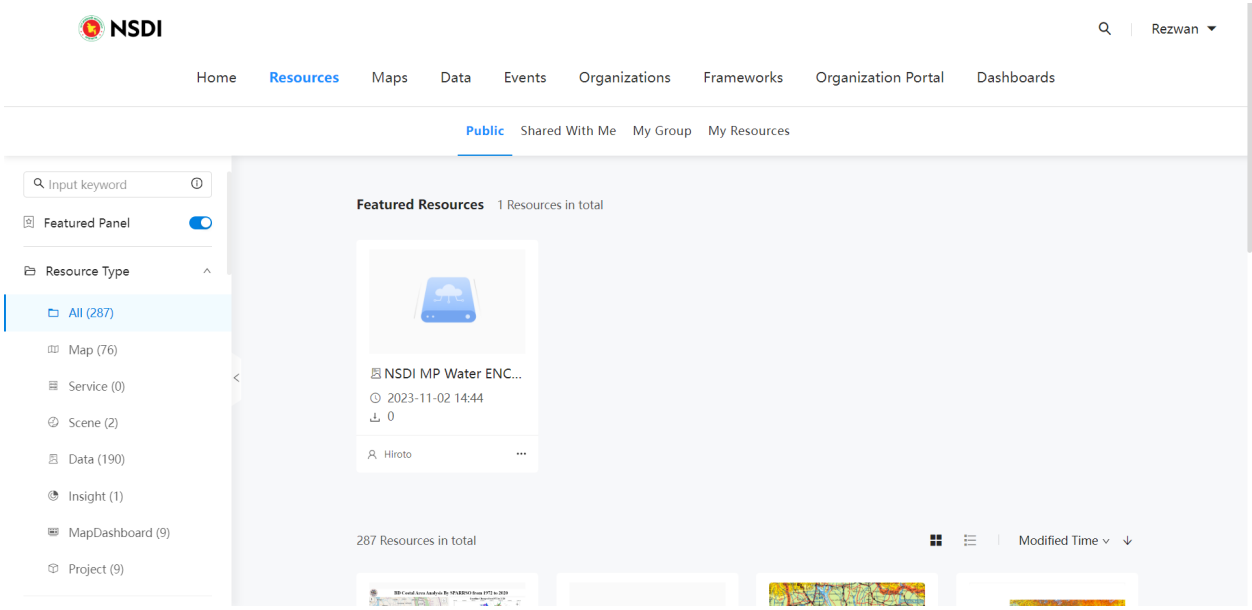
4. Once you're logged in, if you want to logout from your account, hover over your username at the top right corner of the website and click on logout.



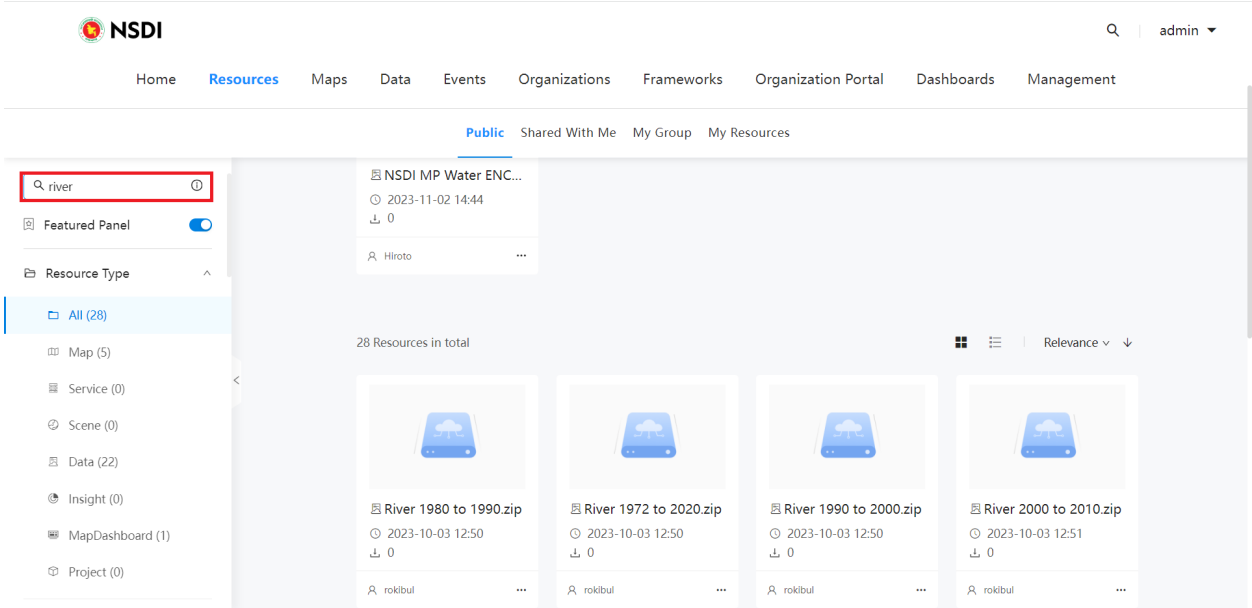
5. If you want to update your profile, then go to My Account and click on Edit Profile to update your profile or modify your password.



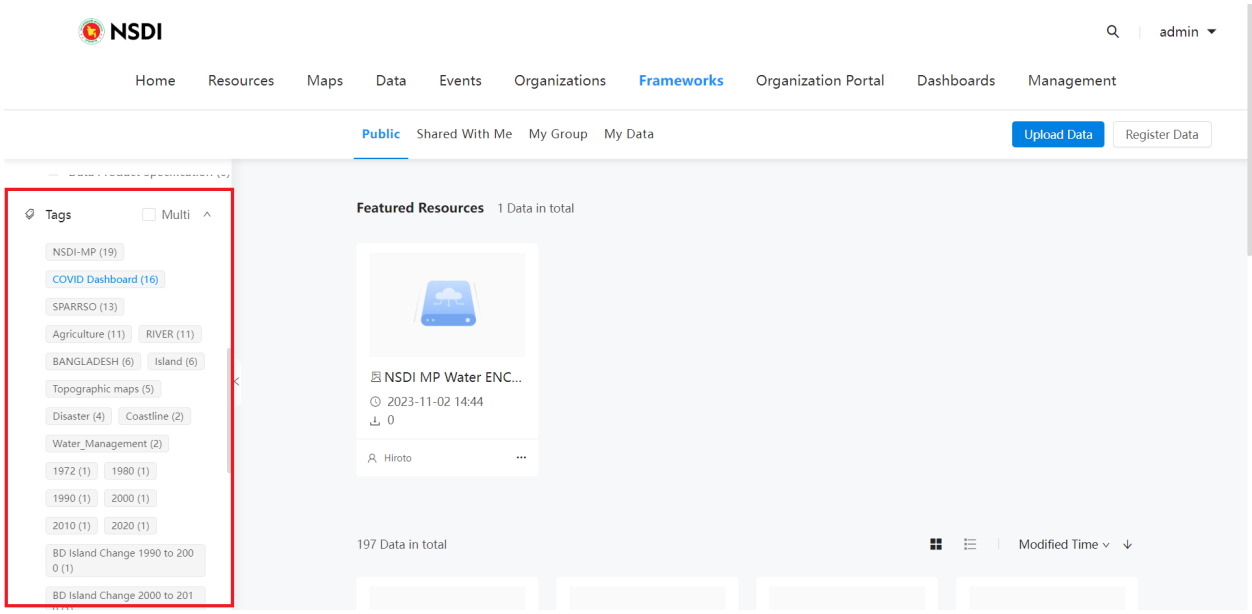
Data Catalog



1. The Data Catalog can be accessed by clicking on the Resources Tab at the top.
2. Data Catalog has been arranged in several organized resource types. For Example, Resource Types can be Map, Service, Scene, Data, Insight, Map Dashboard, Project etc. Just click on the resource you want to view from the left sidebar and it will bring up all the data relevant to that particular resource type.
3. If you want to search a specific resource, then just input the keywords of the file that you're looking for and the data should automatically come up. For example, if you type river, all the data that has river in its name and tags should pop up.



4. If you scroll down on the left of the sidebar, then you can also search by a specific tag that has been used by a NSDI Portal user.

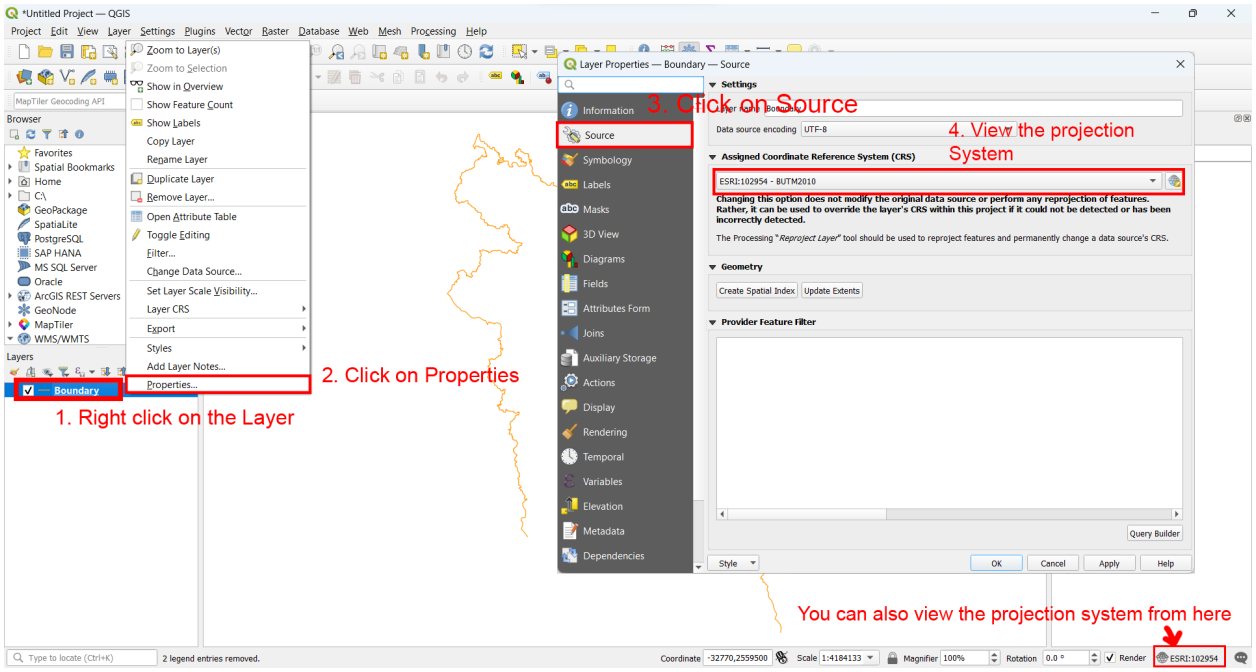


Data Uploading Procedure

Data Preprocessing

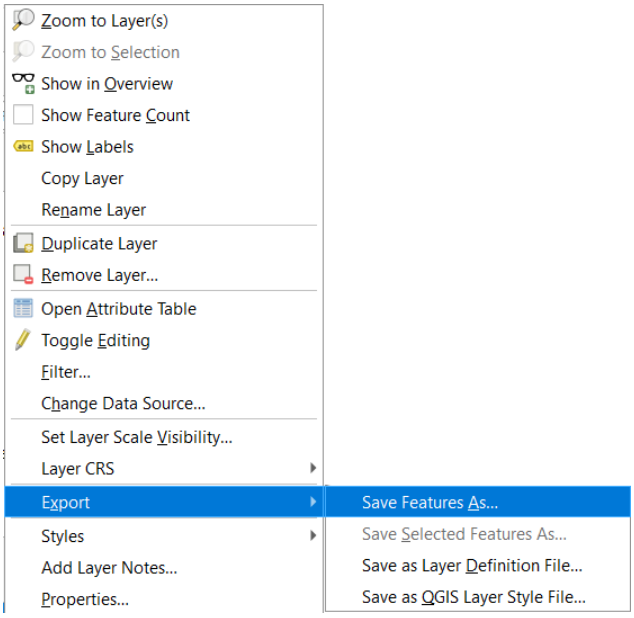
Uploading and Downloading data in NSDI is quite simple. But before doing that, we need to do some pre-processing to the data we're about to upload. For now, only two projection systems are supported due to the fact that NSDI is supposed to standardize the dataset into a single projection system. These two projections are WGS 84 (EPSG 4326) and Web Mercator (EPSG 3857). However, the NSDI Development team is currently working to develop a dynamic projection system where the uploaded data will automatically be converted into one of these two projection systems. So in future updates this data pre-processing step might not even be required.

To convert any data that doesn't have a WGS 84 projection system, you can convert it using any GIS softwares like QGIS, ArcGIS Pro, ArcMap etc. Here's a brief overview on how to convert the projection system in different softwares.

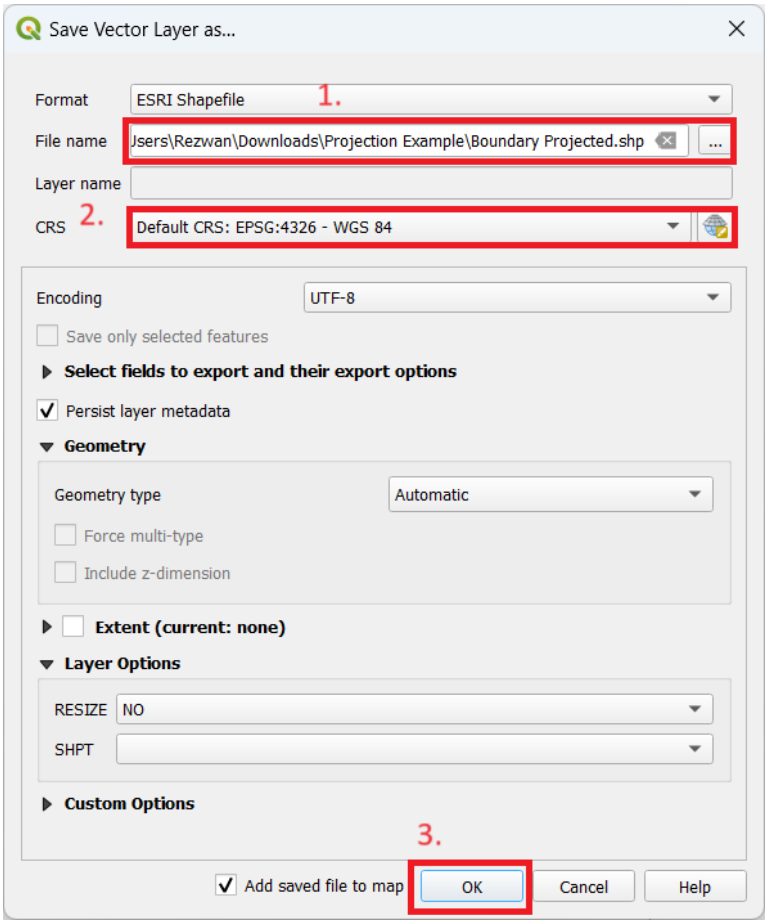


QGIS:

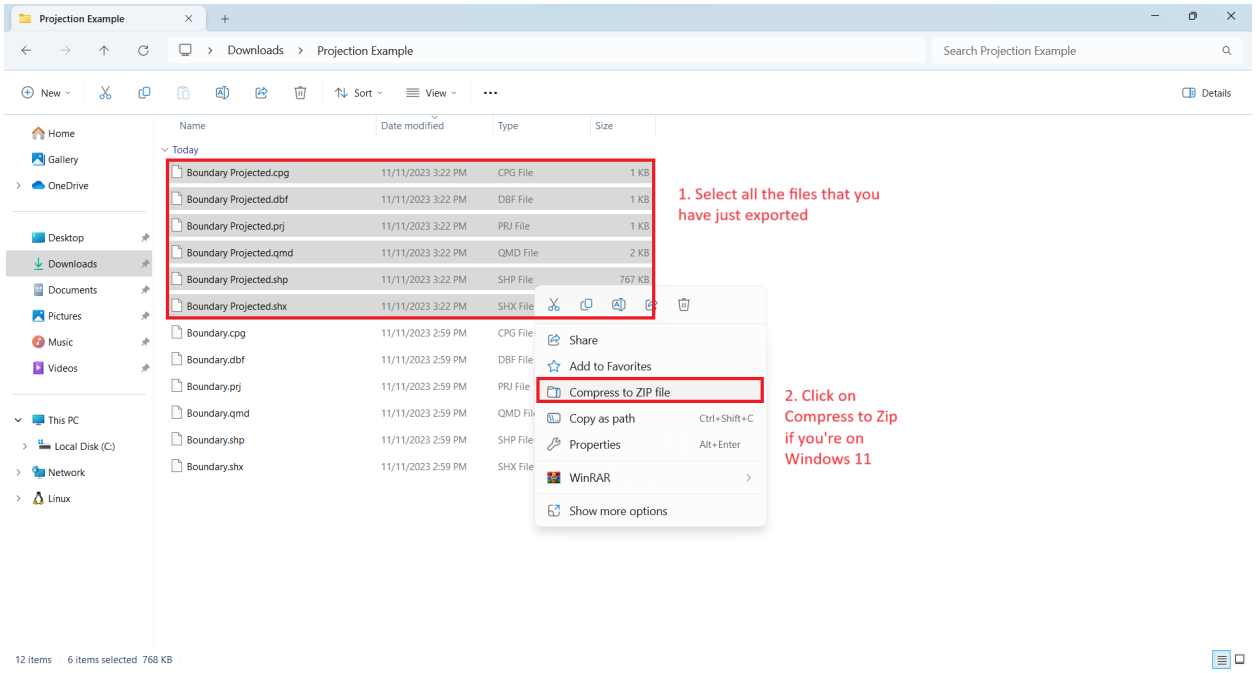
1. First load the data into QGIS.
2. Right click on the layer and the click on **properties**.
3. Then click on source and you can view the assigned coordinate reference system (CRS)
4. That's how you can view the projection system of a geospatial data in QGIS.



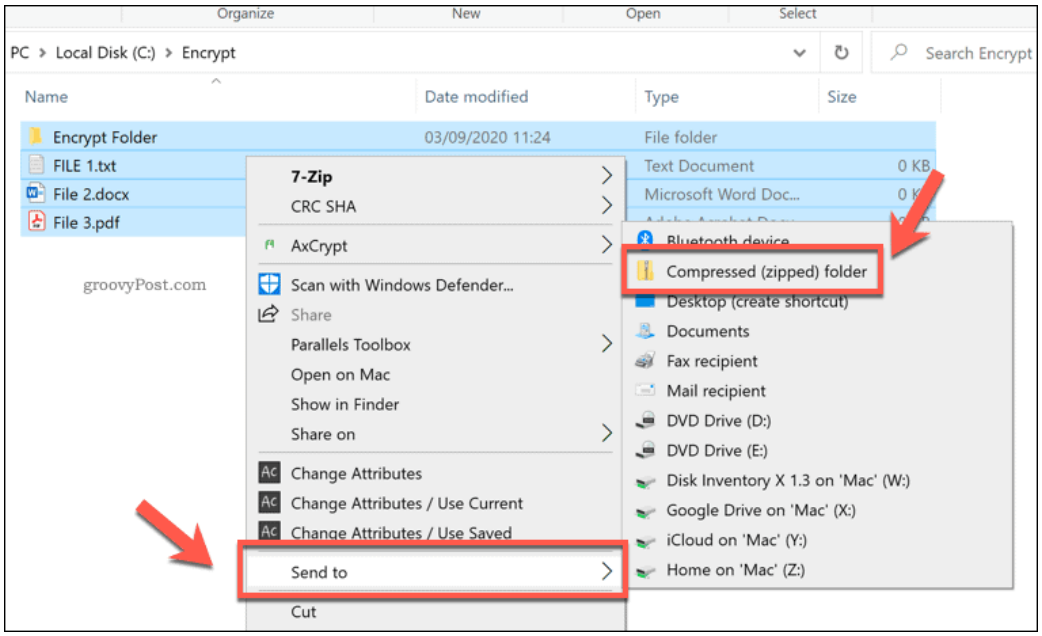
5. If the file isn't in WGS 84 or Web Mercator Projection system, again right click on the data and then click on **Export** > **Save Feature As.** Then an export window will popup. On that window, set the location where you want to export the data to and then click on **CRS** to **WGS 84** and then on **OK** to export the file in WGS 84 projection system.



6. Now go to the location where you have exported the layer. Select all the files related to the shapefile that you just exported and then click on Compress to Zip File if you're on Windows 11.

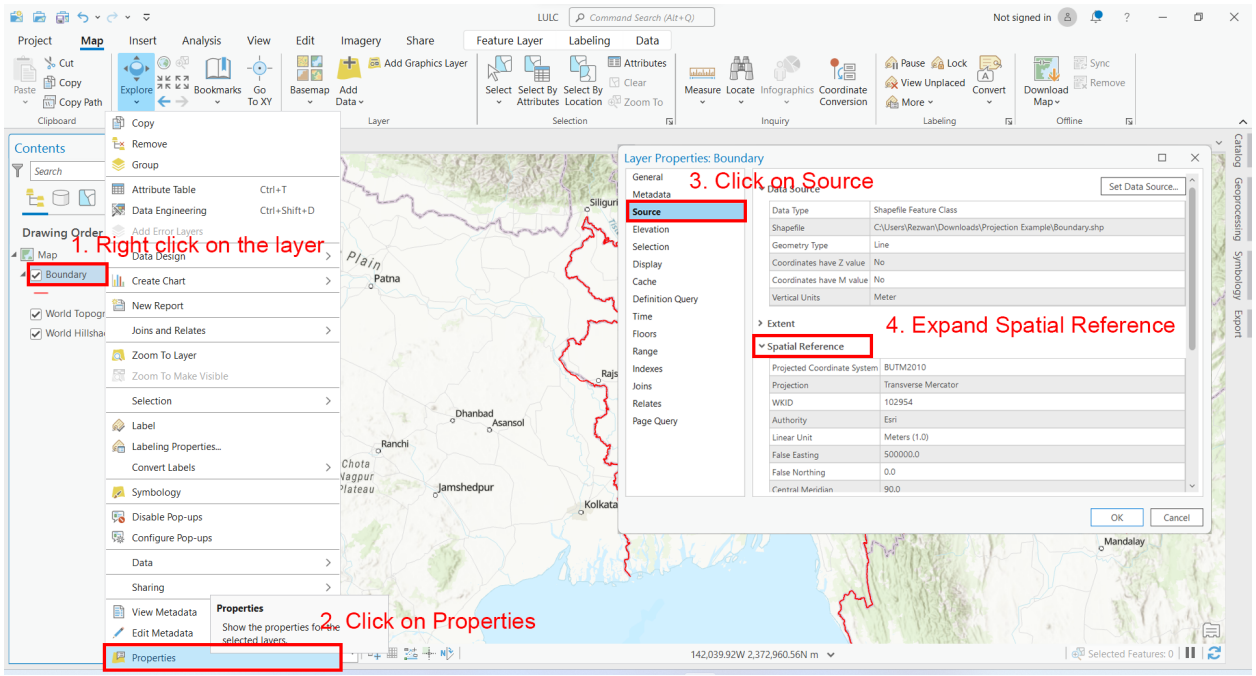


7. If you're using Windows 10, select all the files that you just exported, thenright click on the files and select Send to > Compressed (zipped) folder.



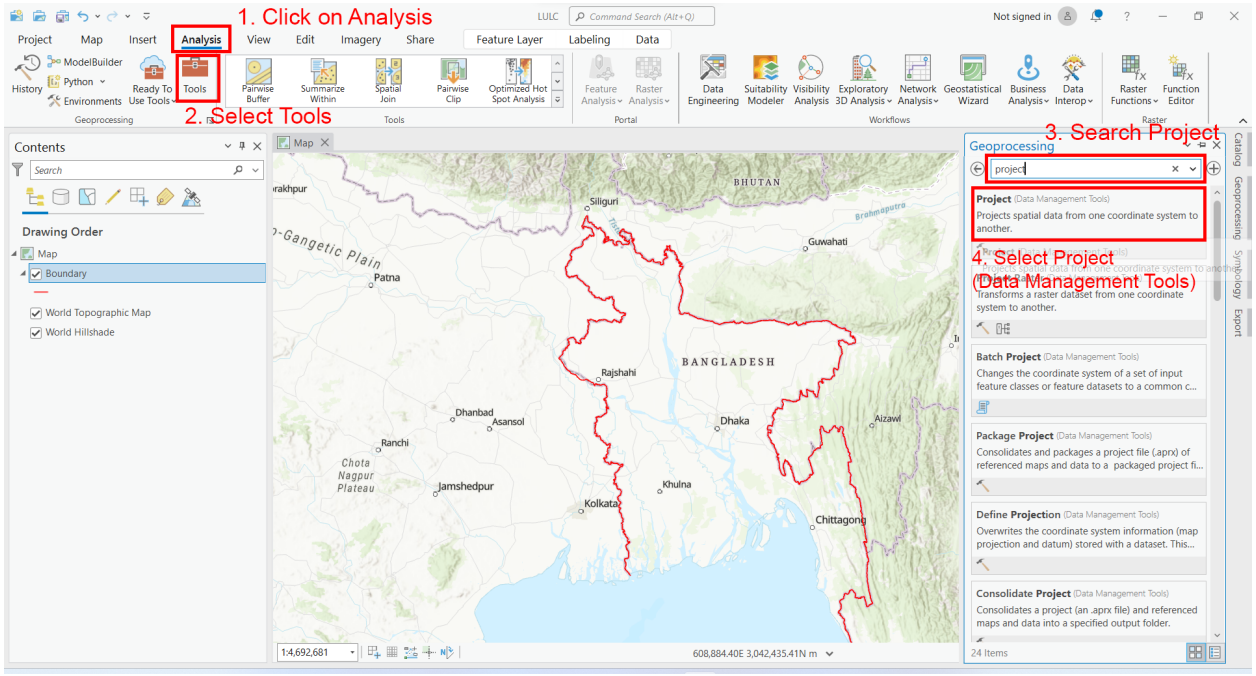
8. You can also use WinRAR / 7Zip like softwares to achieve the same outcome. The main idea is to just zip the files.
9. Now that you have projected the files into WGS 84 and zipped the folder, it's now ready for publishing into NSDI Portal.

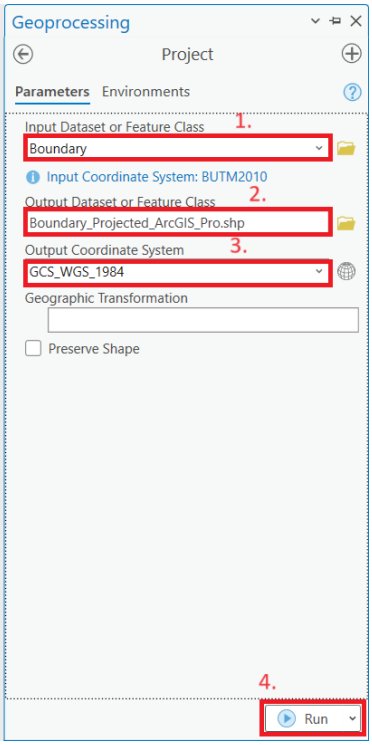
ArcGIS Pro:



1. First load the data into ArcGIS Pro.
2. Right click on the layer and click on **Properties**.
3. A **Layers Properties** window will pop up.

4. On the Layer Properties window, go to **Source** and expand the **Spatial Reference**.
5. You can view the reference system of the layer.
6. If the layer is not in WGS 84, then we need to convert the projection system of the layer to WGS 84 or Web Mercator.
7. To do that, first click on the Analysis tab and then click on **Tools**. Once you click Tools a **Geoprocessing** window will pop up on the left. Search Project on the search bar and hit enter. This will bring up the **Project (Data Management)** tool. Click on that tool.

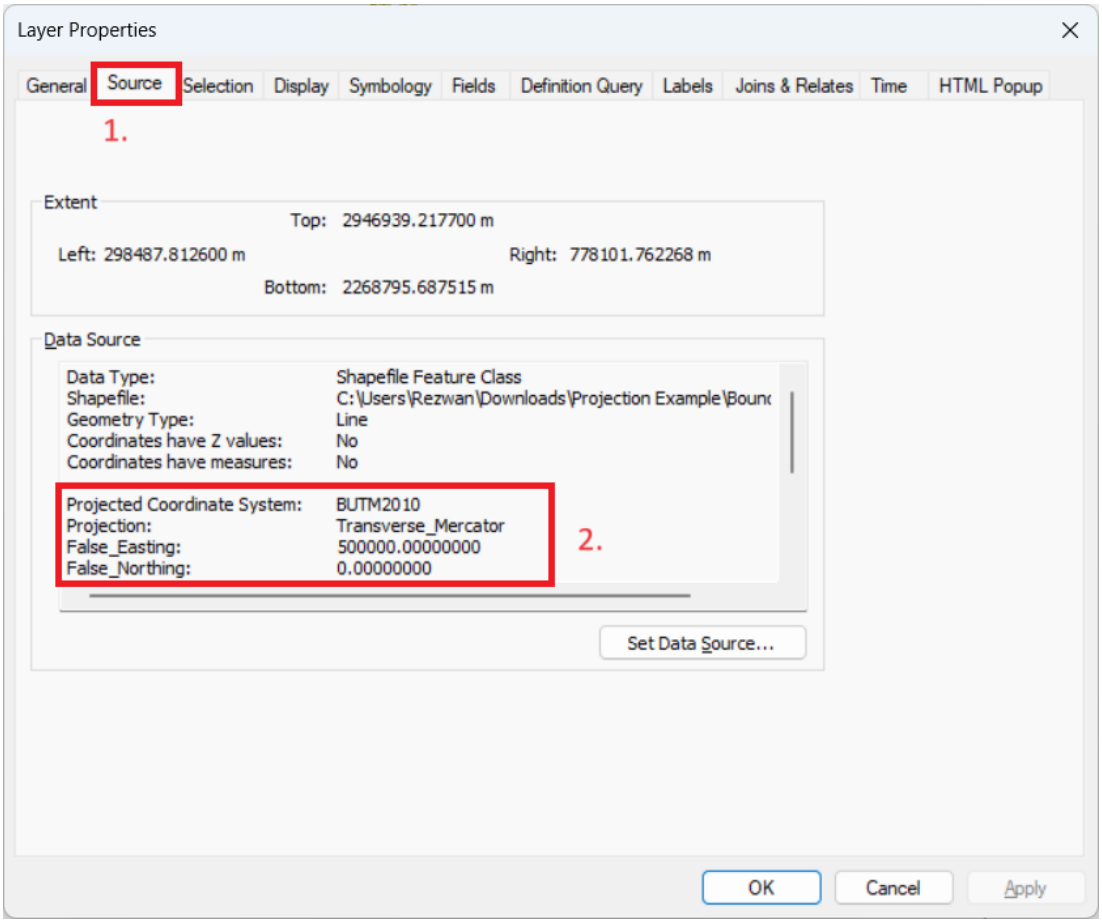




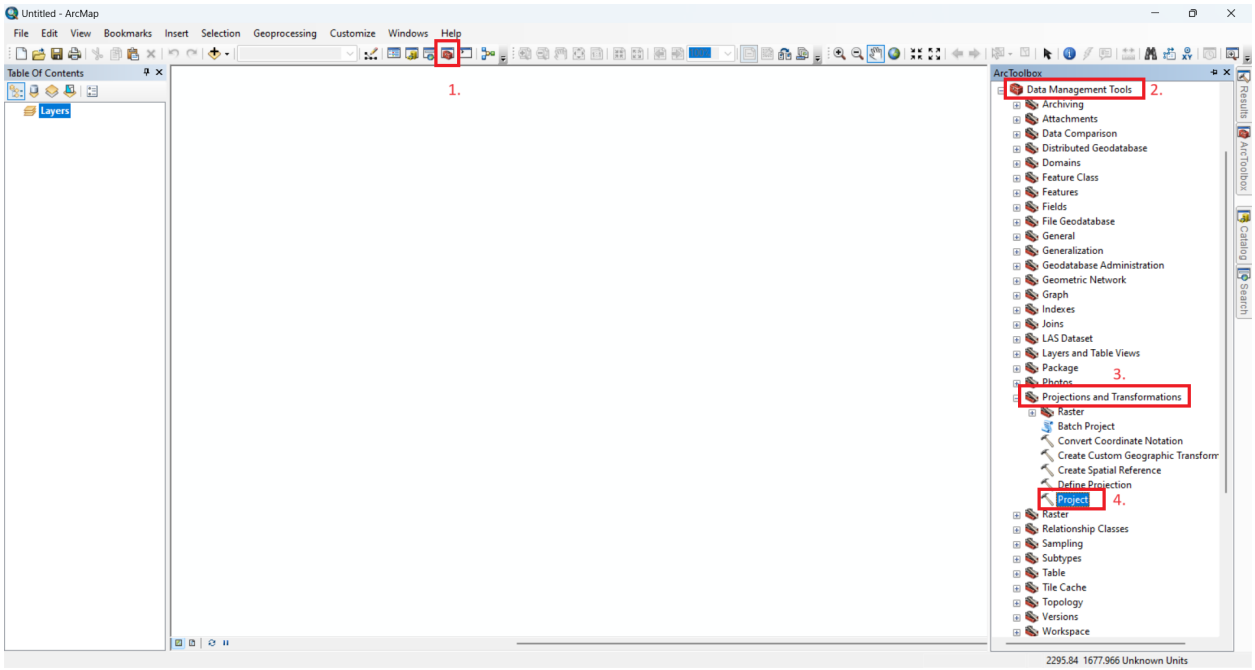
8. Then input the layer that you want to change the projection system of in the **Input Dataset or Feature Class.**
9. Select where you want to export the file to in the Output **Dataset or Feature Class.**
10. Set the output Coordinate System to **GCS_WGS_1984** and then finally click on **Run**.
11. This will save the output in WGS 84 projection in the location you have defined. Then just follow QGIS's point 6 to 9 to zip the files and upload it into NSDI Portal.

ArcMap:

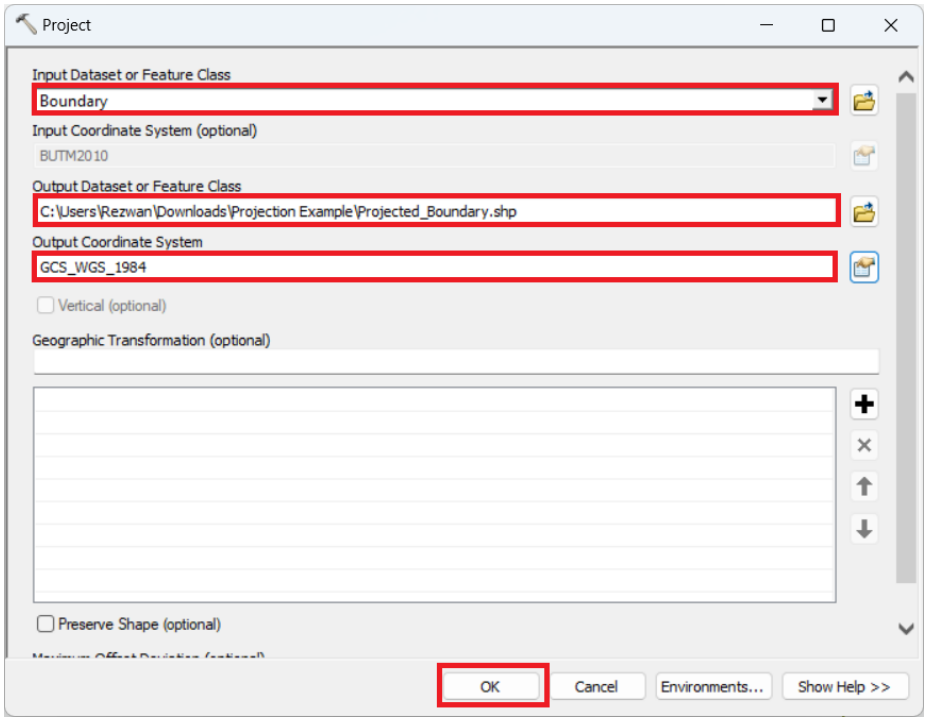
1. First load the dataset into ArcMap.
2. Right click on the layer and click on **Properties**.
3. A **Layers Properties** window will pop up.
4. On the Layer Properties window, go to **Source** and expand the **Spatial Reference**.
5. You can view the reference system of the layer.



6. If the projection system of the layer is not in WGS 84, then we need to convert it to WGS 1984.
7. To do that, first click on the **Tools** button at the navigation bar, then **ArcToolbox** will open up. Then navigate to **Data Management > Projection and Transformation > Project**. Double click on the tool and a **Project** window will pop up.



8. Then input the layer that you want to change the projection system of in the **Input Dataset or Feature Class.**

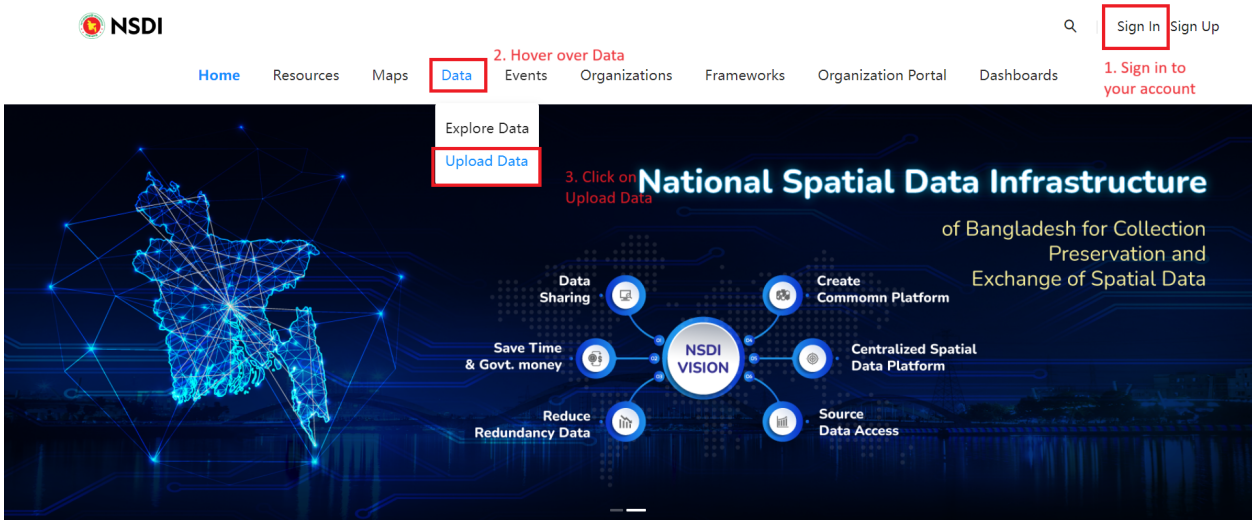


9. Select where you want to export the file to in the Output **Dataset or Feature Class.**
10. Set the output Coordinate System to **GCS_WGS_1984** and then finally click on **Run**.
11. This will save the output in WGS 84 projection in the location you have defined. Then just follow QGIS's point 6 to 9 to zip the files and upload it into NSDI Portal.

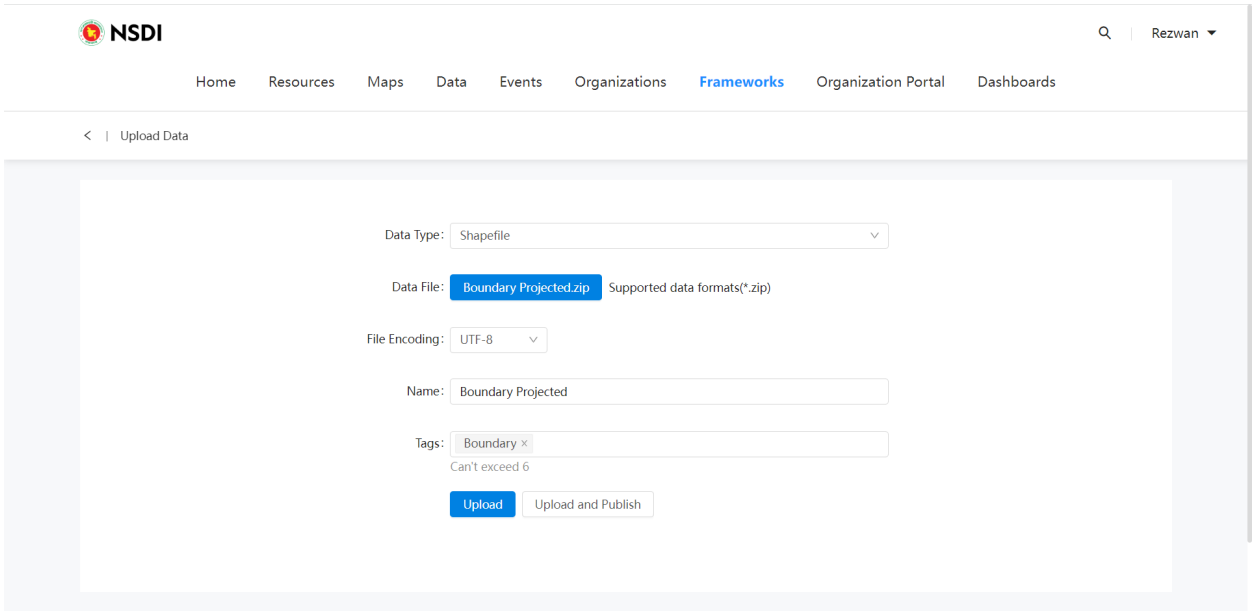
Data Uploading

Once you have preprocessed the data and it's finally ready for uploading it to NSDI Portal. To upload the data, follow these specific steps:

1. First go to geoportal.nsdi.gov.bd and **Sign in** to your user account.
2. Then hover over **Data** and then select **Upload Data**.



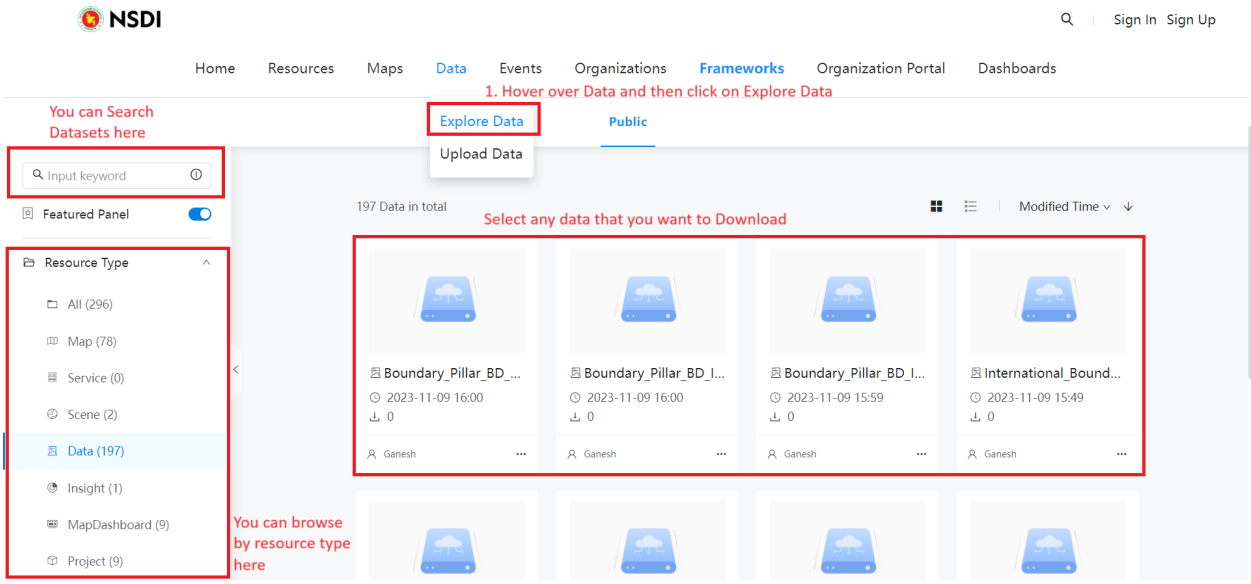
3. Now Select the type of data you want to upload from **Data Type**. If the file type is not listed in the drop down, select **Others** option.



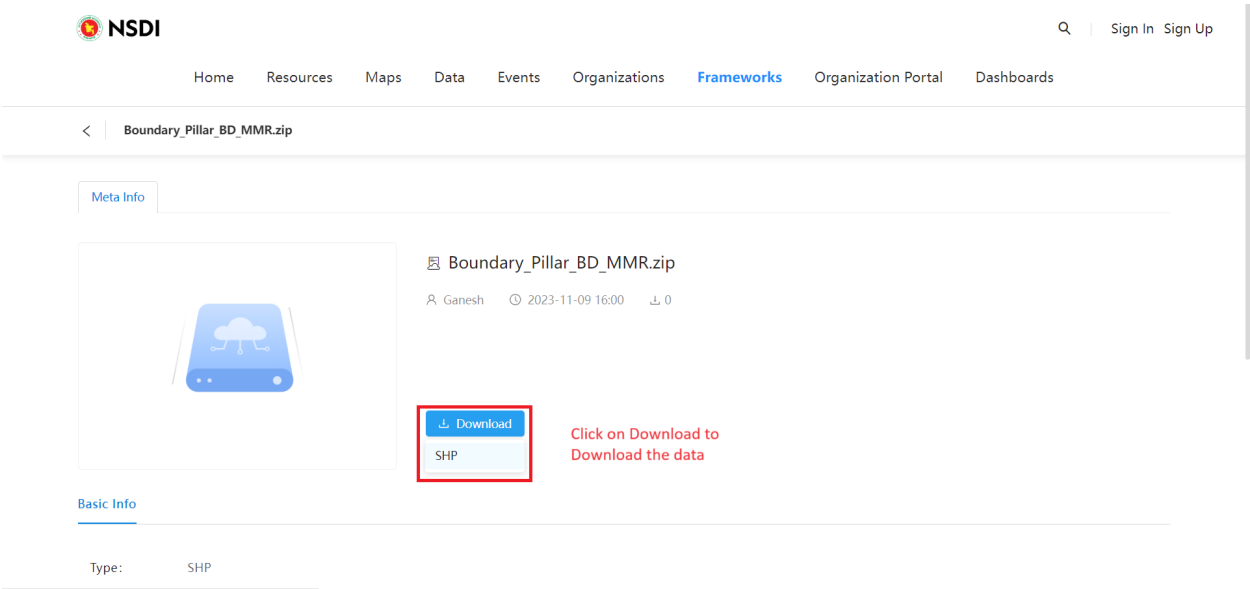
4. Add a name and select the appropriate tags for the dataset so that users can easily find the data that they're looking for.
5. Once you've done it, click on Upload.
6. Once the data is uploaded you can share it with your organization or colleagues.

Data Downloading

1. To download the data, first hover over Data and then select Explore Data.



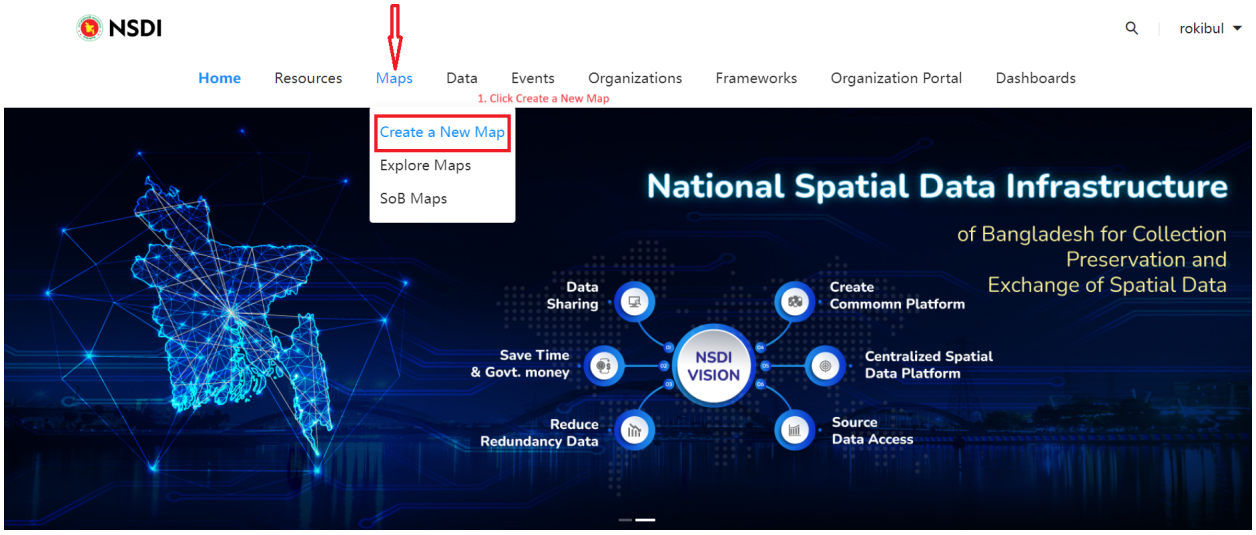
2. Once you view the catalog, you can search for Data or Navigate to that data source.
3. Once you find the data you want to download, click on that data and it should take you to a new page.



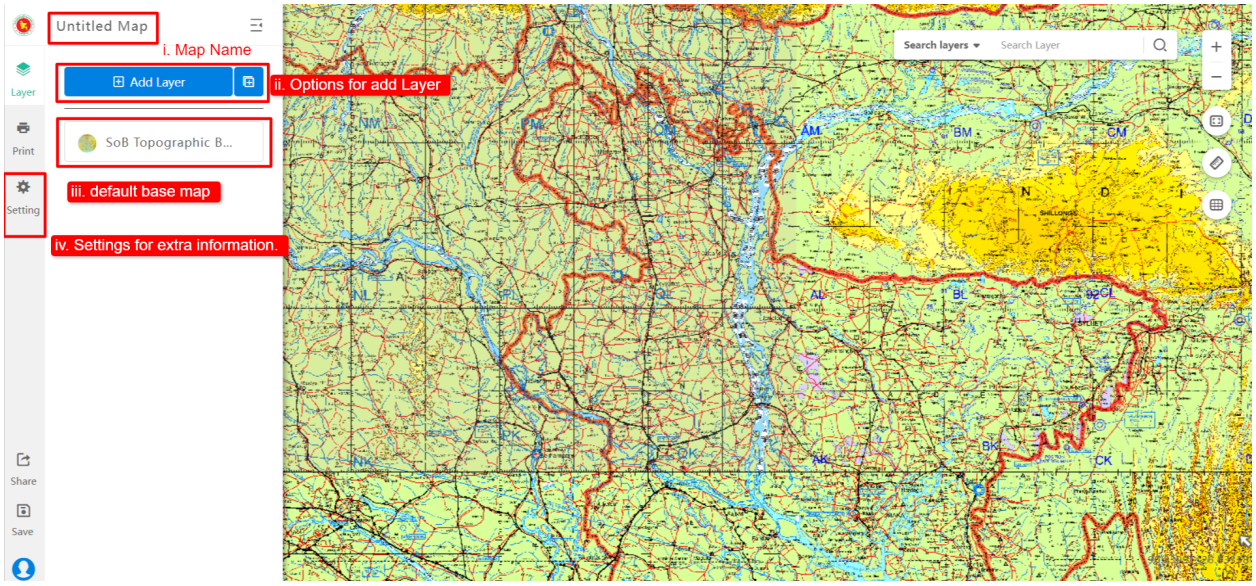
4. Click on Download and the SHP to download the data as shapefile.

Data Visualization

1. To Create a New Map, first hover over Maps and then select Create a New Map.



2. This will open DataViz. We will see that the default SoB BaseMap is selected.



i) In this section, we can set a name for our map.

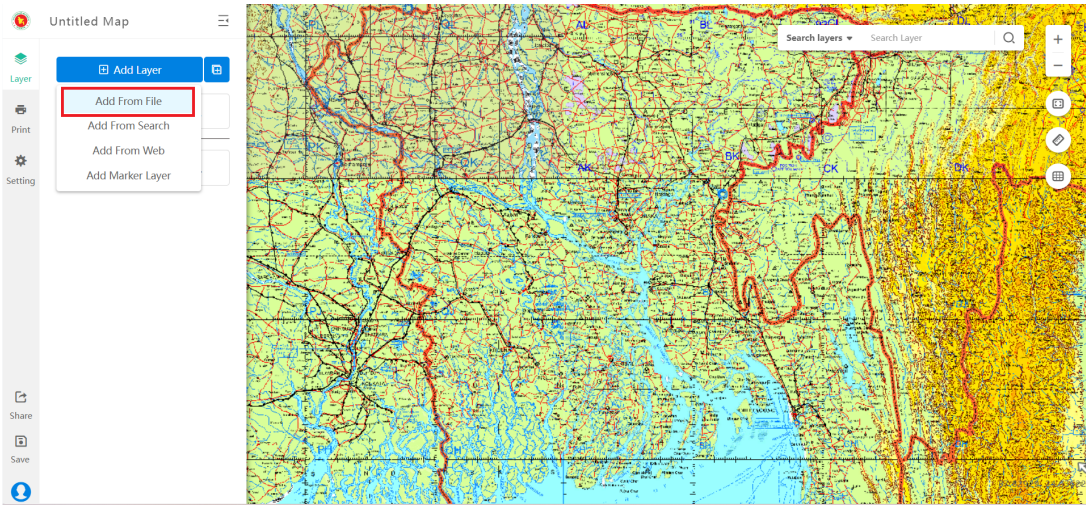
ii) Using the "Add Layer" button, we can add multiple layers to our map.

iii) This is the default base map. If we want to change the base map, we can do so by clicking here.

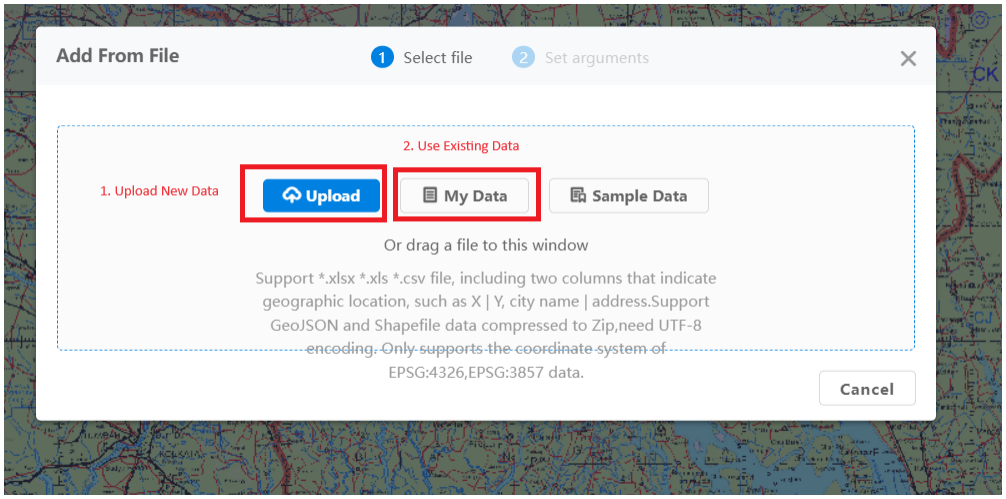
iv) To add more information to our maps, we can use the settings.

Layer Add:

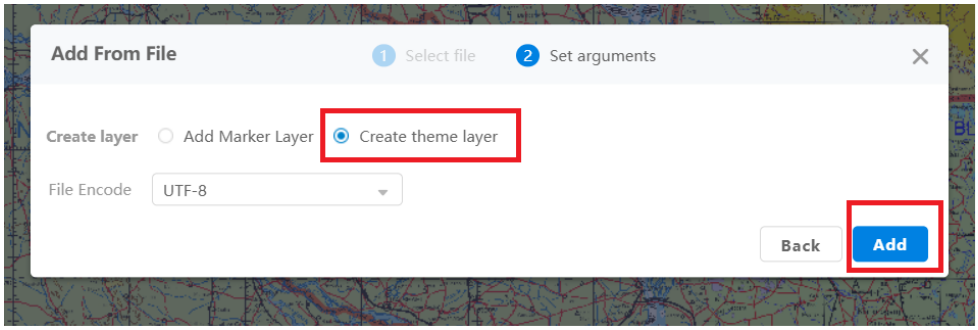
1. Click “Add Layer” then select “Add From File”



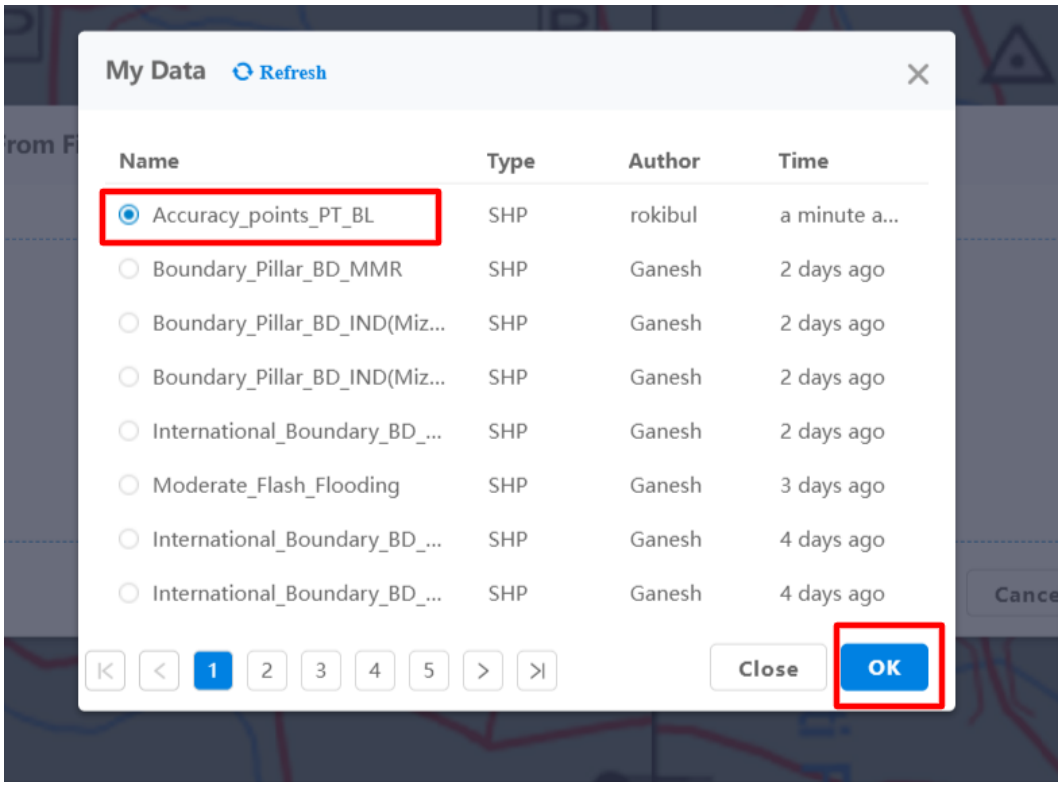
2. Then we can upload New Data using “Upload” button or we can use Existing Data From “My Data” button.



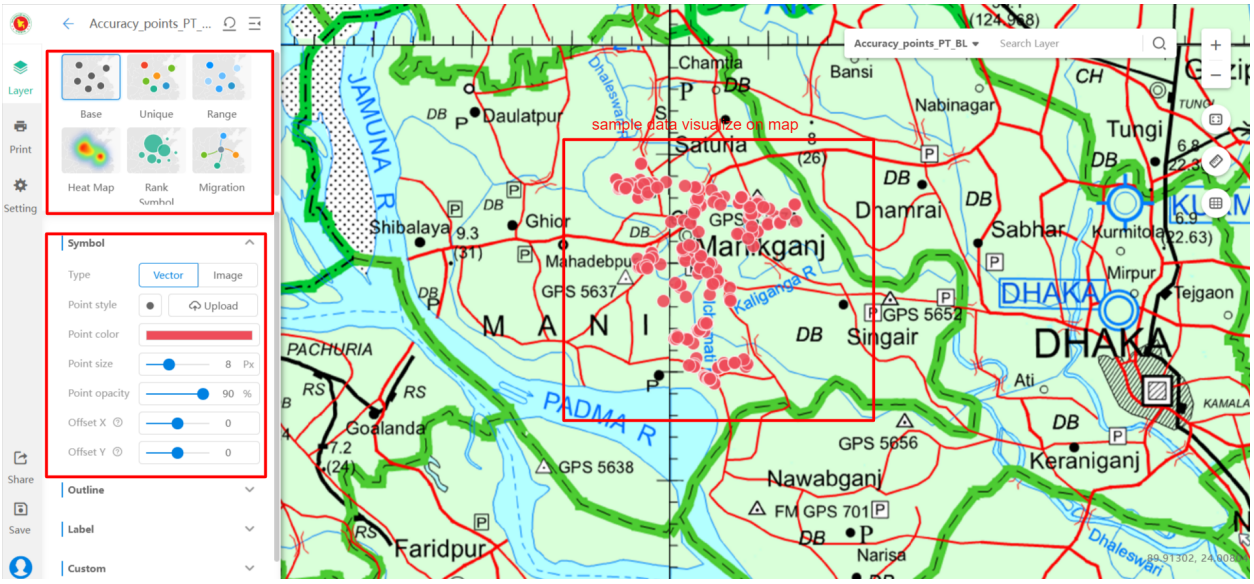
3. We can directly upload GeoJSON or Shapefile using “Upload” button. After selecting the file, click the “Add” button, and the data will be visualize on map.



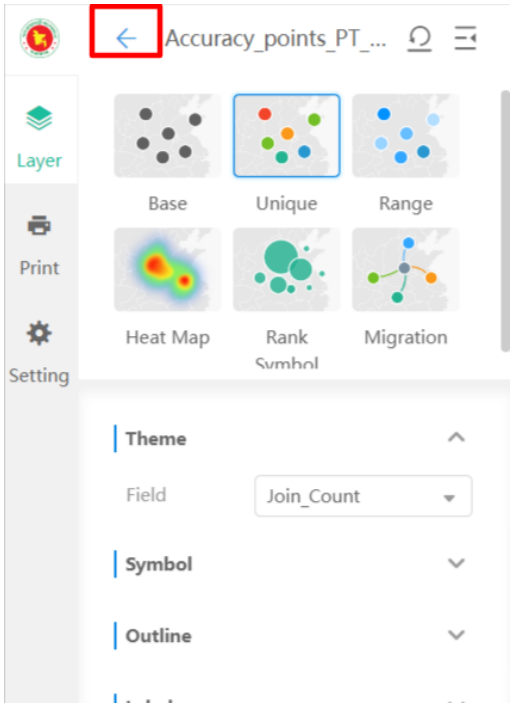
4. If we want to use existing data after clicking “My Data” we can select any data and click “OK”. After selecting OK click the “Add” button, and the data will be visualize on map.



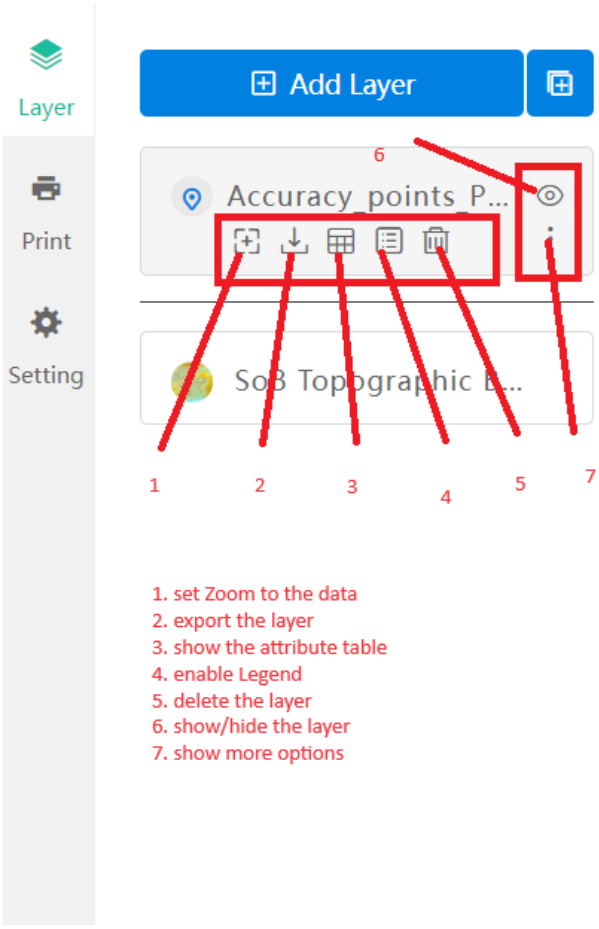
5. There is many option to visualize the data. We can change Symbol, Outline, Label etc.



6. Then we can go back to the previous section using back arrow on top left.

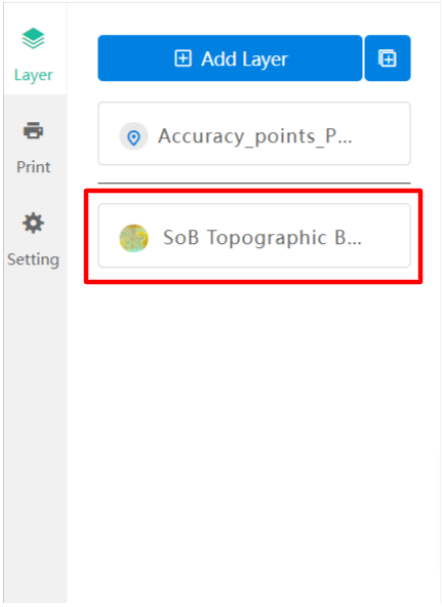


7. When we hover over the layer, additional options for that layer will be displayed.

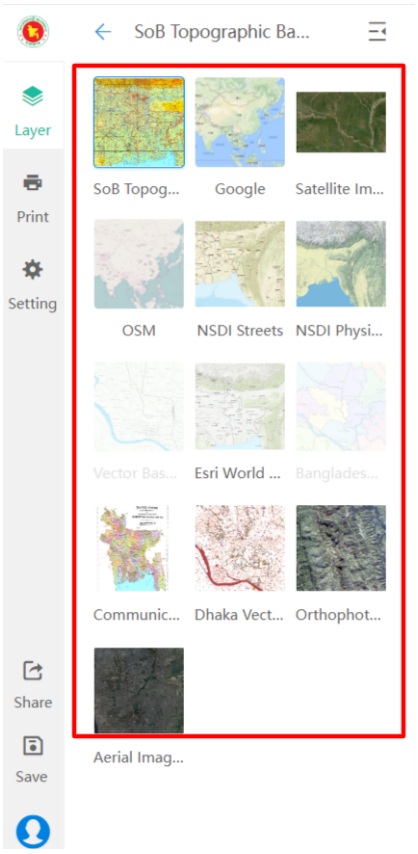


Changing Basemap:

1. Click on the SoB Topographic Basemap.

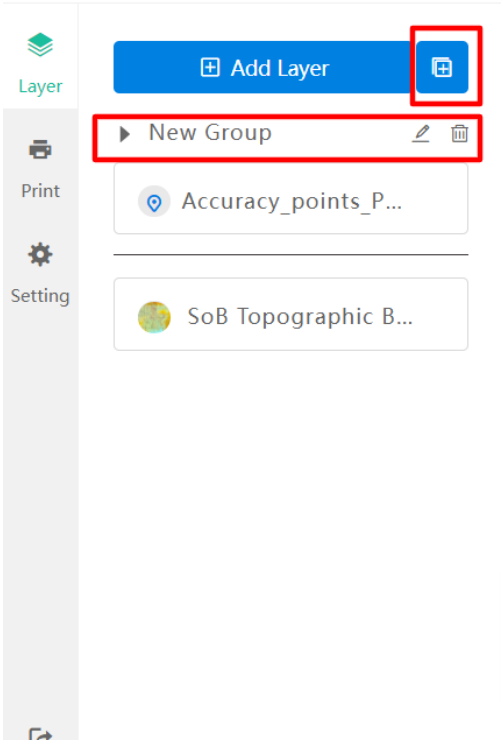


2. We will notice that there are many base maps available. We can select any of them for our map.

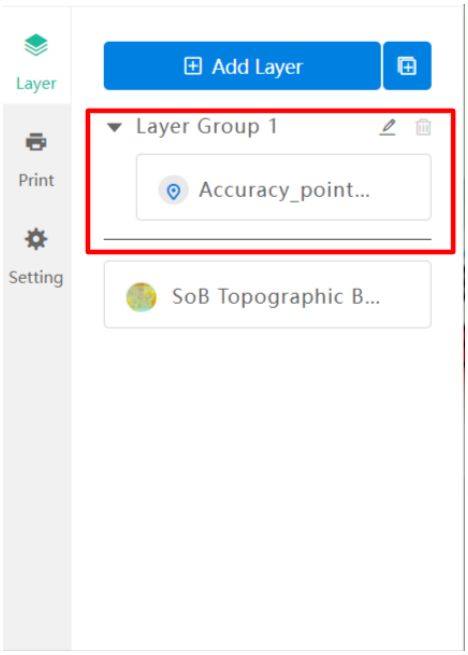


Layer Group:

1. By clicking the plus icon, we can create a group.

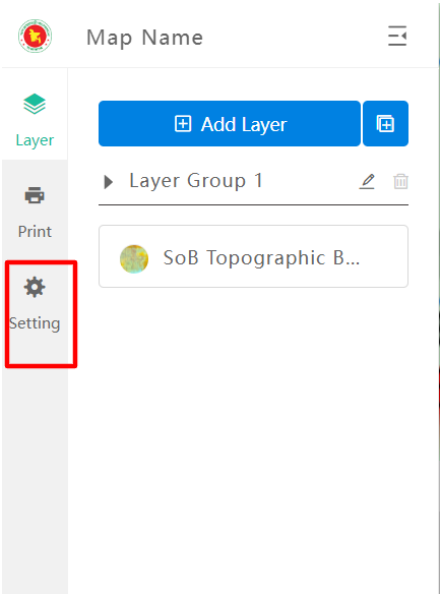


2. Drag and drop we can move the layer to any group.

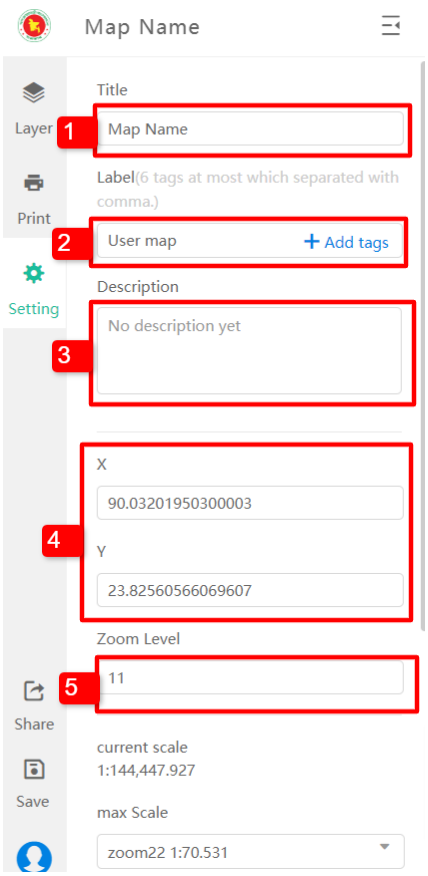


Setting:

1. Click on 'Setting' on the left side to access the map settings area

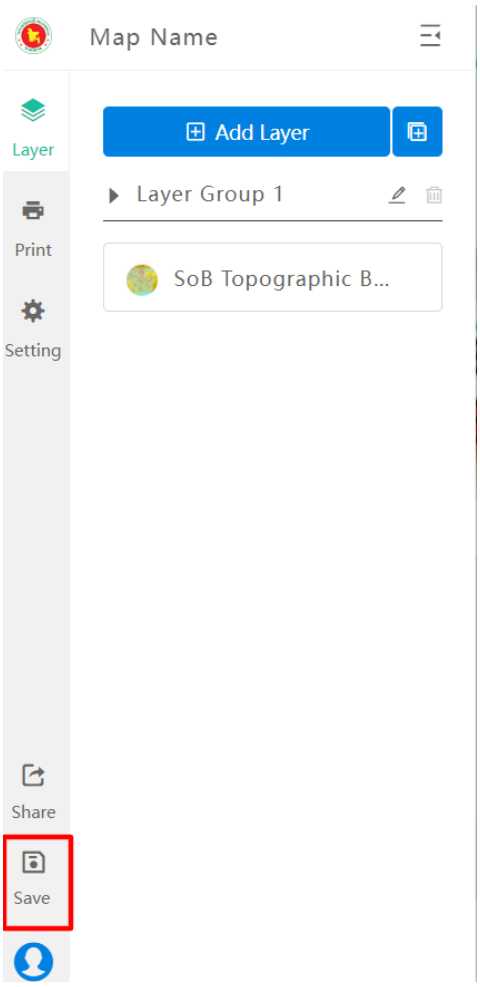


2. We will notice various options that allow us to add or modify.

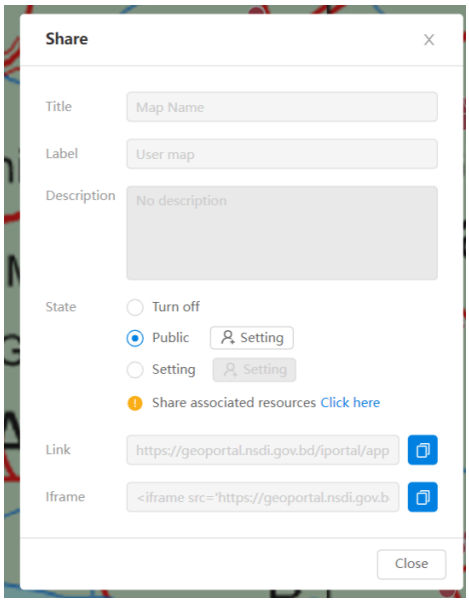


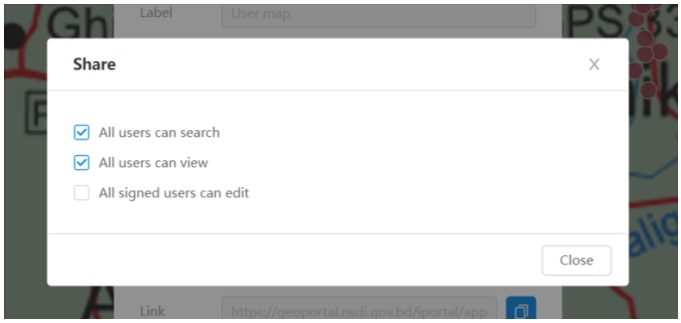
1. Add a map name/title.
2. Add tags for the map; a maximum of 6 tags is supported.
3. Use this to add a description for the map.
4. Set the default map coordinates for the basemap.
5. Set the default zoom level.

After completing the work, we can save the map by clicking the 'save' button.

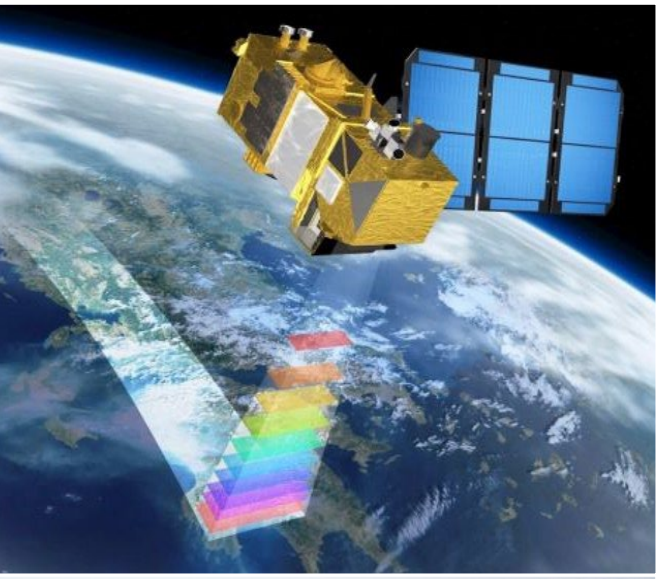


After saving the map, we can share it by clicking the “Share” button.





Attachment 4.4









Model Project on Agriculture Management for National Spatial Data Infrastructure (NSDI) Utilization Project

FINAL REPORT

SUBMITTED BY

ENGR. MD. SHAHADAT HOSSAIN

Consultant, NSDI-MP, Agriculture Management

SUPERVISED BY

DR. FARIDA PERVEEN

Team Leader, NSDI-MP, Agriculture Management

December 2023



Executive Summary

The study outlines the critical role of rice in global agriculture, particularly in Bangladesh, where it contributes significantly to the economy. Despite being the second-largest rice producer globally, challenges such as urbanization, changing climate patterns, and inadequate technology hinder precise crop area estimation. This report emphasizes the need for modernizing agriculture through digital technology, specifically Geographic Information System (GIS) and Remote Sensing (RS). The Japan International Cooperation Agency (JICA) is supporting the establishment of a National Spatial Data Infrastructure (NSDI) in Bangladesh, focusing on agriculture management. The current project aims to create accurate thematic maps of rice areas in Manikganj Sadar Upazila, using satellite images and GIS technology, addressing the urgent need for precise data to enhance agricultural planning and food security. The objectives include delineating rice areas for both Rabi and Kharif seasons, developing a crop database, and building GIS and RS expertise for precision agriculture. The geographical context of Manikganj Sadar Upazila is described, highlighting its significance in the region's agricultural economy. The project aligns with national policies emphasizing the digitization of agricultural services to meet future challenges and contribute to various planning processes.

The methodology employed in this study for identifying and monitoring major crops during the Rabi season is marked by its comprehensive and advanced approach. Leveraging remote sensing technology, particularly Sentinel 1 and Sentinel 2 imagery, the methodology integrates diverse data sources, including drone data, orthophotographic imagery, and field surveys. The process encompasses meticulous steps such as image preprocessing, crop signature preparation, quality control, and the creation of season-specific agricultural masks. Utilizing machine learning, specifically the Random Forest algorithm, the report achieves robust image classification. The image classification methodology implemented in this study involves a meticulous process, beginning with image segmentation using ArcGIS Pro and its Image Analyst Extension. The methodology also includes model training, raster classification, and crucial post-processing steps to refine the classified raster image, eliminating misclassifications and enhancing overall accuracy. The outcome is a highly reliable and precise crop map, contributing significantly to agricultural monitoring and informed decision-making in Bangladesh's agricultural context.

This study investigates the efficacy of Sentinel-1 and Sentinel-2 satellite imagery for crop identification and area estimation in Bangladesh during the Rabi season. Employing three data stacks, including a fusion of both Sentinel-1 and Sentinel-2, rigorous image classification achieved a thematic accuracy of over 92%, offering valuable insights for agricultural management. The crop maps, particularly those derived from the combined imagery, demonstrated superior accuracy, with Sentinel-1 excelling in estimating rice crop areas due to all-weather capability, and Sentinel-2 providing high-resolution multispectral data for precise crop discrimination during cloud-free conditions. The synergy of both datasets enhanced classification accuracy, contributing to detailed insights into cultivation areas and reliable crop statistics. Accuracy assessments underscored the robustness of the classification process, with the combined imagery (Sentinel 1 and Sentinel 2) achieving an impressive overall accuracy of 92%. The report concludes that integrating Sentinel-1 and Sentinel-2 data is optimal for year-round crop monitoring, addressing

challenges posed by varying weather conditions and contributing to sustainable agricultural practices and food security.

The Kharif 2 Crop Signature Data Collection, conducted in the Manikganj Sadar Upazila region of Bangladesh, focused on leveraging the Survey123 app for comprehensive agricultural data gathering during the Kharif 2 season. Four surveyors utilized the app over seven days, collecting 465 crop signatures encompassing crucial information such as crop types, planting dates, growth stages, and soil conditions. The Survey123 app, with its user-friendly interface, facilitated efficient data entry through a detailed questionnaire covering various aspects of crop growth. The data, crucial for remote sensing-based crop classification, highlighted the importance of precise information for future agricultural planning and monitoring. The report emphasizes the successful execution of the data collection process and underscores the significance of the collected dataset for advancing crop classification endeavors in the context of the Kharif 2 season.

The study concludes that the combined use of Sentinel 1 and Sentinel 2 imagery offers substantial potential in accurately estimating crop areas, particularly for rice cultivation. The success of this approach relies on timely and precise field data, forming the basis for machine learning-based remote sensing models. Sentinel 1's sensitivity to water content enhances rice crop estimation, while Sentinel 2's ability to capture cloud-free data proves crucial for winter crop monitoring. The study emphasizes the necessity of integrating both datasets for a more comprehensive understanding of the agricultural landscape. Lessons learned underscore the importance of diverse Earth observation data sources for accurate crop area estimation, contributing to sustainable agricultural practices and food security. The sustainability arrangement outlines key aspects, including remote sensing technology, GIS integration, data processing with machine learning, collaboration, precision agriculture, smart irrigation, climate resilience planning, community engagement, certification programs, policy support, and monitoring and evaluation. However, challenges such as weather conditions, availability of ground truth data, technical issues, and resource constraints are acknowledged. The way forward recommends weather monitoring, collaboration with local stakeholders, regular maintenance, flexibility, and adaptability to overcome challenges and ensure project success.

Acronyms

AI	Artificial Intelligence
BARC	Bangladesh Agricultural Research Council
DPS	Data Product Specifications
GIS	Geographic Information System
GPS	Global Positioning System
JICA	Japan International Cooperation Agency
MSI	Multispectral Imager
NSDI	National Spatial Data Infrastructure
NSDI-WG	National Spatial Data Infrastructure Working Group
QC	Quality Control
RTK	Real-time kinematic
SDG	Sustainable Development Goal
SoB	Survey of Bangladesh
ToR	Terms of Reference
UAV	Unmanned Aerial Vehicle

Acknowledgment

We would like to convey our heartfelt gratitude to Dr. Farida Perveen, Deputy Director and In-charge of GIS and Remote Sensing Unit, Department of Agricultural Extension (DAE), Khamarbari, Dhaka for her invaluable advice, necessary guidance, information, stimulating discussions and comments as well as her valuable assistance throughout the project period in completing the project. She was there to assist us every step of the way, and her motivation is what enabled us to accomplish our task effectively. We express our sincere thanks and appreciation to all the core and support members of the NSDI Model Project for supporting and providing necessary suggestions and guidance.

We would also like to thank other supporting personnel who assisted us by supplying the equipment that was essential and vital, without which we would not have been able to perform efficiently on this project.

We deeply thank JICA for financial support of the NSDI Model Project and for your funding we have accomplished your goals and targets properly.

Sincere thanks to Survey of Bangladesh for providing us the secondary GIS data layers to support the NSDI Model Project.

We would also like to thank our colleagues for their support and encouragement as we worked on this project from March 2023.

We would like to acknowledge different Govt. agencies for their collaboration and permitting access to necessary data, information, maps, reports, and other resources.

We express our sincere thanks to Hattori san, JICA expert for supporting and providing necessary guidance, discussions, and comments on developing DPS.

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1. Introduction

1.1. Background and Rationale

Rice is considered as a major crop worldwide which occupies more than 12% of crop land globally. Rice is a staple food for more than 50% of world population [1]. The contribution of agriculture is very important in the economy of Bangladesh and in the socio-economic development of the rural population. The agriculture sector is playing a vital role in meeting the challenges of the food and nutrition needs of the growing population and achieving food self-sufficiency through increasing agricultural production. Bangladesh is an agrarian country where agriculture is contributing 14.22% of the Gross Domestic product (GDP)[2]. Bangladesh is now the second largest rice producer [1]. The World Bank has reported that agricultural lands occupy 70.63% of total land of Bangladesh [3]. Rice crop covers about 76.7% of agricultural land in Bangladesh [4]. Rice is used as staple food for about 156 million population in Bangladesh [2]. Now, it is important to increase the rice production for feeding the ever-increasing population [2]. When economy around the world are in crisis due to the impact of COVID-19, all emphasis are now given on food security and agricultural production systems. However, due to rapid urbanization, a great transformation has been taken place in Bangladesh which has been estimated that 199.91 acres of agricultural lands are converted into nonagricultural activities such as, cities, roads and other infrastructures [5]. Besides the urbanization, the changing food habits, introducing new crops, the changing precipitation pattern and the rising global temperature are creating a substantial challenge to rice cultivation [1, 2]. Likewise the urbanized Dhaka city, the agricultural lands of Manikganj sadar upazila are transformed into different infrastructural development [5]. Though Manikganj sadar upazila has better communication system, residential facilities as well as food supply for the capital Dhaka city, it needs a proper planning for sustainable land use system [6]. The future of third world countries in particular now depends largely on the long-term success of agricultural production systems. Therefore, the use of new digital technology in agricultural production is the demand of the time because it is possible to change the future agriculture through disseminating new modern technology.

One of the primary challenges in providing agricultural extension services in Bangladesh is the limited use of modern agricultural technology in the agricultural sector. As a result, estimating the total amount of cultivable land in the country is a challenging task, and it is also difficult for government policymakers to make the appropriate decision at the right moment. Furthermore, there is no modern technology for monitoring arable land, gathering crop production data, and no precise database of crop area and production. So, it is necessary to fundamentally change the traditional agricultural system using information technology and introduce digital smart agriculture as well as modern digital agricultural production system. The spatial distribution of rice fields is urgent for effectively monitoring and estimating rice production in time [7]. Accurate mapping of rice field is an important consideration for ensuring food security, sustainable development and socio-economic development [1]. So, accurate rice area estimation is now urgent for the country. Due to climate change, overpopulation, and increased use of agricultural land in the non-agricultural sector, the amount of arable land/rice area continues to decline drastically, which will pose a huge threat to future food security. But the amount of declining cultivable land is still being calculated on the basis of traditional knowledge of the farmers and

using eye-estimations by The Department of Agricultural Extension (DAE) agents. As a result, precise crop area statistics are not available. This is creating a big problem in making proper plans at national level/policy level.

Crop monitoring is an important part of agricultural management. Crop monitoring activities ensure the necessary advice to the farmers while they are in the field. Crop monitoring is basically a bottom-up approach. Subsequently, various monitoring teams consisting of officials of Upazila, District, Regional Offices and Headquarters monitor the condition of field crops and provide necessary advice to the farmers for proper crop production. However, this traditional crop monitoring system is time-consuming and laborious job. Therefore, a concise and efficient mapping method is required for field crop monitoring and mapping to know the amount of total crop land.

The DAE sets national targets for the next year's crop production based on previous year's production. Crop production forecasting is carried out through crop area estimation and crop yield estimation which is often a time-consuming task, costly and there has some possibility of errors [4]. In this case, the use of satellite image can contribute for obtaining information in periodic interval which is economical as well [4]. If this project is being implemented using modern technology, the amount of rice area will be determined based on district/upazila/union, which will help to take the right decision in preparation of upazila master plan. In addition, through the use of modern information technology, information can be processed and databases can be created to provide, collect and present information in the fastest time.

According to Information and Communication Technology (ICT) Policy 2018 of Bangladesh, Action Plan No. 6.4.3 and 6.4.4 it will be possible to adopt Precision Agriculture activities through Geographic Information System (GIS) and Remote Sensing (RS) through proper crop planning, fertilizer recommendation, applied research and innovation in Agriculture. Above all, it will be possible to modernize the agriculture sector and ensure food security through the application of digital information technology as per the work plan 8.4 of the ICT Policy 2018.

Therefore, it is the highest important issue to introduce digital smart agriculture through using modern technology such as GIS and satellite based RS technology for rice area mapping in our agriculture management system.

Japan International Cooperation Agency (JICA) has been assisting the Ministry of Defense (MoD) and Survey of Bangladesh (SoB) on their responsibility not only to formulate a legal framework and form an organizational structure on the National Spatial Data Infrastructure (NSDI), but also to create a geographic information standard and develop a database system of geospatial information and a web GIS platform. In the previous project from 2017 to 2018, 'Project for Strengthen the Capacity on Advanced Mapping of SoB for Building Digital Bangladesh', a roadmap for establishing the NSDI was drafted to facilitate building of the NSDI, the NSDI Pilot Project Working Group was formed, and a small-scale prototype system was created as a pilot project in order to demonstrate the NSDI concept and usefulness, and verify technical and operation issues in 2018.

JICA has launched the Project for Establishment of National Spatial Data Infrastructure (NSDI) in Bangladesh (NSDI-BD project) in August 2019. In this project, NSDI Working Group (NSDI-WG) was established to operate and promote utilization of NSDI platform, and three NSDI Utilization Model Projects (hereinafter referred to as NSDI-MPs), namely 'Agriculture Management', 'Disaster Management' and 'Water Management' were taken up at the 5-day

workshop held in March 2022 to produce thematic maps proposed by NSDI-WG Members (NSDI-WGMs). These NSDI-MPs are to be implemented in cooperation and ownership of all NSDI-WGMs. To smoothly implement the NSDI-MPs, support of a local consultant (hereinafter referred to as 'Consultant') to 'NSDI-MP on Agriculture Management' is necessary.

Bangladesh is an agriculture-based country. Cultivable crop land in the country is constantly decreasing alarmingly while the population is increasing. Nevertheless, still the declining cultivable crop land is calculated using a traditional system and based on farmers' knowledge. As a result, precise crop area statistics are not available which is creating a big problem in making proper plans at national level / policy level. From the national policy level, to name some of them, The National ICT Policy 2018, the National Agriculture Policy 2018, The National Agriculture Extension Policy 2022, SDGs, the 8th Five Year Plan among others emphasize on the need for digitization of the agricultural services. Therefore, Bangladesh must have to change the traditional agriculture system and introduce smart agriculture (or e-Agriculture). On this background, the findings and methodology of this model project is expected to greatly help implement the large-scale crop area estimation in near future and also the government's various planning processes.

This Terms of Reference (ToR) outlines the objectives, scope and other necessary conditions for the 'NSDI-MP on Agriculture Management' consulting work (hereinafter referred to as 'Work') for the Consultant. Refer to Appendix 1 for the Inception Report of the Model Project.

1.2. Objectives

The purpose of the Work is to collect data, and create necessary data layers (datasets) and produce the agricultural thematic map titled ' Area Mapping of Manikganj Sadar Upazila using Medium Resolution Satellite Images ' in a scientific way with members of NSDI-MP. In addition, this Work also involves tasks of providing technical advice and support as well as trainings to members of 'NSDI-MP on Agriculture Management' to create data layers and a thematic map by GIS software for their capacity development. The specific objectives of the Work are as follows:

i. To delineate rice area map of Rabi season (winter season) of Manikganj Sadar Upazila using medium resolution satellite image
ii. To delineate rice area map of Kharif season (summer season) of Manikganj Sadar Upazila using medium resolution satellite image
iii. To prepare accurate crop database for location specific / better agricultural extension services and to help policy makers for proper planning
iv. To select crop cutting location based on scientific method
v. To develop skilled manpower in GIS and Remote Sensing technology for introducing precision agriculture systems

1.3. Geographical Settings of the Study Area

Manikganj Sadar Upazila is one of the seven administrative subdivisions in the Manikganj District of Bangladesh. It is situated in a strategic location with specific geographical and demographic characteristics. Details of the study area is given below:

i. Geographical Boundaries: Manikganj Sadar Upazila is geographically defined by its neighboring upazilas. It is bounded to the north by Saturia Upazila, to the east by Singair

Upazila, to the south by Harirampur Upazila, and to the west by Shivalaya Upazila and Ghior Upazila. These administrative boundaries help define the region's limits.

ii. Distance from Dhaka City: The study area is approximately 50 kilometers away from Dhaka city, making it easily accessible from the capital. This proximity to Dhaka has implications for transportation, trade, and other economic activities.

iii. Population Density and Total Area: The population density in the study area is approximately 4.5 individuals per acre. The total land area of Manikganj Sadar Upazila is 53,080 acres, contributing to its overall demographic and agricultural characteristics.

iv. Administrative Divisions: Manikganj Sadar Upazila is subdivided into eleven unions. Among these, Pourashova serves as the central urban hub of the upazila, playing a pivotal role in local governance and administration.

v. Climate and Environmental Conditions: The study area experiences a range of temperatures, with the highest average monthly temperature reaching 35.1°C and the lowest at 14.2°C. Humidity levels vary between 56% and 83%, contributing to the region's climate. The soil primarily consists of young active Brahmaputra flood plain, characterized by silty and sandy alluvial soil.

vi. Agricultural Economy: Agriculture is the primary source of income for a significant portion of the population in Manikganj Sadar Upazila. Approximately 43.43% of households depend on agriculture as their main source of income, with 27.49% engaged in cropping, livestock, forestry, and fishery, and 15.94% working as agricultural labor.

vii. Cultivated Crops: The major agricultural crops grown in the region include Rice, Jute, Wheat, Pulses, Oilseeds, Vegetables, Spices, Potato, and Sweet Potato. Boro rice covers the largest cultivated area, followed by Aman and Aus rice varieties.

viii. Manikganj Sadar Upazila's geographical and demographic characteristics make it a vital part of the Manikganj District.

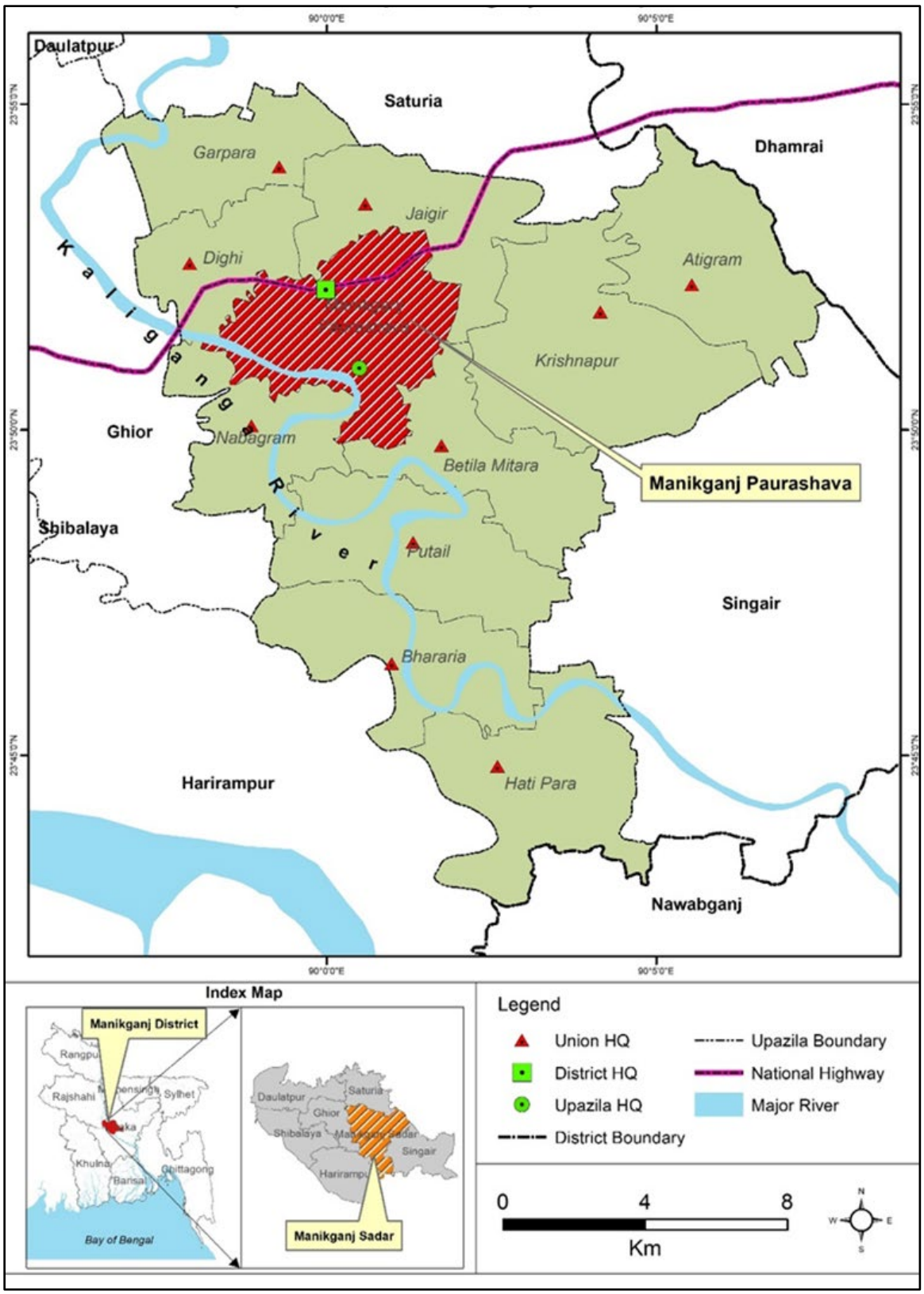


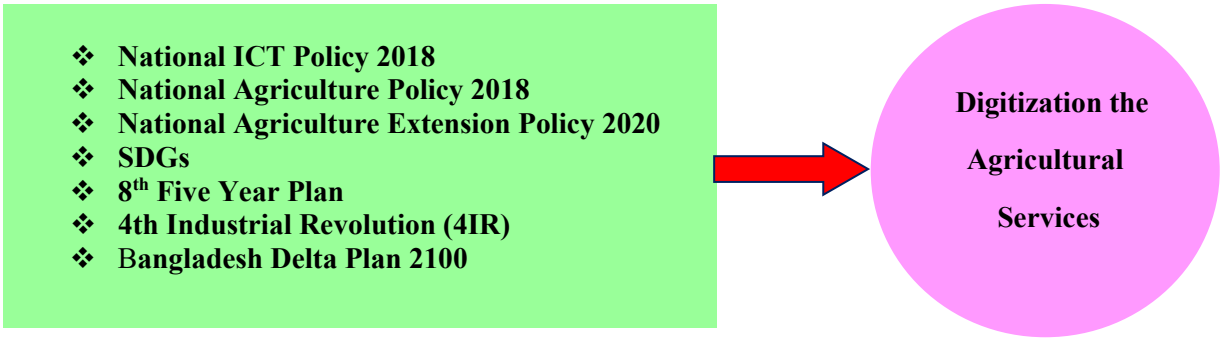
Figure 1-1: Study Area Map

1.4. Scope of work

With the use of modern digital technologies such as GIS, Global Position System (GPS), RS technology, it is possible to provide modern digital services in agriculture by using location specific agricultural technology to determine the amount of crop land, crop monitoring and crop mapping. It is now easier to automate crop monitoring and crop mapping systems using a variety of satellite images through remote sensing technology than the current time-based monitoring method. Through crop mapping, it is easy to know which crop is being cultivated in which area at present and accordingly, which crop is likely to be cultivated in which area in future.

Therefore, this model project has been formulated focusing an agricultural development with modern technology in line with the 8th Five Year Plan (July 2020 – June 2025) 4th Industrial Revolution (4IR), Sustainable Development Goals (SDGs), ICT Policy 2018, National Agriculture Policy-2016 and National Agricultural Extension Policy-2020 for the purpose of introducing digital smart agriculture / modern digital agricultural production system for rice area mapping. Using GIS and satellite based remote sensing technology in crop field, low-cost crop monitoring in a short time, automatic quantification of cultivable land, crop mapping of districts/ upazilas/Unions can be successfully done. Furthermore, the use of modern information technology will help to process information and create databases which can be provided, collected and presented at the fastest time to the decision makers.

Bangladesh Government has formulated several policies and plans to promote smart agricultural extension services in agriculture. We have many policy documents focusing on agriculture sector. All these policies support to digitaize the agricultural servies and disseminate these services to the the farmers of grass root level of Bangladesh.



The following is subject to change, based on needs and requirements:

i. Consult with the Team Leader (primarily) and other Model Project members (when necessary) on a regular basis to conduct needs assessment related to the Model Project.
ii. Identify information to be collected as primary and secondary data, and required tools and equipment including hardware and software, develop a robust methodology and formulate a comprehensive project proposal (as an Inception Report) to achieve the project objectives.
iii. (Conduct field survey, collect primary and secondary data, organize and process the data to produce necessary data layers (datasets) and the thematic map.
iv. Prepare Quality Control (QC) and Data Product Specifications (DPS) of the produced datasets.

v. Provide advice and capacity building trainings to the project members and/or other staff members in the project members' organization.
vi. Work on relevant assignments when required by the Team Leader of the Model Project.

1.5. Work items & implementations schedule

Proposed activities:

i. Papering of work plan
ii. Organizing inception workshop
iii. Collection of existing data from different organizations
iv. Development of customized software (Mobile Apps)
v. Collection of Ground Control Points (GCPs)
vi. Collection of Ground Truth data
vii. NDVI analysis of different growth stages of rice
viii. Satellite image pre-processing
ix. Satellite image processing and classification
x. Validation/accuracy assessment of classified satellite image
xi. Organizing workshops and seminars
xii. Training on geospatial data analysis for capacity building of DAE, BARC & SRDI, SoB personnel on GIS & RS
xiii. Producing thematic maps/rice crop maps
xiv. Selection of crop cutting location based on scientific method for crop yield estimation
xv. Creation of different geospatial data layers and DPS for NSDI portal
xvi. Preparing reports and publications

Table 1.1: Implementation Schedule

	Activities	2022			2023											
Months		O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
1	Submission of Draft Inception Report															
2	Feedback on Draft Inception Report by JICA															
3	Final Inception Report															
4	NSDI Utilization MP Inception Workshop															
5	Collection of existing data from different organizations															
6	Collection of Ground Control Points (GCPs)															
7	Collection of Ground truth data															
8	Satellite image collection															
9	Satellite image pre-processing, processing and classification															
10	NDVI analysis of different growth stages of rice															
11	Accuracy assessment of classified satellite image															
12	Progress Report															
13	NSDI Utilization MP Progress Workshop															
14	Training on geospatial data analysis for capacity building															
15	Producing thematic maps of rice crop															
16	Selection of crop cutting location based on scientific method for crop yield estimation															
17	Creation of geospatial data layers and DPS for NSDI portal															
18	Draft Final Report															
19	Final Report															
20	NSDI Utilization MP Concluding Workshop															

Table 1.2: Implementation Schedule Work items and implementation schedule with budget

S.N.	Work Item / Staff etc.	Jan-23	Feb-23	Mar-23	Apr-23	May-23	Jun-23	Jul-23	Aug-23	Sep-23	Oct-23	Nov 23	Dec-23	Cost (BDT)
														Sub-total
1	Collection of Ground Control Points (GCPs)	5000	5000											20,000
2	Collection of Ground Truth Data	300000												450,000
3	Remote Sensing Analyst		50000											200,000
4	GIS Analyst		30000											100,000
5	Training on Field Data Collection & Geospatial Data Analysis		30000											30,000
6	Miscellaneous (QC, DPS, Data Finalization, Report etc.)	50000												200,000
	Total cost	**470000**												**1,000,000**

1.6. Project Team members

CORE MEMBERS					
Sl.	**Name**	**Organization**	**Role**	**E-mail & Phone no**	**Responsibility**
1	Dr. Farida Perveen	DAE	Team Leader		Overall supervision and management the project
2	Hasan Md. Hamidur Rahman	BARC	Core Member		Support to Team Leader
3	Mohammad Moniruzzaman	SRDI	Core Member		Support to Team Leader
4	Md Abdul Alim Sikder	SoB	Core Member		Support to Team Leader
5	Esmet Ara	SoB	Core Member		Support to Team Leader
6	Mahbuba Haque	SoB	Core Member		Support to Team Leader

7	Abid Kamal	CEGIS	Core Member		Support to Team Leader
SUPPORT MEMBERS					
8	Md Alauddin	SoB	Support Member		Cooperate when assign
9	Mrs. Ismat Ara Begum	SoB	Support Member		Cooperate when assign
10	Dr. Mahmudur Rahman	SPARRSO	Support Member		Cooperate when assign
11	Mohd. Moniruzzaman	DLRS	Support Member		Cooperate when assign
12	Mohammad Zakir Hossain	LGED	Support Member		Cooperate when assign
13	Md. Hasan Hasibur Rahman	DoE	Support Member		Cooperate when assign
14	Shamima Begum Shewli	FD	Support Member		Cooperate when assign
15	Md. Mahmud Hasan	PKSF	Support Member		Cooperate when assign
16	Md. Saidur Rahman	BBS	Support Member		Cooperate when assign
17	Md Ziaur Rashid	BRDB	Support Member		Cooperate when assign

1.7. Kick-off meeting and meeting with working group members

A kick-off meeting was organized on 15th April 2023 at BARC premises to introduce the project team members of both consultant and NSDI and to present the capacity of consultant to meet the expectations of the client and to commence the project activities in a favorable environment. It was a successful participatory meeting. The team leader of agricultural management group presented the inception report. The methodology of image collection, pre-processing and ground truthing and other technical issues were discussed in the meeting. Minutes of the commencement meeting is attached in the annex-1.



Figure 1-2: Commencement Meeting At BARC

Progress meeting of agriculture management group of NSDI model project took place at the conference room of Department of Agricultural Extension (DAE) on 20 September 2023. Team leader, all core members and consultant of model project were participated in the meeting.



Figure 1-3: Progress Meeting At DAE

2. Methodology

2.1. Introduction

The accurate identification of crops based on their geographical distribution holds significant importance for a multitude of critical purposes. It plays a pivotal role in forecasting grain supplies, gathering comprehensive crop production statistics, facilitating the maintenance of crop rotation records, pinpointing factors that influence crop stress, evaluating damage sustained by crops due to adverse weather conditions like storms and droughts, and monitoring agricultural activities. These aspects collectively contribute to the fundamental objective of ensuring food security and empowering policymakers with timely, well-informed insights.

In the realm of modern technology, remote sensing offers an efficient and dependable approach for procuring the requisite data to map various crop types and their respective areas. Leveraging remote sensing technology for the identification and continuous monitoring of diverse crops equips governments with precise and timely data concerning crop production. This valuable information serves as a cornerstone for the formulation of policies related to critical areas such as food security, trade regulations, and agricultural subsidies.

2.2. Methodology

The process of identifying primary crops using remote sensing techniques and quantifying the crop area, is a crucial component of agricultural management and planning. This procedure entails the collection of boundary data for the study area, the creation of a map delineating this area, and the gathering of information on crop varieties and their spatial distribution within the project boundaries. A variety of data sources, including satellite imagery and field surveys, can be utilized to execute this comprehensive process. The accuracy of these estimates is subsequently verified by juxtaposing them with ground-truth data obtained from field surveys or other reliable sources, followed by necessary refinements. The precision of crop area estimation is vital for informed decision-making in agricultural practices and policy formulation. This intricate process comprises several stages, each of which is detailed below, accompanied by a comprehensive workflow diagram shown in figure 2.

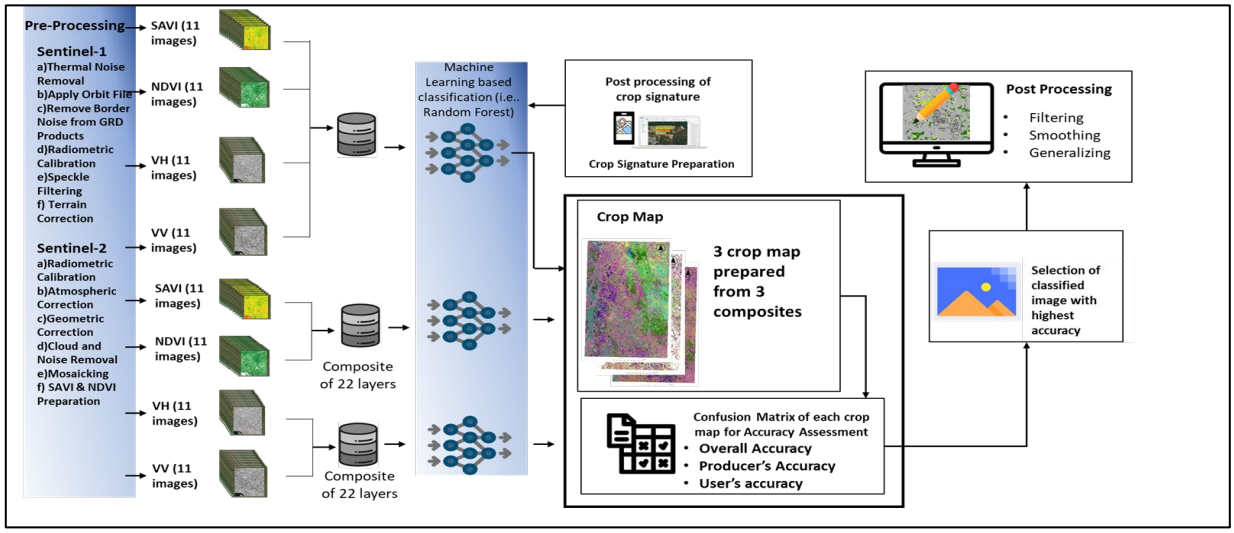


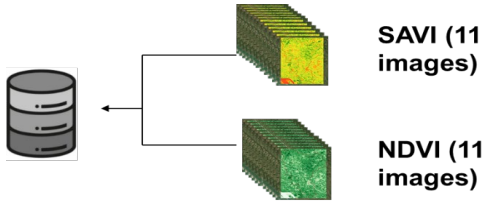
Figure 2-1: Workflow Diagram

In the pursuit of major crop identification during the Rabi season, a meticulous methodology was adopted, integrating a diverse array of data sources. A graphical representation of this meticulous methodology is illustrated in the accompanying diagram, providing a detailed overview of the process.

Before commencing image classification, Sentinel 1 and Sentinel 2 imagery underwent thorough preprocessing to ensure the data's quality and suitability for analysis. This preprocessing phase included radiometric and geometric corrections, as well as the removal of noise and artifacts. Calibrated and atmospherically-corrected imagery was vital for accurate crop identification.

Image classification was carried out on three primary data stacks, each contributing distinct insights into the crop identification process:

Sentinel 2 NDVI and SAVI Stack: This data stack harnessed spectral information from Sentinel 2 satellite imagery, specifically incorporating the Normalized Difference Vegetation Index (NDVI) and Soil-Adjusted Vegetation Index (SAVI). Figure 3 shows the composite band creation process from Sentinel 2 imagery.



Sentinel 1 VV and VH Polarization Stack: Leveraging radar data, this stack focused on both the Vertical Vertical (VV) and Vertical Horizontal (VH) polarizations, drawing from Sentinel 1 imagery. Figure 4 shows the process of making stack of 11 VV and 11 VH images from Sentinel 1 imagery.

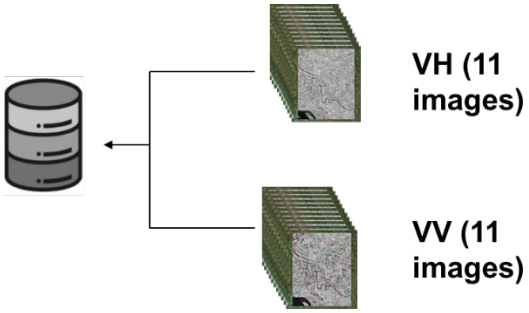


Figure 2-2: Creation of Stack from Sentinel 1 Imagery

Combined Stack of Sentinel 2 and Sentinel 1 Data: A powerful integration of both optical and radar data sources, this stack combined Sentinel 2's NDVI and SAVI data with Sentinel 1's VV and VH bands.

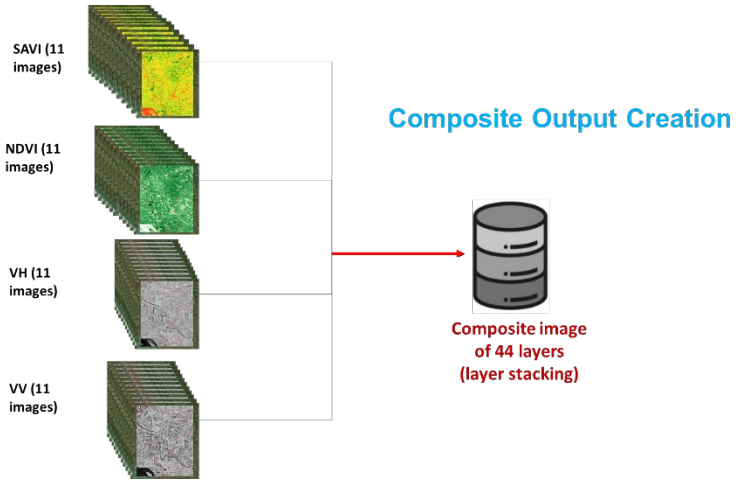


Figure 2-3: Creation of Composite Image from 44 Bands

Moreover, the compilation of an extensive dataset comprised a total of 1000 crop signatures, each serving as a critical reference point for the identification process. These signatures were collected through a multifaceted approach. A portion of these signatures was meticulously gathered by capturing drone data from a selected sample area. Additionally, some signatures were digitized from orthophotographic imagery, adding depth and precision to the dataset. This comprehensive data collection process was executed from February to April, precisely coinciding with the winter season crops. Kobo Toolbox was the chosen tool for systematic and uniform field data collection. This meticulous amalgamation of diverse data sources and the subsequent application of machine learning (Random Forest) in crop classification resulted in robust and accurate crop identification. The highest level of accuracy was achieved through the classification of the combined data stack, which seamlessly integrated optical and radar data. This approach, underpinned by sound methodology and extensive data resources, contributes significantly to the enhancement of informed decision-making in agriculture and land management.

2.3. Crop Signature Data collection

The data collection process for crop signatures during the Rabi season is characterized by its meticulous and comprehensive nature. It commences with the careful preparation of a robust procedure for data collection, followed by the implementation of Kobo Toolbox to ensure systematic and uniform field data gathering. Additionally, a portion of the data is meticulously digitized from drone imagery. this drone imagery was captured during field visit. however, this data collection process unfolds through several distinct phases, each of which is elaborated in the following section.

2.3.1. Crop signature collection

Crop signature collection is a rigorous process. The signatures are collected from the field. Surveyors were sent to the field. A survey form was created using Kobo Toolbox to collect the data and send it to the server through Kobo Toolbox using Smartphone application. First field visit was conducted in 21 January 2023. Figure 6 shows the photos of first field visit.



Figure 2-4: First Field Visit

On the 23rd of February, 2023, a second field visit was meticulously carried out. This visit was an integral part of our ongoing efforts to gather comprehensive data and insights. A visual representation of the activities and observations made during this visit is captured in Figure 7. This image serves as a testament to the rigorous fieldwork conducted on this day and provides a detailed account of the proceedings.



Figure 2-5: Second field visit





Figure 2-6: Third field visit

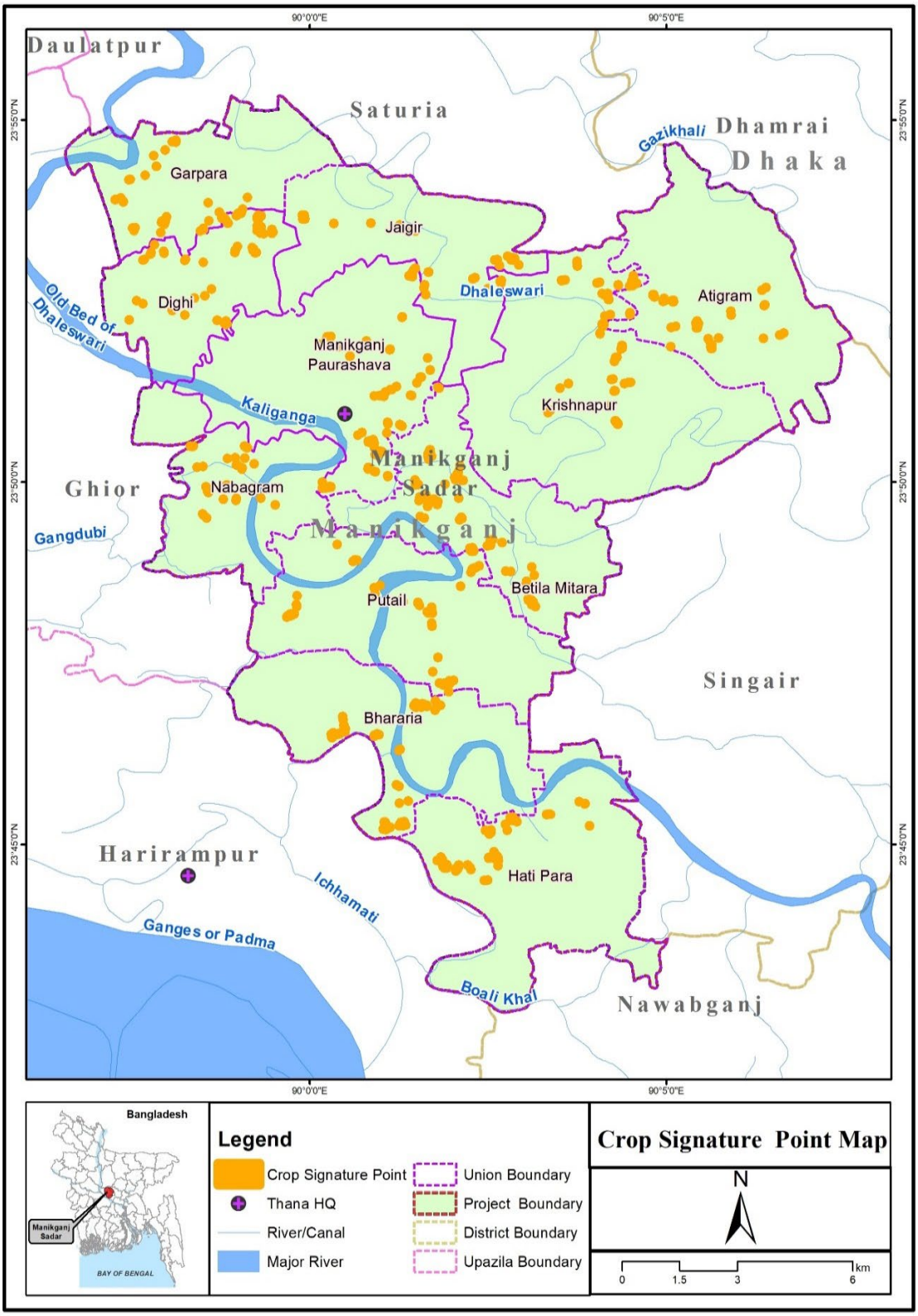


Figure 2-7: Crop Signature Point Map

2.3.2. Crop calendar Data Collection

Furthermore, crop calendars are indispensable in the realm of remote sensing and crop signature field data collection. They provide a structured time-based framework for understanding the growth and development of crops throughout the agricultural season. This temporal alignment offers several advantages, including precise data collection planning, training data selection for machine learning, and accurate crop classification. The defined growth stages in the calendar guide researchers in scheduling field visits, remote sensing data acquisition, and drone flights at optimal times, ensuring that data is collected when crops exhibit distinctive spectral and spatial characteristics. Additionally, ground truth data collected during field visits aligns with specific crop growth stages, serving as reference points for remote sensing and image classification. The temporal consistency facilitated by crop calendars, with data collected consistently across seasons and years, is valuable for creating time series data. This time series data is critical for monitoring changes in crop health and land use patterns over time. Moreover, crop calendars aid in precision crop classification by allowing remote sensing technology to effectively distinguish between different crops based on their spectral and spatial characteristics. This temporal synchronization enhances the accuracy of crop classification models and supports informed land use planning and harvest forecasting, crucial for food security and market planning. Hence the crop calendar of Bangladesh is collected from DAE. Figure 8 shows the crop calendar.

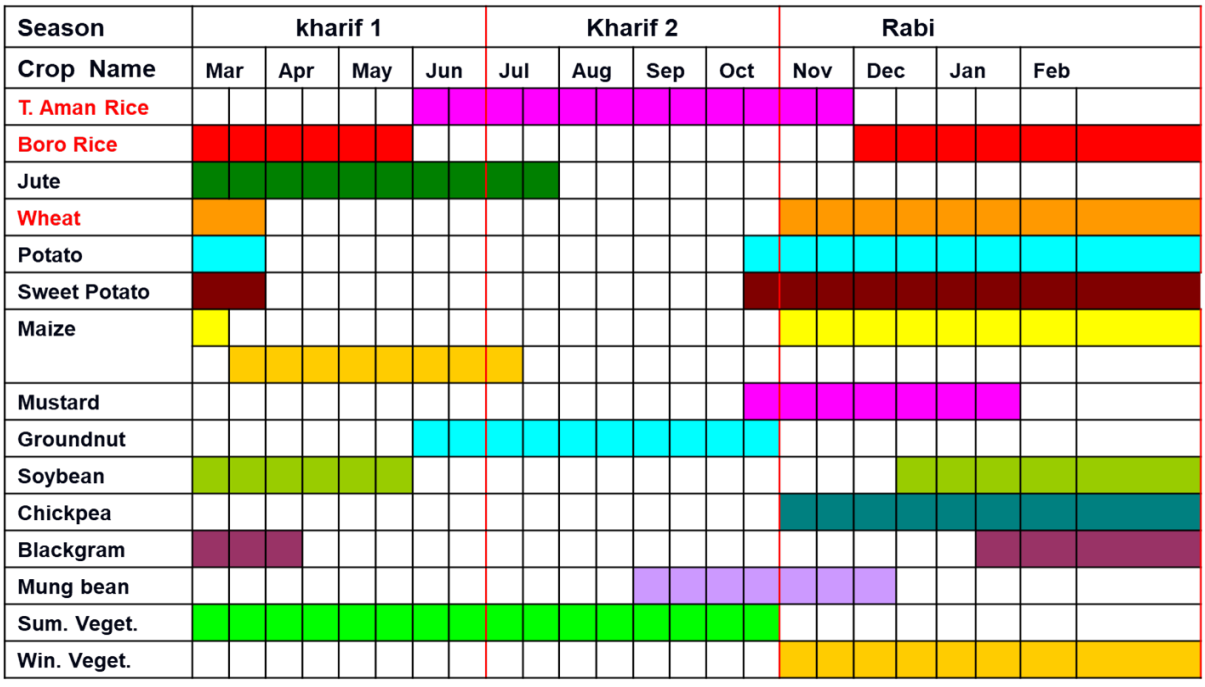


Figure 2-8: Crop Calendar of Bangladesh

2.3.3. Drone Imagery Capture and Crop Signature Digitization

Ground control point data collection, an essential step in ensuring high position accuracy, was executed using Real-Time Kinematic (RTK) GPS technology. A minimum of 20 points were collected for each feature, guaranteeing precision in geospatial positioning. For other crops

and land use data, standard GPS devices and mobile technology were employed. The survey plan for ground truth data collection is shown in below figure. The ground truth data were collected using Kobo Toolbox.

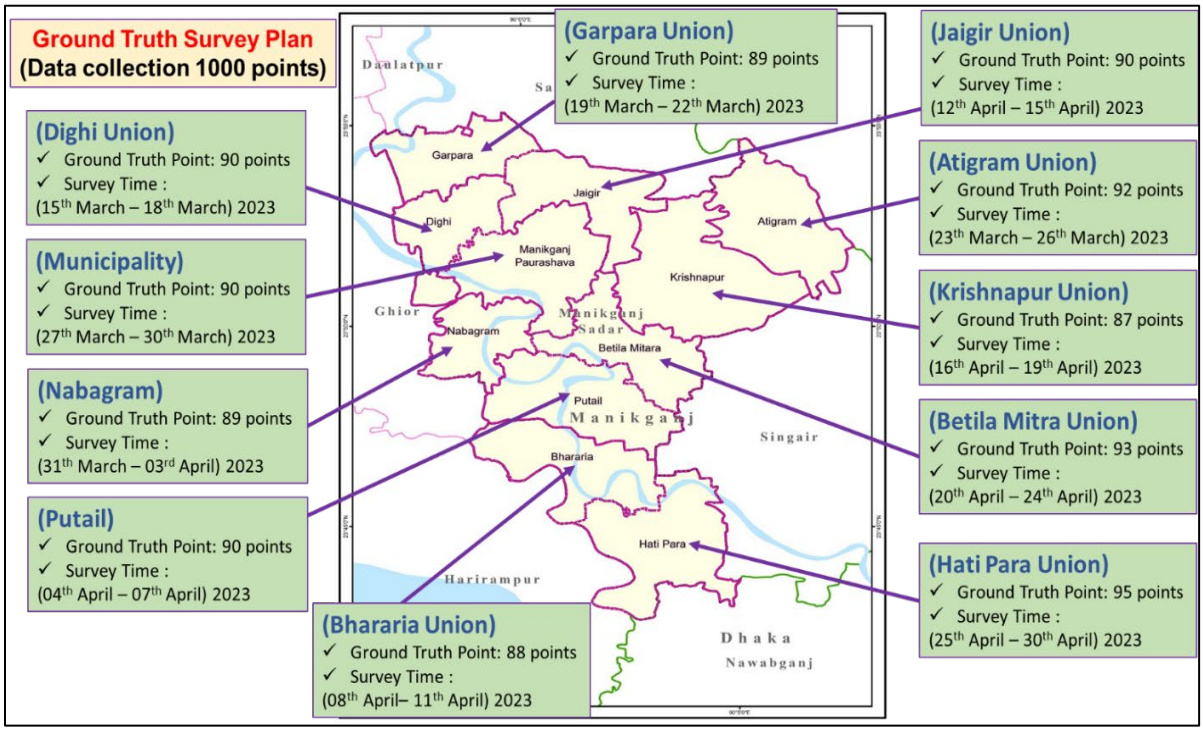


Figure 2-9: Ground Truth Data Collection Survey Plan





Figure 2-10: Setup for GCP Collection



Figure 2-11: Ground truth data colletion using KoboToolbox

In addition to ground control points, drone imagery played a pivotal role in data collection. A comprehensive drone survey was conducted, capturing imagery that was subsequently pre-processed to create orthophotos. The generated drone image served as the foundation for preparing crop polygons, a vital element in the study's data collection process.



Figure 2-12: Drone Survey and Aerial Photos

The integration of Real-Time Kinematic (RTK) Global Positioning System (GPS) technology for ground control point collection and the utilization of drone technology for imagery acquisition culminated in a robust and comprehensive data collection process. This synergistic approach not only facilitated precise geospatial positioning but also leveraged the benefits of drone technology for capturing high-resolution imagery and generating orthophotos.

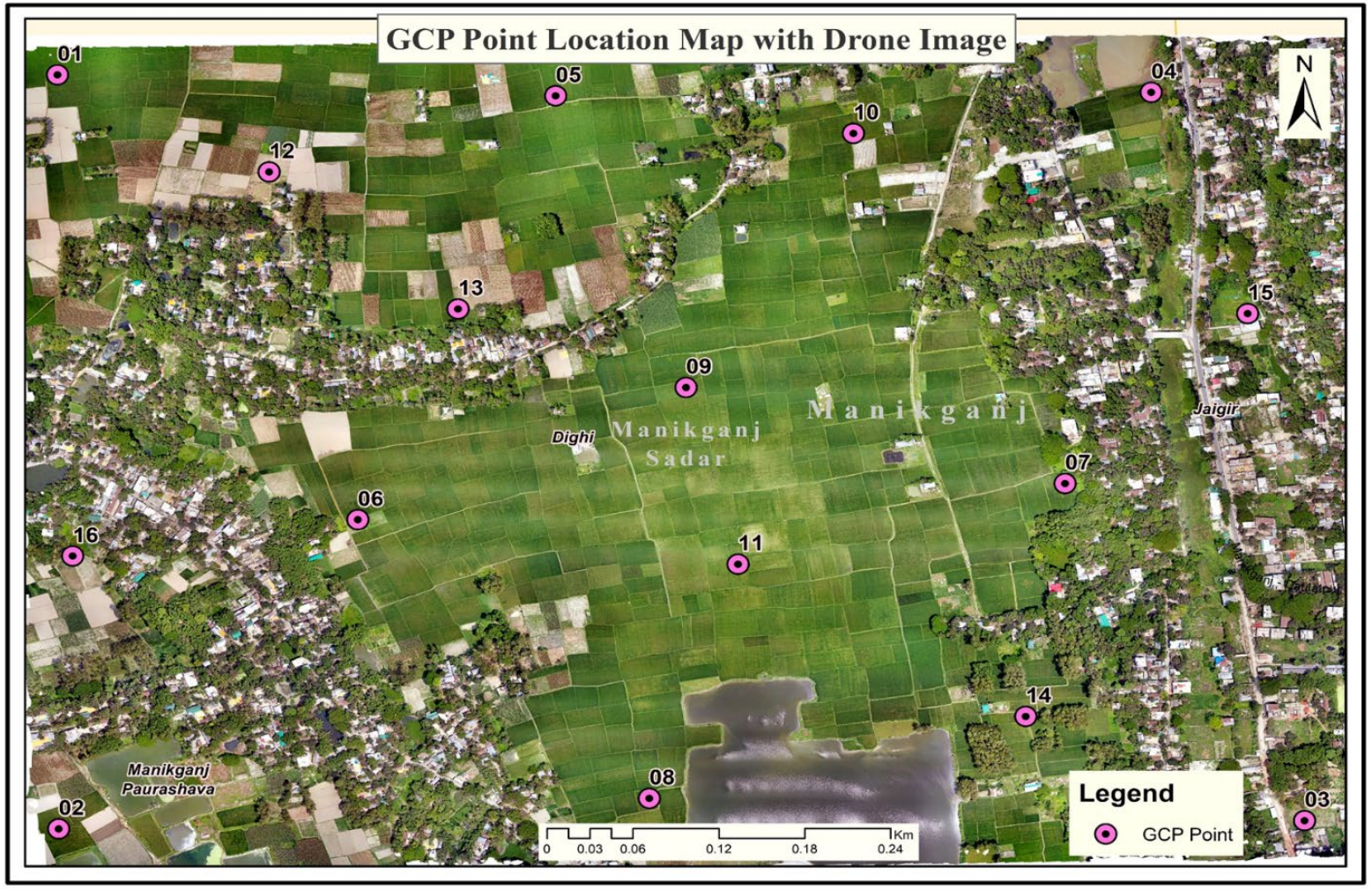


Figure 2-13: GCP point location map with drone image

This holistic methodology was instrumental in digitizing crop signatures derived from the drone imagery, thereby enhancing the precision and effectiveness of the study. The drone imagery, prepared through meticulous drone surveys, is depicted in Figure 12. This image stands as a testament to the advanced technological integration employed in our data collection process, underscoring our commitment to accuracy and detail.

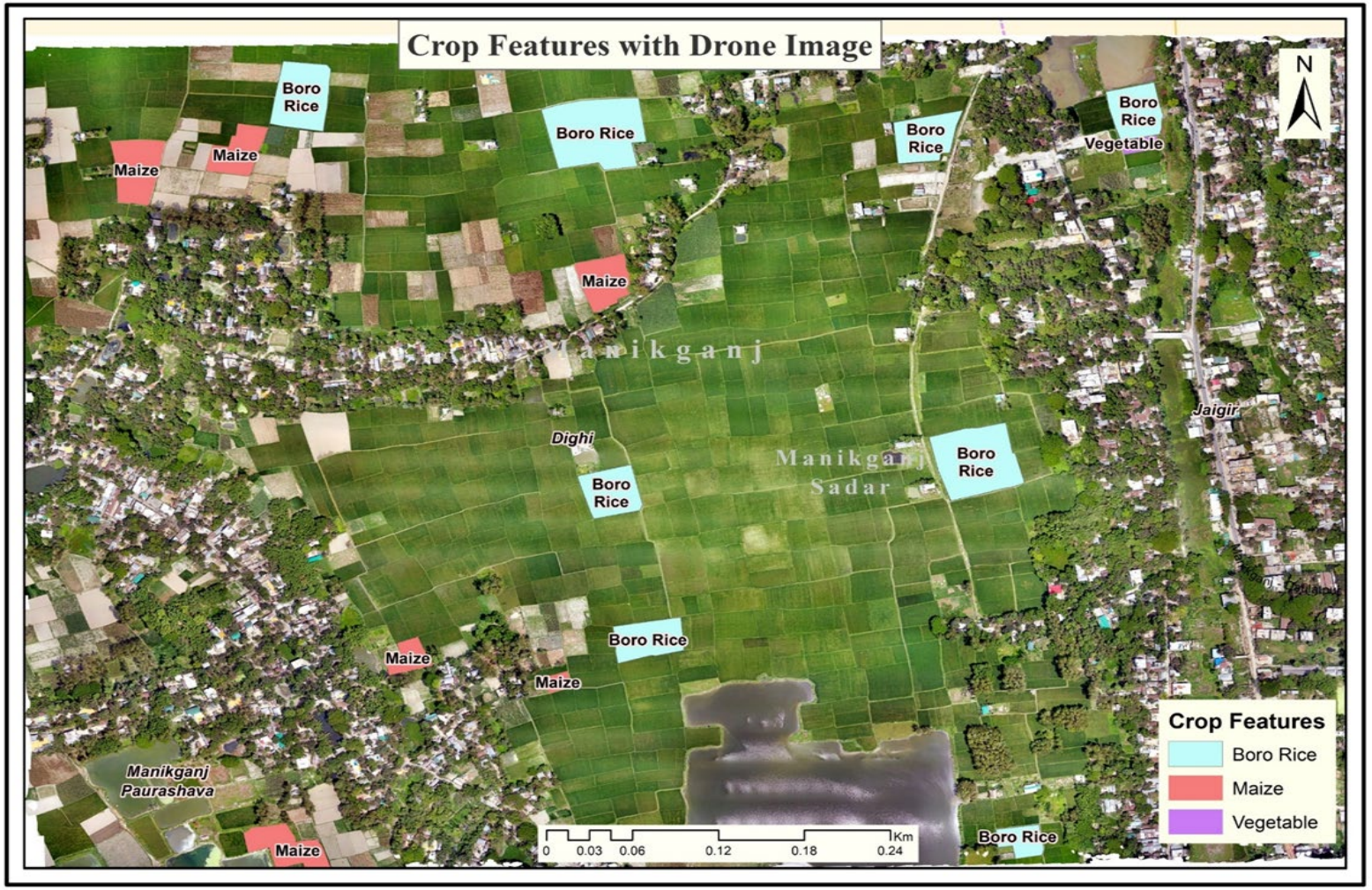


***Figure 2-14*: Drone imagery**

Table 2.1 shows the required equipment and software for data collection and data processing.

Table 2.1: Required components

Description	Quantity	Remarks
RTK receivers	1 set	
Handheld GPS	5 sets	
Drone	1 set	
Mobile Apps	1	
ERDAS IMAGINE	2 units	Version 2016
ArcGIS Pro/ Desktop PC	1 unit	Version 2.9
	2 PC	

2.3.4. Collection of Satellite imagery

Satellite imagery of the area of interest must be collected for the entire crop growth season, specifically the Rabi season spanning November 2022 to April 2023. This constitutes a time-series collection of satellite imagery. However, in the realm of satellite imagery for crop identification in Bangladesh, various platforms offer distinct advantages and limitations. A comparison between Sentinel-1 and Sentinel-2 with MODIS and Landsat 8-9 reveals unique characteristics that influence their utility in this context.

Furthermore, Sentinel-1 and Sentinel-2, both products of the European Space Agency's Copernicus program, provide a comprehensive solution for crop identification in Bangladesh. Sentinel-2 excels in offering high-resolution optical imagery, with a spatial resolution of 10-20 meters and multiple spectral bands. This characteristic allows it to capture fine details in the agricultural landscape, making it ideal for distinguishing between different crop types and monitoring their growth stages. Moreover, the frequent revisit times of Sentinel-2, typically occurring every 5 days, ensures a regular influx of data, enabling precise crop monitoring and change detection. Sentinel-1 complements Sentinel-2 with its synthetic aperture radar (SAR) technology. SAR imagery penetrates cloud cover and offers consistent observations, irrespective of weather conditions. In Bangladesh, where weather conditions can be challenging, this characteristic becomes particularly valuable. The 10-meter spatial resolution of Sentinel-1 data allows for reasonably detailed observations of the agricultural landscape, and its sensitivity to crop structure, moisture content, and surface roughness makes it well-suited for crop identification and monitoring.

On other side, MODIS, part of NASA's Earth Observing System, offers a global perspective for crop monitoring. Its multispectral bands are suitable for studying vegetation and land cover in a meso-scale. However, MODIS lags behind Sentinel-2 in terms of spatial and temporal resolution. The spatial resolution of MODIS imagery ranges from 250 meters to 1 kilometre, which is insufficient to capture fine details in densely populated agricultural areas.

Regarding, Landsat 8 and Landsat 9, both operated by NASA and the U.S. Geological Survey, offer moderate spatial resolution (30 meters) and multispectral bands, making them suitable

for mid-scale agricultural monitoring. They strike a balance between spatial and spectral resolution, allowing for relatively detailed land cover and crop type classification. However, like MODIS, Landsat satellites suffer from less frequent revisit times, occurring approximately every 16 days. This reduced temporal resolution may result in gaps in data coverage, potentially leading to incomplete crop monitoring.

Comparison among these satellites are depicted in table below:

Table 2.2: Comparison of Free Satellite Imagery

Sl.	Satellite	Spatial & Spectral resolution	Revisit time	Sensor Type	Agricultural Application
1	MODIS	250m	1 to 2 days	Optical	Too coarse resolution. It will mix up agriculture with other land uses.
2	Landsat 8-9	30m Spatial resolution for the following bands: i. Band 2 - Blue ii. Band 3 - Green iii. Band 4 - Red iv. Band 5 - Near Infrared (NIR)	16 Days	Optical	Resolution is coarse and revisit time is higher compared to Sentinel-2.
3	Sentinel 2	10m Spatial resolution i. Band 2 - Blue ii. Band 3 - Green iii. Band 4 – Red iv. Band 8 - Near Infrared (NIR) It also has additional 4 Vegetation Red Edge bands of 20m Spatial resolution	Sentinel 2A and Sentinel 2B two sensors combined 5 days. Single sensor 10 days	Optical	The available best option for optical imagery (in terms of Spatial resolution and revisit time)
4	Sentinel 1	10m Spatial resolution in two polarization options: i. Vertical-Vertical (VV) ii. Vertical-Horizontal (VH)	12 days	SAR or RADAR	The available best option for SAR or RADAR imagery (12 days revisit time is also good for agricultural applications)

In summary, while MODIS and Landsat satellites have their strengths in global coverage and multispectral capabilities, their limitations in spatial and temporal resolution may impede accurate crop identification in regions like Bangladesh, where frequent and detailed observations are crucial. Sentinel-1 and Sentinel-2, with their high-resolution optical and radar

imagery and frequent revisit times, offer a more comprehensive solution for crop identification and monitoring in this context, ensuring precision and accuracy in agricultural assessments.

2.4. Image preprocessing

The process of satellite image preprocessing, a critical component in satellite image analysis, entails the refinement and enhancement of raw satellite images to render them apt for subsequent analysis. The following discussion delineates the preprocessing steps specific to Sentinel-2 satellite imagery.

2.4.1. Preprocessing Sentinel 2 imagery

Sentinel-2, a renowned Earth observation satellite system devised by the European Space Agency (ESA), furnishes high-resolution multispectral imagery of our planet's surface. Upon downloading the data, the following preprocessing steps are executed for Sentinel-2 imagery:

Radiometric Calibration: While Sentinel-2 Level-1C products are already radio metrically calibrated, Level-1B products necessitate further radiometric calibration to rectify variations in sensor sensitivity and atmospheric effects.

Atmospheric Correction: The reflectance values of the pixels in Sentinel-2 imagery can be influenced by atmospheric scattering and absorption. Tools such as the Atmospheric Correction for Sentinel-2 (ATCOR) or the Sen2Cor algorithm can be employed to perform atmospheric correction.

Geometric Correction: Although Sentinel-2 imagery is already geometrically corrected, additional geometric corrections may be required to amend any residual geometric distortions or misalignments in the imagery.

Cloud masking, gap filling and Noise Removal: Clouds, haze, and other atmospheric effects can obscure the underlying features in Sentinel-2 imagery. Techniques for cloud and noise removal is applied to enhance the accuracy and quality of the imagery. Figure shows the effect of cloud and noise removal process. Figure 11 shows the cloud masking and gap filling process.

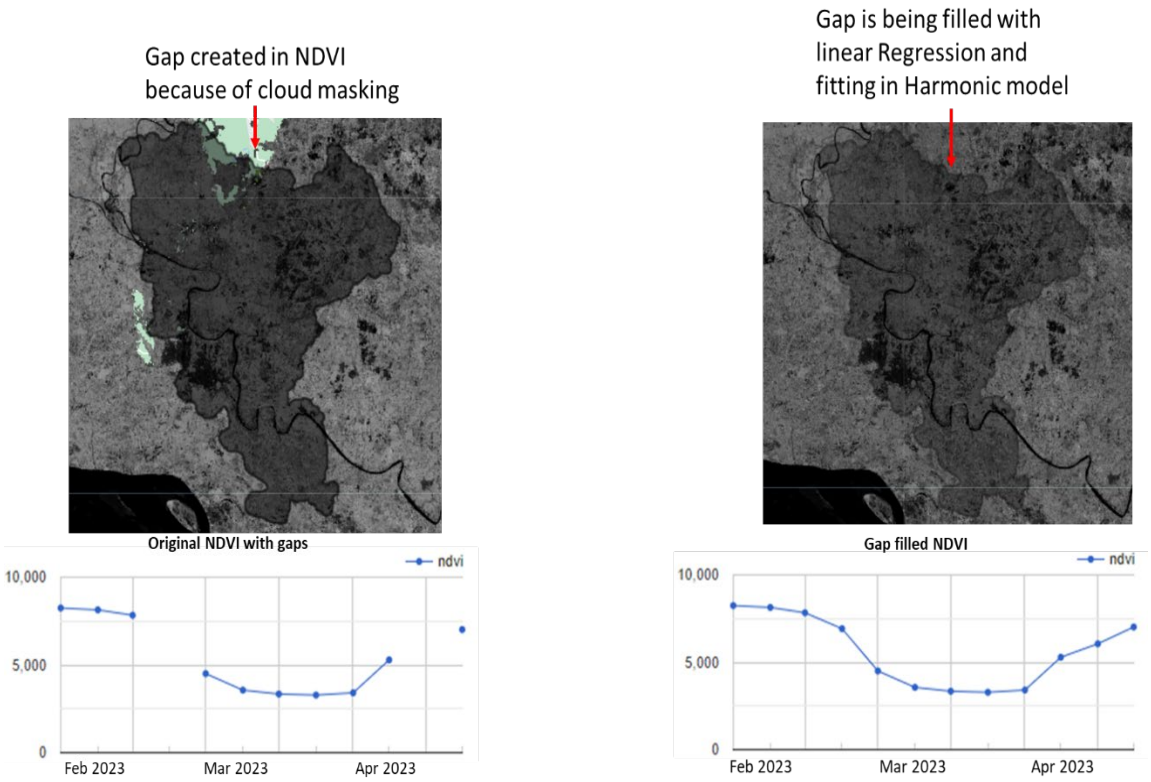


Figure 2-15**: **Cloud Masking And Gap Filling

Mosaicking: Sentinel-2 imagery that covers the entirety of Bangladesh during a specific period will be amalgamated using mosaicking techniques to generate a seamless composite image. For this reason a fortnightly mean image was calculated after completing all the preprocessing steps

Indices calculation: In the context of this analysis, one essential task involves the calculation of various indices to extract valuable information from satellite imagery. As an example, the Normalized Difference Vegetation Index (NDVI) is derived from the red and near-infrared bands of Sentinel 2 imagery. The NDVI serves as a powerful indicator of vegetation health and density. In the context of crop identification, this index proves invaluable as different crop types exhibit varying degrees of greenness at different phenological stages. By analyzing time series imagery or NDVI values, we generate a dataset encompassing distinct data points for different crops. This dataset becomes a valuable resource for the application of machine learning techniques in crop identification. Equation 1 illustrates the formula for calculating the normalized vegetation index.

Equation 1: NDVI = (NIR - R) / (NIR + R)

Here, NIR = pixel values from near infrared band (band 8 of Sentinel 2)
R = pixel values from red band (band 4 from Sentinel 2)
Figure 12 shows the average NDVI value of study area from 1st to 15th March 2023.



Figure 2-16: NDVI of the First Half of March

In this crop identification process, the Soil-Adjusted Vegetation Index (SAVI) has also been employed as an essential indices. SAVI is computed from the red and near-infrared bands of Sentinel 2 imagery, similar to NDVI, but with an additional soil adjustment factor. This adjustment makes SAVI particularly valuable for crop identification, as it helps mitigate the influence of bare soil, enhancing the accuracy of vegetation detection. By analyzing the SAVI values derived from the satellite data, we gather crucial information about crop health and density. These SAVI data points serve as significant inputs for the machine learning techniques, facilitating the precise identification of different crop types. Equation 2 outlines the formula for calculating the Soil-Adjusted Vegetation Index, a key component of our crop identification process.

Equation 2: SAVI = ((NIR - Red) / (NIR + Red + L)) x (1 + L)

Here, NIR = pixel values from the NEAR INFRARED band (Band 8 of Sentinel 2)
Red = pixel values from the RED band (Band 4 of Sentinel 2)
L = amount of green vegetation cover
Figure 13 shows the average SAVI value of study area from 1st to 15th March 2023.

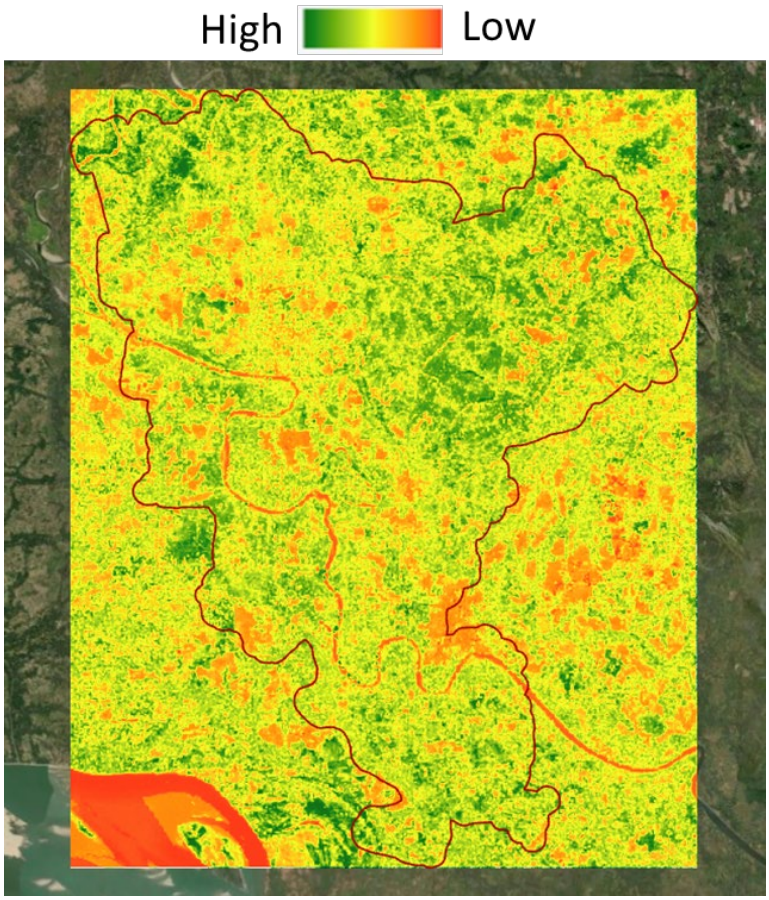


Figure 2-17: SAVI for the first half of March 2023

2.4.2. Preprocessing Sentinel 1 imagery

Sentinel-1, a radar imaging satellite system engineered by the European Space Agency (ESA), delivers high-resolution Synthetic Aperture Radar (SAR) imagery of the Earth's surface. The pre-processing steps for Sentinel-1 imagery are delineated below:

- **Applying Orbit File**: For the accurate processing and interpretation of the radar images procured from Sentinel-1, it is imperative to possess precise data about the satellite's position and orientation at the time of image acquisition. This data is encapsulated in an orbit file, which details the satellite's position and velocity during its Earth orbit. This file is separately downloaded and applied on the Sentinel 1 imagery.
- **Radiometric Calibration**: While Sentinel-1 imagery is already radiometrically calibrated, additional calibration may be necessitated to rectify any residual variations in sensor sensitivity and signal strength.
- **Speckle Filtering**: Speckle noise can affect Sentinel-1 radar images, complicating the interpretation of underlying features. Techniques for speckle filtering can be employed to mitigate this noise and enhance the quality of the Sentinel 1 imagery.
- **Terrain Correction**: This correction is utilized to eliminate geometric distortions due to terrain relief. Sentinel-1 radar images exhibit a mirror effect until terrain correction is

applied. A digital elevation model (DEM) will be used to correct for topographic effects. Through this process the geocoding of the imagery is also completed.

These pre-processing steps are vital for the accurate and reliable analysis of satellite data, significantly augmenting the quality and utility of the resultant images. Figure 14 shows the outcome of pre-processing Sentinel 1 imagery.

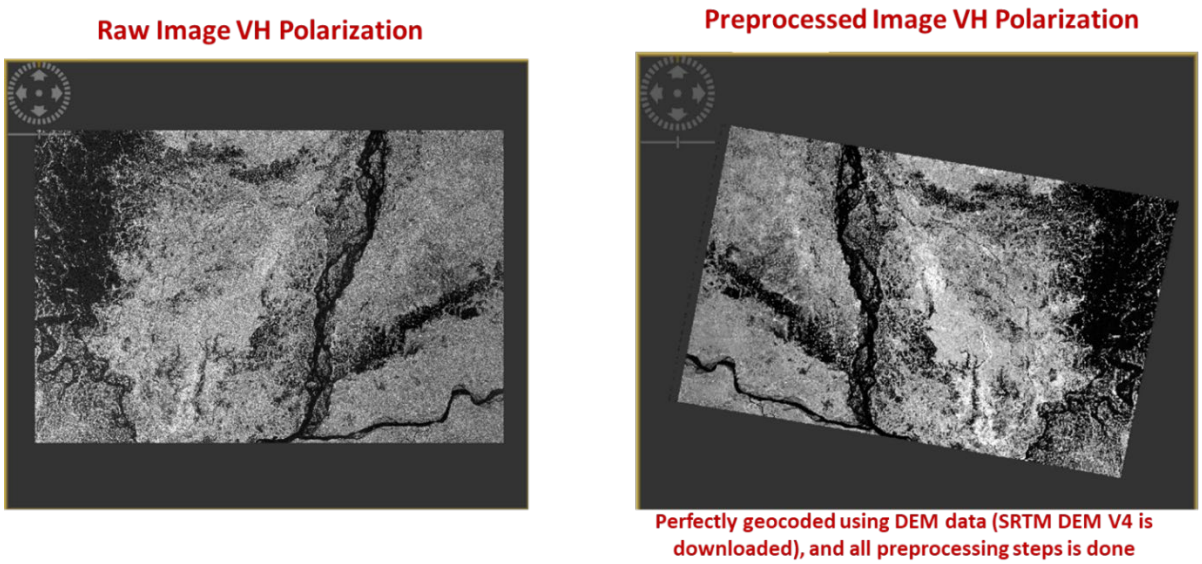


Figure 2-18: Difference between Raw and Pre-Processed Sentinel 1 Imagery

The VV and VH polarization of Sentinel 1 imagery is also merged into a stack. Figure 15(a) shows the VV and figure 15(b) shows VH imagery.

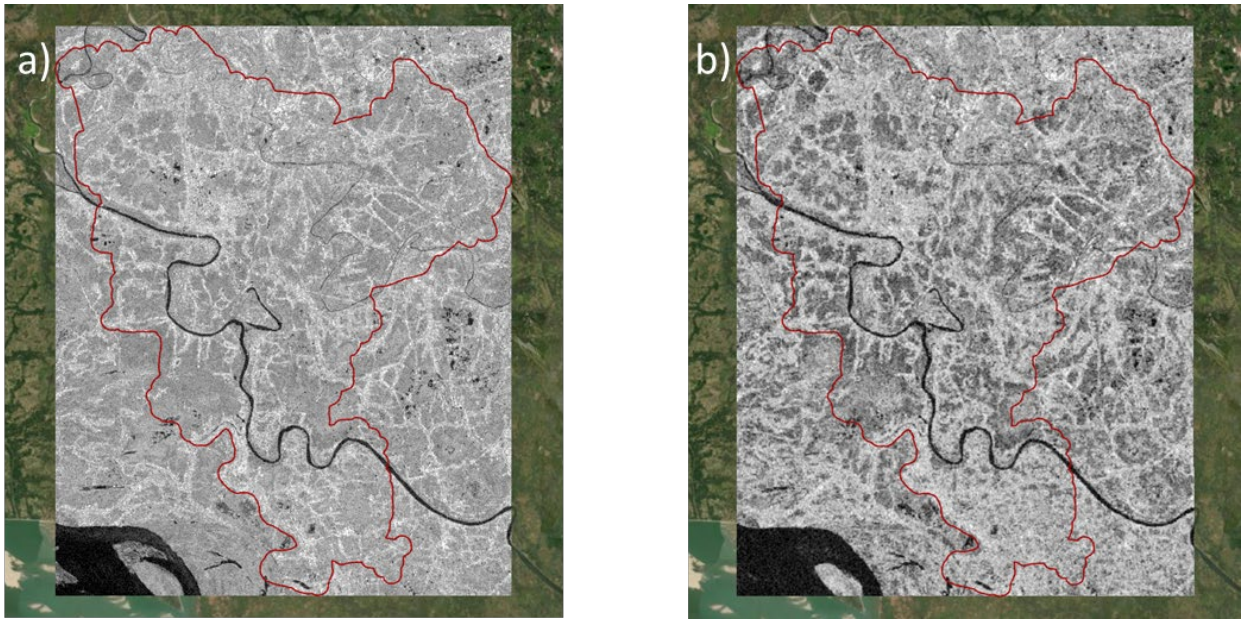


Figure 2-19: A) VV Polarization B) VH Polarization of January 11, 2023.

2.5. Crop signature preparation

The preparation of crop signatures stands as a pivotal element in the remote sensing-based crop mapping and monitoring procedure. The proposed methodology for crop signature preparation comprises a series of systematic steps critical to this process. Initial steps involve the categorization of crops, taking into account their respective cropping seasons, planting schedules, and primary crop classes. This categorization ensures that a single crop type may possess subclasses. In the context of Bangladesh, where agricultural practices predominantly revolve around Rabi (winter crops), Kharif 2 (monsoon crops), and Kharif 1 (summer crops) cropping seasons, it becomes imperative to determine the specific cropping season under consideration. For this study, focusing on Rabi season crops, the period between November 15, 2022, and April 30, 2023, was chosen for satellite imagery collection.

Subsequently, within each cropping season, multiple crop varieties are sown at distinct times, necessitating the identification of precise planting dates for each crop type. These planting dates can be sourced from crop calendars or obtained through field survey data. Once these critical dates are established, the major crop classes for the designated season are delineated, which could encompass categories such as rice, wheat, maize, or onion. In scenarios where multiple crop combinations are prevalent during the Rabi season, such as potato-Boro and Mustard-Boro, these combinations are reclassified as separate classes to enable more comprehensive and accurate signature classification. This reclassification process is indispensable in identifying the principal crop classes and training the machine learning model effectively.

Finally, the generation of crop signatures involves the computation of average spectral reflectance values for each specific crop type, utilizing time series data. This computational task is typically executed using remote sensing software. As illustrated in Figure 16, the crop signature preparation process culminates in the creation of essential data inputs vital to the accurate classification and monitoring of crops using remote sensing techniques.

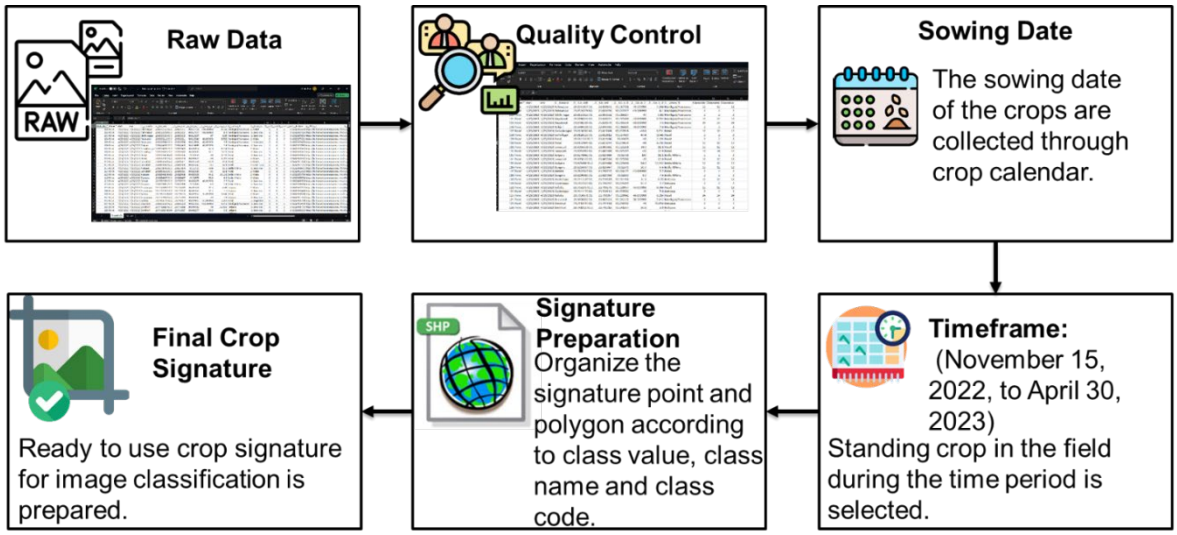


Figure 2-20: Crop signature preparation process

Furthermore, after the crop signature preparation, a meticulous quality control procedure is executed to ensure the accuracy and reliability of the data. Table 3 presented below delineates

the various crop classes and the outcomes subsequent to the meticulous quality control assessment. Out of a total of 1066 crop signatures, 939 successfully passed the stringent quality control evaluation. It is noteworthy that each of these signatures underwent a comprehensive manual scrutiny as a part of the quality control process.

Table 2.3: List of Qualified Crop Signatures

Crop class	Collected crop signature	Qualified crop signature
Boro rice	160	147
Spices	150	135
Potato & Boro rice	50	38
Maize	200	189
Mustard	70	54
Vegetable	30	21
Potato	15	10
Wheat	20	15
Sugarcane	20	11
Mustard & Boro rice	200	186
Tobacco	6	3
Total	921	809

Upon the completion of crop signature preparation and quality control, a portion of the signature in each class is reserved for accuracy assessment, while the remainder is utilized for the training of the crop classification machine learning model. Specifically, 25% of the signatures in each class are allocated for accuracy evaluation, and the remaining 75% are employed for model training. Table 4 shows the splitting of crop signatures for accuracy assessment.

Table 2.4: Splitting Of Crop Signature for Accuracy Assessment

Crop class	Signature for training ML Algorithm	Signature for accuracy assessment
Boro rice	110	37
Spices	101	34
Potato & Boro rice	29	10
Maize	143	47
Mustard	40	14
Vegetable	17	4
Potato	8	2
Wheat	11	3
Sugarcane	8	2
Mustard & Boro rice	139	47
Tobacco	2	1
Total	608	201

2.6. Agricultural mask preparation

An agricultural mask is fundamentally a binary mask employed to pinpoint the regions of the satellite image that correspond to agricultural land. Utilizing an agricultural mask allows the

classification algorithm to concentrate on these areas and disregard non-agricultural zones, thereby enhancing the accuracy of the classification.

In the context of Bangladesh, the agricultural mask fluctuates from season to season due to the seasonality of water movement. Consequently, specific season-based agricultural masks will be devised to augment the accuracy of the output. In this instance, a supervised image classification algorithm is applied to time series images to identify the agricultural area.

This generic agricultural mask data is fine-tuned with seasonal water masks. The Otsu method, also known as the maximum variance method, is employed on time series satellite imagery data to generate water masks.

Ultimately, by amalgamating both generic agricultural masks and seasonal water masks, an agricultural mask specific to the Rabi season is prepared. This mask is then applied to the pre-processed Sentinel 1 and Sentinel 2 data.

2.7. Image stacking

Image stacking is a technique that amalgamates multiple images of the same region, captured at different times or via different sensors, to generate a single composite image. The objective of image stacking is to augment the overall image quality and amplify the quantum of information contained in the image. This method is employed to eliminate atmospheric effects, diminish noise, and enhance the spatial resolution of the satellite image. By integrating multiple images, atmospheric disturbances such as haze or cloud cover can be minimized, yielding clearer images with more precise information. The procedure entails procuring and preprocessing the satellite images, selecting the spectral bands for stacking, and stacking the chosen bands to create a composite image. This composite image can then be scrutinized to monitor crop area and growth over time. In remote sensing, a spectral band denotes a specific range of light wavelengths captured by a satellite sensor. Each spectral band imparts unique information about land surface characteristics, including vegetation health and water content. In this study, an average image over 15 days is selected for stacking (Band stacking). The primary reason for this selection is the satellite revisit time. This duration ensures comprehensive satellite coverage of the entire Bangladesh. Within this time frame, different indices (i.e., NDVI, SAVI, etc.) are calculated from the images. Then 15 days average images were calculated and finally stacked of chosen bands from the average imagery were generated. Furthermore, utilizing a 15-day average for stacking strikes a balance between the temporal and spatial coverage of the data. A shorter duration, such as 5 days, may enhance temporal resolution but would result in lower spatial coverage due to an increased number of individual images in the stack. Conversely, a longer period, such as 30 days, would offer higher spatial resolution but may not capture changes in vegetation indices occurring within the 30-day interval.

For Sentinel 1 and Sentinel 2 an average of fortnightly imagery is prepared. A collection of imagery is downloaded for each fortnight and processed for this study and an average is prepared of the collected imagery.

The collection dates of Sentinel 2 imagery are shown in figure 17 and collection dates of Sentinel 1 imagery is shown in Figure 18.



Figure 2-21: Sentinel 2 Image Collection Dates And Fortnightly Average Image Generation.



Figure 2-22: Collection Dates Of Sentinel 1 Images And Fortnightly Average Image Generation

For each fortnight a collection of satellite image downloaded, and an average of the imagery is prepared. As a result, for the duration of the study 11 images of each index is prepared making a total of 44 bands.

Sentinel 2 NDVI and SAVI Stack (Stack 1): This data stack harnessed spectral information from Sentinel 2 satellite imagery, specifically incorporating the Normalized Difference Vegetation Index (NDVI) and Soil-Adjusted Vegetation Index (SAVI). Figure 3 shows the composite band creation process from Sentinel 2 imagery.

Sentinel 1 VV and VH Polarization Stack (Stack 2): Leveraging radar data, this stack focused on both the Vertical Vertical (VV) and Vertical Horizontal (VH) polarizations, drawing from Sentinel 1 imagery. Figure 4 shows the process of making stack of 11 VV and 11 VH images from Sentinel 1 imagery.

Combined Stack of Sentinel 2 and Sentinel 1 Data (Stack 3): A powerful integration of both optical and radar data sources, this stack combined Sentinel 2's NDVI and SAVI data with Sentinel 1's VV and VH bands.

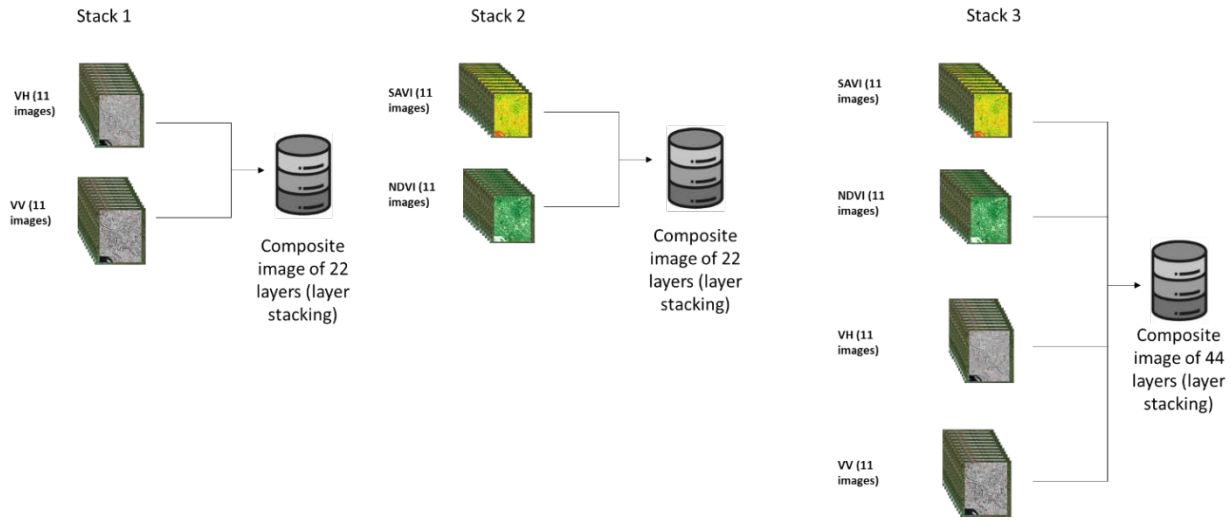


Figure 2-23: Stack preparation workflow

2.8. Image classification using machine learning algorithm

Image classification is a procedure that assigns predefined classes to the pixels of imagery. In this study, either pixel-based or object-based classification techniques are employed to classify major crops.

In this context, the object of interest is the cropping field, and the spatial resolution of Sentinel 1 and Sentinel 2 is 10 meters by 10 meters (approximately 0.025 acres). Additionally, there will be mixing in the spectral domain for different crops. Therefore, scientific testing will be required for these methods. A small area is selected to apply and test both methods. For this purpose, 75% of the signature data of that sample area is used for classification and the remaining 25% is utilized for accuracy assessment. The method with the highest accuracy is finally adopted.

Ultimately, a machine learning-based classification algorithm is applied. This method can handle both spectral and spatial features and is particularly useful when dealing with complex data sets with many classes and mixed pixels. Machine learning techniques such as Random Forest, Support Vector Machines, and Convolutional Neural Networks have a wide range of applications in remote sensing. In this study Random Forest algorithm was used.

2.9. Accuracy assessment

Evaluating the precision of image classification is a crucial component of any categorization task. This process involves comparing the categorized image with another data source, known as ground truth data, which is deemed accurate. Ground truth data can be sourced from field collection, interpretation of high-resolution data, or from reference maps.

The accuracy assessment can be described as the degree of precision with which a classifier performs image categorization in relation to the reference (ground truth). It employs a reference dataset to ascertain the accuracy of the classification outcome. In this research, a quarter of the datasets will be utilized for accuracy assessment.

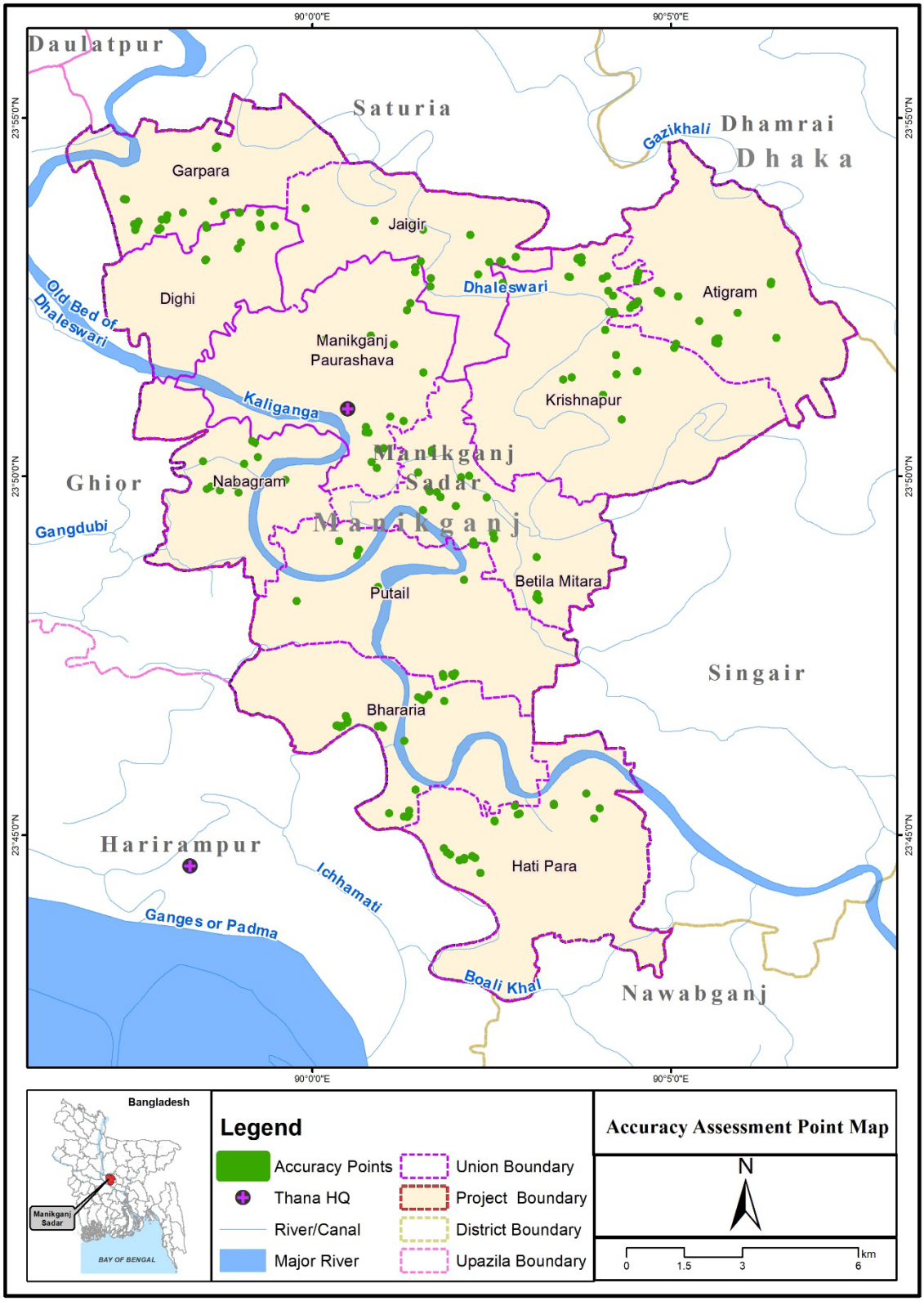


Figure 2-24: Accuracy Assessment Point Map

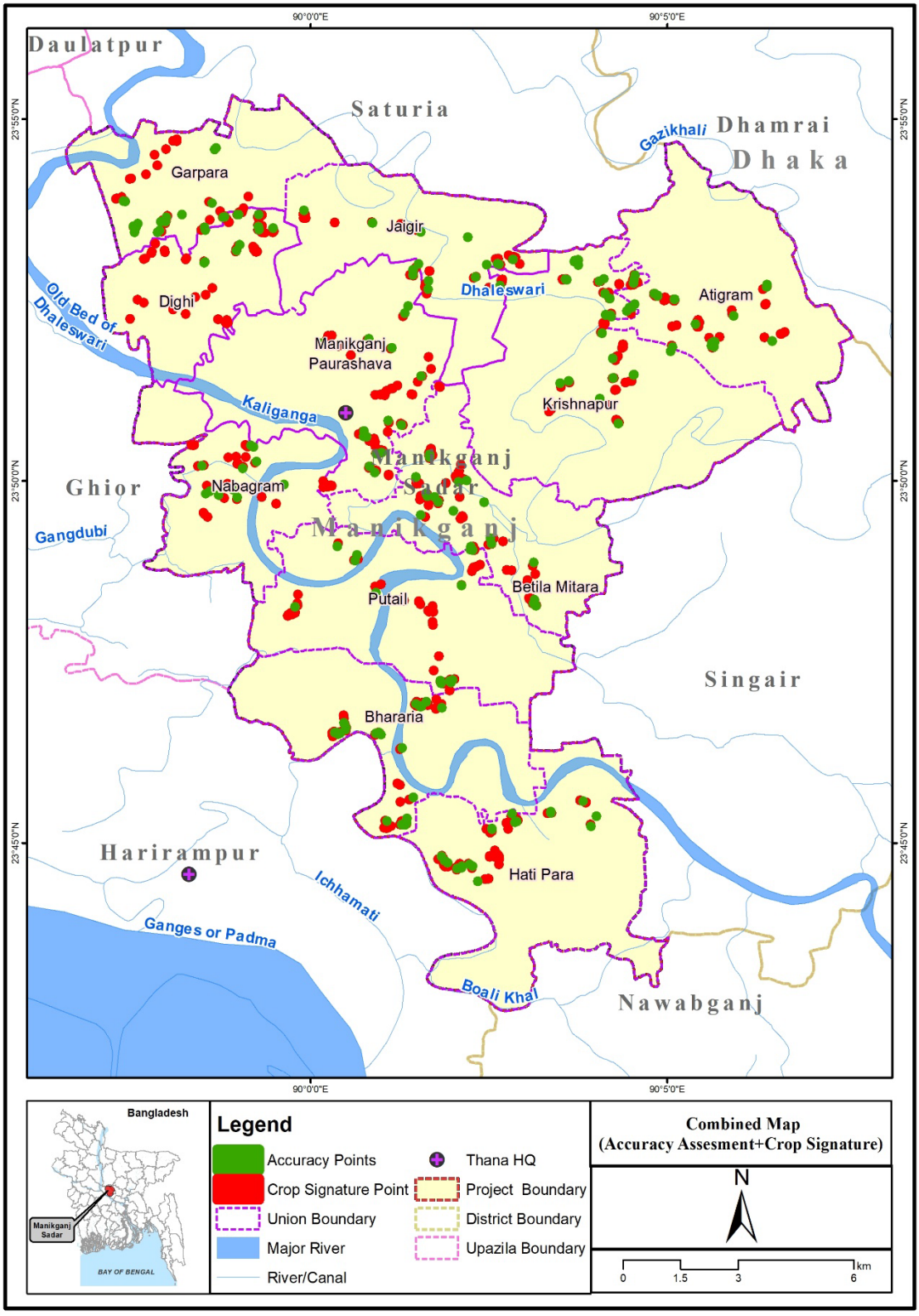


Figure 2-25: Combined Map (Accuracy Assessment + Crop Signature)

3. Image Classification

3.1. Introduction

Image classification is a meticulous process that involves the allocation of predefined classes, as per a land cover and land use classification system, to each pixel in a remotely sensed image. This system is commonly referred to as the schema. The execution of this process demands a significant amount of time and careful attention to detail, given its sensitive nature. A minor error during this procedure can potentially disrupt the entire progression. This chapter provides an in-depth explanation of the image classification methodology employed in this work.

3.2. Image segmentation

Segmentation, an integral part of image classification workflow, involves the grouping of adjacent pixels that share similar color and specific shape attributes. The segmentation process is governed by three parameters:

a) **Spectral detail**: This parameter, which can be set with a value between 1 and 20, determines the significance of spectral detail. Smaller, clustered features require a higher value. In this study, as the features of interest are crops which are typically small and clustered, a higher value is assigned during segmentation.

b) **Spatial detail**: Like spectral detail, the importance of spatial detail is set with a value between 1 and 20. Smaller, clustered features are given more importance. Given that the features of interest in this study are crops, a higher value is assigned to spatial detail.

c) **Minimum segment size**: The values for this parameter are associated with the minimum mapping unit. In this study, the minimum mapping unit is equivalent to the spatial resolution of the satellite image.

The determination of the values for the three segmentation parameters is achieved through a meticulous research and development approach. This process involves an in-depth analysis and evaluation of various factors, ensuring that the selected values are optimally suited for the task at hand.

The segmented image of the chosen area, as depicted in figure 3.1 is a testament to the effectiveness of this approach. The image provides a detailed visual representation of the segmentation process, highlighting the distinct segments that have been identified within the area.

This segmentation process is carried out using ArcGIS Pro, a leading geographic information system (GIS) software, along with its Image Analyst Extension. This software provides a comprehensive suite of tools and functionalities that facilitate advanced image processing and analysis. The Image Analyst Extension, in particular, offers specialized capabilities for performing image segmentation, making it an invaluable tool in this context.

Through this rigorous and methodical approach, we are able to achieve precise and accurate segmentation results, thereby enhancing the overall quality and reliability of our data.

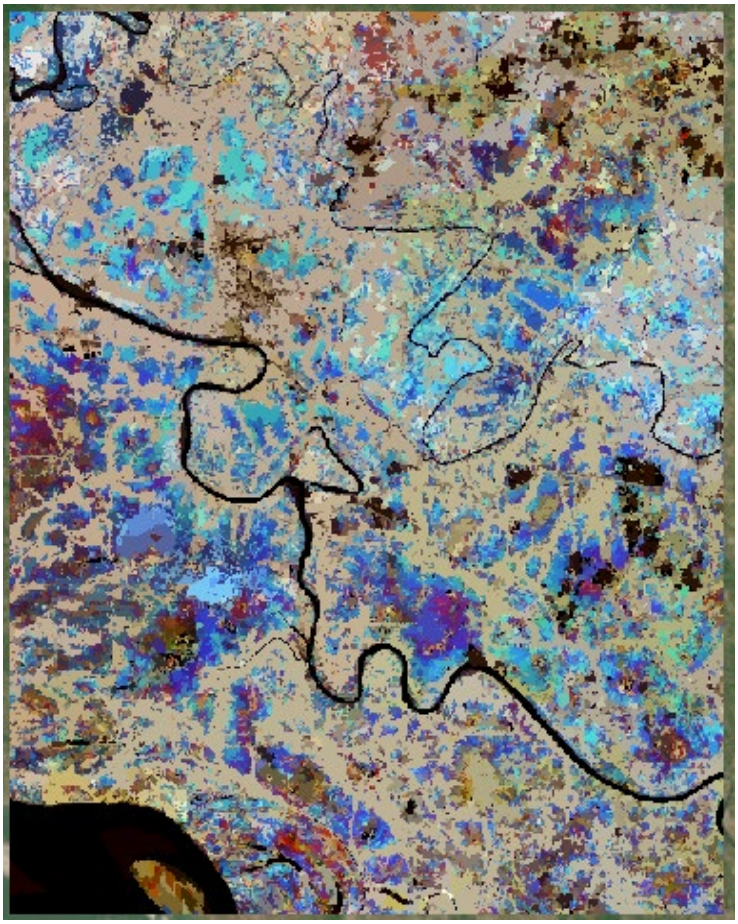


Figure 3-1: Segmented Image

3.3. Selection of proper classification algorithm

The selection of the classification algorithm, a critical component in image classification, necessitates meticulous investigation. A specific test area is chosen for this procedure, and all potential classification methodologies are scrutinized by implementing them within the designated area. The outcomes are then compared to ascertain the most suitable algorithm for this study. ArcGIS Pro encompasses a suite of five distinct image classification algorithms. Among these, four are dedicated to supervised classification, while one is designed for unsupervised classification. The supervised classification algorithms are as follows:

a) **Random Trees (RT)**: This robust image classification technique is immune to over fitting and can handle segmented images along with other ancillary raster datasets. It accepts multiband imagery of any bit depth for standard image inputs and conducts the random trees classification on a pixel-by-pixel basis, guided by the input training feature file.

b) **Support Vector Machine (SVM)**: The SVM classifier offers a potent, supervised classification method capable of processing either a segmented raster input or a standard image. It exhibits a lower susceptibility to noise, correlated bands, and imbalances in the

number or size of training sites within each class. This method is extensively utilized by researchers.

c) **Train K-Nearest Neighbor (KNN)**: The K-Nearest Neighbour classifier is a nonparametric method that classifies a pixel or segment based on the majority vote of its neighbours, where 'K' represents the predetermined number of neighbours participating in the voting process.

d) **Maximum Likelihood**: This traditional image classification technique operates on two principles: the assumption that pixels in each class sample in the multidimensional space follow a normal distribution, and the application of Bayes' theorem for decision-making.

Through in literature review it is found that the random trees algorithm is best suited for this study and therefore this algorithm is used in this project to prepare a crop map.

3.3.1. Machine Learning algorithm Random Trees Classification of ArcGIS Pro

ArcGIS Pro, a versatile Geographic Information System (GIS) software, offers a powerful arsenal of tools for image analysis, with the Random Trees classification method at the forefront. This method represents a significant advancement, harnessing the principles of machine learning to enhance the precision and reliability of image classification.

At its core, Random Trees is a machine learning algorithm that belongs to the decision tree family, specifically known for its stochastic and ensemble characteristics. It combines the strength of multiple decision trees, each providing its insight into the classification process. This ensemble approach introduces an element of randomness, wherein subsets of data are randomly selected for training each tree. From a machine learning perspective, this randomness helps mitigate overfitting, a common challenge in complex datasets, and yields a more robust and generalized classification model. The machine learning aspects of Random Trees in ArcGIS Pro are pivotal to its effectiveness:

- **Ensemble Learning:** The creation of an ensemble of decision trees enables Random Trees to benefit from the collective intelligence of multiple models. Each tree learns from the data and contributes to the final classification, reducing the risk of model bias and improving accuracy.
- **Stochastic Training:** The stochastic nature of Random Trees involves the random selection of data subsets for each tree. This randomness enhances the algorithm's ability to handle variability and noise in the data, making it particularly adept at addressing real-world complexities.
- **Generalization:** Machine learning models are assessed by their ability to generalize beyond the training data. Random Trees excel in this aspect, accurately classifying unseen or unlabeled data, a crucial feature when mapping and categorizing crops over extensive areas.
- **Multispectral Data Integration:** From a machine learning perspective, Random Trees can seamlessly handle multispectral and multitemporal imagery. This is especially valuable in applications like crop mapping, where data from various sources, such as Sentinel-1 and Sentinel-2, must be integrated for a comprehensive analysis.
- **Feature Discrimination:** Random Trees' ensemble approach makes it proficient in distinguishing between classes with similar spectral characteristics. In the context of crop identification, this is invaluable in accurately categorizing different crop types, even when their spectral profiles overlap.

In our analysis, the use of the Random Trees classification method, guided by machine learning principles, has led to the creation of a highly reliable and precise crop map. This map, featuring major crops like Boro rice, mustard, potato, and wheat, is an outcome of the fusion of cutting-edge technology and machine learning, and it significantly contributes to agricultural monitoring, land management, and well-informed decision-making in the context of Bangladesh's agricultural landscape.

3.3.2. Suitability of Random Trees for Crop Identification

The Random Trees classification method is particularly suitable for crop identification due to several key attributes and advantages that align well with the complexity of agricultural. Landscapes and the nuances of crop differentiation:

- **Ensemble Learning:** Random Trees harnesses the power of ensemble learning, where multiple decision trees work together to make classifications. This ensemble approach increases the robustness of the classification process, reducing the risk of overfitting and improving the overall accuracy of crop identification.
- **Handling Complex Data:** Crop identification is inherently complex, as different crops may have similar spectral characteristics, and the landscape often includes various factors like mixed land use, changing growth stages, and the presence of multiple crop types. Random Trees excels in handling this complexity by considering the collective decision of multiple trees.
- **Stochastic Training:** The randomness introduced in the training process is a significant advantage. By randomly selecting subsets of data for each tree, the method mitigates overfitting and enhances generalization. This is essential when working with diverse and noisy agricultural data, as it helps the model adapt to real-world variability.
- **Effective Multispectral Analysis:** Crop identification often involves the analysis of multispectral data from sources like Sentinel-1 and Sentinel-2. Random Trees can efficiently integrate and utilize such data, making it well-suited for applications that require a holistic understanding of the landscape.
- **Generalization:** Machine learning algorithms are evaluated on their ability to generalize well to unseen data. Random Trees' ensemble of models excels in this regard, ensuring that the crop identification model can accurately categorize crops in areas it hasn't been explicitly trained on.
- **Feature Discrimination:** One of the strengths of Random Trees is its ability to distinguish between classes with similar spectral profiles. This is crucial in crop identification, where crops may share common spectral characteristics but still need to be accurately differentiated.
- **Thematic Accuracy:** Random Trees has proven to provide high thematic accuracy, which is a critical factor when it comes to crop identification. A high level of thematic accuracy ensures that the identified crop classes are correct and can be relied upon for decision-making.

In summary, the suitability of the Random Trees classification method for crop identification lies in its ability to handle the complexity and variability inherent in agricultural landscapes. By leveraging ensemble learning, stochastic training, and its capacity for multispectral analysis, Random Trees excels in providing accurate and reliable crop

identification results, making it an invaluable tool for agricultural monitoring and management. Hence in this project this Random Trees classification method is adopted and utilized through ArcGIS Pro software

3.4. Model training

The chosen algorithm for this procedure is the Random Tree (RT). Consequently, the training data was utilized to educate the Random Tree classification algorithm.

3.5. Raster classification

The refined raster image of the study area is categorized using the educated model. Post-categorization, the classified raster undergoes processing to identify and rectify any misclassified classes, with the data being reclassified as needed. Furthermore, any classes necessitating consolidation are merged in accordance with the stipulated requirements.

3.6. Post processing

While the process of image classification demonstrates a high degree of precision, it is not entirely comprehensive without the incorporation of post-processing. This subsequent phase refines the image, eliminating errors and mitigating the 'salt and pepper' effect observed in the classified output raster.

The 'salt and pepper' effect refers to the presence of misclassified isolated pixels or small pixel regions that have been incorrectly labeled within the classified image. These anomalies appear as specks of noise within the image, akin to grains of salt and pepper, hence the term.

Post-classification processing serves as a method to eradicate this noise, thereby enhancing the quality of the classified raster image. It involves a series of corrective measures designed to identify and rectify these misclassifications, resulting in a more accurate and reliable output.

Figure 3.2 provides a visual comparison between a normal image and a post-processed image. It clearly illustrates the impact of post-processing in reducing noise and improving overall image quality. This comparison underscores the importance of post-processing in achieving high-quality, accurate image classification results.

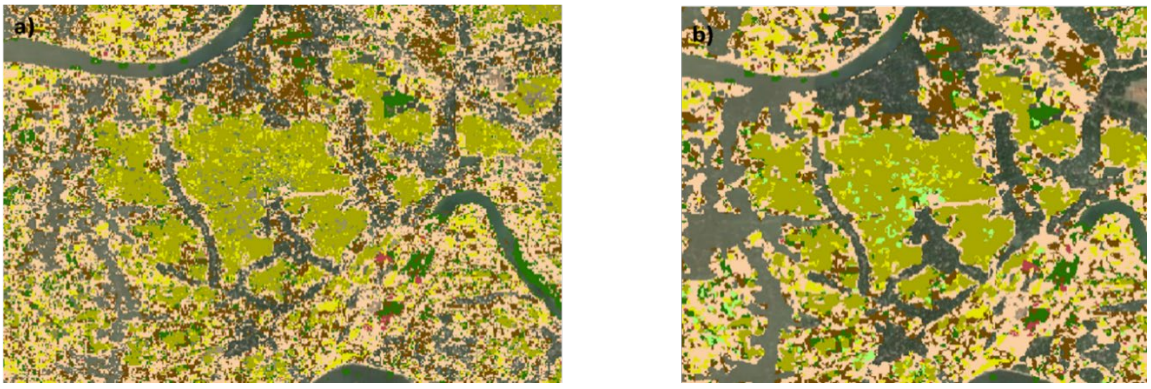


Figure 3-2: a) Before post processing b) After post processing. After post processing the noise is reduced.

4. Result Discussion

4.1. Introduction

Within the realm of agricultural monitoring, the identification and accurate estimation of crop areas are paramount. This chapter delves into the meticulous process of crop identification and area estimation, specifically targeting the four major crops—Boro rice, mustard, potato, and wheat, Maize of Rabi season in Bangladesh. To achieve this, a robust methodology was employed, harnessing the power of three data stacks. The first stack incorporated Sentinel-1 data, comprising VV and VH polarizations, while the second stack leveraged Sentinel-2 imagery, featuring the Normalized Difference Vegetation Index (NDVI) and Soil-Adjusted Vegetation Index (SAVI).

The third and comprehensive stack fused both Sentinel-1 and Sentinel-2 data sources, creating a holistic perspective on the agricultural landscape. Through rigorous image classification and statistical analysis, this chapter not only discerns the types of crops grown but also provides precise estimations of their spatial extent. The resulting thematic accuracy of over 92% underscores the reliability and confidence in this crop identification and area estimation process. These findings significantly contribute to informed decision-making and agricultural management in Bangladesh.

4.2. Crop Map

Using remote sensing for agricultural monitoring has improved its efficiency and effectiveness. One of the main uses of remote sensing in the agricultural sector is creating crop maps. A crop map is a map that displays the regions of the chosen area with detailed information about crop production. Moreover, the map has geo-referencing that provides useful information about the area's crop yield. Creating a crop map involves integrating geolocation with satellite imagery and machine learning based classification with information about crop production. Image classification relies on statistics. Machine learning algorithms are mainly a fusion of computer science and statistics. Combining these two factors with GIS and remote sensing has enabled the crop map and crop area is being estimated.

A well-made crop map is a virtual representation of the real-world situation of crop area and spatial coverage. The crop map is one of the main sources of information for agricultural monitoring that helps decision makers to take timely informed decision.

4.2.1. Crop map prepared from Sentinel 1 (SAR) imagery

Sentinel-1 imagery, utilizing Synthetic Aperture Radar (SAR) technology, plays a significant role in crop area estimation. The SAR technology allows Sentinel-1 to capture high-resolution images of the Earth's surface at microwave frequencies, which are less affected by weather conditions and cloud cover than optical sensors1. This enables Sentinel-1 to acquire data in all seasons and at any time of the day or night, providing a consistent and reliable source of information for crop area estimation.

The imagery captured by Sentinel-1 can reveal the structural and dielectric properties of crops, which vary among crop types and change as crops grow. This allows Sentinel-1 to accurately identify crop types and estimate crop biophysical parameters such as leaf area index, biomass, canopy height, and yield.

Moreover, Sentinel-1 imagery can detect changes in crop conditions, such as moisture stress, pest infestation, disease outbreak, and damage from natural disasters. This can help monitor crop health and productivity and provide early warning for crop management interventions.

Furthermore, Sentinel-1 imagery can be integrated with other types of imagery, such as optical and thermal, to enhance the accuracy and reliability of crop area estimation. This can also provide complementary information on crop phenology, growth stages, and stress facto.

The crop map prepared from Sentinel 1 imagery is shown in 4.1. The crop map has an overall accuracy of 84%. It has lower accuracy than the crop map prepared from Sentinel 2. The accuracy for Boro rice is very high (0.97) indicating precise classification. But all crops do not have high accuracy. Especially the mustard has an accuracy of 52% representing some miscalculations. Also, the high kappa value represents high reliability of the outcome.

Finally, it is evident that the Sentinel 1 imagery is useful source of earth observation data for crop area estimation of rice due to its high sensitivity of water content.

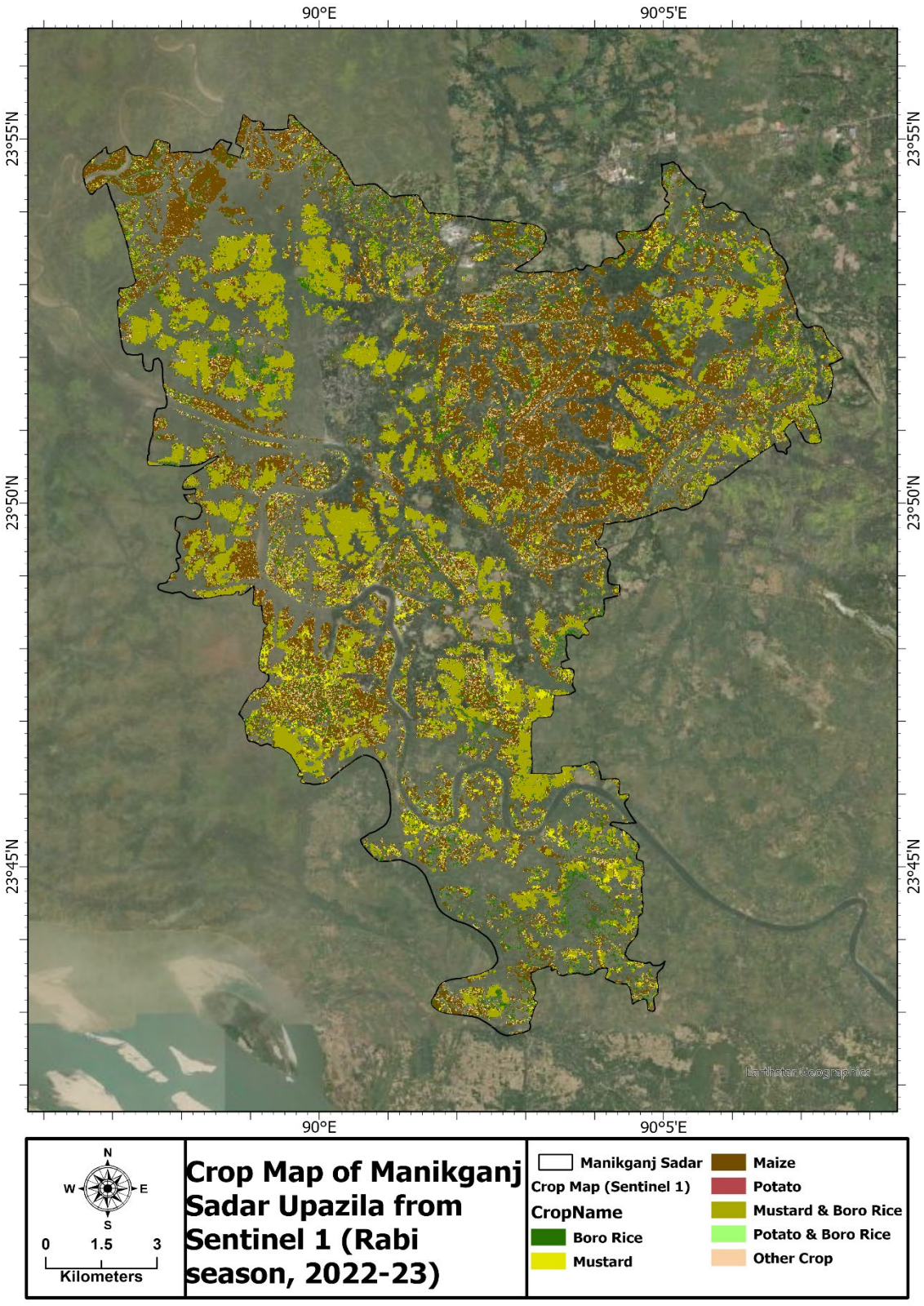


Figure 4-1: Crop Map Prepared from Sentinel 1 Imagery

4.2.2. Crop map prepared from Sentinel 2 (optical) imagery

Sentinel-2 imagery, with its high-resolution multispectral capabilities, plays a pivotal role in crop area estimation. The imagery captured by Sentinel-2 encompasses a wide range of spectral bands, providing detailed information about the Earth's surface. This data is particularly useful in distinguishing between different types of vegetation and assessing their health, which is crucial for accurate crop area estimation.

The high spatial resolution of Sentinel-2 imagery allows for precise delineation of individual crop fields, even in complex agricultural systems with small field sizes. This level of detail is essential for accurate crop area estimation and can significantly improve the reliability of agricultural statistics.

Moreover, the frequent revisit time of the Sentinel-2 satellites ensures that up-to-date imagery is consistently available. This allows for regular monitoring of crop growth stages and timely detection of any changes in crop conditions, further enhancing the accuracy of crop area estimation.

In addition, the wide swath width of Sentinel-2 imagery enables large-scale coverage, making it possible to estimate crop areas at regional, national, or even continental scales. This can be particularly useful for large-scale agricultural surveys and for monitoring trends in crop production over time.

The crop map prepared from Sentinel 2 imagery is shown in Error! Reference source not found. The crop map has an overall accuracy of 87%. It has higher accuracy than the crop map prepared from Sentinel 1 imagery but lower accuracy than the crop map prepared from Sentinel 2 imagery. The accuracy for Boro rice is exceptionally high indicating precise classification. All crops have high accuracy indicating high quality classification. Also, the high kappa value represents high reliability of the outcome.

Finally, it is evident that the Sentinel 2 imagery is useful source of earth observation data for crop area estimation for winter season as the sky is cloud free.

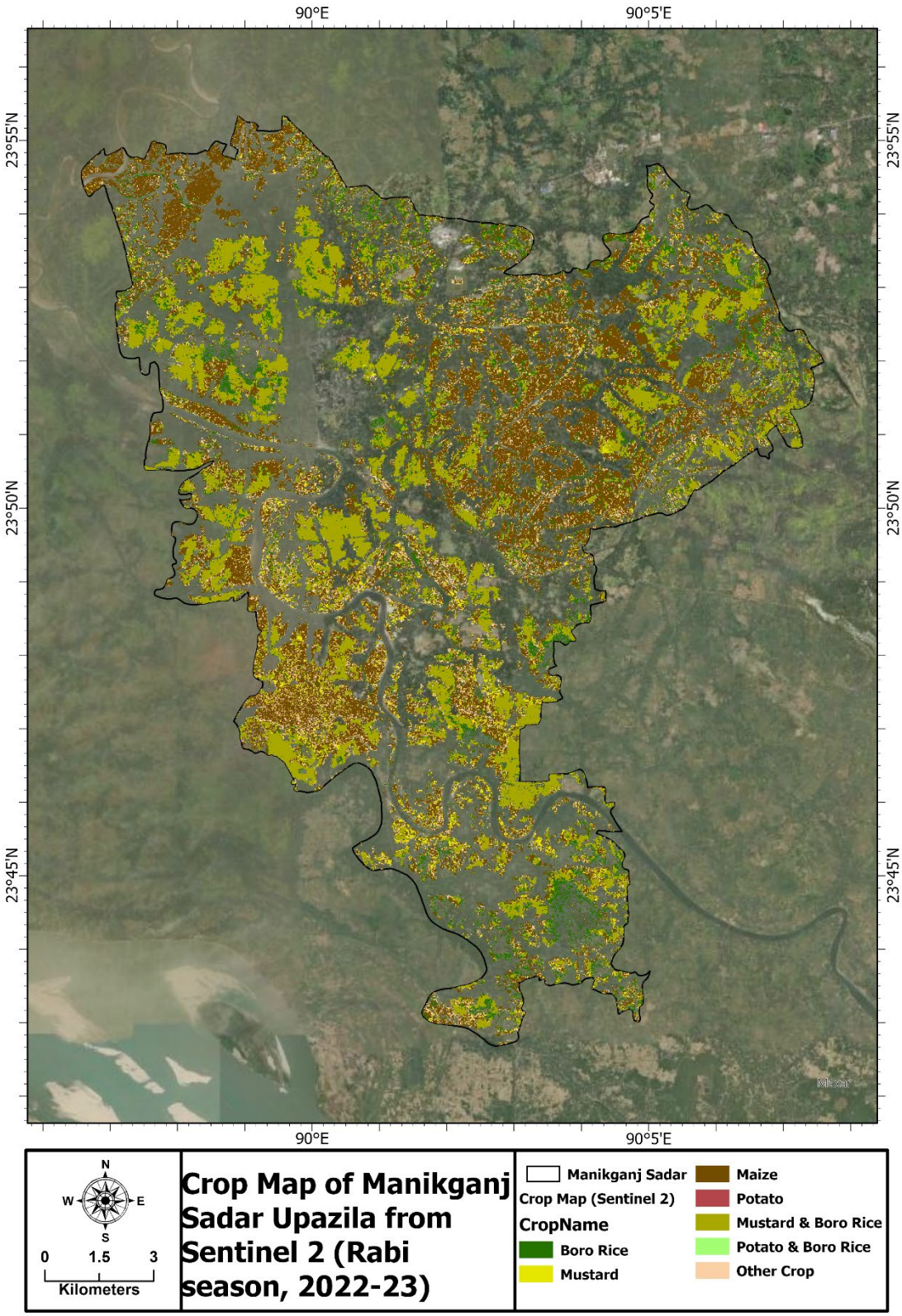


Figure 4-2: Crop Map Prepared from Sentinel 2 Imagery

4.2.3. Crop map prepared from both Sentinel 1 (SAR) and Sentinel 2 (optical) imagery

The combination of Sentinel-1 and Sentinel-2 imagery, which utilize Synthetic Aperture Radar (SAR) and optical sensors respectively, offers a multitude of benefits. The two types of sensors capture different but complementary information about crops, leading to improved classification accuracy compared to using them individually. SAR and optical imaging methods react differently to different land surface parameters and thus provide highly complementary information. For instance, SAR can capture the structural and dielectric properties of crops, while optical sensors can capture their spectral characteristics.

Moreover, SAR imagery from Sentinel-1 is unaffected by weather conditions and cloud cover. This allows for reliable data acquisition in all seasons and at any time of the day or night, complementing the optical imagery from Sentinel-2 which can be affected by clouds. This all-weather capability is a significant advantage in regions with frequent cloud cover or for applications that require regular monitoring regardless of weather conditions.

The combination of Sentinel-1 and Sentinel-2 can greatly improve the ability to monitor crop growth at a regional scale. This is due to the high revisit frequency of Sentinel satellites and the wide coverage of their imagery. This enhanced monitoring capability is particularly useful for large-scale agricultural surveys, monitoring trends in crop production over time, or assessing the impact of agricultural policies or interventions.

Finally, the synergistic use of radar and optical data for crop classification leads to richer information, increasing classification accuracies compared to optical-only classification. This increased precision is crucial for applications that require detailed and accurate information about crop types, growth stages, or conditions.

The crop map created from the combined stack of Sentinel 1 and Sentinel 2 imagery is shown in 4.3. In this figure, it can be seen that various types of crops are grown all over the area of interest. But the focus is given to the 4 crops. Among these 4 crops Boro rice is the most grown crop. The least grown crop is potato. The second most grown crop is mustard, and the third most is wheat for the Rabi season 2022-2023. The overall thematic accuracy value for this crop map is ≈ 92%. The thematic accuracy being above 80% indicates that the created crop map is acceptable with a high level of confidence. In 4.3 the crop map prepared by processing both Sentinel 1 and Sentinel 2 is shown.

The map prepared from the combined stack of both Sentinel 1 which utilizes synthetic aperture radar (SAR) technology and Sentinel 2 imagery which uses optical sensors, has a higher accuracy. The reasoning behind this outcome is that using both imagery provides a better understanding of the situation. As the machine has ample amount of data from different perspectives it can easily differentiate between different crops.

In conclusion, it is evident that the outcome from the combined stack is best for year-round crop monitoring.

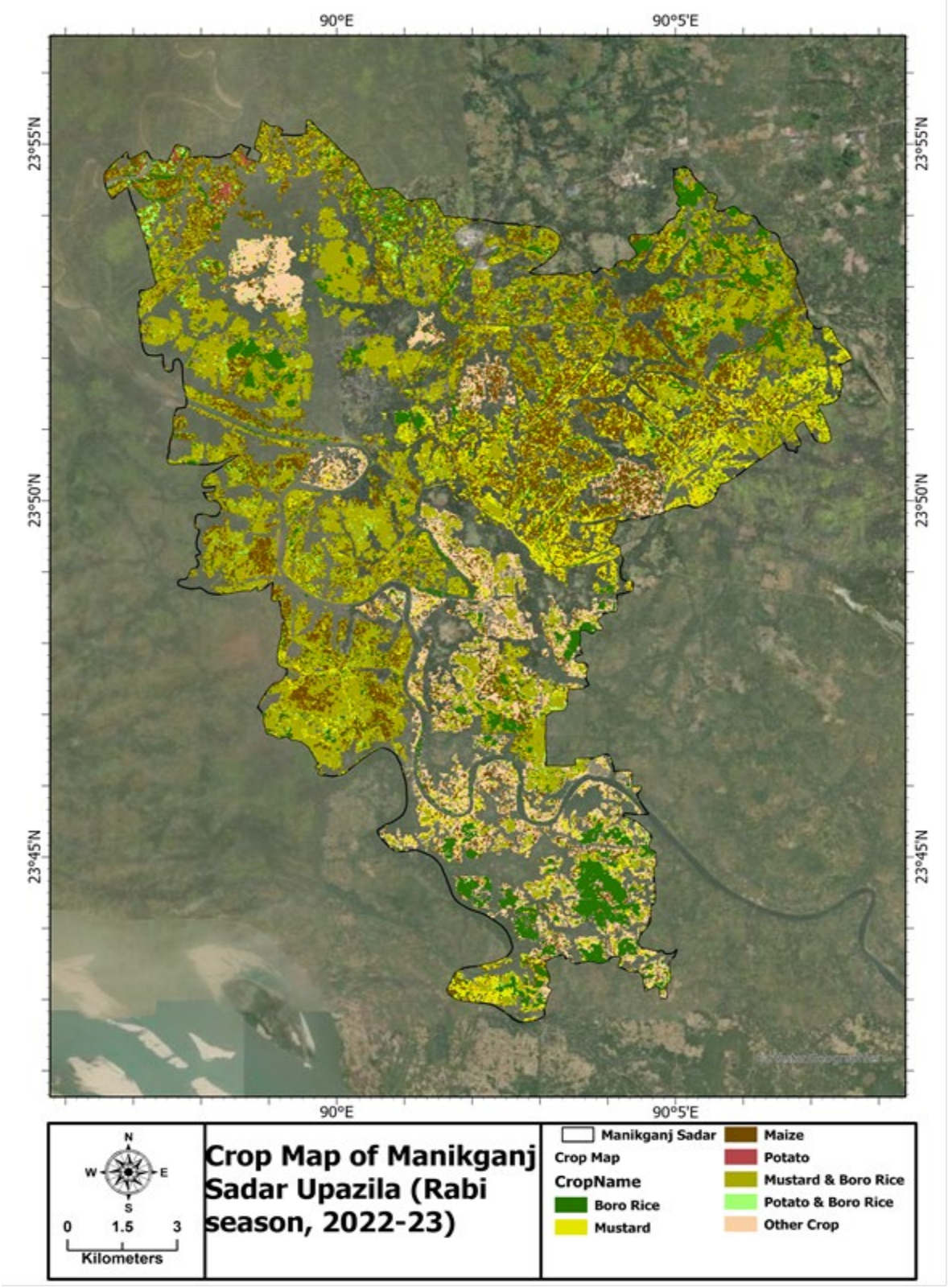


Figure 4-3: Crop Map Prepared From Both Sentinel 1 And 2 Imagery

4.2.4. Accuracy assessment

The accuracy assessment results provide valuable insights into the quality and reliability of our crop classification. Table 5 offers a detailed classification matrix for different crops, including Boro Rice, Mustard, Maize, Potato, Mustard & Boro Rice, Potato & Boro Rice, and Other crops, as observed in the Sentinel 1 stack. This stack involves rigorous preprocessing of VV and VH polarization data. Within the matrix, the diagonal elements represent accurate classifications for each crop, while off-diagonal elements signify misclassifications.

Of particular note, Boro Rice showcases an exceptional user's accuracy of 0.97, with 36 correct classifications out of a total of 37. Similarly, both Potato and Potato & Boro Rice demonstrate perfect classifications with a user's accuracy of 1. However, Mustard reveals a somewhat lower user's accuracy of 0.52, with 11 correct classifications out of 21.

Turning to producer's accuracy, Potato stands out once more with a perfect score of 1, indicating its precise identification. Boro Rice and Maize also exhibit commendable producer's accuracies of 0.97 and 0.93, respectively.

Furthermore, the Kappa statistic, which assesses the level of agreement between predicted and actual classifications, yields a value of 0.84, reflecting a substantial overall agreement. Overall accuracy may increase if only Mustard's accuracy can be increased.

These results underscore the reliability of the classification, particularly for Boro Rice and Potato, but also highlight the need for further investigation into improving accuracy for crops like Mustard. This findings affirm the suitability of Sentinel 1 for crop monitoring, especially in cloud-prone seasons (Kharif 1 and Kharif 2), while recognizing that enhancements can be made to extend this capability to a broader range of crops.

Table 4.1: Confusion Matrix for classified Sentinel 1 imagery

Crop Name	Boro rice	Mustard	Maize	Potato	Mustard & Boro rice	Potato & Boro rice	Other crop	Total	User's Accuracy	Kappa
Boro rice	36	0	0	0	0	1	0	37	0.97	0
Mustard	0	11	1	0	7	0	2	21	0.52	0
Maize	0	2	43	0	1	1	6	53	0.81	0
Potato	0	0	0	2	0	0	0	2	1	0
Mustard & Boro Rice	1	1	0	0	39	0	1	42	0.93	0
Potaot & Boro rice	0	0	0	0	0	7	0	7	1	0
Other crop	0	0	2	0	0	0	37	39	0.95	0
Total	37	14	46	2	47	9	46	201	0	0
Producer's Accuracy	0.97	0.79	0.93	1	0.83	0.78	0.80	0.00	0.87	0
Kappa	0	0	0	0	0	0	0	0	0	0.84

In the pursuit of precision, we conducted an accuracy assessment of the classified layer derived from Sentinel 2 imagery. Table 6 provides a comprehensive overview, including the confusion matrix, Kappa statistics, and overall accuracy. The matrix furnishes a detailed

breakdown of the classification performance for a range of crops, encompassing Boro Rice, Mustard, Maize, Potato, Mustard & Boro Rice, Potato & Boro Rice, and Other crops. Within this matrix, the diagonal elements denote correct classifications for each specific crop type, while the off-diagonal elements signify instances of misclassifications.

Notably, Boro Rice emerges as a standout, showcasing a perfect user's accuracy of 1, with 34 precise classifications out of 34. Likewise, Potato achieves a user's accuracy of 1, reflecting impeccable classification. Furthermore, Mustard, Maize, and Mustard & Boro Rice all maintain high user's accuracies, registering at 0.86, 0.85, and 0.86, respectively.

In terms of producer's accuracy, both Potato and Potato & Boro Rice shine with perfect scores of 1, underlining their precise identification. The rest of the crops, including Boro Rice, Mustard, Maize, Mustard & Boro Rice, and Other crops, also exhibit commendable producer's accuracies, ranging from 0.87 to 0.92.

The Kappa statistic, with a value of 0.87, signifies a strong overall agreement between the predicted classifications and the ground truth, attesting to the robustness and reliability of our classification results

Table 4.2: Confusion Matrix for classified Sentinel 2 imagery

Crop Name	Boro rice	Mustard	Maize	Potato	Mustard & Boro rice	Potato & Boro rice	Other crop	Total	User's Accuracy	Kappa
Boro rice	34	0	0	0	0	0	0	34	1	0
Mustard	1	12	0	0	0	0	1	14	0.86	0
Maize	1	0	40	0	3	0	3	47	0.85	0
Potato	0	0	0	2	0	0	0	2	1	0
Mustard & Boro Rice	1	0	4	0	43	0	2	50	0.86	0
Potato & Boro rice	0	2	0	0	0	9	0	11	0.82	0
Other crop	0	0	2	0	1	0	40	43	0.93	0
Total	37	14	46	2	47	9	46	201	0	0
Producer's Accuracy	0.92	0.86	0.87	1	0.91	1	0.87	0	0.90	0
Kappa	0	0	0	0	0	0	0	0	0	0.87

An in-depth accuracy assessment was conducted for the classified layer produced from the combined Sentinel 1 and Sentinel 2 imagery. **Error! Reference source not found.** provides a detailed view of this assessment, encompassing the confusion matrix, Kappa statistics, and overall accuracy. The matrix delivers a comprehensive breakdown of the classification performance across various crops, including Boro Rice, Mustard, Maize, Potato, Mustard & Boro Rice, Potato & Boro Rice, and Other crops. Within this matrix, the diagonal elements signify accurate classifications for each specific crop type, while the off-diagonal elements reveal instances of misclassifications.

Remarkably, Boro Rice commands a high user's accuracy, registering at 0.97, with 35 precise classifications out of 36. Similarly, both Potato and Potato & Boro Rice achieve a user's accuracy of 1, denoting flawless classification. Additionally, Mustard, Maize, and

Mustard & Boro Rice all attain high user's accuracies, scoring at 0.92, 0.92, and 0.96, respectively.

Producer's accuracy also shines in this classification, with Potato and Potato & Boro Rice receiving perfect scores of 1. Other crops, including Boro Rice, Mustard, Maize, Mustard & Boro Rice, and Other crops, exhibit impressive producer's accuracies ranging from 0.86 to 0.96.

The overall accuracy for this layer stands at an impressive 94%, attesting to the quality and reliability of the classification results. Furthermore, the Kappa statistics value for this layer, computed at 92%, indicates a robust level of agreement between the predicted classifications and the ground truth.

Table 4.3: Confusion Matrix for outcome from combined imagery (Sentinel1 and Sentinel2)

Crop Name	Boro rice	Mustard	Maize	Potato	Mustard & Boro rice	Potato & Boro rice	Other crop	Total	User's Accuracy	Kappa
Boro rice	35	0	0	0	0	1	0	36	0.97	0
Mustard	0	12	0	0	0	0	1	13	0.92	0
Maize	1	0	44	0	1	0	2	48	0.92	0
Potato	0	0	0	2	0	0	0	2	1.00	0
Mustard & Boro Rice	0	2	0	0	44	0	0	46	0.96	0
Potaot & Boro rice	0	0	0	0	0	8	0	8	1.00	0
Other crop	1	0	2	0	2	0	43	48	0.90	0
Total	37	14	46	2	47	9	46	201	0.00	0
Producer's Accuracy	0.95	0.86	0.96	1.00	0.94	0.89	0.93	0	0.94	0
Kappa	0	0	0	0	0	0	0	0	0	0.92

The three matrices provide a comprehensive overview of the classification performance for different crops using different imagery stacks. The first matrix uses Sentinel 1 imagery, the second uses Sentinel 2 imagery, and the third uses a combination of both Sentinel 1 and 2 imagery.

In terms of user's accuracy, Boro Rice consistently performs well across all three matrices, with scores of 0.97, 1, and 0.97 respectively. Potato and Potato & Boro Rice also show perfect user's accuracy in all matrices. However, Mustard shows a noticeable improvement from the first matrix (0.52) to the second (0.86) and third (0.92) matrices.

In terms of producer's accuracy, Potato and Potato & Boro Rice again stand out with perfect scores in all matrices. Boro Rice, Mustard, Maize, Mustard & Boro Rice and Other crops also show high producer's accuracies across all matrices. The Kappa statistic, which measures the agreement between the predicted and actual classifications, shows a steady increase from the first matrix (0.84) to the second (0.87) and third (0.92) matrices. This indicates an overall improvement in classification performance.

The improvement in accuracy and Kappa statistic in the third matrix can be attributed to the combined use of Sentinel 1 and 2 imagery. Each Sentinel sensor has its unique strengths - Sentinel 1 is a Synthetic Aperture Radar (SAR) sensor which is excellent for detecting surface structures and is unaffected by cloud cover or light conditions, while Sentinel 2 is an optical sensor which captures high-resolution multispectral images ideal for distinguishing between different types of vegetation. By combining these two types of imagery, we can leverage the strengths of both sensors, leading to more accurate crop classification results. However for final result all the training samples (100%) were used for classification. So the overall accuracy result is more than 92%.

4.2.5. Comparison of crop map prepared from three stacks

The crop map derived from Sentinel 1 imagery, exhibits an overall accuracy of 84%. While this is lower than the accuracy achieved with Sentinel 2 imagery, it is noteworthy that the accuracy for boro rice is exceptionally high at 0.97, indicating a precise classification. However, not all crops demonstrate such high accuracy. For instance, mustard has an accuracy of only 52%, suggesting some degree of misclassification. Despite these discrepancies, the high kappa value underscores the reliability of the outcome. It is evident that Sentinel 1 imagery, due to its high sensitivity to water content, serves as a valuable source of Earth observation data for estimating rice crop areas.

In contrast, the crop map prepared from Sentinel 2 imagery, has a higher overall accuracy of 87%. This map demonstrates superior accuracy compared to the one derived from Sentinel 1 imagery. The accuracy for Boro rice remains exceptionally high, and all crops exhibit high accuracy, indicating a high-quality classification. The high kappa value further attests to the reliability of these results. Given that Sentinel 2 imagery can effectively capture data during cloud-free conditions typical of the winter season, it proves to be a useful source of Earth observation data for crop area estimation.

The crop map prepared from the combined stack of both Sentinel 1 and Sentinel 2 imagery demonstrates the highest accuracy. The rationale behind this outcome is that the use of both types of imagery provides a more comprehensive understanding of the situation. With ample data from different perspectives, it becomes easier to differentiate between various crops. Therefore, it is evident that the outcome from the combined stack is optimal for year-round crop monitoring. With its highest accuracy, it is clear that utilizing the combined stack of both Sentinel 1 and Sentinel 2 imagery is the best option for freely available imagery. **Error! Reference source not found.** shows the comparison between the outcomes from the three different stacks. From the comparison it is evident that the crop map prepared from combined stack is the best outcome. So, for the final crop map this map is selected and refined

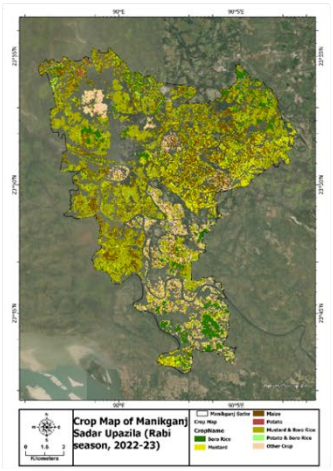
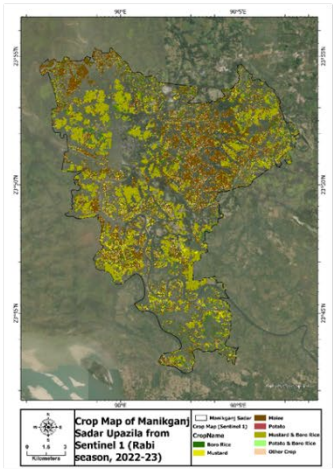
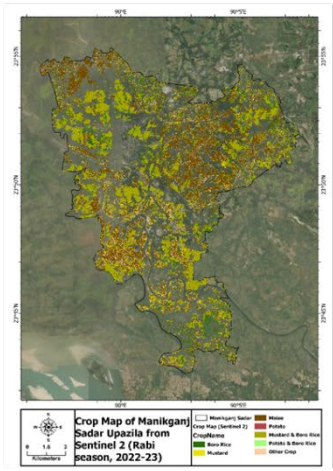
Stack	Combined stack	Stack containing Sentinel 1 imagery	Stack containing Sentinel 2 imagery
Crop Map			
Accuracy	94%	87%	90%
Result	Mostly accurate	Less accurate	Comparatively more accurate
Remarks	• Consistently high user's accuracy across multiple crop types • Perfect user's accuracy for potato and potato and boro rice • Remarkable overall accuracy 94% and kappa 92% • Effective for crop monitoring year round, offering the most accurate results for various crop types.	• High user's accuracy for boro rice(0.97). • Mustard represents lower user's accuracy (0.57) suggesting some miscalculations. • Kappa statistics (0.84) signify a good overall level of agreement. • Best suited for rice identification due to it's sensitivity to water content	• Exceptional user's accuracy for Boro rice (1) confirms precise classification. • All crop categories demonstrate high user's accuracies, indicating reliable results • A high kappa statistics (0.87) indicates high quality of classifications • Ideal for crop monitoring during cloud free seasons.

Figure 4-4: Comparison of Outcome from the 3 Stacks

4.3. Crop layers

The different crop layers and their maps are shown in this chapter. The number of crop layers prepared is 6. These layers provide information about Boro rice, mustard, maize, potato, mustard & Boro rice, potato & Boro rice and other crop. The other crop layer contains different types of crops other than the major 4 crops. Although 3 different maps are produced the major findings are shown only from the outcome prepared from the combined stack containing both Sentinel 1 and Sentinel 2 images.

4.3.1. Boro rice

The Boro rice layer is shown below map. This map has 3 layers. The layers are Boro rice, mustard and Boro rice, potato, and Boro rice. The Boro rice layer shows areas where only Boro rice grows. The mustard and Boro rice layer shows the areas where both mustard and Boro rice is grown. And the potato and Boro rice layer shows areas where potato and Boro rice is grown. The Boro rice layer has an overall accuracy of 97%.

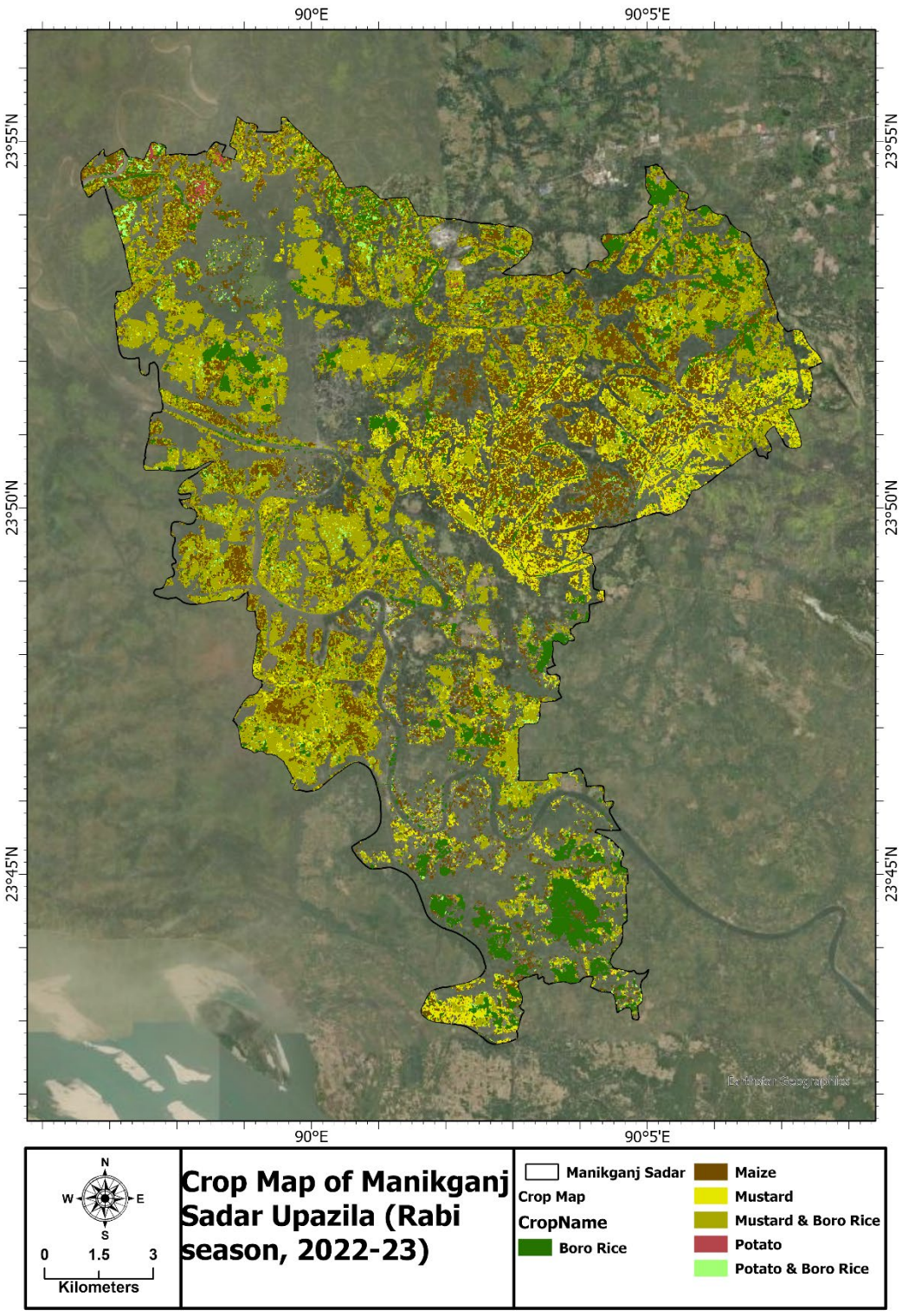


Figure 4-5: Boro rice

4.3.2. Maize

The maize layer is shown in the map below. The Maize layer shows a high level of accuracy. The user's accuracy for Maize is 0.92, indicating that 92% of the areas classified as Maize were correct. The producer's accuracy is also high at 0.96, meaning that 96% of the actual Maize areas were correctly classified.

However, there are some misclassifications. For instance, one unit that was actually Boro Rice and two units that were Other Crops were incorrectly classified as Maize. Similarly, one unit of Maize was misclassified as Mustard & Boro Rice, and two units were misclassified as Other Crops.

Despite these minor errors, the overall classification performance for the Maize layer is quite good. This is likely due to the combined use of Sentinel 1 and 2 imagery, which provides a more comprehensive set of data for classification.

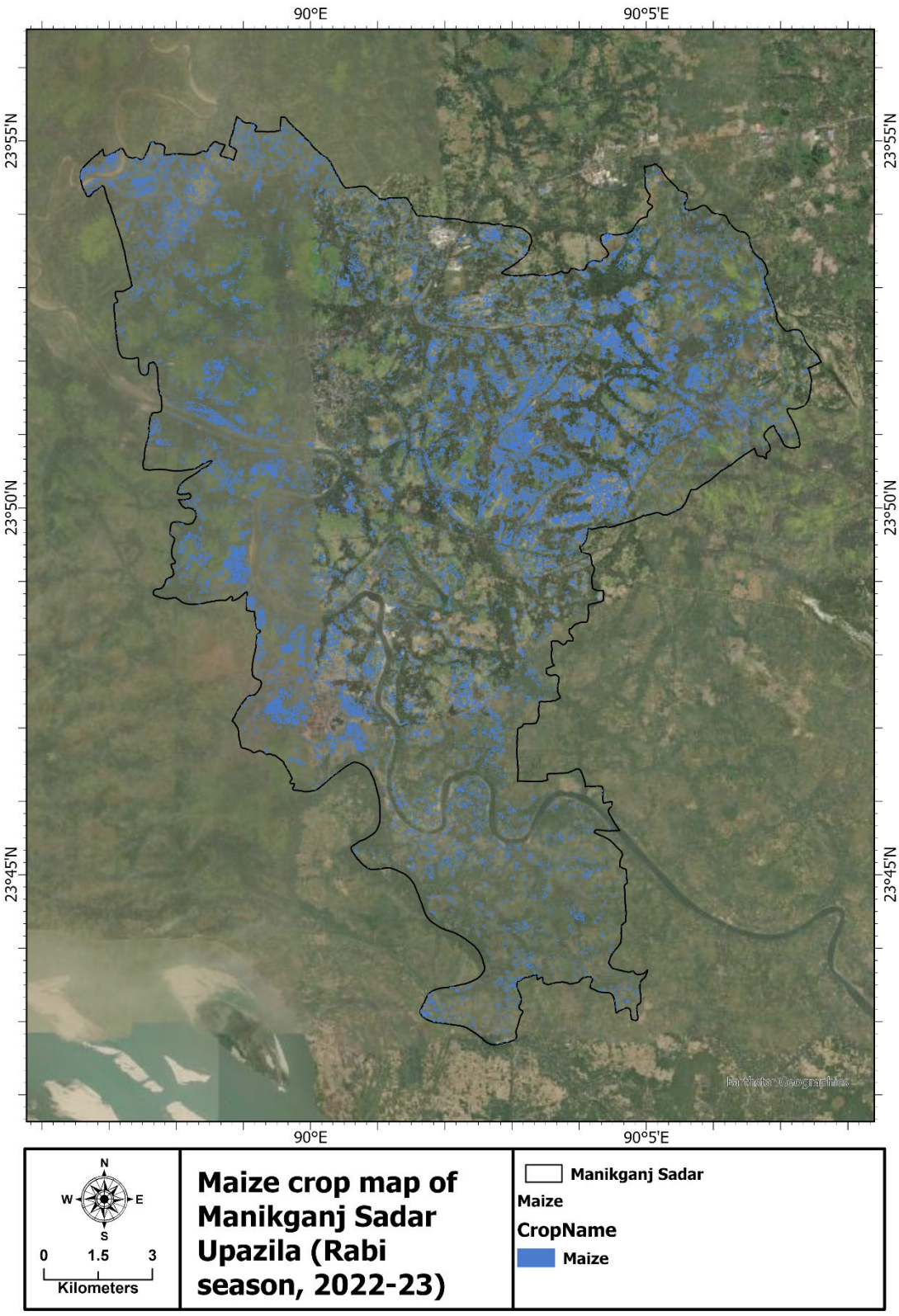


Figure 4-6: Mize

4.3.3. Mustard

The Maize layer, as depicted in the map below, comprises two distinct classifications: Maize and Maize combined with Boro Rice. The classification performance for the Maize layer is commendable, with an overall user's accuracy of 92%, indicating that 92% of the areas classified as Maize were indeed correct. However, there are some instances of misclassification. For example, one unit that was actually Boro Rice and two units that were Other Crops were incorrectly classified as Maize. Similarly, one unit of Maize was misclassified as Mustard & Boro Rice, and two units were misclassified as Other Crops. Despite these minor discrepancies, the overall classification performance for the Maize layer is quite impressive. This high level of accuracy can be attributed to the combined use of Sentinel 1 and 2 imagery, which provides a more comprehensive dataset for crop classification. The producer's accuracy for the Maize layer is also high at 96%, meaning that 96% of the actual Maize areas were correctly identified.

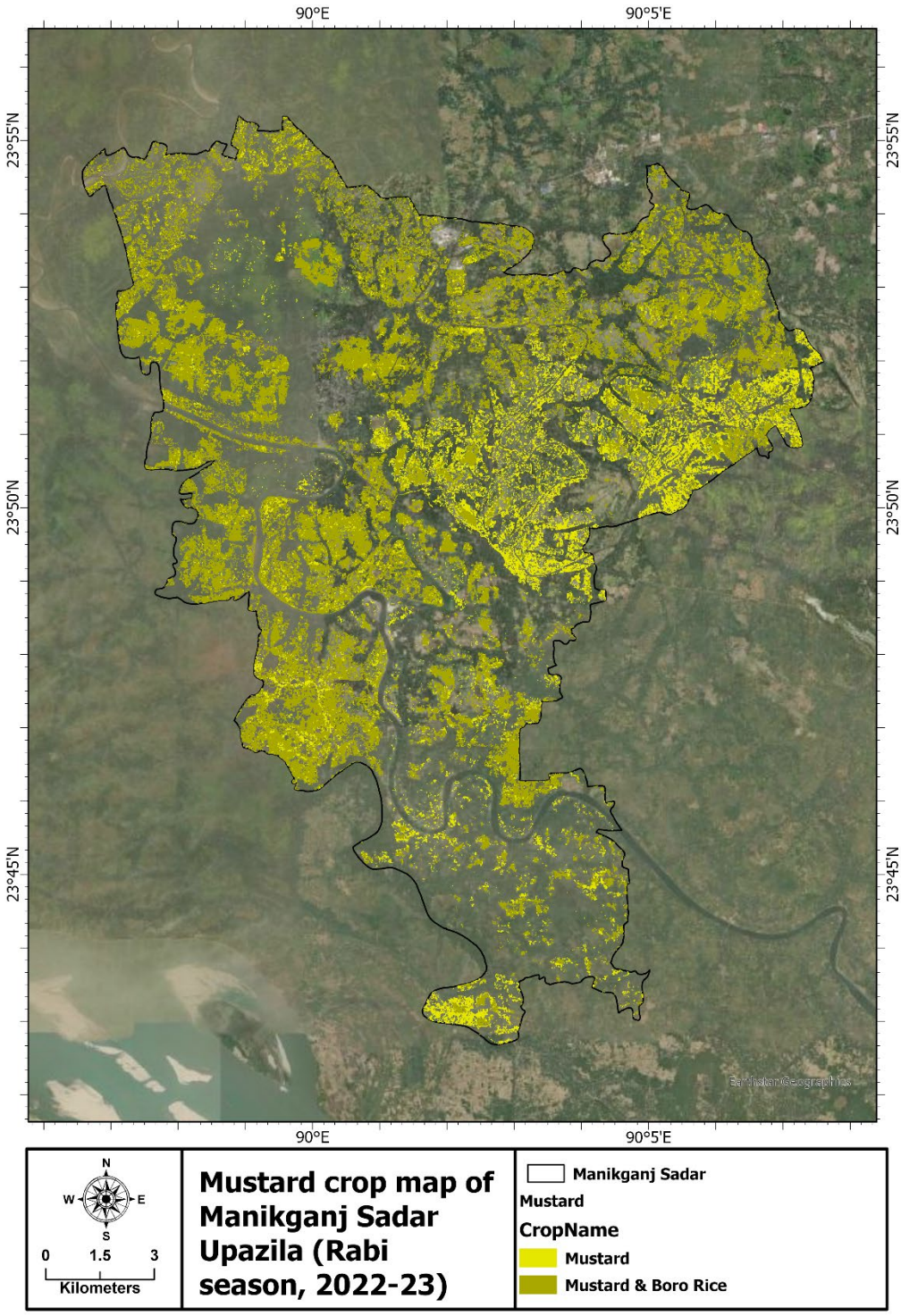


Figure 4-7: Mustard

4.3.4. Potato

The Potato layer, as depicted in the map below, comprises two distinct classifications: Potato and Potato combined with Boro Rice. The Potato layer, as depicted in Figure 8, comprises

two distinct classifications: Potato and Potato combined with Boro Rice. The classification performance for the Potato layer is commendable, with an overall user's accuracy of 1, indicating that 100% of the areas classified as Potato were indeed correct. However, there are some instances of misclassification. For example, one unit that was actually Boro Rice was incorrectly classified as Potato. Despite these minor discrepancies, the overall classification performance for the Potato layer is quite impressive. This high level of accuracy can be attributed to the combined use of Sentinel 1 and 2 imagery, which provides a more comprehensive dataset for crop classification. The producer's accuracy for the Potato layer is also high at 1, meaning that 100% of the actual Potato areas were correctly identified.



Figure 4-8: Potato

4.3.5. Crop statistics

Table 8 The table provides a comprehensive view of the agricultural landscape, detailing the areas cultivated for various crops in hectares (Ha). Boro Rice stands out with the largest cultivation area, covering an impressive 8596.308 Ha. Mustard follows closely, occupying a significant area of 7970.073 Ha. Maize, although not as expansive, still covers a considerable area of 3631.376 Ha. In addition, the practice of growing multiple crops is evident, with the combined area for Boro Rice and the other crops reaching a substantial figure. Potato crops, while not as prevalent, still cover a noteworthy area of 440.343 Ha. The total cultivation area, encompassing all these crops, amounts to a substantial 20638.1 Ha. This reflects the diversity and scale of the agricultural practices in the region.

Although the crop statistics is very accurate, some crop areas are missing in this as these areas are mainly orchard, garden crops, house agriculture etc.

Table 4.4: Crop statistics

Cropname	Area (Ha)
Boro Rice	8596.308
Mustard	7970.073
Maize	3631.376
Potato	440.343
Total	20638.1

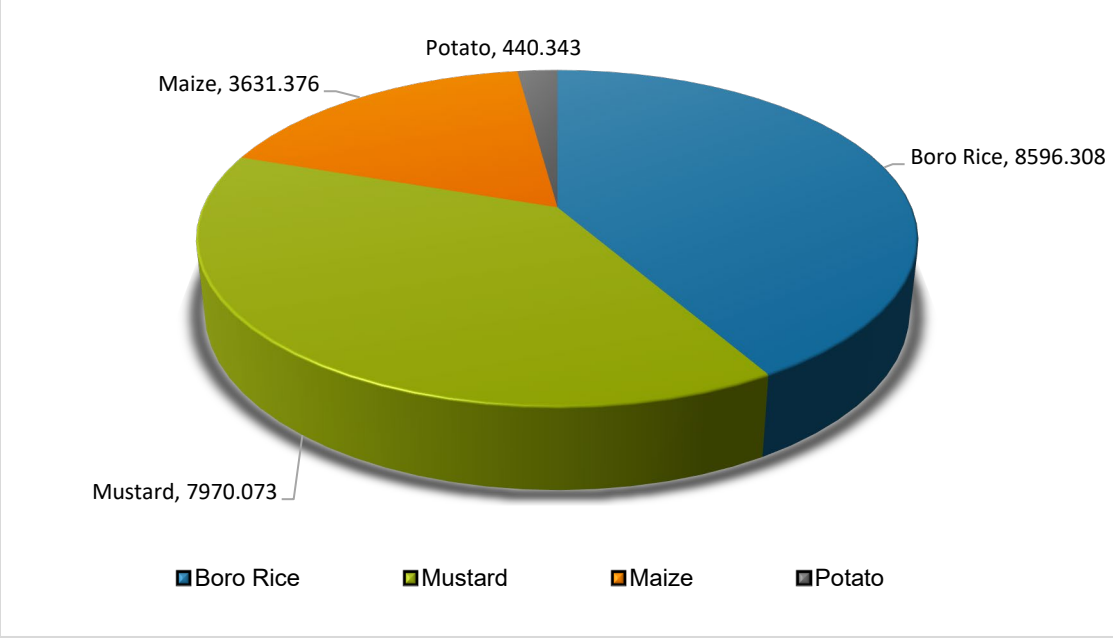


Figure 4-9: Land acquisition of Crops in ha

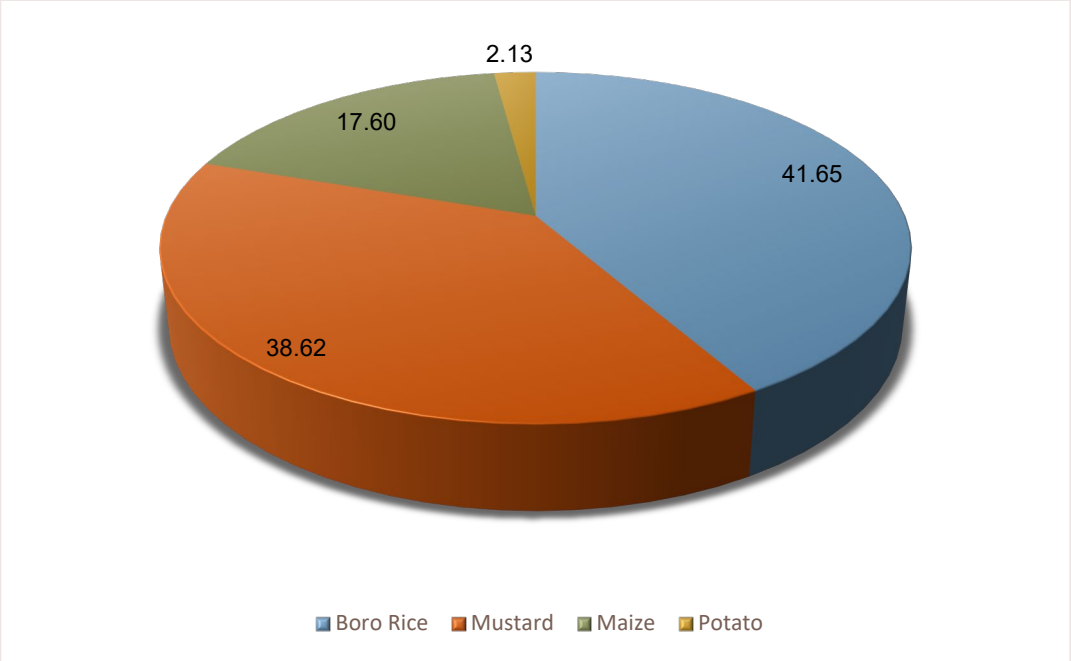


Figure 4-10 Percentage of area covering by Crops

4.4. Conclusion

In summary, this study illustrates the remarkable potential of Sentinel 1 and Sentinel 2 imagery in crop area estimation. While each of these satellite datasets possesses distinct advantages, the synergistic use of both Sentinel 1 and Sentinel 2 data emerges as the most effective approach, ensuring precision in crop classification and area estimation. It is crucial to note that this success is contingent upon the collection of timely and accurate field data, which serves as the foundation for machine learning-based remote sensing models.

Sentinel 1, with its remarkable sensitivity to water content, emerges as a valuable asset in estimating rice crop areas. Meanwhile, Sentinel 2, renowned for its ability to capture cloud-free data, proves instrumental in crop area estimation during the winter season. However, it is the combined stack of both Sentinel 1 and Sentinel 2 imagery that surpasses the individual utility of each dataset. The integration of these two types of imagery yields a more comprehensive understanding of the agricultural landscape and enhances the differentiation of various crops. Consequently, for winter crop monitoring, the use of the combined stack is the optimal choice, given the heterogenous crop diversity and minimal cloud cover during this season. In contrast, Sentinel 1 remains the primary resource for crop monitoring during other seasons when cloud cover prevails.

This study underscores the significance of amalgamating diverse Earth observation data sources to enhance the accuracy and reliability of crop area estimation. Furthermore, it underscores the pivotal role of freely available satellite imagery in bolstering sustainable agricultural practices and fortifying food security. By harnessing the power of remote sensing and geospatial technology, this project contributes to the broader vision of advancing agricultural management and land use planning in a rapidly evolving world.

5. Kharif 2 Crop Signature Data Collection Utilizing the survey 123 Application.

5.1. Introduction

Crop signature data collection stands as a fundamental step in the realm of remote sensing and machine learning-based crop classification. This particular endeavor focused on the Kharif 2 season and involved the concerted efforts of a team of four surveyors who worked concurrently to assemble a comprehensive dataset. The collected dataset encompasses a wide array of information related to crop types, planting dates, growth stages, soil conditions, and various factors influencing crop growth and appearance.

This report offers an extensive overview of the data collection process and presents findings derived from the Kharif 2 season crop signature data collection initiative conducted in the Manikganj Sadar Upazila region of the Manikganj district in Bangladesh. Employing the versatile Survey123 app, the surveyors successfully gathered 465 crop signatures over the course of seven days. The report aims to provide a comprehensive account of the data collection process, the collected information, and its paramount relevance for future crop classification endeavors.

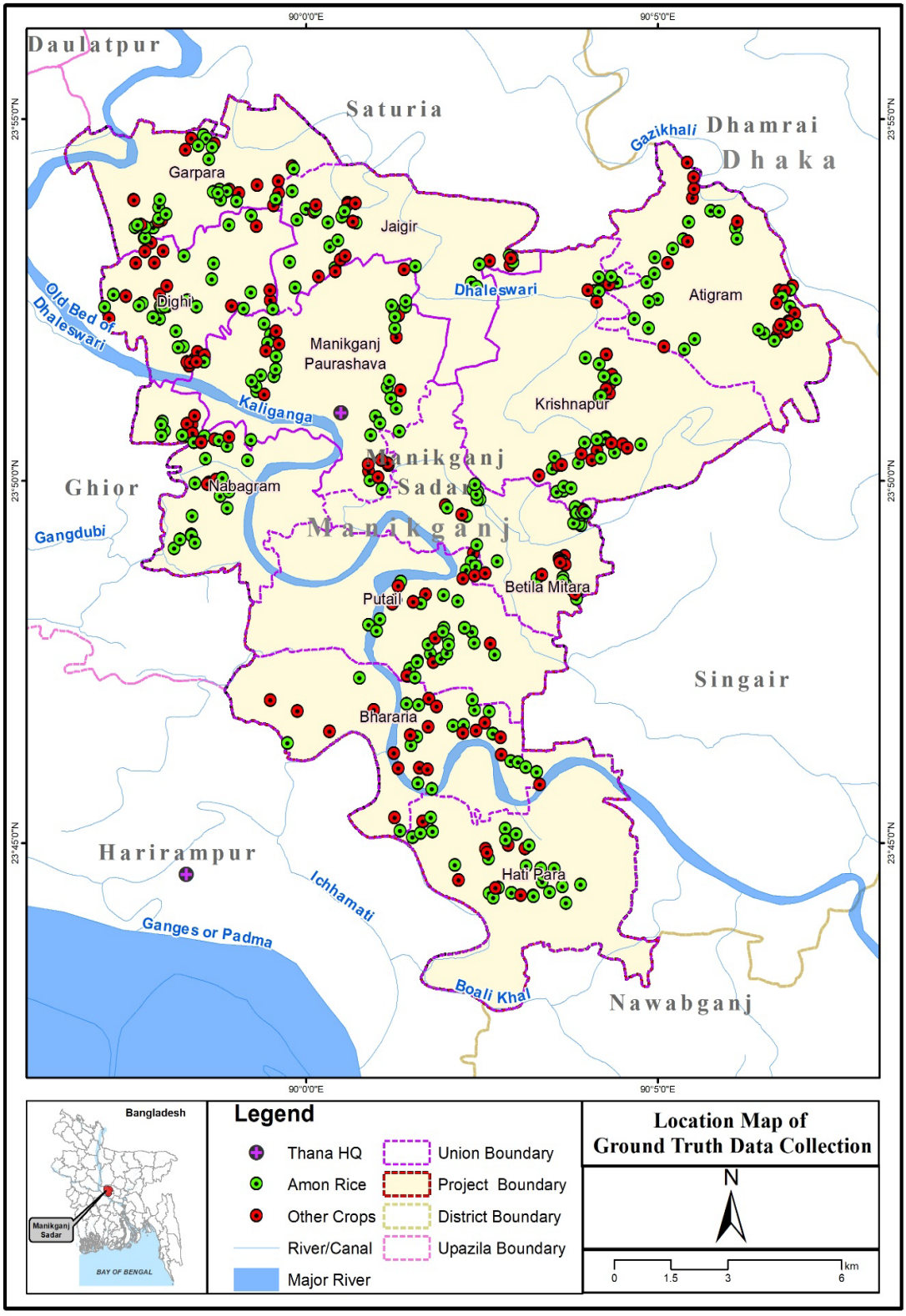


Figure 5-1: Data Collection Map for Amon Rice (Kharif 2)

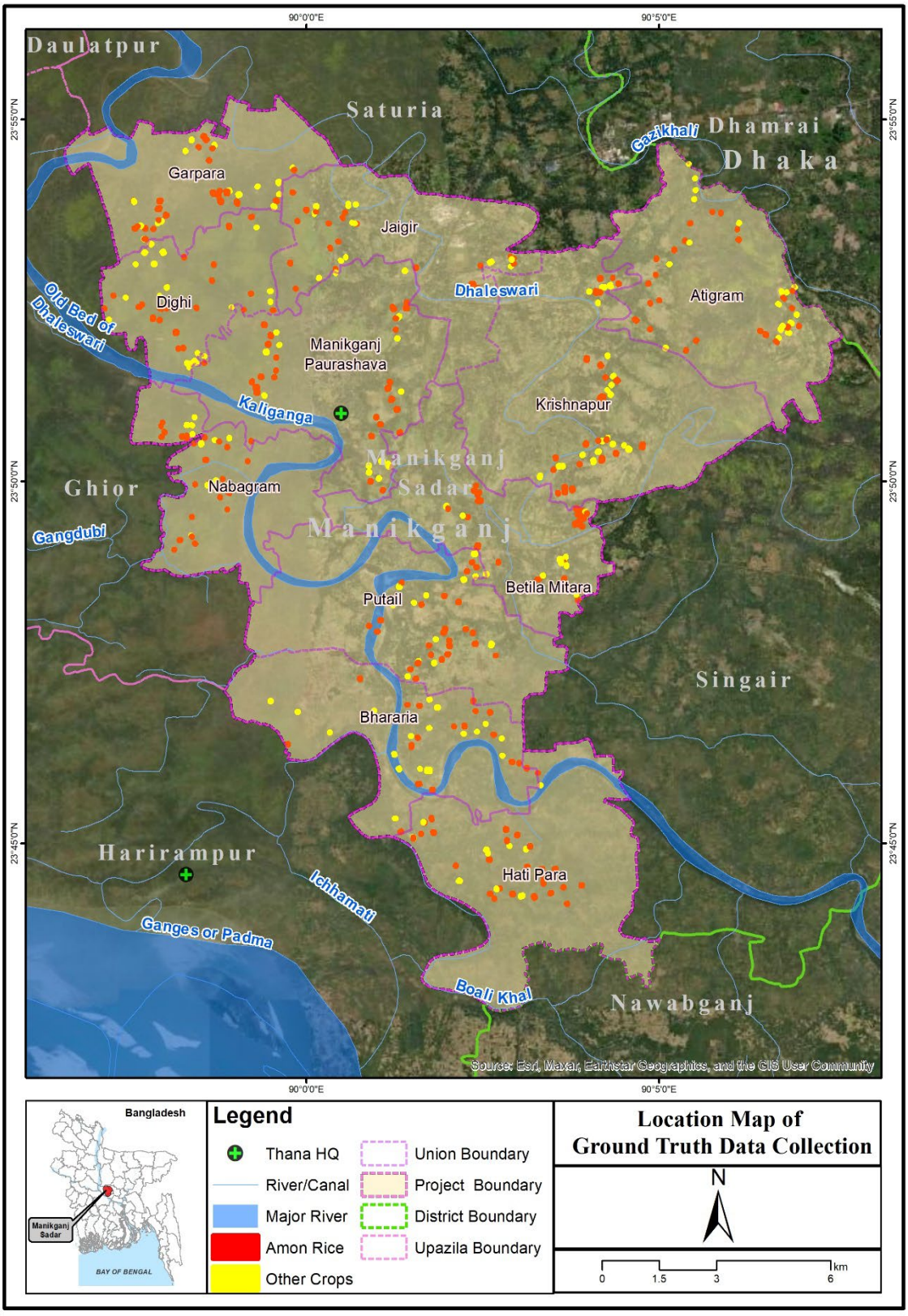


Figure 5-2: Data Collection Map with Image for Amon Rice (Kharif 2)

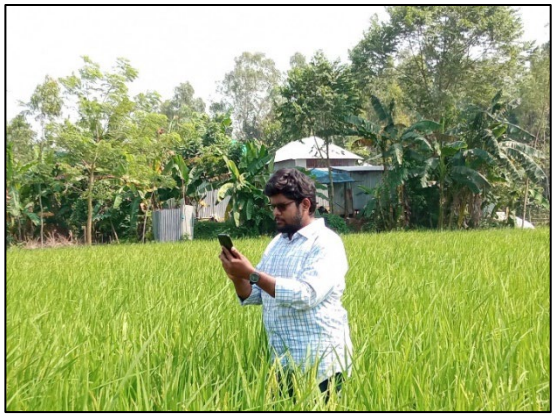











Figure 5-3: Surveyors Working in The Field And Interviewing Farmers.

5.2. DATA Collection Process

The data collection process for the Kharif 2 season crop signature was meticulously conducted over a period of 7 days by a team of four surveyors. The surveyors employed the Survey123 app, which served as a versatile tool for capturing a wide range of agricultural data with precision. The following steps provide a detailed account of the data collection process:

App Installation: To initiate the data collection, the surveyors first downloaded and installed the Survey123 app from the Play Store on their Android devices. This mobile application was selected for its user-friendly interface and compatibility with the survey objectives.

App Launch: After successful installation, surveyors launched the Survey123 app, which presented them with a welcoming screen. To expedite the data collection process, the option to "Continue without signing in" was chosen, ensuring swift access to the survey form.

Form Retrieval: The Crop Signature form, designed for the collection of Kharif 2 season agricultural data, was retrieved by scanning a unique QR code. This action triggered the download of the survey form into the Survey123 app. Surveyors closely monitored the download process, which took a few moments.

Form Access: Once the form was downloaded, surveyors had the option to view or add data. They selected the "Collect" button to initiate the data collection process.

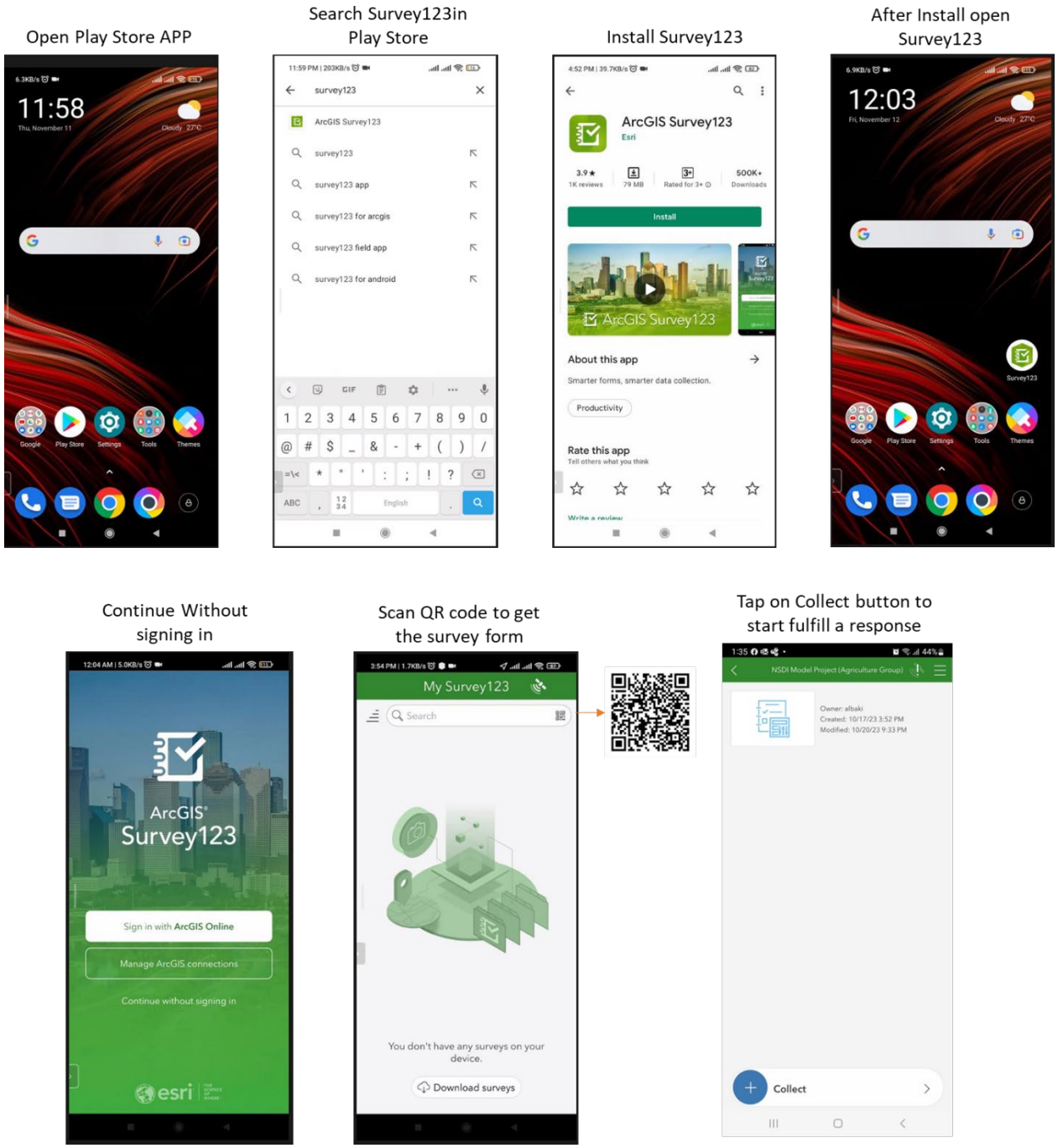


Figure 5-4: App Installation to Data Collection Form Opening Workflow.

Questionnaire Completion: The surveyors, equipped with sound knowledge of local agricultural practices, proceeded to fill out the form comprehensively. A series of structured questions and options were presented within the survey form, covering various aspects of crop growth and seasonal conditions. The data collection process involved answering specific questions such as:

- Season Name (Kharif 2 was defaulted and read only)

- Selected Crop for the current season (many crops of kharif season was listed with "other' option)
- Name of "Other" Crop (if "Other" was selected in the previous question)
- Planting/Transplanting Date
- Tentative Harvest Date
- Plant Height (inches)
- Plant Growth Stage (select a growth stage from the list or select "specify Growth Stage" for defined by the surveyor)
- Specify Plant Growth Stage (if not in the selection list of the previous question)
- Status of Crop being on Self ('maacha' in Bangla) for vegetables or betel leaf
- Last Irrigation/Rainfall Date
- Current Soil Condition (options: Inundated/irrigated, Wet condition and As usual dry soil)
- Last Season Crop (select a last season crop or fallow land or select "other")
- Other Last Next Season Crop (if "Other" was selected in the previous question)
- Planned Crop for the Next Season (select the next season planed crop or fallow land or select "other")
- Other Crop Next Season (if "Other" was selected in the previous question)
- Field Size (>15 decimal) – (yes or no option is provided. If yes is selected a polygon drawing option comes otherwise if no is selected a point drawing options will come. In both cases It will help to draw the geometry on an imagery base Map. The imagery-based map shows high resolution imagery and current location of the surveyor.)
- Surveyor's Name
- Current Date (automatically generated)

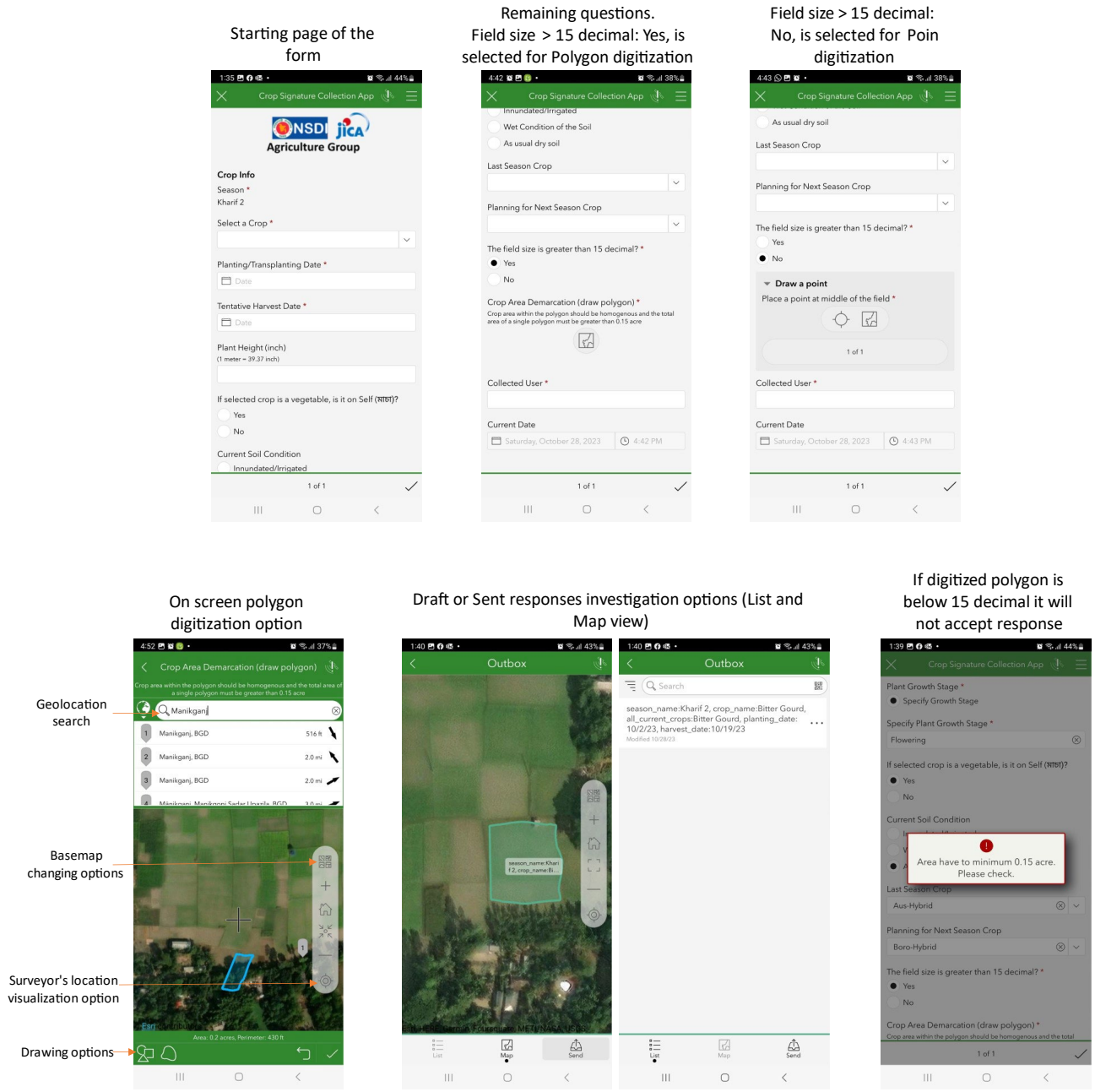


Figure 5-5: Survey Form Questions and Interactive Options for Facilitating Field Survey.

The data collected via these questions painted a comprehensive and season-specific picture of agricultural conditions. The surveyors ensured the accuracy and reliability of this data through careful cross-referencing with their direct observations in the field. The utilization of mobile devices in conjunction with the Survey123 app streamlined the data entry process, allowing for real-time input. Furthermore, an option to edit and resend the survey was available, providing surveyors with the opportunity to review and amend their submissions as needed.

5.3. Central survey monitoring panel of Survey 123

The Survey123 app integrated a central survey monitoring panel within the ArcGIS Online platform, enabling comprehensive data management. This web-based facility permitted the configuration and real-time monitoring of surveyor responses, data statistics, and user collaboration. Throughout the fieldwork, this panel was instrumental in monitoring surveyor responses in near-real time. In cases where quality issues were identified, immediate communication was facilitated, allowing surveyors to rectify and promptly resubmit their responses.

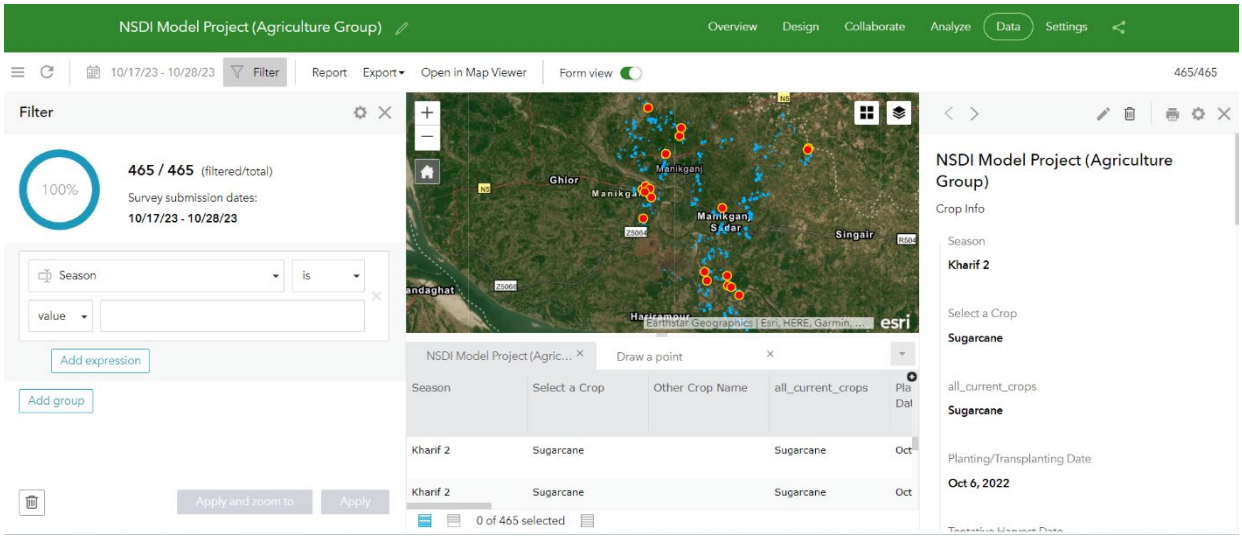


Figure 5-6: Survey Monitoring Panel within the Arcgis Online Platform.

5.4. Importance of Crop Signature Data Collection for Kharif 2

The data collected during this initiative holds substantial importance for future crop classification endeavors. It offers nuanced insights into the distinctive characteristics and conditions of crops during the Kharif 2 season. Critical factors such as planting dates, growth stages, and soil conditions are essential for accurate crop identification using remote sensing and machine learning techniques.

5.5. Data Analysis and Applications

The dataset amassed will be pivotal in the development of crop signatures tailored to the Kharif 2 season. These crop signatures will serve as reference data for the refinement of crop classification algorithms. The amalgamation of field data and satellite imagery will enable the precise identification and mapping of various crops within the region. This has significant practical applications in agricultural monitoring, land-use planning, and food security.

5.6. Conclusion

In summation, the Kharif 2 season crop signature data collection, facilitated by the Survey123 app, was executed seamlessly within the Manikganj Sadar Upazila region. The data amassed is a valuable resource for crop classification endeavors, underscoring the efficacy of mobile

applications for agricultural data collection. This report has provided a comprehensive elucidation of the data collection process and has accentuated the importance of the collected data for prospective work in the domain of crop classification and agricultural monitoring, specifically for the Kharif 2 season.

6. Data Products Specifications (DPS)

6.1. Overview

6.1.1. Information about the creation of the data product specifications

a. Title: Rice Area Mapping of Manikganj Sadar Upazila under NSDI Model Project
b. Date: 15 July 2023
c. Responsible organization: NSDI Model Project, Agriculture Management Team, funded by JICA
d. Language: English
e. Topic category: Agriculture
f. Document format: Microsoft Word

6.1.2. Objectives

The Department of Agricultural Extension (DAE) is responsible for making annual crop production target and area estimation for different crops. But cultivable crop land of different crops is calculated based on eye estimation by Sub-Assistant Agricultural Officer (SAAO) and farmers' traditional knowledge. As a result, precise crop area statistics based on scientific method are not available which is creating a big problem in making proper plans at national policy level.

In this scenario a more scientifically accurate method of data collection is needed for the national food related policy and planning. So, through this model project, funded by JICA, a remote sensing-based crop estimation pilot work has been done on Manikganj Sadar Upazila of Manikganj district. The findings and methodology of this model project will greatly help to implement the large-scale crop area estimation in Bangladesh in near future and also will help the government's various planning processes. Furthermore, this technologically advanced workflow will help DAE to contribute to building a smart Bangladesh.

6.2. Extent of the data

Manikganj Sadar Upazila of Bangladesh.

The projection system is BUTM2010:

Top: 2,645,610.178400 m

Bottom: 2,622,269.673900 m

Left: 494,188.621800 m

Right: 512,905.118500 m

6.3. Normative references

- Report for the NSDI Model Project (NSDI-MP) Workshop
- Inception report on Model Project: Rice Area Mapping of Manikganj Sadar Upazila using Medium Resolution Satellite Image
- Agricultural Extension Manual 2016
- National Agriculture Policy 2018
- National Agriculture Extension Policy 2020
- National ICT policy 2018

- Guidelines for Data Product Specifications (NSDI)
- Guidelines for Data Quality (NSDI)
- Guidelines for Metadata (NSDI)
- 8th Five Year Plan
- 4th Industrial Revolution (4IR)

6.4. Scope

6.4.1. Scope identification

Data Product specification on a model project named "Rice Area Mapping of Manikganj Sadar Upazila using Medium Resolution Satellite Image" funded by Japan International Cooperation Agency (JICA). The work of model project has been implemented using Sentinel 1 and Sentinel 2 satellite images for Rabi Season (Winter Season) rice area mapping of Manikganj Sadar Upazila of Manikganj district. Both optical and SAR satellite images are utilized from 15 November 2022 to 30 April 2023. For this reason, the output of this analysis (crop classification raster file) will be produced in 10 m spatial resolution.

6.5. Data Product Identification

6.5.1. Name

Data Product Specifications on Rice Area Mapping of Manikganj Sadar Upazila under NSDI Model Project

6.5.2. Date of data creation

Data analyzed from November 2022 to May 2023 (Rabi Cropping Season or Winter Season) of Manikganj Sadar Upazila).

6.5.3. Contact information

Dr. Farida Perveen
Deputy Director & In-charge of GIS & RS Unit
Department of Agricultural Extension (DAE)
Ministry of Agriculture, Bangladesh
Cell:
E-mail:
Web: www.dae.gov.bd

6.5.4. Geographic description

The area of interest is the Manikganj Sadar Upazila which is under Manikganj District of Bangladesh.

6.6. Data Content and Structure

Detail data structure is attached in the annex 01.

Spatial Database Summary Table:

Spatial Database Theme	Data Type(Vector/Raster/Table)	Dataset	Feature Class/Data Name

		Administrative base map of Manikganj Sadar Upazilla	District, Upazila, Union
	Crop area map	Topographic dataset of Manikganj Sadar Upazilla	Settlement All Water bodies Agriculture land, Forest, shrubs, Orchards Road/Railway Grass land Urban areas Fellow land (permanent) Wet land, Swamp
Classified crop area map Ground truth data Point shape of Rabi crops Point shape of Kharif crops			
	Raster	Sentinel 1	
	Raster	Sentinel 2	

6.7. Reference Systems

6.7.1. Spatial reference system

Geographic Coordinate System: WGS 1984

Angular Unit	Degree (0.0174532925199433)
Prime Meridian	Greenwich (0.0)
Datum	D WGS 1984
Spheroid	WGS 1984
Semimajor Axis	6378137.0
Semiminor Axis	6356752.314245179
Inverse Flattening	298.257223563

6.7.2. Temporal reference system

Reference system identifier: Gregorian calendar

Note: It is created for Rabi or winter season (rice crop) of Bangladesh (November 2022 to April 2023)

6.8. Data Quality

The Satellite imagery used:
Optical satellite image Sentinel-2 (NDVI and SAVI) and SAR satellite image Sentinel-1 (VV and VH): Spatial resolution is 10 meter by 10 meter.

6.8.1. Secondary data:

1: 25,000 scale base map data of Survey of Bangladesh

6.8.2. Ground truth data

Ground truth data/crop signature data: Accuracy of RTK GPS (Horizontal accuracy: 5-10 cm, Vertical accuracy: 10-30 cm) approximately.
Smart Phone's GPS (Horizontal accuracy: 1-5 m) approximately.

6.8.3. Statistical accuracy of Classified Crop Raster:

Will be added in future (when the calculation will be done)
Method: Accuracy of the classified image will be evaluated by obtaining a classification error matrix. The quantitative evaluation of the results will be carried out by calculating Producer's accuracy, User's accuracy, Overall accuracy (OA) and the Kappa coefficient (KC).

6.9. Data Product Delivery

6.9.1. Name of data formats

Vector data: ArcGIS Shapefile format

Raster data: Tagged Image File Format (.tif)

Table: xlsx

6.9.2. Unit

Administrative shape file

Road shape

River shape

Forest coverage

Land use/cover

GCP

6.9.3. Spatial reference system

Projected Coordinate System: BUTM2010
Projection Transverse_Mercator
Projection parameters
False_Easting 500000.0
False_Northing 0.0
Central_Meridian 90
Scale_Factor 0.9996
Latitude_Of_Origin 0.0
Linear Unit Meter (1.0)

6.9.4. Structure of the delivery file

Structure of data set
Detail structure of the dataset can be found in Annex 01
Encoding rules
ArcGIS Shape file and Tagged Image File Format

MS Excel format
Language: English

6.10. Metadata

To be prepared according to Guidelines for Metadata (NSDI)

SN	Item	Contents
1	Data format	
2	Acquisition procedure	
3	Resolution	
4	date of acquisition	
5.	……	

6.10.1. Additional Information

Data / Layer	File format
Administrative base map of Bangladesh (District,Upazila,Union)	Shape file
Land use Map of Bangladesh	Shape file
Topographic maps of Manikganj district	Shape file
Settlement of Manikganj district	Shape file
Water bodies of Manikganj district	Shape file
Forest, shrubs of Manikganj district	Shape file
Road/Railway of Manikganj district	Shape file
Grass land of Manikganj district	Shape file
Urban areas of Manikganj district	Shape file
Fellow land (permanent) of Manikganj district	Shape file
Wet land of Manikganj district	Shape file

Appendix
Annex 01 Data content and structure document.

Table Data
Raw field data structure

Question No	Field Name/ Questions	Description	Example	Field Type
1	start	Survey Start Time		Date
2	end	Survey End Time		Date
3	Surveyor Name	Name of the surveyor		String
4	Location Name	Local name of a location like village (if any)		String
	_A1_latitude			Double
	_A1_longitude			Double

	_A1_altitude	Latitudes and longitudes of a homogeneous crop field (it will help to delineate the field)		Double
	_A1_precision			Double
	_A2_latitude			Double
	_A2_longitude			Double
	_A2_altitude			Double
	_A2_precision			Double
	_A3_latitude			Double
	_A3_longitude			Double
	_A3_altitude			Double
	_A3_precision			Double
	_A4_latitude			Double
	_A4_longitude			Double
	_A4_altitude			Double
	_A4_precision			Double
	_A5_latitude			Double
	_A5_longitude			Double
	_A5_altitude			Double
	_A5_precision			Double
5	Union Name	Name of the Union under Manikganj Sadar Upazila		String
6	Crops type	Crop that was in the field during the survey time	Boro ice	String
7	How many crops types did you get from November to April?	Total number of crops standing in the field during November 2022 to April 2023		Short integer
8	What was the date of showing for 1st crop?	1st crop's sowing date from November 2022 to April 2023		Date
9	What was the date of showing for 2nd crop?	2nd crop's sowing date from November 2022 to April 2023		Date
10	What was the date of showing for 3rd crop?	3rd crop's sowing date from November 2022 to April 2023		Date
11	What was the name 1st crop?	Name of the 1st crop cultivated during November 2022 to April 2023		String
12	What was the name 2nd crop?	Name of the 2nd crop cultivated during November 2022 to April 2023		String
13	What was the name 3rd crop?	Name of the 3rd crop cultivated during November 2022 to April 2023		String
14	Picture_URL	Picture of the crop field		String

Vector Data

Signature polygon structure

Feature Name	Field	Geometry Type	Definition	Field Type
crop_signature_data.shp	FID	Polygon	Object ID	OID
crop_signature_data.shp	start	Polygon	Survey Start Time	Date
crop_signature_data.shp	end	Polygon	Survey End Time	Date
crop_signature_data.shp	Surveyor_Name	Polygon	Name of the surveyor	Text
crop_signature_data.shp	Location_Name	Polygon	Local name of a location like village (if any)	Text
crop_signature_data.shp	Shape	Polygon	Geometry of a crop homoginious field	Geometry
crop_signature_data.shp	Union_Name	Polygon	Name of the Union under Manikganj Sadar Upazila	Text
crop_signature_data.shp	Crops_Name	Polygon	Crop that was in the field during the survey time	Text
crop_signature_data.shp	total_c_nov_apr	Polygon	Total number of crops standing in the field during November 2022 to April 2023	Short integer
crop_signature_data.shp	showing_D_of_1st	Polygon	1st crop's sowing date from November 2022 to April 2023	Date
crop_signature_data.shp	showing_D_of_2nd	Polygon	2nd crop's sowing date from November 2022 to April 2023	Date
crop_signature_data.shp	showing_D_of_3rd	Polygon	3rd crop's sowing date from November 2022 to April 2023	Date
crop_signature_data.shp	1st_crop_Nam	Polygon	Name of the 1st crop cultivated during November 2022 to April 2023	Text
crop_signature_data.shp	2nd_crop_Name	Polygon	Name of the 2nd crop cultivated during November 2022 to April 2023	Text
crop_signature_data.shp	3rd_crop_Name	Polygon	Name of the 3rd crop cultivated during November 2022 to April 2023	Text
crop_signature_data.shp	Pic_URL	Polygon	Picture of the crop field	Text

Raster data:
Classified crop map
File name:
Spatial resolution: 10 m by 10m
File format: .tif
Extend
- Top
- Bottom
- Left
- Right

Pixel depth: 8 bit

Legends of classified crops

Crops	Color	Remarks
Boro Rice	Green	
Wheat	Pink	
Maize	Light Green	

7. Training on Geo-spatial data analysis for Crop Classification for Capacity Building

As a component of the project, training sessions were organized to enhance the skills of team members. These sessions predominantly covered the following topics:

(i) Image Analysis (Annex – I)

(ii) Global Navigation Satellite System (GNSS) technology, (Annex III),

(iii) Ground Control Points (GCP) using RTK GPS for establishing geospatial accuracy (Annex IV)

(iv) Ground Truth Data Collection for crop signature utilizing Kobo Toolbox (Annex IV)

(v) The role of Drones in Modern Surveying Techniques for Rice Area Mapping (Annex IV), and

(vi) Mainstreaming Disaster and Climate Risks into Development Planning with a focus on Development Project Proposal (DPP). (Annex IV)

8. Conclusion and Way Forward

8.1. Conclusion

The comprehensive analysis presented in this study demonstrates the significant strides made in the field of agricultural monitoring, specifically focusing on the identification and precise estimation of crop areas in Bangladesh during the Rabi season. Leveraging the power of remote sensing, machine learning, and geospatial technology, the study utilized Sentinel-1 and Sentinel-2 imagery, both individually and in combination, to create accurate crop maps and layers for major crops such as Boro rice, mustard, potato, and wheat. It is crucial to note that this success is contingent upon the collection of timely and accurate field data, which serves as the foundation for machine learning-based remote sensing models.

The results reveal that each imagery stack—Sentinel-1, Sentinel-2, and the combined stack—has its unique strengths and advantages. Sentinel-1, with its Synthetic Aperture Radar (SAR) technology, excels in capturing high-resolution images irrespective of weather conditions, making it particularly useful for year-round monitoring. Sentinel-2, with its high-resolution multispectral capabilities, proves valuable for crop area estimation during cloud-free conditions, especially in the winter season. The combined stack of Sentinel-1 and Sentinel-2 emerges as the most effective approach, offering a comprehensive understanding of the agricultural landscape and enhancing the accuracy of crop classification.

The study's accuracy assessments highlight the reliability of the classification results, with user's and producer's accuracies consistently high for major crops. The Kappa statistics indicate a strong overall agreement between predicted and actual classifications, further affirming the robustness of the methodology.

8.2. Lesson Learned

We have learned that this study underscores the significance of amalgamating diverse Earth observation data sources to enhance the accuracy and reliability of crop area estimation. The integration of these two types of imagery yields a more comprehensive understanding of the agricultural landscape and enhances the differentiation of various crops. Consequently, for winter crop monitoring, the use of the combined stack is the optimal choice, given the heterogenous crop diversity and minimal cloud cover during this season. In contrast, Sentinel 1 remains the primary resource for crop monitoring during other seasons when cloud cover prevails. Furthermore, it underscores the pivotal role of freely available satellite imagery in bolstering sustainable agricultural practices and fortifying food security. By harnessing the power of remote sensing and geospatial technology, this project contributes to the broader vision of advancing agricultural management and land use planning in a rapidly evolving world.

The findings of this study provide a valuable foundation for continued research and application in agricultural monitoring and land management. The integration of advanced image classification techniques, particularly those involving machine learning principles, opens avenues for improved decision-making in the context of Bangladesh's diverse agricultural landscape. As technology evolves, further refinements and enhancements in image classification methodologies can be explored, promising even greater accuracy and efficiency in crop mapping and related applications. Additionally, ongoing collaboration between

researchers, GIS professionals, and policymakers can ensure the effective implementation of these technologies for sustainable agricultural practices and informed decision-making.

8.3. Sustainability Arrangement

A sustainability arrangement for a rice area mapping project involves considering various aspects to ensure that the project is environmentally friendly, socially responsible, and economically viable.

Remote Sensing Technology:

- Utilize satellite imagery and remote sensing technology to monitor rice fields. Platforms like Landsat, Sentinel, and other Earth observation satellites can provide high-resolution images for accurate mapping.
- Employ spectral analysis to differentiate between various crops and identify rice fields.

GIS (Geographic Information System):

- Integrate remote sensing data into GIS for spatial analysis and mapping. GIS can provide a comprehensive overview of rice cultivation areas, helping in efficient management and planning.

Data Processing and Machine Learning:

- Apply machine learning algorithms to process and analyze remote sensing data. This can help automate the identification and classification of rice fields.
- Train models to detect changes in land use, assess crop health, and predict potential issues such as disease outbreaks.

Data Sharing and Collaboration:

- Establish a platform for data sharing and collaboration among stakeholders, including farmers, government agencies, research institutions, and non-governmental organizations.
- Encourage the open sharing of data to facilitate research, monitoring, and sustainable management practices.

Precision Agriculture:

- Implement precision agriculture techniques to optimize resource use and reduce environmental impact. This includes the precise application of water, fertilizers, and pesticides based on real-time data.

Smart Irrigation Systems:

- Integrate smart irrigation systems that use sensors and data analytics to optimize water usage. This not only conserves water but also improves crop yields.

Climate Resilience Planning:

- Use historical data and climate modeling to anticipate changes in weather patterns. Develop plans to adapt rice cultivation practices to changing climate conditions.

Community Engagement:

- Involve local communities in the mapping process. Collect traditional knowledge from farmers and incorporate it into the mapping framework.
- Raise awareness about sustainable rice cultivation practices and involve local communities in decision-making processes.

Certification Programs:

- Establish sustainability certification programs for rice cultivation. This can incentivize farmers to adopt environmentally friendly practices and provide consumers with assurance about the sustainability of the rice they consume.

Policy Support:

- Advocate for policies that promote sustainable rice cultivation. This may include incentives for adopting environmentally friendly practices and regulations to minimize the negative impacts of rice farming.

Monitoring and Evaluation:

- Regularly monitor and evaluate the impact of sustainability initiatives. Use feedback from monitoring to make continuous improvements and adjustments to the sustainability arrangement.

By combining these elements, a comprehensive sustainability arrangement for rice area mapping can be developed, promoting environmentally responsible and socially beneficial rice cultivation practices.

Financial support:

- The study was conducted in a small location, we require support from JICA to carry out this type of work on a larger scale throughout Bangladesh. As a result, we strongly recommend JICA to assist Bangladesh in making this effort sustainable.

8.4. Overall Challenges and Limitation of the Project

Some potential challenges and Limitations include:

- **Weather conditions:** The success of the project is highly dependent on the weather conditions during the satellite image acquisition process. Cloud cover or poor visibility could impact the quality and quantity of the data collected and could potentially delay the project timeline.
- **Availability of ground truth data:** Collecting and verifying ground truth data is an important aspect of the project, but it may be difficult to obtain reliable and accurate data for all areas of the study site. This could potentially impact the accuracy of the rice area estimates obtained from the satellite imagery.
- **Technical issues:** Technical issues such as hardware or software malfunctions, power outages, or internet connectivity problems could disrupt the data collection and processing activities and delay the project timeline.
- **Changes in project scope or timeline:** unexpected changes in project scope or timeline due to external factors such as funding constraints or stakeholder input could impact the overall success of the project and may require adjustments to the work plan.

Also, it is important to address that the project budget and manpower was not sufficient to execute the project properly though with the shortage of manpower and budget work has been done which was really challenging.

8.5. Some Key Recommendations

- **Weather monitoring and contingency planning:** Monitoring weather conditions closely and having contingency plans in place to address potential issues such as cloud cover or poor visibility during satellite image acquisition could help minimize the impact of adverse weather on the project timeline.
- **Collaboration with local stakeholders:** Working closely with local stakeholders such as farmers, extension agents, and government officials to obtain ground truth data and verify the accuracy of the rice area estimates could help ensure that the project is grounded in local knowledge and is more likely to be successful.
- **Regular maintenance and troubleshooting:** Regular maintenance and troubleshooting of equipment and software could help prevent technical issues from disrupting the data collection and processing activities and ensure that the project stays on track towards its goals.
- **Flexibility and adaptability:** Being flexible and adaptable in response to changes in project scope or timeline could help ensure that the project remains relevant and impactful and can continue to move forward towards its goals and objectives.

By incorporating these recommendations, the consultant can better address the challenges and risks identified and ensure that the project stays on track towards its goals and objectives.

8.6. Way forwards

- **Integration of Sentinel Data**
  Going forward, the integration of Sentinel data should remain a priority. The study demonstrates the synergy of SAR and optical imagery, providing a rich dataset for accurate crop classification. Continuous advancements in satellite technology and data processing techniques should be embraced to enhance the capabilities of future monitoring initiatives.

- **Machine Learning Refinement**
  The accuracy assessments identify areas for improvement, particularly in the classification of certain crops like mustard. Further research and refinement of machine learning algorithms can address these challenges, ensuring higher accuracy across all crops. Incorporating additional ground truth data and fine-tuning classification models may contribute to more precise results.

- **Temporal Monitoring**
  Expanding the temporal dimension of monitoring efforts should be considered. Regular and frequent revisit times of Sentinel satellites enable real-time monitoring of crop growth stages and timely detection of changes. Continuous monitoring throughout the crop lifecycle can provide valuable insights for adaptive agricultural management.

- **Crowdsourced Data Validation**
  In addition to traditional ground truth data collection, exploring the potential of crowdsourced data validation can enhance the validation process. Involving local communities and farmers in data collection and validation can provide real-time, on-the-ground insights that complement satellite-derived information.

- **Seasonal Specificity**
  The study emphasizes the importance of season-specific data. As demonstrated in the Kharif 2 season crop signature data collection, understanding the unique characteristics of different seasons is crucial for accurate crop classification. Similar initiatives for other seasons can further enrich the dataset and improve the applicability of the methodology.

- **Policy Integration**
  To maximize the impact of agricultural monitoring, integrating the findings into agricultural policies and practices is essential. Collaboration with government agencies, agricultural extension services, and policymakers can ensure that the information generated is used for evidence-based decision-making and sustainable agricultural practices.

In conclusion, the study showcases the tremendous potential of Earth observation data and advanced technologies in revolutionizing agricultural monitoring. By embracing continuous improvement, technological advancements, and collaborative approaches, future initiatives can contribute significantly to informed decision-making, sustainable agriculture, and food security.

9. References

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Annex I: Minutes of Commencement Meeting

JICA NSDI MODEL PROJECT: Rice Area Mapping of Manikganj Sadar Upazila using Medium Resolution Satellite Image

Minutes of Commencement Meeting

Time: 10:00 AM -11:30 AM

Date: 15 April 2023

Venue: Bangladesh Agricultural Research Council (BARC)

Attendees

1. Dr. Farida Perveen, Deputy Director, DAE & Team Leader, Agriculture Management
2. Muhammad Abdul Alim Sikdar, Project Officer, NSDI- Core Member
3. Hasan Md. Hamidur Rahman, Computer & GIS; BARC- Core Member
4. Mohammad Moniruzzaman, SRDI- Core Member
5. Abid Kamal, GIS Specialist; CEGIS- Core Member
6. Mahbuba Haque, Technical Team member; SOB- Core Member
7. Esmetara , Technical Team member ; SOB- Core Member
8. MD. Shahadat Hossain, Consultant, MD &CEO; Onushondhai Creeds Ltd-Consultant
9. Raisul Islam Hridoy, GIS Analyst, Onushondhani Creeds Ltd

Commencement meeting of agriculture management group of NSDI model project took place at the conference room of Bangladesh Agricultural Research Council (BARC). Team leader, all core members and consultant of model project were participated in the meeting. In the meeting following issues have been discussed:

- At the very outset, the model project team leader greeted all participants and thanked them for their presence in the meeting. The meeting commenced with as short round of in introduction of the participants.
- The model project team leader briefly presented the inception report of the project and requested all participants to give their expert opinion on technical issues.
- It has opined in the meeting that, for image classification, supervised, unsupervised and machine learning algorithm will be used.
- Regarding ground truth data it has decided that, a significant number of ground truth data will be collected from the study area.
- It has opined that; all core members will visit the study area before Boro rice harvesting.

- It has decided that, Sentinel-2 satellite image will be used for rice area demarcation and estimation
- BUTM 2010 projection will be used for all generated GIS dataset.

As there were no other issues to be discussed, the project Team Leader concluded the meeting with vote of thanks.

Title of the NSDI Model Project: Rice Area Mapping of Manikganj Sadar Upazila using Medium Resolution Satellite Image

'Agriculture Management Group'

Attendance Sheet

Date: 12/04/2023

Sl. No.	Name & Designation	Organization	Mobile No.	Email	Signature
1	Mahbuba Hoque NSDI Technical Team member	SOB			Mahbuba
2	Esmetajia Technical Teammember	SOB			
3	Muhammad Abdul Alim Sikder, Project officer, NSDI	SOB			
4	Abid Kamal, Core member, CEGIS	CEGIS			
5	Hasan Md. Haidar Rahman Director (Computer & GIS)	BARC			15/04/23
6	Mohammad Monirozzaman PSO, SRDI, Dhaka	SRDI			15/4/23
7	Dr. Farida Perveen Deputy Director	DAE			

Annex II: Minutes of Progress Meeting

JICA NSDI MODEL PROJECT: Rice Area Mapping of Manikganj Sadar Upazila using Medium Resolution Satellite Image

Minutes of Progress Meeting

Time: 11.00 AM -1:00 PM

Date: 20 September 2023

Venue: Department of Agricultural Extension (DAE)

Attendees

10. Dr. Farida Perveen, Deputy Director; DAE & Team Leader, Agriculture Management
11. Mohammad Moniruzzaman, SRDI- Core Member
12. Muhammad Abdul Alim Sikdar, Project Officer, NSDI- Core Member
13. Al-Helal, Programmer, BARC
14. Mahbuba Haque, Technical Team member; SOB- Core Member
15. Esmetara, Technical Team member; SOB- Core Member
16. Md. Mosharaf Hossain, NSDI -MP Coordinator, Asia Air Survey
17. Raisul Islam Hridoy, Urban Planner, Onushondhani Creeds Ltd

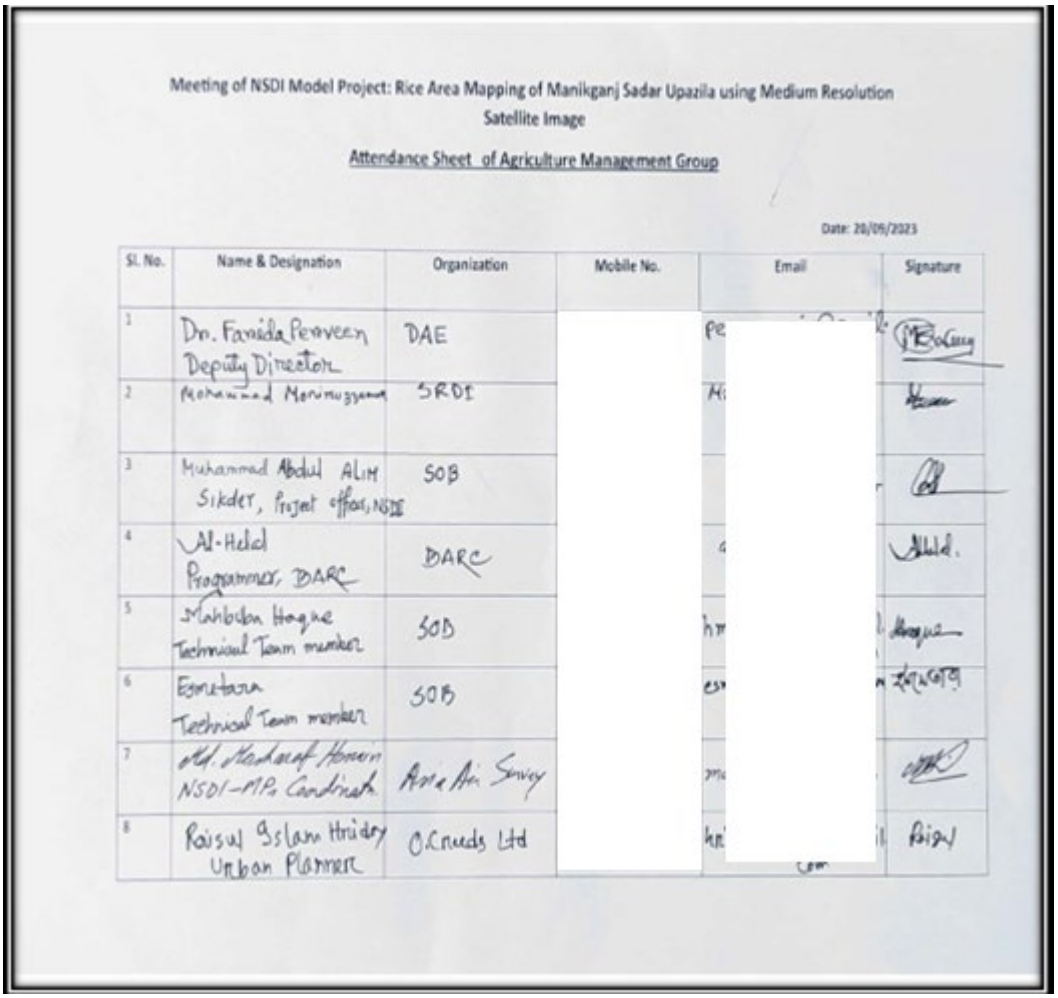
Progress meeting of agriculture management group of NSDI model project took place at the conference room of Department of Agricultural Extension (DAE) on 20 September 2023. Team leader, all core members and consultant of model project were participated in the meeting.

In the meeting following issues have been discussed:

- At the very outset, the model project team leader greeted all participants and thanked them for their presence in the meeting. The meeting commenced with as short round of in introduction of the participants.
- Ground truth data collection and field data analysis
- Progress of the Model Project up to date
- Brief presentation on progress of the project
- Requested all participants to give their expert opinion on technical issues.
- Methodology of image classification
- Discussion on upcoming training on October e.g.
    - Selection of training topics
    - How many sessions will be done per day?
    - Resource speaker
    - Preparing training module
    - Budget
- It has decided that the findings will be submitted within October, 2023.
- Sentinel 1 and Sentinel 2 has been classified separately and combinedly but the result of the accuracy assessment is on the processing level.
- It has been said that, after completing the Boro rice area calculation, Amon rice area will be done which is on the data collection level.

- A hands-on training will be held for 3 days on "Data Collection & Image Analysis".
- In the meeting, trainees will be the whole core and support members of the model project.
- Participants will be core and support members of NSDI MP
- Participants will bring their personal laptop
- Training venue will be DAE, Khamarbari, Dhaka

As there were no other issues to be discussed, the project Team Leader concluded the meeting with vote of thanks



Meeting of NSDI Model Project: Rice Area Mapping of Manikganj Sadar Upazila using Medium Resolution Satellite Image

Attendance Sheet of Agriculture Management Group

Date: 20/09/2023

Sl. No.	Name & Designation	Organization	Mobile No.	Email	Signature
1	Dr. Farida Perveen, Deputy Director	DAE			
2	Mohammad Monirujjaman	SRDI			
3	Muhammad Abdul Alim Sikder, Project officer, NSDI	SOB			
4	Al-Helal, Programmer, BARC	BARC			
5	Mahbuba Hague, Technical Team member	SOB			
6	Egnetara, Technical Team member	SOB			
7	Md. Mashiur Rahman, NSDI-MP, Coordinator	Agro Met Survey			
8	Raisul Islam Hridoy, Urban Planner	C.Creeds Ltd			

Annex III: Training Manual for Image Analysis

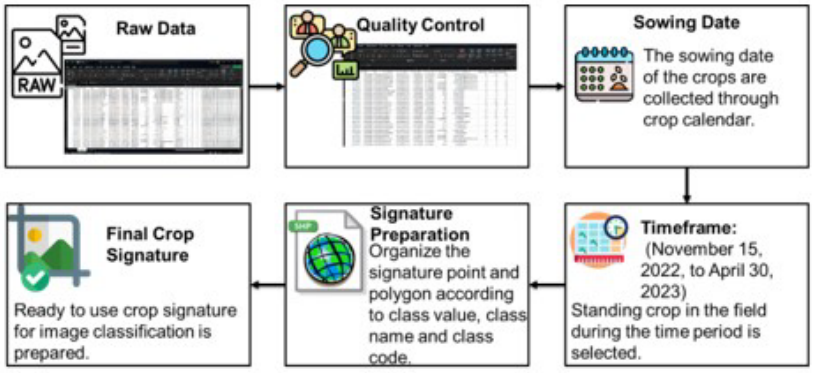
Please find the separate document attached as Annex III

"Model Project on Agriculture Management for
National Spatial Data Infrastructure (NSDI) Utilization Project"

ANNEX -III

TRAINING MANUAL FOR IMAGE ANALYSIS

(Agriculture Domain)



Model Project on Agriculture Management for
National Spatial Data Infrastructure (NSDI) Utilization Project

Annex IV: Manual for Capacity Building Sessions

Please find the separate document attached as Annex IV

"Model Project on Agriculture Management for
National Spatial Data Infrastructure (NSDI) Utilization Project"

Annex - IV

TRAINING MANUAL FOR CAPACITY BUILDING SESSIONS

Session modules for GNSS, GCP-RTK, Kobo Toolbox, & Drone Survey



**Model Project on Agriculture Management for
National Spatial Data Infrastructure (NSDI) Utilization Project**

FINAL REPORT

December 28, 2023

Model Project

on

Disaster Management

for

National Spatial Data Infrastructure (NSDI)

Utilization Project

Model Project on Disaster Management for National Spatial Data Infrastructure (NSDI) Utilization Project

Report on

Surface and Subsurface characterization of Purbachal Town, Dhaka for Seismically Hazardous zone (Micro zonation) Identification

Submitted By

Disaster Management Group
And
Team Leader
Syed Nazrul Islam
Director and Head of RS and GIS
Geological Survey of Bangladesh

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ACKNOWLEDGEMENTS

This work was undertaken while the Technical Assistance Project Proposal (TAPP) of the project of establishment and promotion of NSDI was authorized in July 2021 and as the 5-day workshop held in March 2022 to produce thematic maps proposed by NSDI-WG Members (NSDI-WGMs), I want to express my thanks to all attended participants for voting our Group. Disaster Management Group Members would like to thank to JICA Bangladesh for funding and encouragement in the creation of the DPS and model project.

I would like to express gratitude to the Director General of the Geological Survey of Bangladesh for permitting me to work with the NSDI Project as a focal point and for providing administrative support. As a Team Leader, I would like to express thanks and gratitude to all core and supporting working group members for their continuous support during this project.

I am deeply grateful to Surveyor General of Survey of Bangladesh (SoB) for providing the necessary data during the implementation of the Model Project. I am also grateful and extend my thanks to the Project Director and his teams for supporting me during the Model Project implementation.

Abstract

Dhaka is one of the most rapidly expanding cities in the world. Over the past few decades, the city has grown in every direction without properly considering subsurface information. Ground information plays a vital role in understanding and visualizing the spatial distribution of sub-surface conditions. This study aims to improve understanding of the Purbachal Town area through subsurface analysis and area zoning with the help of lithologic data and continuous (top and base) surface modeling for the target stratigraphic formations. This model also helped in utilizing the NSDI platform for colleting Data and analysing these This model project compares and contrasts the features of cross-section-based and borehole-based (3D and 2D) modeling. This model project illustrates the results of 2D and 3D models within the boundaries of Purbachal Town near Dhaka. This 3D model might help to reduce construction risk as well as ensure financial savings in the project area. Through a 3D model, it is possible to evaluate the distribution of rocks and soil, both in space and time. The results would be available on the NSDI platform which might be helpful for researchers and city dwellers for further research and identification of the weak zones in area respectively. The results highlight the sub-surface various layering distribution as well as potential hazardous zone distribution and direction of the future studies. This output might help to the planners and decision-makers to make proper decisions for sustainable urbanization in Purbachal area and utilization of the spatial Data in infrastructure platform.

1. INTRODUCTION

1.1 Background of the Model Project

The Japan International Cooperation Agency (JICA) has been assisting the Ministry of Defence (MoD) and Survey of Bangladesh (SoB) in carrying out the Project on “The Establishment of National Spatial Data Infrastructure’(NSDI). The objective of the project is to formulate a legal framework and form an organizational structure on the National Spatial Data Infrastructure (NSDI), to create a geographic information standard, and to develop a database system of geospatial information and a web GIS platform. NSDI was drafted to facilitate the building of NSDI and is the ancestor of the previous project titled ‘Strengthen the Capacity on Advanced Mapping of SoB for Building Digital Bangladesh' completed from 2017 to 2018. The project aimed to form a Working group of members, a small-scale prototype system developed to demonstrate the NSDI concept and usefulness and verify technical and operation issues in 2018.

JICA launched the Project for Establishment of National Spatial Data Infrastructure (NSDI) in Bangladesh (NSDI-BD project) in August 2019. In this project, the NSDI Working Group (NSDI-WG) was established to operate and promote the utilization of the NSDI platform, and the three NSDI Utilization Model Projects namely 'Agriculture Management', 'Disaster Management ‘and 'Water Management ‘were taken up at the 5-day workshop held in March 2022 to produce thematic maps proposed by NSDI-WG Members (NSDI-WGMs). These NSDI-MPs are to be implemented in cooperation and ownership of all NSDI-WGMs.

Dhaka Metropolitan City has now been turned into a mega city. Millions of people live permanently in Dhaka city, the capital of Bangladesh for better livelihood. The dwelling places required for a large number of people are quite inadequate. As a result, the residential areas of Dhaka city are becoming overcrowded and creating an unhealthy environment day by day. It is possible to reduce the pressure on the population of Dhaka city to a great extent by developing the surrounding area of Dhaka city in a planned way and establishing permanent residential accommodation for these vast populations.

On behalf of the Disaster Management Group Purbachal, a town located 10 km NE of Dhaka city, is a newly developing town designed by the Government of Bangladesh as a Model Town and is selected as a model project site. It is planned to be a residential area of 10 million or more people in the coming 10 years. Several high-rise buildings and many multi-storied buildings are to be built in this town. Subsurface characterization of the study area is necessary to study Seismic ground motion behavior.

In Purbachal might vary due to the spatial variation of near-surface and subsurface soil conditions that are not uniform everywhere. Moreover, it is not far from the seismically active zone (Dhaka City). Therefore, subsurface soil characterization for future seismic response analysis of the town is important.

Artificial filling and removal of topsoil materials have filled the developing Purbachal site to make it flat. In the future, for determining and analyzing of the building response to earthquakes it is necessary to know the subsurface soil and type as well as the filling material. Site response will not be uniform for all the areas and it depends on the subsurface soil characteristics and morphology of the area before. It is important to make a geomorphologic map using old aerial photos of that area before filling and correlating it with present topography for zoning of the area with modeling of the subsurface of the area.

1.2 Location and Description of the Study Area

It is the biggest Planned Township in the country. The Project area comprises about 6213 acres of land located in between the Shitalakhya and the Balu River at Rupgonj thana of Narayangonj district and at Kaligonj Thana of Gazipur district,in the north-eastern side of Dhaka. 'Purbachal New Town Project' is situated at Rupgonj thana of Narayangonj district and Kaligonj thana of Gazipur district in between river Balu and Sitalakhya at a distance of 16 KM from zero point of Dhaka

RAJUK is implementing this project in a few views to reduce the pressure on the population in Dhaka city, maintain the balance of environment by proper urbanization, create an environment-friendly and sustainable atmosphere, and reduce the existing acute problem of housing as well as upcoming.

1.3 Purpose and Scope of the Study

Purbachal new township is developing with modern facilities. It is bounded by two rivers and geologically underlain by the Madhupur Red Clay and Dupi Tila sand unit of the Plio-Pleistocene age. For climate change resilience Smart City, it is important to characterize Surface and Subsurface conditions. To visualize the surface and subsurface conditions through 2D and 3D Models, logs, and sections this model project is taken to give a primary Idea about the surface and subsurface conditions of the area and surroundings.

This model project contains a comprehensive description of various fields and laboratory phases of the geotechnical investigations and the general subsurface soil conditions as well as geology encountered during the field investigation of the area is taken into consideration.

1.4 Objectives of the Model Project Work

The main objective of the Model Project is to create subsurface 2D and 3D models (thematic maps) for seismically hazardous zone identification.

2. METHODOLOGY

2.1 Field Investigation

2.1.1 General

The Subsurface field investigation program included drilling boreholes and collecting soil samples at desired intervals for subsequent observation and laboratory testing. During the field investigation program, 15 boreholes were drilled in various depths to better portray the subsurface condition and lithological variation of the study area.

The objective of the investigation is to ascertain the depth, sequence, and thickness of various subsurface soils for zoning of the area in future detail further characterization of subsurface condition and settlement behavior of the subsurface soils under a sustained loading condition of the future structure.

2.1.2 Boring and Sampling

The geotechnical investigation work was carried out in March-April of 2023 under the CREATIVE SOIL INVESTIGATION, a leading geotechnical consulting firm in Dhaka.

Mechanical boring has been carried out using the wash boring method. In the mechanical wash boring method, water is pumped through a string of hollow boring rods and is released under pressure through narrow holes in a chisel attached to the lower end of the rods. The soil is loosened and broken up by the water jets and the up-and-down movement of the chisel. The soil particles are washed to the surface between the rod and the side of the borehole and are allowed to settle out in a slump. The rig consists of a derrick, a winch, and a water pump. The winch carries a light steel cable that passes through the sheaf of the derrick and is attached to the top of the boring rod. The string of the rod is raised and dropped utilizing the winch unit, producing the chopping action of the chisel.

It is used as a means of advancing a borehole to perform a Standard Penetration Test (SPT) at required depths and to collect disturbed samples using a split-spoon sampler. An advantage of the method is that the soil immediately below the hole remains relatively undisturbed. Soil stratification, sampling, and SPT N-values are presented in the borehole logs. In the study area, 15 borehole is drilled at various depth ranging from 30m to 70m. The Boreholes location is depicted in Figure: 2.1

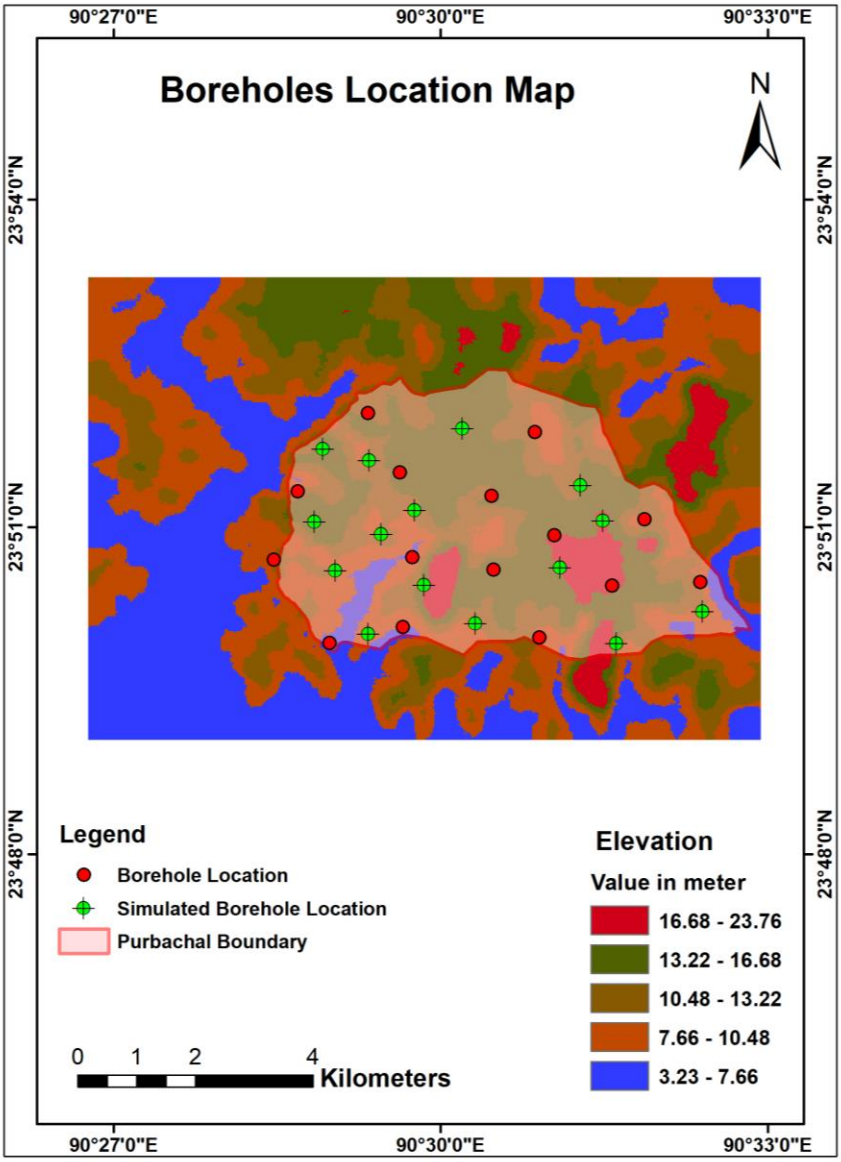


Figure 2.1 The map showing the borehole's location in the study area.
(Data Source: NSDI-MP Field Data)

2.1.3 Standard Penetration Test (SPT)

The Standard Penetration Test (SPT) was performed at each 1.5 m interval up to the required depth of drilling in all boreholes. Tests were executed by using a split-spoon sampler of 35 mm internal diameter and a 63.5 kg hammer falling freely from a constant height of 76 cm on the drill rod. The number of blows (N-value) necessary to produce the penetration was recorded in three 15-cm intervals. The N-value was taken as the summation of blow counts for the 2nd and 3rd 15 cm penetration (ASTM D1586/D1586M-18,2018). The N-values of the boreholes are shown in the borehole log chart against the respective intervals of the depths.

2.2 Laboratory Analysis

2.2.1. Sieve Analysis

Grain size distribution is one of the most important characteristics of sediment. This is true because grain size is a powerful tool for describing a site's geomorphic setting, interpreting the geomorphic significance of fluid dynamics in the natural environment, and distinguishing local versus regional sediment transport mechanisms as grain size is a dominant controlling factor in sediment and sedimentary environment. Characterizing the physical properties of sediment is important in determining its suitability for various uses and studying sedimentary environments and geologic history. The test is done by Sieve analysis, which determines particle gradation. Sieving is the most basic of the particle sizing techniques. It consists of having the sediment pass through (by agitation) a series of stacked sieve meshes with defined opening sizes. The sediment fraction retained in each sieve is weighed to obtain its percentage relative to the whole sample. To carry out sieve analysis, 100 gm of sample is taken from different formations. ASTM D 422 - Standard Test Method is used to determine the pattern of grain size distribution.





Figure 2.2: Apparatus used in the grain-size analysis using a sieve shaker.

3. GEOMORPHOLOGY OF PURBACHAL NEW MODEL TOWN AND ITS ADJOINING AREAS

3.1 Geomorphological Units and their Descriptions

The study area is covered mainly by Pleistocene Madhupur clay and Holocene sediments. The Madhupur clay uncomfortably overlies the sediments of the Dupi Tila. A marked unconformity also exists between it and the overlying recent alluvium (Khan, 1991). The existing area is bounded by two rivers (Sitalakshya and Balu River) and numerous streams. The surface feature of the area is undulating in nature and characterized by various geomorphic features. Based on geomorphic features the study area is mainly divided into two broad groups- fluvial or depositional landforms like gully, active channels, perennial streams, point bar, lateral bar, natural levee, and erosional landforms like Madhupur terrace and Madhupur slope.

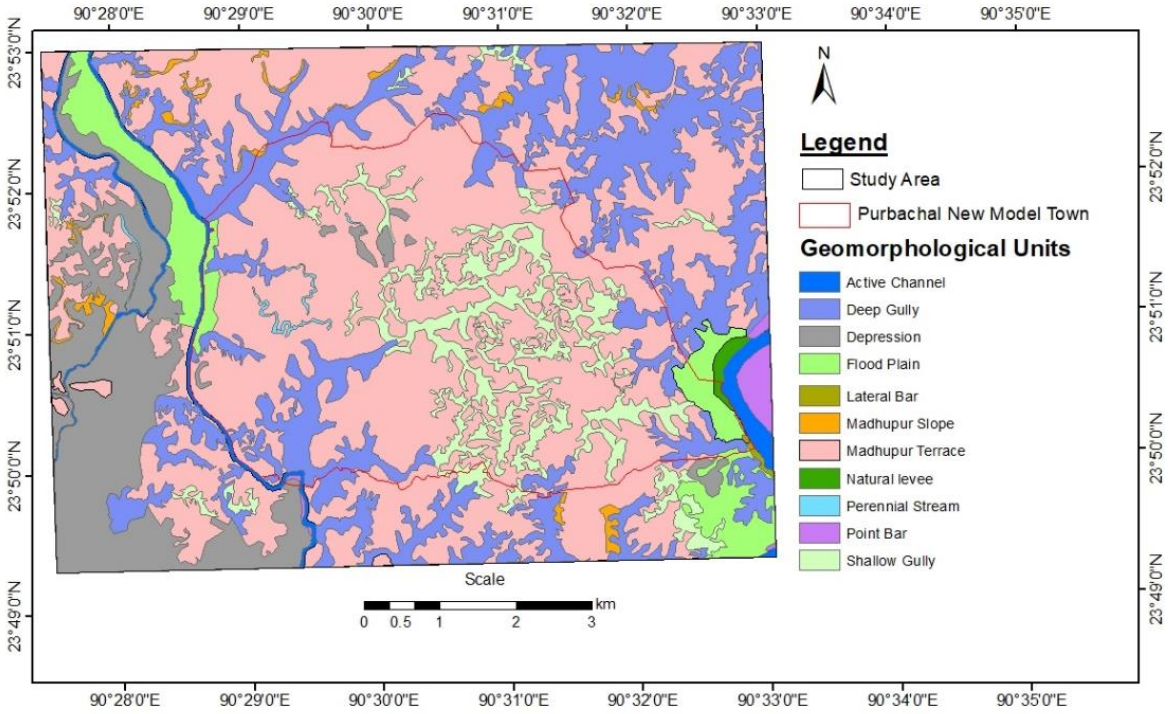


Figure 3.1 Geomorphological Map of Purbachal New Model Town and its surrounding areas.
(Data Source: Aerial Photo-1954)

Madhupur Terrace: This unit consists of reddish brown to yellowish brown highly oxidized sticky silty clay unit of the study area which shows dark to medium grey tone and blocky texture in aerial photographs.

Madhupur slope: It is the fringe skirt area around the exposed Madhupur tract which shows light to medium grey tone and smooth texture in aerial photographs.

Shallow Gully: This unit shows a dendritic drainage pattern and fine drainage density with light to whitish-grey tones in aerial photographs.

Deep Gully: This unit shows a dendritic drainage pattern and fine drainage density with a dark grey tone in aerial photographs. This unit consists of silty clay and is comparatively less elevated than a shallow gully.

Depression: Depressions are small to large-sized oval to elongated-shaped low areas that contain water in a major portion of the year. These units are mainly composed of dark grey to very dark grey clay, silty clay, clayey silt, and fine sands occasionally peat/peaty clay/clayey peat with decomposed organic substances and shell fragments. Very big depressions are observed in the southwestern part of the mapped area.

Natural Levee: Natural levees are wedge-shaped ridges of sediment bordering stream channels and floodplains, formed by deposition of overflowed sediments. These units are characterized by sand, silt, and mud units.

Flood Plain: Floodplain sediments are deposited during the over-bank flow of the rivers. These are irregular in shape with variable sizes. This unit is mainly used for cultivation.

Perennial Stream: Perennial channels maintain their flow throughout the year. There are a number of perennial channels flowing through the study area.

Active Channel: Active channels maintain their flow throughout the year. These channels provide the drainage facilities of these areas. Two types of channels are present: (i) the Meandering channel (Sitalakshya River) and (ii) the Straight channel (Balu River).

4. LAND USE AND LAND COVER STUDY

Land use and land cover (LULC) changes are frequently applied in the same context [Fonji &Taff, 2014]. Land cover describes the natural characteristics of the earth's surface, i.e., the dissemination of vegetation, water, soil, and other elements of the land. On the contrary, land use considers the human aspect of land use, emphasizing the economic aspects [Rawat & Kumar, 2015]. Physical and socio-economic factors are the primary determinants influencing land use and land cover in an area. The changes in land cover/land use, mainly due to human intervention, play a vital role in comprehensively changing the atmosphere [Jensen, 2005].

Bangladesh is quickly moving toward further development and achieved the status of a lower-middle-income country in 2015, with a GDP growth rate of 8.2% in 2019 [World Bank, 2020]. With the development, Bangladesh requires more infrastructure including residential and industrial amenities. Purbachal Model Town is a government-owned housing scheme that is situated at Rupganj Upazila of Narayanganj District and Kaliganj Upazila of Gazipur District in between river Balu and Sitalakhya [Rajuk, 2020]. The aerial photograph of 1956 was considered for land use land cover study of the area. The digitization was accomplished by using geographical information system (GIS) software with a UTM projection system [Dewan &Yamaguchi, 2009]. Then, the features were identified by extensive study and previous related kinds of literature of and around the area.

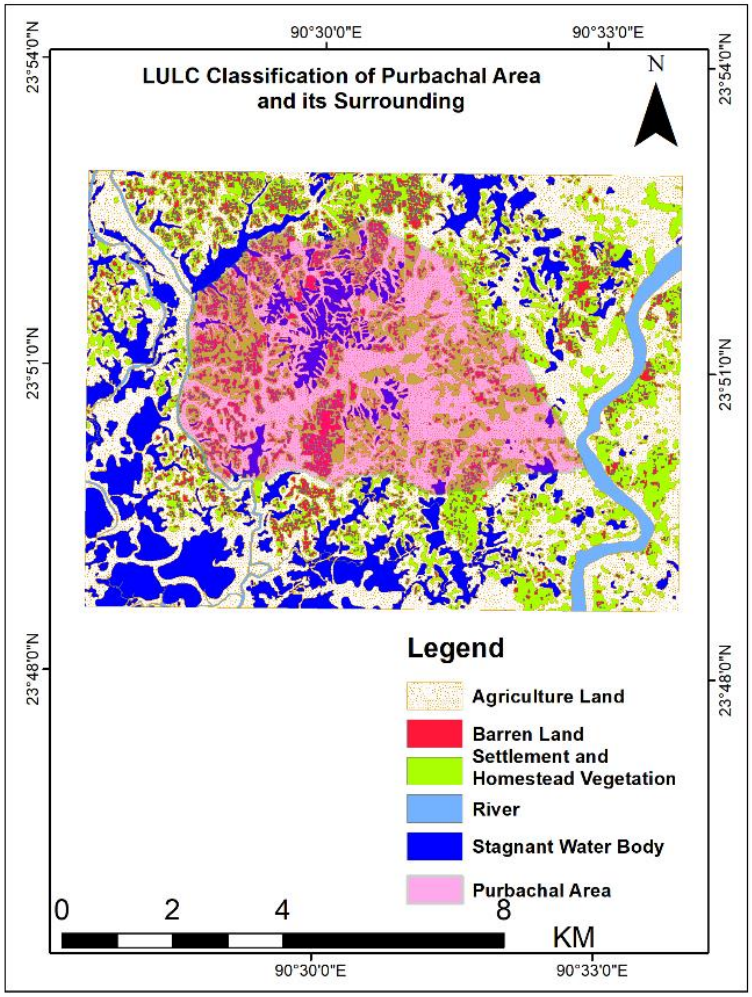


Figure 4.1 Showing the LULC Classification of Purbachal Area and its Surrounding.
(Data Source: Aerial Photo-1954)

According to Anderson classification scheme level 1 [Anderson et. al., 1976], four (04) land types are considered (figure 4.1) including 1. Water body (River and stagnant water body i.e., pond, lake, etc.) 2. Agricultural land (paddy, vegetable, crop, etc., 3. Settlement and homestead vegetation (Settlement and its surrounding vegetation) and Barren Land (yard, playground, open field, grazing field, uncultivated land, etc.). Area of the individual class is shown in Table 1. The detailed land use land cover classification has been illustrated in the following literature.

1. Water body: In the image, the water body was identified by its darker tone and comparatively massive shape. The water body was divided into types.

I. River: Two rivers named Balu and Sitalakhya surround the area. The Balu River runs from north to south direction in the western side and the Sitalakhya River runs in the same direction on the eastern side of the area.

II. Stagnant water body: Several stagnant water bodies were found in the area which were darker in the image. The stagnant water bodies were randomly distributed in the area. There were also a few intermittent channels in the area.

2. Agricultural land: As agriculture is the principal activity in Bangladesh, so, agricultural land is frequently seen around the country. In the area, cropland was identified by its comparatively darker or darker to lighter tone. The boundaries of the agricultural land were normally seen in the image. Agricultural land was commonly seen all over the area.
3. Settlement and homestead vegetation: In the rural area of Bangladesh, it is obvious that every house has few trees or vegetation. In the area, only vegetation or forest was not observed. The darker shape of slightly elongated, rectangular, circular, or square confirmed rural settlements with vegetation i.e., homestead vegetation. This type of land class was found everywhere in the study area.
4. Barren land: Barren land is commonly seen everywhere in the country. It is usually whitish in aerial photographs and has no sharp boundary line. Settlement attached yard is a common phenomenon of barren land which is used for some domestic purposes. Local playgrounds, unused land, graveyards, and uncultivated land are also categorized into barren land.

Table 1: Land Use Classification Results

SL	Class Names		Area (Acores)
1	Water Body	River	1.13
2		Stagnant water body	644.24
3	Agricultural land		2922.98
4	Settlement and homestead vegetation		1902.25
5	Barren land		717.55
Total			6188.15

5. GEOLOGY OF PURBACHAL NEW MODEL TOWN AND ITS ADJOINING AREAS

Tectonically Bangladesh occupies the major part of the Bengal Basin and forms the largest delta complex of the world. It is bounded in the east by the Indo-Burma ranges, in the west by the Indian shield, in the north by the Shillong massif and the Himalayan thrust fault, and in the south, it is open towards the Bay of Bengal for a considerable distance (Alam et al., 1990). The investigated area is covered by Pleistocene deposits which are surrounded by the floodplains of Balu and Sitalakhya rivers. The investigated area was studied with satellite images, available maps, and field checking. The

sediments of the area consist mainly of a mixture of clay, silt, and fine sand. Geologically, the area is mainly covered by the recent Alluvium deposits, the Pleistocene Madhupur Clay deposits which are overlain by alluvium, and the older sediment sequence of sandstone of the Dupi Tila Formation that is underlying the Madhupur Clay Formation. The map units of this area have been described below:

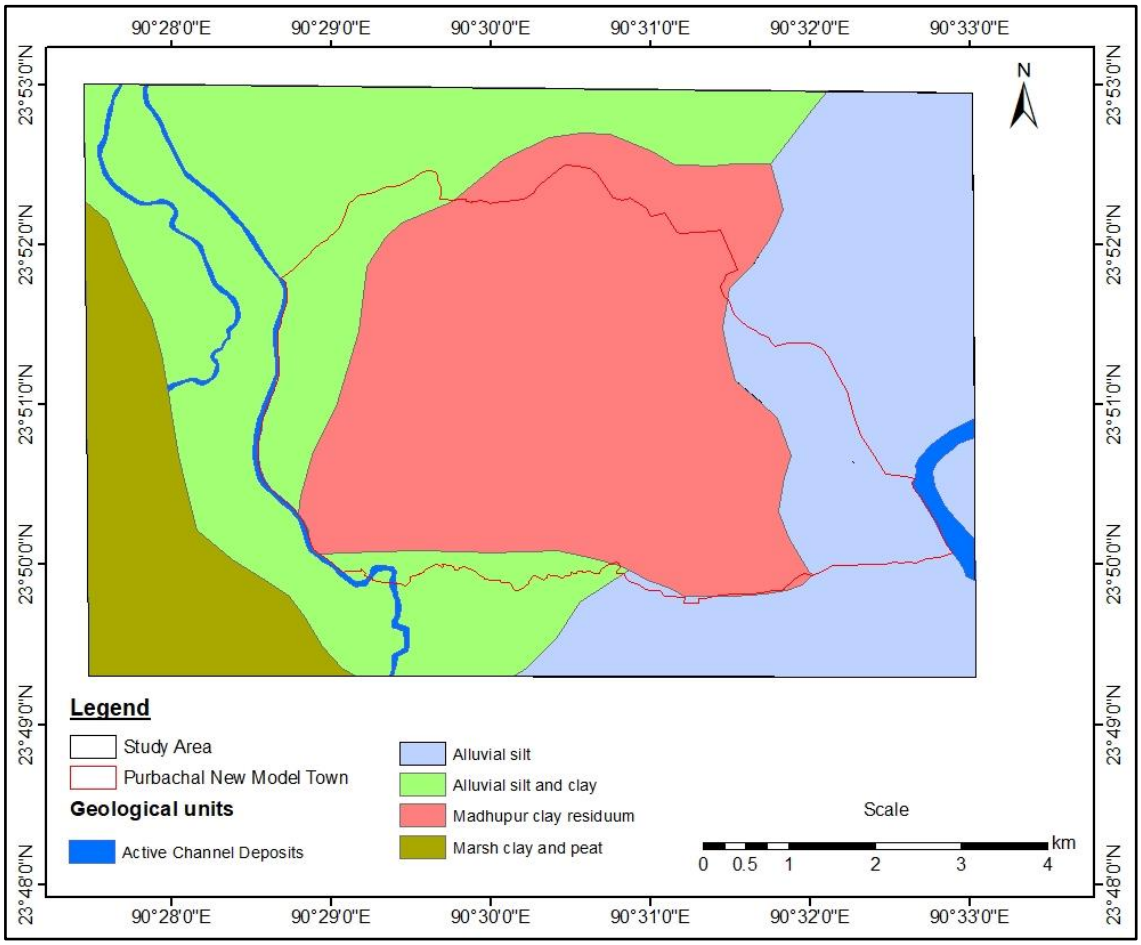


Figure 5.1. Geological Map of the Purbachal New Model Town and Its Adjoining Areas.
(Data Source: Aerial Photo-1954)

5.1 Description of Geological Units:

Active Channel Deposits: The channels tend to be void of vegetation and display evidence of recent stream flow activity. Channel sand is found which is dark gray in color, and loose, vegetal matter is present. Due to avulsion water flow in this channel gradually decreases. In a lower flow regime, vegetal matter along with peat deposition starts in comparatively low-lying reaches and bars. Clay, peaty clay, and wood fragments are found in the channel bed of Shitalaksyha and Balu River.

Alluvium: This unit mainly consists of alluvial silt and alluvial silt & clay deposits

i) Alluvial Silt: This deposit is mainly composed of light to medium gray, fine sandy to clayey silt. It includes small back swamp deposits and varying amounts of thin, interstratified sand, deposited during episodic or unusually large floods. Illite is the most abundant clay mineral (Alam et al., 1990). The map unit also includes organic-rich clay in the study area. This unit is spread on the Northeastern side of the study area.

ii) Alluvial Silt and Clay: This unit consists of medium to dark grey silt to clay. The color is darker due to the presence of organic materials. It includes flood-basin silt, backswamp silty clay, and organic-rich clay in sag ponds and large depressions (Alam et al., 1990). It is on the western and southern sides of the study area.

Madhupur Clay: Madhupur Clay is characterized by red clay at the top and mottled clay at the bottom. The red clay is red to brick red and yellow, massive, and contains ferruginous nodules and laterite. The mottled clay is bluish to grey with mottling of red, brown, yellow, and orange color. the massive and sticky clay contains ferruginous nodules. the thickness of Madhupur clay is 5 to 7m in the study area but towards Dhaka city, the thickness of this clay is very high. This clay is impermeable and caps the underlying Dupi Tila sandstone aquifers. This unit is distributed almost everywhere in the study area.

Dupi Tila: Yellow, brown, and pink color, grain size, and pebbles beds of the Dupi Tila sandstone readily distinguish it from the mottled Girujan clay and the rocks of the older formation below and Madhupur red clay or Recent alluvium above (Khan,1991). The upper part is dominated by fine to medium-grained sandstone with subordinate clay. It contains lenses of Kaolinitic clay and thin discontinuous bands of sand with secondary iron oxide cement. The lower part is dominated by sandstone, locally cross-bedded. Feldspar commonly weathered clay, oxidized, iron-rich clayey residual zones (Paleosols) present within this formation (Alam et al., 1990). This unit is not exposed in the study area but is almost uniformly distributed in the subsurface under the Madhupur Clay. In the study area, the thickness of Dupi Tila has been started from 7+ m.

6. SEDIMENTOLOGICAL ANALYSIS

Grain size analysis is a sedimentological analysis that has been carried out to determine the size of the different particles that constitute a particular unconsolidated sedimentary deposit and sedimentary rock. The analysis of 140 samples from different depths of the study area has been performed in Petrology and Mineralogy and Engineering Laboratories. This analysis includes the grain-size distribution by sieve method. Grain size is a fundamental tool for classifying unconsolidated sediments, clastic sedimentary rocks, and sedimentary environments. Particle or grain size is a fundamental attribute or physical property of particulate samples or sediments and sedimentary rocks (Folk, 1980; Friedman and Sanders, 1978). Grain size distribution of sediments to determine whether they are suitable for particular applications that we need to use either in concrete mixing, designing soil, or geotechnical structure. The soil is generally composed of a mixture of gravel, sand, silt, and clay. Therefore, the analysis of grain size is important to look at the type of soil and percentage of grain size present in each sample. The particle size distribution curve is a graph that is generated to illustrate the average particle size, the smallest particle size, and the largest particle size. The curve illustrates either the amount of material that passes through or is retained on each sieve. For this purpose, the grain size distribution curves (Annexure-III) have been constructed by summing the percentage of sand, silt, and clay which indicates that almost all grain size distribution curves are unimodal and moderately sorted. The analysis found that the clay (<0.004mm) ranges from 1.4-61.95% in all the samples, silt ranges from 8.7-79.91% and sand ranges from 2.92-89.9% (Table 2). In the study area, the maximum percentage of grain falls between the mesh sizes of 120-325 which interprets the grain sizes 0.125 mm and 0.045 mm. The grain size distribution of individual boreholes is attached in ANNEXURE-III

Table 2: Grain size and Grading Properties with depth in of two Boreholes.

BH0100				
Depth from (m)	**Depth to (m)**	**Sand**	**Silty**	**Clay**
0.00	1.50	37.01	44.96	17.40
1.50	3.00	36.94	47.83	14.18
3.00	4.50	33.62	47.92	17.75
4.50	6.00	51.16	43.08	5.08
6.00	7.50	64.2	31.3	4.1
7.50	9.00	74.55	23.2	1.5
9.00	10.50	61.3	37.17	1.53
10.50	12.00	65.2	31.4	2.7
12.00	13.50	72.1	25.7	1.6
13.50	15.00	73.04	24.76	1.76
15.00	16.50	77	20	2.58
16.50	18.00	70.25	26.65	2.65
18.00	19.50	76.35	20.5	2.75
19.50	21.00	69.9	25.5	4.2
21.00	22.50	79.25	19.17	1.33
22.50	24.00	74.75	22.02	2.53
24.00	25.50	73.62	22.14	3.49
25.50	27.00	65	33.43	0.86
27.00	28.50	62.2	34.4	2.4
28.50	30.00	85.7	11.8	2.0
30.00	31.50	85.83	13.08	1
31.50	33.00	82.34	15.73	1.6
33.00	34.50	65.6	29	5.
34.50	36.00	89.9	8.7	1.4
36.00	37.50	75	21	3.85
37.50	39.00	81.40	15.2	2.6
39.00	40.50	76.10	20.5	3.0
40.50	42.00	50.13	38.84	10.64
42.00	43.50	67.66	19.03	10.72
43.50	45.00	72.16	18.03	9.56
45.00	48.00	78.54	20.67	0.67
48.00	51.00	67.27	21.69	10.90
51.00	54.00	72.89	22.65	4.09
54.00	57.00	31.92	48.05	19.56
57.00	60.00	72.28	24.85	2.57
60.00	63.00	66.77	31.35	1.18
63.00	66.00	70	25.33	4
66.00	69.00	58.83	39.41	11.39

BH0200				
Depth from (m)	**Depth to (m)**	**Sand**	**Silty**	**Clay**
0.00	1.50	14.6	77.71	22.66
1.50	3.00	33.31	30.93	35.31
3.00	4.50	53.98	26.36	12.86
4.50	6.00	69.26	20.18	5.53
6.00	7.50	56.79	33.70	9.33
7.50	9.00	63.03	28.44	8.42
9.00	10.50	52.89	29.82	13.83
10.50	12.00	58.88	28.08	12.93
12.00	13.50	54.71	26.25	15.61
13.50	15.00	65.25	22.08	12.45
15.00	16.50	71.42	16.87	11.42
16.50	18.00	75.29	15.35	8.9
18.00	19.50	72.37	15.39	11.18
19.50	21.00	76.09	14.72	8.89
21.00	22.50	77.01	12.47	10.16
22.50	24.00	73.75	11.69	11.38
24.00	25.50	77.64	11.73	7.43
25.50	27.00	76.74	16.73	5.76
27.00	28.50	75.75	15.73	8.36
28.50	30.00	78.4	13.31	8.1
30.00	31.50	74.22	15.16	7.58
31.50	33.00	74.28	14.69	7.52
33.00	34.50	72.27	12.17	8.78
34.50	36.00	74.99	13.77	9.72
36.00	37.50	73.69	12.91	10.41
37.50	39.00	74.34	17.48	7.9
39.00	40.50	71.06	15.65	8.96
40.50	42.00	69.32	17.25	11.93
42.00	43.50	73.03	21.42	5.26
43.50	45.00	70.38	14.71	9.31
45.00	48.00	72.25	17.36	7.88
48.00	51.00	71.78	15.44	8.33
51.00	54.00	68.44	22.68	8.28
54.00	57.00	67.23	26.14	6.26
57.00	60.00	68.83	18.64	10.07
60.00	63.00	66.88	16.86	13.08
63.00	66.00	69.98	13.8	14.19
66.00	69.00	71.37	13.11	13.66

7. SUBSURFACE MODEL OF THE STUDY AREA

Owing to the complexity of subsurface conditions and the multiplicity of its data sources, a variety of modeling methods have been established to accomplish different purposes. Based on the dominant data source the methods of 3D subsurface modeling can be grouped into four main categories:(I) borehole-based modeling (Lemon and Jones,2003; Zhu et al.,2004; Zhu and Pan,2005; Zhang et al.,2005) (II)Parallel cross section based modeling (Tipper,1976; Herbert et al.,1995; Qu et al.,2006; Kaufmann and Martin,2008; Bistacchi et al.,2008);(III)Net cross section based modeling (Ming,2010)and (IV) multi Source interactive modeling (Mallet,2002; Wu,2005). In the study area category, I and II were implemented for modeling.

The dataset used for the subsurface model is 30 borehole logs among them 15 logs were drilled and 15 Simulated from drilled logs (Figure 2.1). These borehole logs are converted to a common data format and spatial information is converted to planner earth projection UTM (Universal Transverse Mercator) for better area and 3-D analysis. The study was conducted by ArcGIS 10.5 and Rockworks version 16 (RockWare Inc. Golden, CO, USA) for various analyses.

7.1 Building a Framework of Model

The geometric framework is the foundation for static modeling. This orients the zoning site in three dimensions relative to the defining boreholes.

7.1.1 Modeling based on borehole data

Borehole data, which has a simple data structure is the most available and reliable data in geological surveys. Horizons Method proposed by Lemon and Jones (2003) is the basis of later methods aiming at 3D geological modeling based on borehole data. Improvement of the horizon elevation adjustment in Horizons Methods was proposed by Zhu et al. (2004). A series of more detailed improvements and complete solutions were proposed by Ming et al. (2009). The existing borehole-based modeling has been used in the Model project to build a strata model.

7.1.2 Maps and Cross Sections

For many years, maps and cross-sections formed the entire framework for modeling. With modern computer software, maps, and cross-sections are done in immersive 3D environments that facilitate spatial conceptualization. However, maps and cross-sections still underpin the 3D interpretations in many ways. The study area is approximately 6213 acres in size and has been characterized by 15 boreholes and 15 simulated boreholes. The boreholes are arranged randomly and were drilled through unconsolidated sediments and terminated at the top and middle of the Dupi Tila sand unit. The ground surface of the study area and surroundings is between 6-20 meters above sea level, and slopes towards

the south (Figure 7.2). The subsurface geometric details used to construct the 2D and 3D interpretation framework are shown in Figure 7.3 where the 5 cross sections have been arranged with 4 in West –East and 1 in North- South direction on the western Periphery side.

In addition, the Rockworks Borehole Manager tool was utilized to create the grid models for the subsurface of each lithological unit to visualize them in 2D cross-sections and 3D diagrams.

7.1.3 Surface Creation

Geologic interpretation involves dividing the subsurface into layers. Stratigraphers are interested in horizons and zones representing specific geological times, structural geologists try to identify surfaces that were originally horizontal, and geophysicists look for layers with contrasting acoustic rock properties. No matter the basis, constructing three-dimensional surfaces is essential to subsurface geological modeling. In the study area, stratigraphic surface modeling is performed to visualize the individual surface of each stratigraphic formation with the Rockworks Borehole Manager tool. These individual surfaces are shown in the Figure 7.1. A digital elevation model is created using the surface elevation data collected through the fieldwork and from Google Earth and a contour map is created (Figure:7.2)

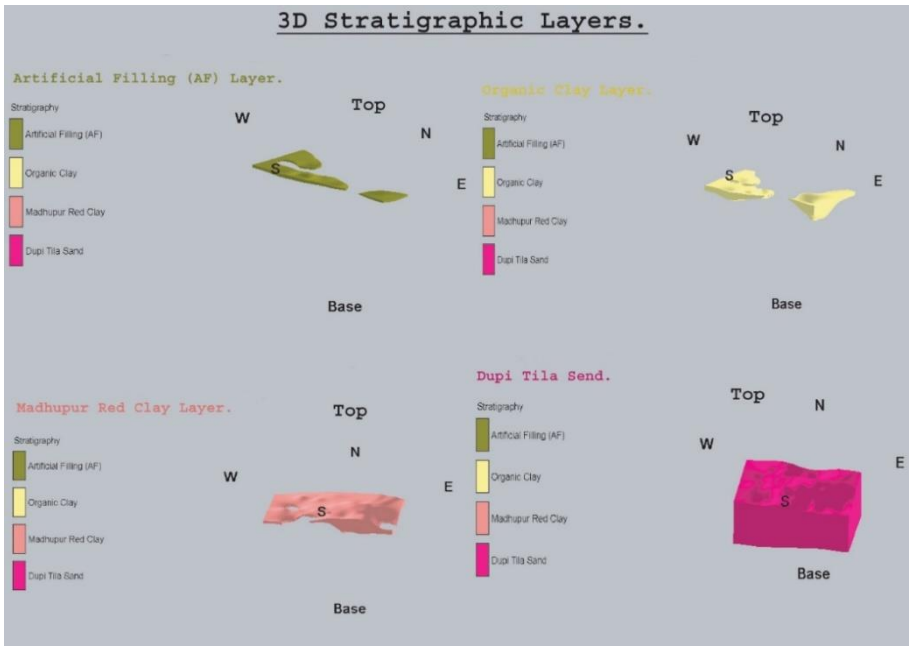


Figure 7.1 The map showing Individual Stratigraphic Layers of the Purbachal Area.

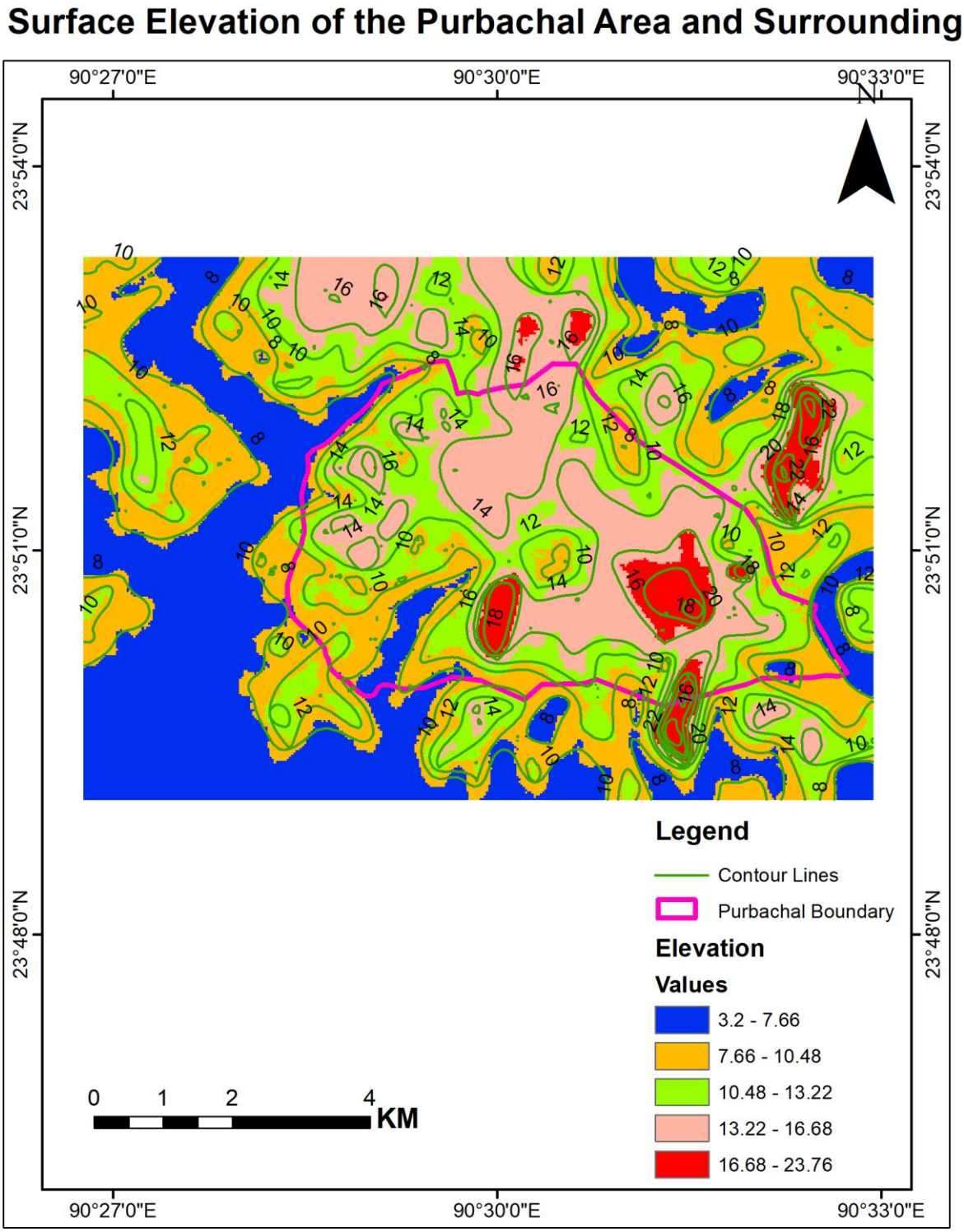


Figure 7.2 The map showing the Surface elevation of the Purbachal Area and surrounding (Data Source: NSDI-MP Field and Google Earth).

7.2 Building a Static Model Based on Lithologic Data

The lithological sequences are not the same spatially and vertically. They are composed of Sand, silt, and clay. Lithological modeling shows the distribution of all lithology in 3-D. Some of the lithological units are also patchy like artificial filling and organic clay. In the subsection below firstly lithologic units and secondly stratigraphic formations divided the study area and with these lithostratigraphy data, the study area is modeled. Clay and sandstone are teemed in the surface and the grans become coarser gradually with depth. The formation thickness increases proportionally as it approaches the northern part.

7.2.1 Lithologic Units:

15 boreholes are drilled at various depths in the study area. Subsurface borehole data is classified into 4 lithologic units that have been used in Lithologic Modelling. An individual lithologic unit is found in each borehole except a few. All the lithologic unit distribution is shown in section **7.2.2.**

Artificial Filling: This unit consists of aggregated sand, silt, and clay. It does not maintain any uniform constitutional composition. Among 15 boreholes a few boreholes, artificial filling materials are found. These boreholes are situated in the periphery of the study area.

Organic Clay:

Out of 15 organic clay is present in Boreholes BH0300, BH0400, BH0600, BH0700. Depths vary from 3 to 26 m. The highest thick of organic clay is present in borehole BH0300 depths from 3 to 26 m situated in north eastern corner of the study area. The rest of the organic Clay is present along the strip of east-west direction on the southern side.

Silty Clay:

The silty clay unit is almost homogeneously distributed in the study area. It is reddish to brownish. The thickness of this unit is not uniform and it varies from 0 to 5m. In some boreholes, it is at the depth, and in someone's, it is at the surface. This layer is in Dhaka city and has a thickness of 100 to 200 m but it in the study area is at most 5-6 m in thickness. Geologists call it Madhupur Red Clay. Geologically and Geotechnically it is a very significant unit.

Medium to Find Sand:

The distribution of this unit in the study is almost uniform all over the region. The unit consists of very fine to fine and medium to fine sand. In some boreholes, very fine to fine sand has overlain the medium to fine sand. It is the thickest unit in the area.

7.2.2 Lithologic Cross Sections:

To depict the subsurface lithologic variation in the study area 5 cross-sections are done. They are **A- A′, B- A′**, **C- A′, D-E, and A-D.** All section runs from left to right. Figure7.3. An individual Cross-section is described below.

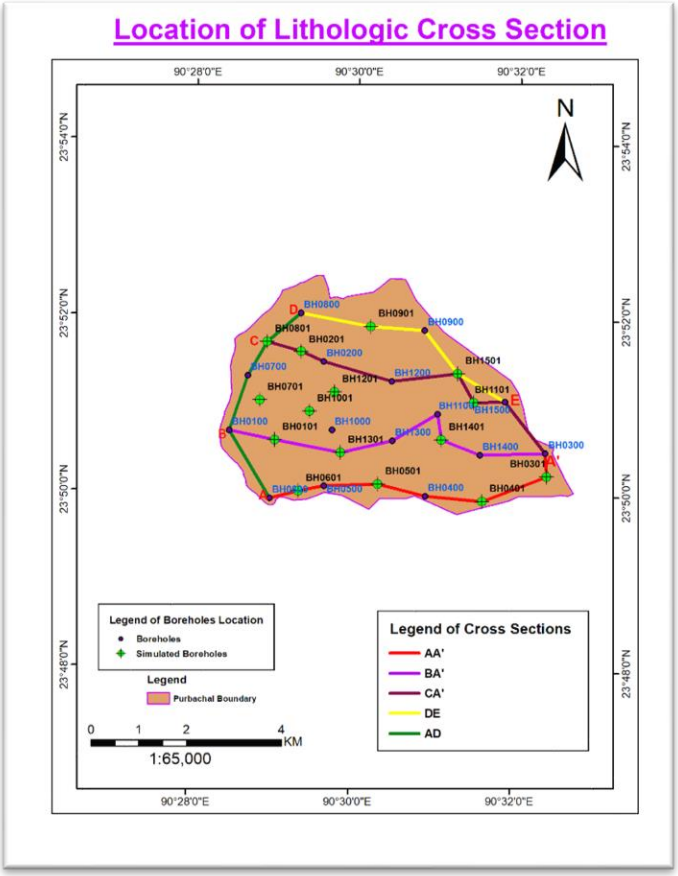


Figure 7.3: The Figure Showing the Location of Lithologic Cross-Section Lines

Cross-Section A- A′:

The cross-section A-A′ comprises the southernmost part of the study area from west to east. This cross-section includes 08 boreholes named BH0600, BH0601, BH0500, BH0501, BH0400, BH0401, BH0300, and BH0301. The average depth of these boreholes ranges from 0-50 meters below the surface. The basal part of these boreholes is mostly composed of fine to medium sand. In the western part of the area, sand deposits are dominated rather than the eastern part. In the eastern part, the

dominant lithology of the basal part is very fine to fine sand and an Organic clay layer overlies by this unit. The organic clay layer is not present in BH0400 and BH0401 and in BH0300 and BH0301 is in a thick layer. In BH0400 and BH0401 instead of organic clay a very thick layer of silty clay is found which ranges from 05-25 meters depth below the surface. The anthropogenic layer of artificial filling overlies organic clay and silty clay deposits and is found in every borehole in approximately 0-5 meters depth below the surface. From the observation

of these lithological units through the cross-section, it can be said that the eastern and western part area needs extra engineering attention for construction work.

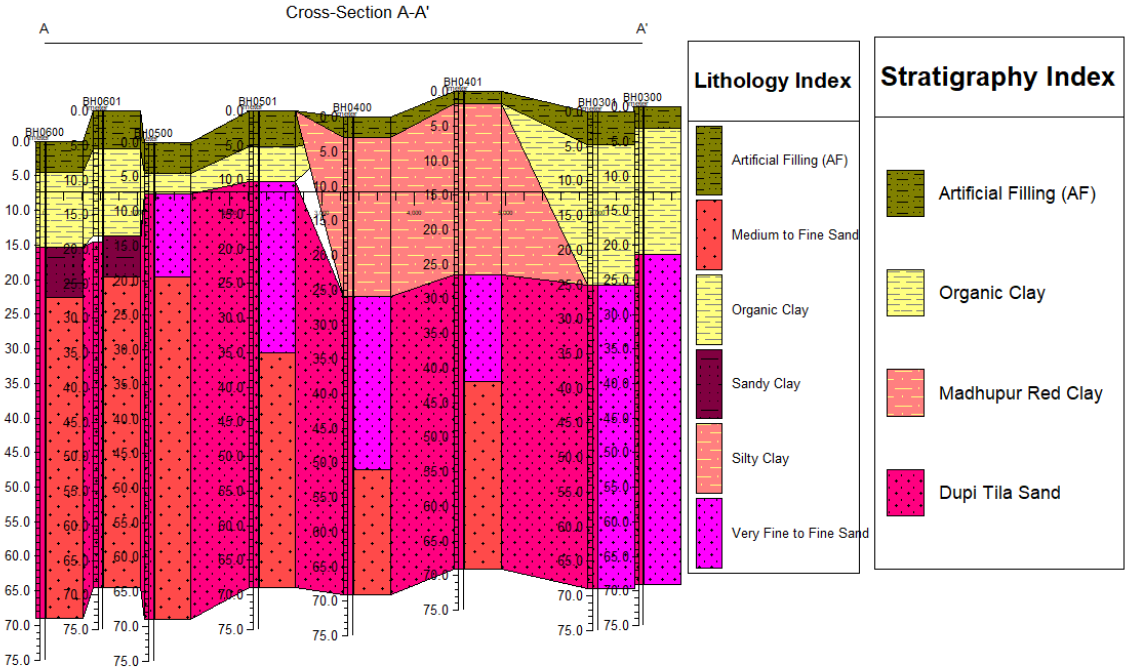


Figure 7.2.1: Lithologic Cross Section along AA′

Cross-Section B-A´:

The lithological cross section B-A´ includes 09 boreholes (BH) named BH0100, BH0101, BH 1000, BH 1301, BH1300, BH1100, BH1401, BH1400 and BH0300. The section is in the southern part of the study area and shows a west-to-east trend. The depth of the boreholes is about 70 meters each. The uppermost part of the boreholes is silty clay (0 to 10 meters maximum) dominant except for the easternmost borehole (BH 0300) which is artificially filled (0 to 5 meters). The upper silty clay is underlain by medium to fine-grained sand (up to 40 meters).

Exceptions are found in BH0101 and BH1000, which are very fine to fine sand (35 meters and 70 meters respectively), and BH0300 whose constituent is organic clay (up to 20 meters). The medium to fine-grained unit is underlain by a fine to very fine sand layer (up to 70 meters). An exception is seen in the BH 0101 in which a very fine to fine sand unit is underlain by medium to fine-grained sand (35 to 70 meters). Only in BH 1000, there is no medium to fine sand layer. Overall, the zone is encompassed with a silty clay layer which is followed by a sand layer (very fine to fine and medium to fine) and the easternmost part is an organic clay-rich zone that indicates swampy condition. Therefore, the easternmost zone requires special attention to commence the development activity.

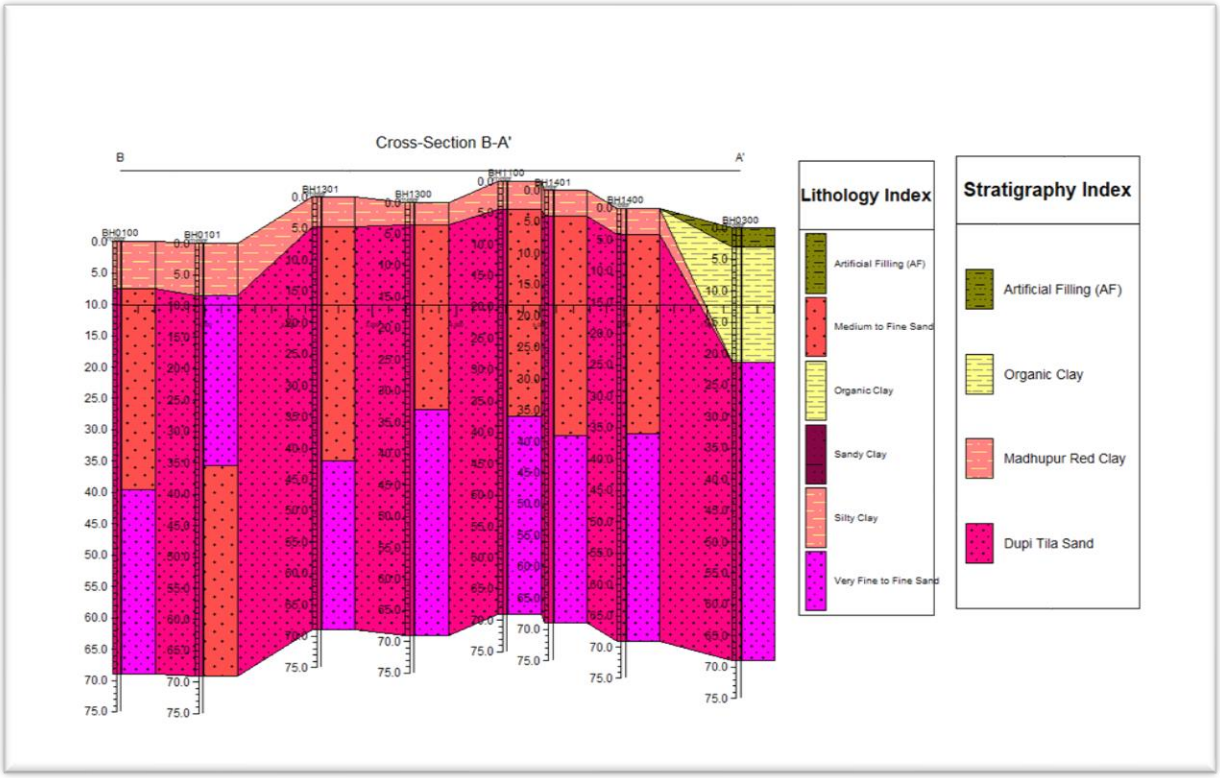


Figure 7.2.2: Lithologic Cross Section along BA′

Cross-Section C- A′:

The cross-section C-A′ comprises the upper-middle part of the study area directed from west to east. This cross-section includes 09 boreholes named BH0700, BH0801, BH0201, BH0200, BH1200, BH1501, BH1101, BH1500, and BH0300. The average depth of those boreholes is ranges from 0-70 meters below the surface. The basal part of these boreholes is mostly composed of very fine to fine sand except BH0700 which is mostly medium to fine sand deposits. In the cross-section, it is observed that

medium to fine sand deposits overlie the very fine to fine sand deposits. From the middle to the upper part of each borehole (BH0201, BH1200, BH1501, BH1101, and BH1500) dominated by medium to fine sand deposits which range from 05-45 meters below the surface.

Organic clay which is not found in every borehole but is present in BH0700 and BH0300 is overlying the medium to fine sand. These clay deposits are found in the eastern and western periphery of the cross-section but are completely absent in the middle part of the section. In the middle part, silty clay deposits are exposed with an average thickness is around 05 meters. The exposed silty clay is completely absent in the eastern and western portions where artificial filling is present in the surface with a thickness is about 03 meters.

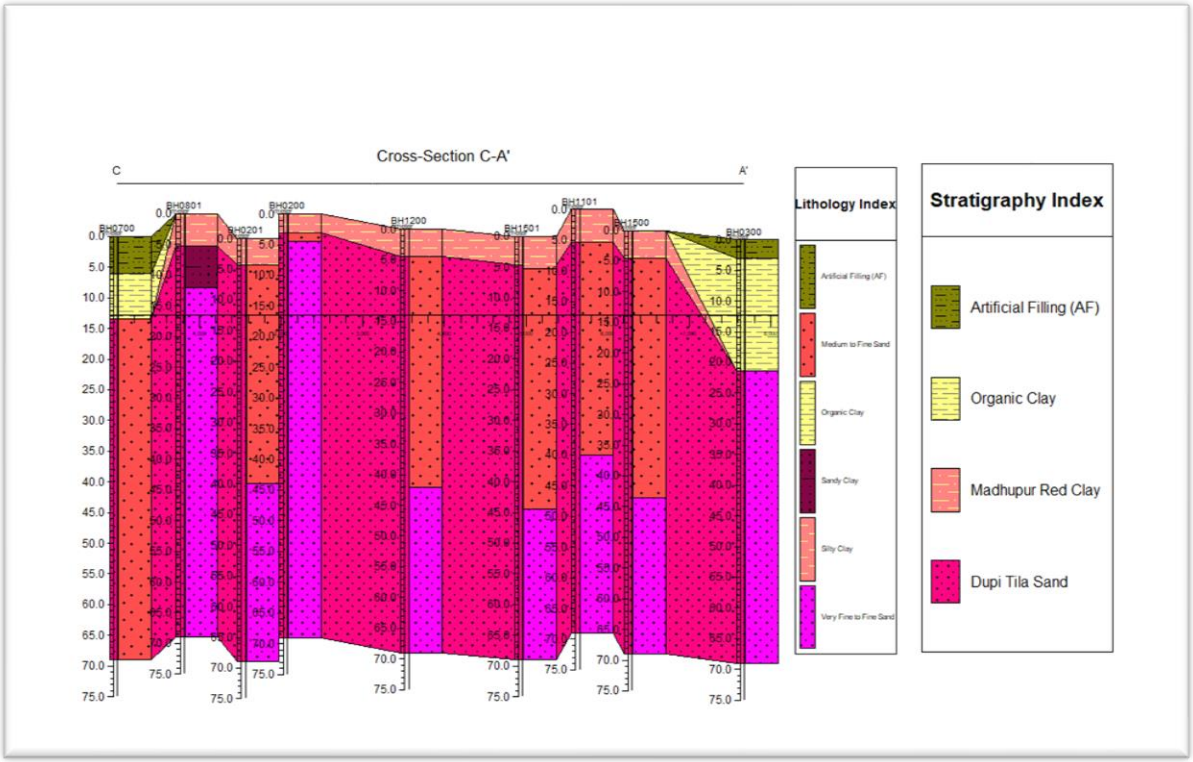


Figure 7.2.3: Lithologic Cross Section along CA′.

In the eastern part, thick organic clay deposits are found with an average thickness is about 17 meters. These clay deposits signify that there was a paleo-channel or back swamp present in the area. So, from the geological point of view, it can be said that the area may be used for development activities except the eastern and western portions. Both of the portions need further engineering attention to improve the ground quality.

Cross-Section D- E:

The cross-section D-E comprises the northernmost part of the study area directed from west to east. This cross-section includes 05 boreholes named BH0800, BH0901, BH0900, BH1501 and BH1500.

The average depth of these boreholes ranges from 0-70 meters below the surface. The basal part of these boreholes is mostly composed of very fine to fine sand except BH0900 and BH0901 which bore holes basal part that are dominated by medium to fine sand.

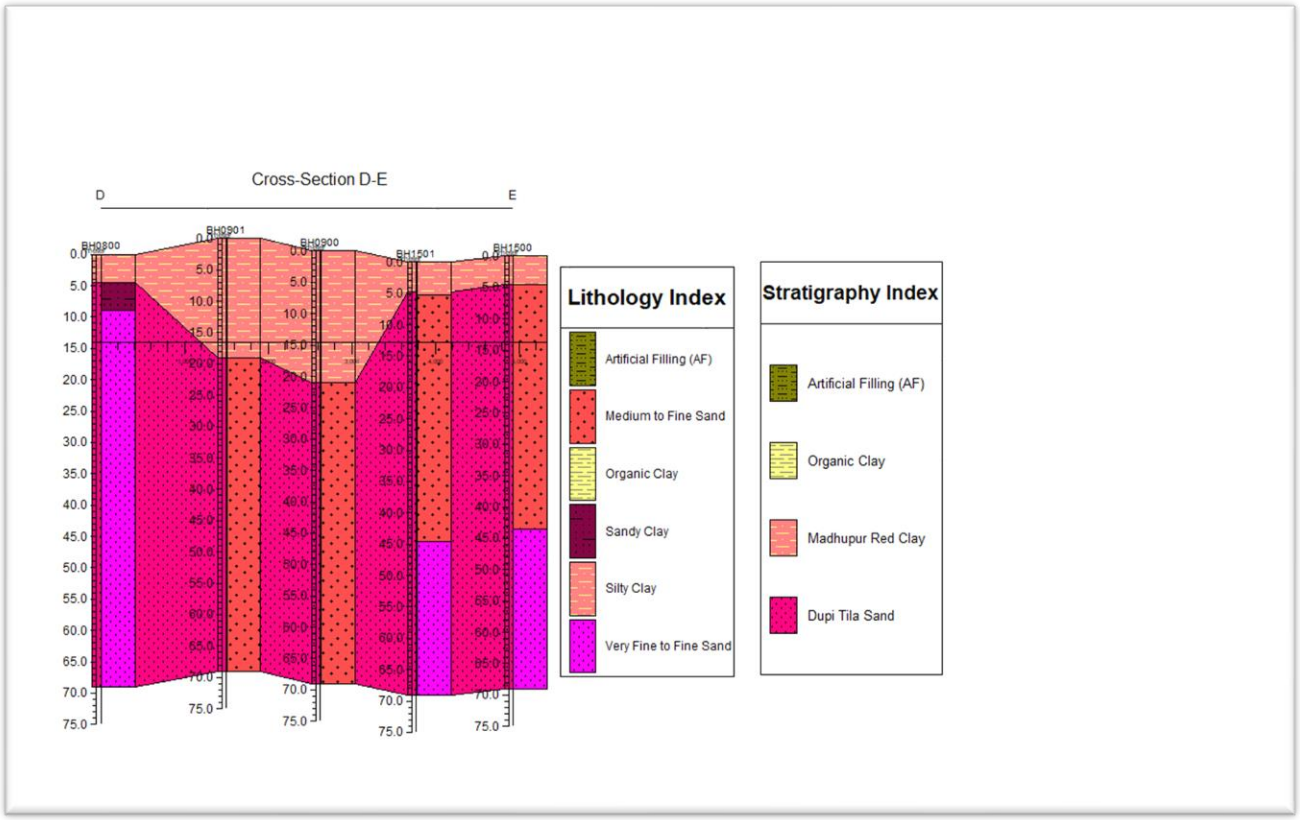


Figure 7.2.4: Lithologic Cross Section along D-E

The very fine to fine sand deposits thickness is about 25 meters as well as medium to fine sand deposits thickness is about 40 meters. Very fine to fine sand overlies by medium to fine sand in this section. Silty clay is another dominating deposit found in the cross-sectional area. In the boreholes, BH0901 and BH0900, the maximum thickness of these deposits is encountered which is about 18 meters. The thickness of these deposits becomes thinner towards the eastern and western direction. In the westernmost bore holes named BH0800 and easternmost bore holes named BH1500, its thickness is around 05 meters. This silty clay deposit is exposed throughout the area. From the geological point of view, it may be said that the area may be good for development activities.

Cross- Section A-D:

The lithological cross-section A-D includes 06 (six) boreholes (BH) named BH 0600, BH 0100, BH 0700, BH 0801, BH 0800, and BH 0901. The section is in the western part of the study area showing to

south-to-north trend. The approximate depth of the boreholes is about 70 meters each. Generally, the section can be divided into 2 parts i.e., the southern half and the northern half. In the southern part, organic clay indicates the prevailing depression/ swampy condition which is overlain by artificial fillings. Individually, BH 0600 and BH 0700 imply ideal depression/ swampy conditions containing the top artificial filling materials (0 to 5 meters), and the unit is underlain by a silty clay unit (5 to 15 meters maximum).

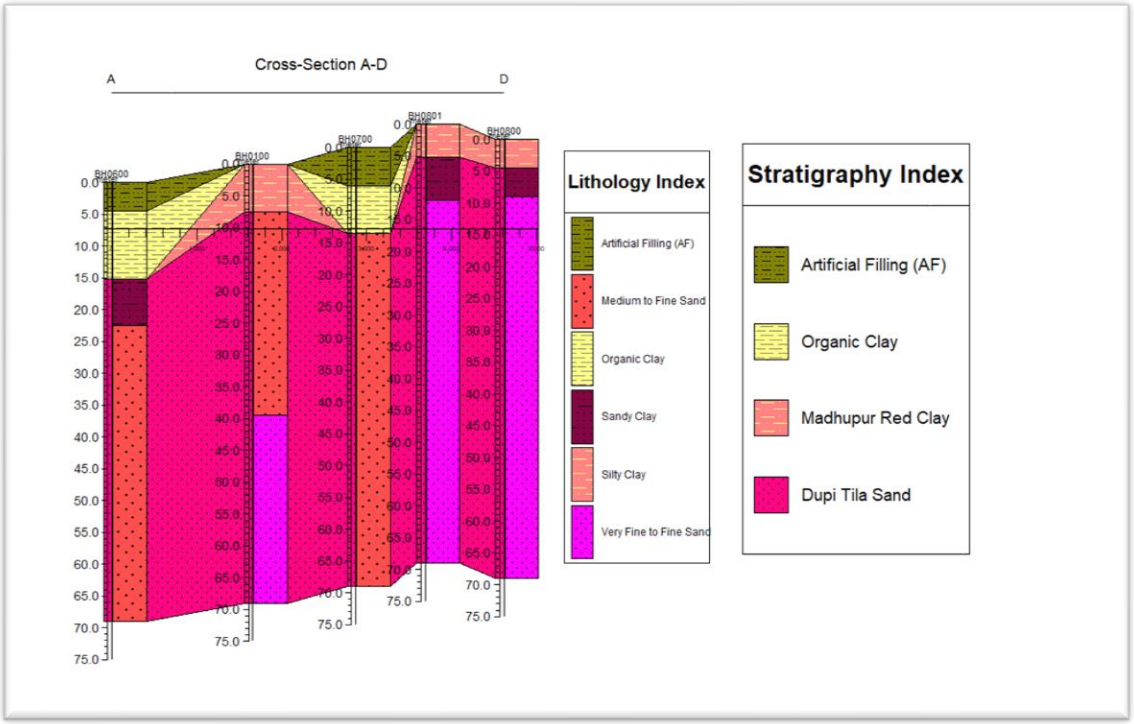


Figure 7.2.5: Lithologic Cross Section along A-D

The silty clay unit is underlain by a medium to fine-grained sand unit which is found to the 70 meters vertically. A sandy clay layer is observed in BH 0600 (15 to 22 meters). In the case of BH 0100, the silty clay (0- 5 meter) unit is witnessed as the top layer which is underlain by a medium to fine sand (5 – 35 meter) unit. Then the unit is followed by very fine to fine sand (35 to 70 meters). In the northern half, the dominance of silty clay and sand layer is observed and the silty clay unit spreads vertically more (up to 20 meters) in the northernmost part. A sandy clay unit is observed in BH 0801 and BH 0800 (5 to 10 meters). The unit is underlain by a huge medium to fine sand layer (up to 70 meters). Hence, the southern part requires more attention, and the northern part of the area is quite ready for further development activity.

7.2.3 3D Lithologic Model

Different interpolation algorithms were used for the 3D Litho-modeling of the subsurface. The choice of the most appropriate interpolation method was based on the type of model to be realized and the reasonableness of results obtained. The lithological model was created by using the lithology data directly observed by borehole surveys and the lithoblending interpolation algorithm which is the only available method for the lithological modeling of lateral lithological transitions, such as heterotopic facies and geological bodies with lenticular geometries. Lithoblending is an algorithm that extrapolates lithology types from the borehole data into a solid block model. It reconstructs lithozones around each borehole which can end suddenly when a lithological zone from a near borehole is encountered. More specifically, this algorithm works as a nearest-neighbor geospatial methodology, exclusively designed for lithological modeling. After the reconstruction of the 3D model, the software allowed the extraction of cross-sections and fence diagrams, using the respective lithology section and lithology fence diagram tools. A 3-dimensional solid or block model representing interpolated lithology is created using the borehole lithology in individual bore logs. The lithologies are represented in the model using the numeric "G-values" declared in the Lithology Types table and in the Diagram using the background colors defined for the patterns as well. Lithological modeling shows the distribution of all lithology in 3 dimensions. The vertical sedimentary sequence is dominated by silt clay and sand. Some lithological units are also patchy like artificial filling and organic clay. On the surface the dominant material is silt-clay.

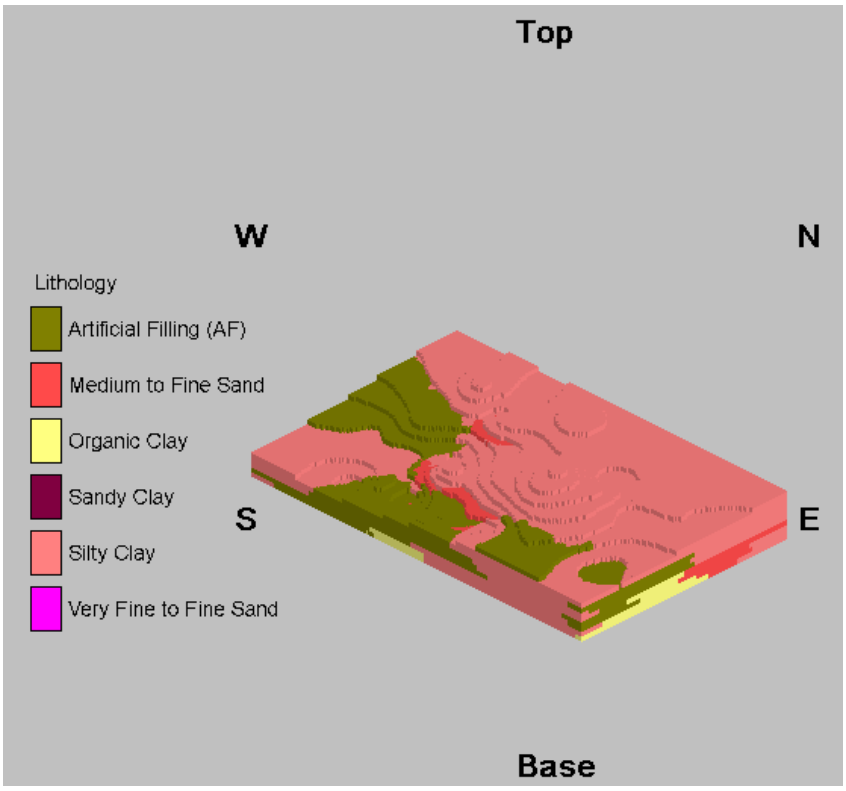


Figure 7.2.6 3D Lithologic Model of the Study Area.

Specifically, the subsurface model of the investigated area was reconstructed by RockWork modeling software. The software can manage data of different natures (lithological, stratigraphic, geophysical, geochemical, hydrogeological, and geotechnical data) and apply different interpolation methods to create 3D models, consisting of the reconstruction of overlapping regular mesh surfaces (grid model) or voxel matrices (solid model).

A 3D lithological model is a representation of the subsurface geological formations and their composition. This 3D lithological model in (Figure 7.2.6) shows the distribution of lithology types directly observed by boreholes. The investigated area is characterized for the most part by very fine to fine sand, silty clay, sandy clay, organic clay, medium to fine sand, and artificial filling.

The basal part of this model is mostly composed of very fine to fine sand in the southeastern part of the study area. The middle part of the southern side is composed of sandy clay deposits from base to top. The Organic clay unit is only seen in the eastern corner of the study area at the base which is covered by sandy clay unit at the top. The south-western and north-eastern corners of the area contain isolated silty clay units which are exposed to the earth's surface. The artificial filling layer overlies the sandy clay layer on the western side.

The 3D lithological model was generated using several 2D representations or lithostratigraphic cross-sections of the studied area.

7.3. **Building a Static Model Based on Stratigraphic Data**

By using a model, it is possible to evaluate the distribution of subsurface formation, both through space and time. A model of subsurface lithology and stratigraphy is needed before doing micro-zonation. The use of models (2D and 3D) in subsurface investigation is becoming an increasingly important and rapidly expanding discipline. Not only do these models provide as much information about a site as possible, but they are also very powerful tools used in the planning and design of site investigations and zoning. Models give information relating to engineering properties such as foundation conditions, and parameters relating to consolidation, hydrogeology, and geophysics. A good understanding of the shallow subsurface or ground geologic conditions helps to reduce costs significantly and allows for effective decision-making. It is also important to do micro-zonation regarding the seismic behavior of the ground. Rockware’s Rockworks17 and ESRI ArcGIS 10.4 software were used for geomodelling and spatial analysis processing tasks. The Rockworks software is a geomodeling software able to create block models and cross-sections in an area, providing the option to convert the exported data into ArcGIS shape easily or grid files and vice versa as input data.

The borehole logs are recoded to a common data format and spatial information is converted to planner earth projection UTM in a Rockwork project. In the case of 3-D analysis, both Lithology and Stratigraphy were considered. This is not trivial. Creating the lithology model can take some time, depending on the resolution of the model and the detail of the data. By modeling, one can identify the hazardous zone in the study area.

The study area is more or less elongated with the largest axis directed to NW-SE. The lithologic analysis is conducted by the 5 layers for convenience (section 7.2.1). All these lithological layers are not encountered in every hole. These data were imported and managed in the borehole data manager of the software by the lithology tool which is connected to the lithology type, a table defining a representative keyword, and a G value for each lithology observed. The G-value, appearing in the lithology type, is an integer numeric value used to represent the lithologies in the interpolated lithologic models. Finally, these lithologic layers are stratified in four stratigraphic formations like an artificial filling, Organic Clay, Madhupur Clay, and Dupi Tila for modeling . Mahdupur Clay is the dominant material exposed in the surface that is progressively thinner and absent in the periphery of the western and southern side of the study area. Dupi Tila formation is dominant and almost uniformly present in the study area. These four individual stratigraphic Formations are depicted in Figure 7.2.8,7.2.9

7.3.1 Stratigraphic Cross Section:

The lithostratigraphy of the area has been prepared mainly based on the collected borehole data to provide the 2-dimensional vertical view of the sub-surface lithostratigraphic conditions. The thickness of the lithological Formation was measured based on AMSL (Average Mean Sea Level) which data was collected during a field survey and Google Earth images. The overall lithology might be classified into four major categories and designated into Dupi Tila Sand, Madhupur Red Clay, Organic Clay, and

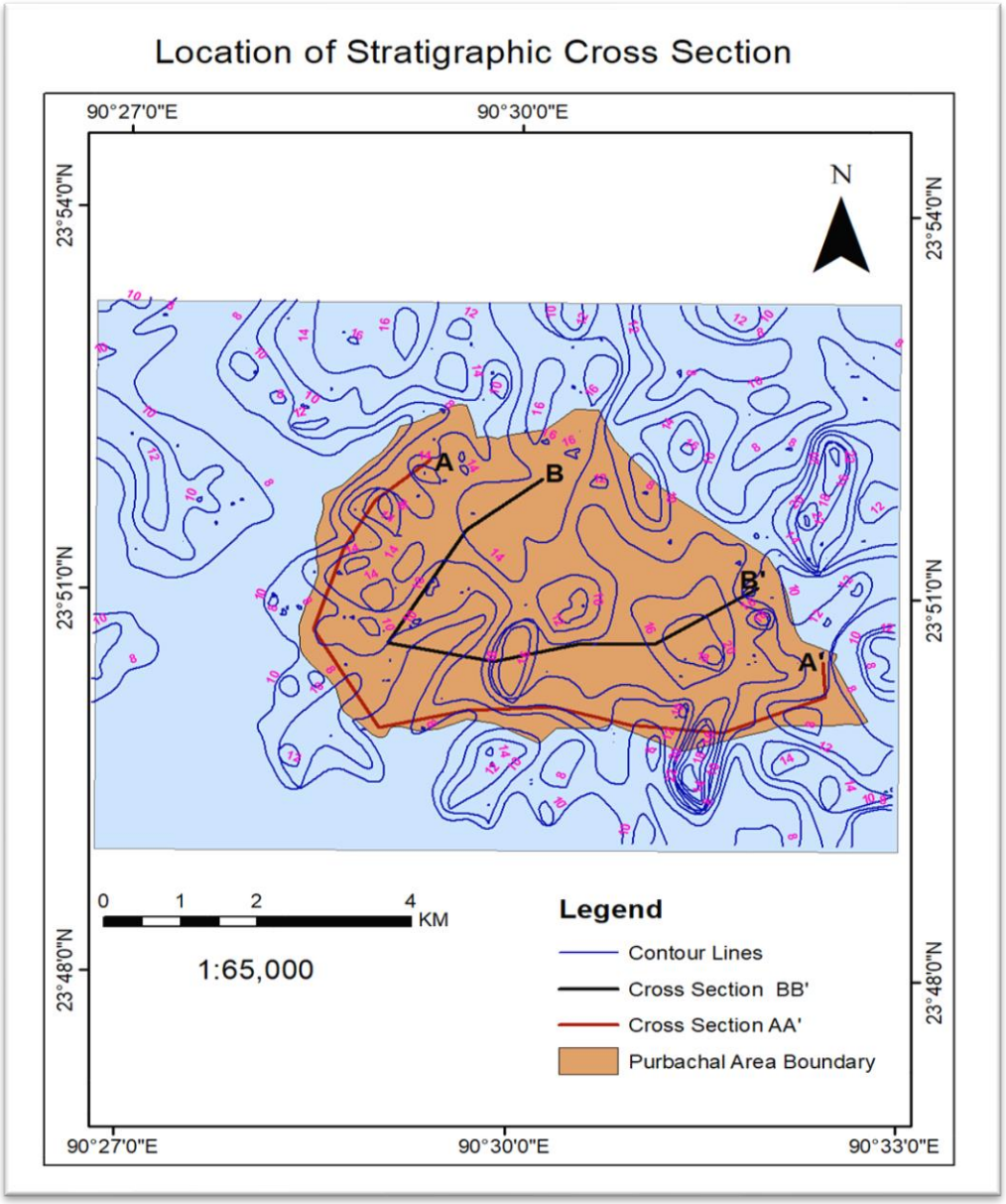


Figure 7.2.7 Showing the Location of the Stratigraphic Cross Section

Artificial Filling. To describe lithostratigraphy, cross sections along A-A′ and B-B′ have been prepared. Cross-section A-A′ runs along the western and southern periphery & and B-B′ along the mid-western and southern part of the study area Figure 7.2.7. The encountered sediments of that area are mainly sand, silt, and clay particles that are divided into four stratigraphic formations.Straratigraphic data is shown in in Annexure-IV

The stratigraphy of the study has been described below:

Dupi Tila along cross-section A-A′: Dupi Tila Formation lies in the basal part of this lithostratigraphy. Its depth extended nearly +10 to -55 meters AMSL. The average thickness of the Formation is about 50 meters. The depth of the Dupi Tila Formation is higher in the western part and lower in the southern part along the cross-section. The upper surface is not smooth and plain.

Depending on various depths from each borehole it can be said that the upper part of the layer exhibits undulations. The whole Formation is underlain by Madhupur Red Clay except the south-eastern part which has direct contact with the Organic Clay Formation along A-A′ cross-section. It indicates that the area was characterized by local channel incision. This Dupi Tila sand formation is mainly characterized by yellowish grey to yellowish brown colored medium to fine-grained sand particles.

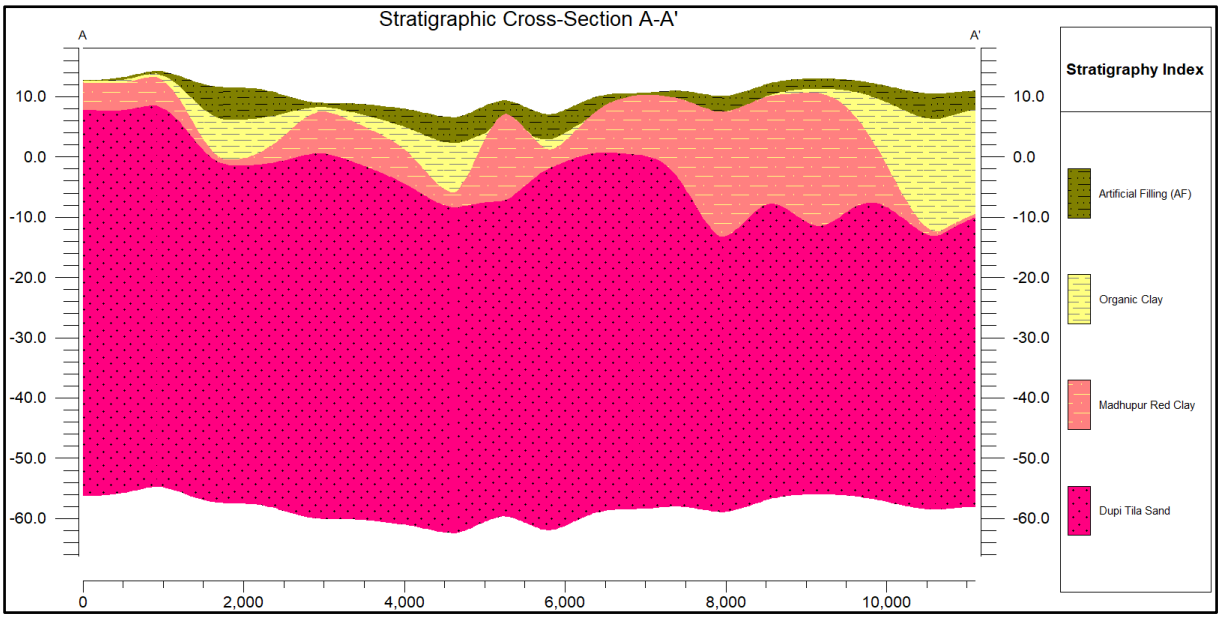


Figure: 7.2.8 The Figure showing the Stratigraphic Formation distribution in the study area along A- A′

Dupi Tila along cross-section B-B′: Dupi Tila Formation lies in the basal part of this lithostratigraphy. Its depth extended nearly +10 to -55 meters AMSL. The average thickness of the Formation is about 50 meters. This layer is thicker in the south than in the west part of the area. Various depths from each borehole exhibit undulations at the upper part of the layer. This Dupi Tila sand formation is mainly characterized by yellowish grey to yellowish brown colored medium to fine-grained sand particles.

Madhupur Red Clay along cross-section A-A′: Madhupur Red Clay Formation comprises the middle part of the Lithostratigraphy. It is highly plastic and reddish brown in color. This clay is hard and compact as well as sticky. The thickness of the clay varies in different bore holes along the cross-section. Western regions of the clay are thinner than southern regions, which are thicker. In the western part it is only 05 to 10 meters and southern part it is around 20 meters.

Madhupur Red Clay along cross-section B-B′: The middle section of the lithostratigraphy is made up of the Madhupur Red Clay Formation. It is reddish brown in color with high plasticity. This clay is both sticky hard and compact. This clay is found in a uniform thickness of about 06 meters along the cross-

section B- B′, except the western part, which has about 10 meters. However, in the northwestern and southern portions, this layer is exposed to the earth's surface

Organic Clay along Cross-section A-A′: The Organic Clay layer in this stratigraphic cross-section comes next. It is dispersed irregularly in various locations. There are two separate Organic Clay deposits have been found along the A-A′ cross-section in the western part with an average depth of around 7-8 meters. This unit is characterized by its high organic content and dark coloration suggesting that it was channel fill or back Swamp deposits. The southern part is completely devoid of these clay deposits except in the southeastern part, where around 20 meters thick clay unit is found. It was clearly a paleo-channel fill deposit due to its shape and characteristics.

Organic Clay along cross-section B-B′: The following stratigraphic cross-sectional layer is the Organic Clay layer. It is scattered randomly in various places. Cross-section B-B′ exhibits a very thin layer of this clay deposits only in the western and south-eastern part.

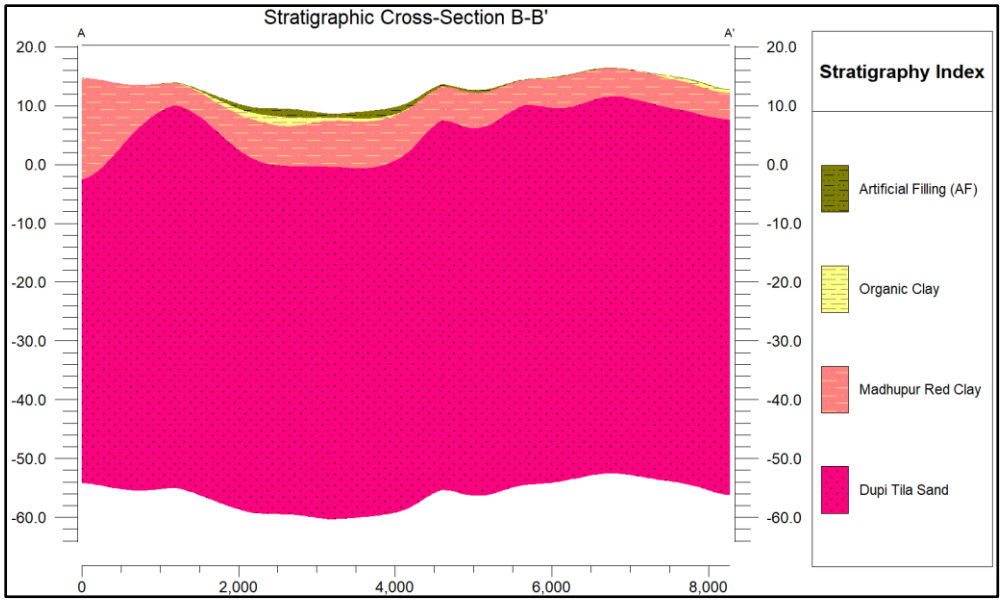


Figure:7.2.9 The Figure showing the Stratigraphic Formation distribution in the study area along B- B′

Artificial Filling along cross-section A-A′: At the top of the Organic Clay unit the artificial filling unit is present. This unit is composed of sand, silt, clay, rock fragments, brick fragments, etc. This artificial filling has been used to level the area for further development. In the cross-section A-A′ the thickness is less than 05 meters.

Artificial Filling along cross-section B-B′: The artificial filling unit can be found on top of the Organic Clay unit. Sand, silt, clay, rock, and brick fragments, among other materials, make up this unit. The area has been leveled with the help of this man-made filling. In cross-section B-B′, this layer is found in very thin thickness in the western and southern portions.

In this stratigraphic cross-section, the Dupi Tila Sand, Madhupur Red Clay, and Organic Clay units together offer a window into the region's dynamic geological past because of the different depositional

environments of these sediments. The Organic Clay and Artificial filling of both units has an impact on seismic hazard analysis and infrastructural works. Organic Clay has the potential to liquefy which is usually responsible for ground rupture during an earthquake. Artificial filling units which are admixture of different materials, potentially weaken the area. It is affected by seismic propagation and increases the risk of ground failure. It is significant to note that the precise effects of organic clay and artificial filling on construction work depend on clay composition and type. So, it is important to consider during development activities of the area.

7.3.2 3D Stratigraphic Model:

The 3D Stratigraphical model is a representation of the subsurface geological formations and their composition. It allows modeling the development of stratigraphic sequences of any region. This model is also used to signify topography and layer alignment. The distribution of subsurface geologic formation is displayed in this prepared 3D stratigraphical model (fig:7.2.10)for the study area. The Geological formations found here are identified as Dupi Tila Formation and Madhupur Clay Formation. In addition to these notable lithological deposits, the region hs been shown to contain artificial filling and organic clay.

In the prepared model, the Dupi Tila Formation covers the basal part of the area. This Formation is mainly sand-dominating and its contact is uniform with the upper layer. The average formation thickness is about 50 meters. Madhupur Clay Formation overlies the Dupi Tila Formation which is composed of highly plastic, hard, and compact red clay. This formation is thick in the middle part but becomes thinner towards the east and west direction. The average thickness is about 15 meters. The organic Clay layer is only present in the eastern direction of the modeled area. It is composed of loose sticky clay. The depth of this layer varies from 07-08 meters. The artificial Filling layer can be seen irregularly at the top of the model prominently on the western side of the region with 0-5 meters of thickness. This layer was used to level the area for development works.

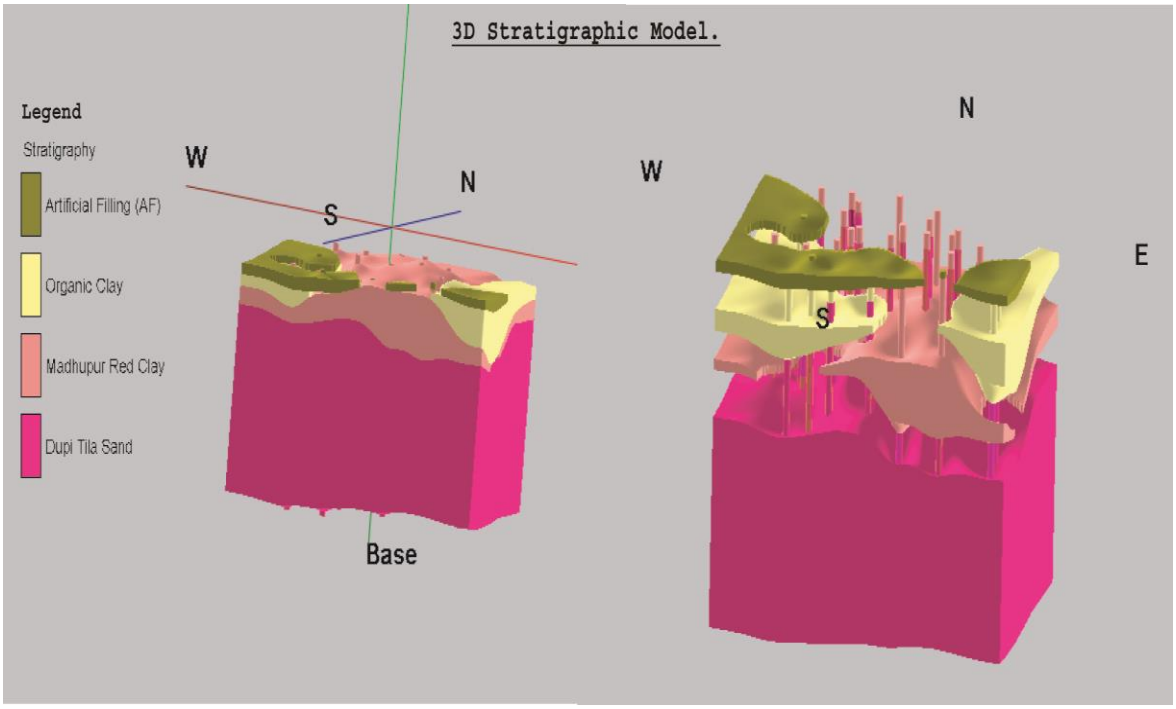


Figure 7.2.10 The figure showing the 3D Stratigraphic Model of the study area.

8. CONCLUSION

Dhaka is rapidly expanding into a megacity at present that is home to millions of people. It is both the administrative and commercial center of Bangladesh. To meet the increasing housing demand of a large number of people, urbanization is expanding in all directions of present-day Dhaka city. For sustainable development, the Japan International Cooperation Agency (JICA), in partnership with the Ministry of Defence (MoD) and the Survey of Bangladesh (SoB), is currently working on the Purbachal model project. The ultimate objective of this model project is the characterization of the surface and sub-surface condition of Purbachal area. The main focus is identifying hazardous zones that may havoc for future infrastructural development.

Based on Geomorphological features the study area is classified into fluvial or depositional landforms and erosional landforms. The fluvial landforms found in this region are gully, active channels, perennial streams, point bar, lateral bar, and natural levee whilst erosional landforms are Madhupur terrace and slope. From the Geological point of view, the area is mainly covered by the recent Alluvium deposits, the Pleistocene Madhupur Clay deposits, and the Pliocene Dupi Tila sand deposits. The majority of the recent deposits are made up of artificial fillers and organic clay.

To obtain the sub-surface lithology there are 15 boreholes with SPT values have been carried out. Another 15 boreholes were simulated based on those 15 SPT field borehole data for better 3D subsurface modeling. The 2D and 3D cross-sections of lithological and stratigraphical features offer a comprehensive continuous geological overview and imprints of the studied area. Based on boring data,

the area has been classified into four lithological units. These units are Dupi Tila Sand which has a uniform pattern of more than 50 meters of thickness. Second is Madhupur Clay Formation which is exposed in the southern part of the region. Subsequently, the Holocene deposits are visible everywhere.

Based on the land use classification, 47% of the study area is classified as agricultural land, making up the majority of the land. On the other hand, rivers make up only 0.02%, stagnant water bodies 10%, bare land 12%, and settlement and homestead vegetation 31

The outcomes of the current Model Project help to understand the surface and sub-surface conditions of the Purbachal area for future urbanization. Analysis reveals that the northwest, southwest, and northeast corners of the Purbachal area are vulnerable to different geological hazards. In the aforesaid areas, more geological, and geotechnical investigation is needed for better detailed seismic hazardous understanding. So, it may be said that these areas may not be suitable for further construction work in the present ground condition.

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ANNEXURE-I

Data Product Specifications on

Geological and Geomorphological Spatial Database of GSB-Purbachal City

20 November, 2023

Geological Survey of Bangladesh (GSB)

Overview

Information about the creation of the data product specifications

a. Title: Geological and Geomorphological spatial database of GSB-Purbachal City
b. Responsible organization: Geological Survey of Bangladesh
c. Language: English
d. Category Geological and Geomorphological Map
e. Document format: Microsoft Word

Objectives

Geologic layer of Purbachal Town are required for several purposes:

- Geological mapping of Purbachal area and surroundings.
- Geophysical, geotechnical, geo-hazards Study and
- Support for public and private organizations relating geo-scientific activities.

This data might help organizations to perform geo-scientific activities for sustainable development.

Extent of the data

Projection: WGS 1984 UTM Zone 46N

The spatial extent in respect to UTM:

Top: 2631170.621100m

Bottom: 2643265.463200m

Left: 544673.551600m

Right: 559456.379700m

Normative references

Guidelines for Data Product Specifications (NSDI)

Guidelines for Data Quality (NSDI)

Guidelines for Metadata (NSDI)

ISO 19139,19115,19131

Seminar and Workshop NSDI

Inception Report and Project completion report.

AST for Sample collection.

Scope

Scope identification

Geological and Geomorphological Spatial database of GSB-Purbachal. Area, geological and geomorphological description.

Hierarchical level

Root level to City level.

Data Product Identification

Name

Geological and Geomorphological data of Purbachal Town

Date of data creation

2023

Contact information

Syed Nazrul Islam

Designation: Director

Mobile:

Email:

Geological Survey of Bangladesh, 153 Pioneer Road, Segunbagicha, Dhaka-1000.

Geographic description

The database covers Purbachal Town and Adjoining Area [Map /Photo]

Data Content and Structure

Detail data structure is attached in the annex 1.

Vector Data

Shapefile Name: geology.shp, geomorphology.shp, lulc.shp

Geometry Type: Polygon

Field	Field Type	Definitions
FID	OID	Object ID
Shape	Geometry	Polygon

Geological category 5 categories	Text	Legends of boundaries: Study Area Purbachal New Model Town Legends of geological categories: **Geological units** Active Channel Deposits Alluvial silt Alluvial silt and clay Madhupur clay residuum Marsh clay and peat
Geomorphic category 11 categories	Text	Legends of geomorphologic categories: **Geomorphological Units** Active Channel Deep Gully Depression Flood Plain Lateral Bar Madhupur Slope Madhupur Terrace Natural levee Perennial Stream Point Bar Shallow Gully
LULC category 5 categories	Text	Legends of LULC classifications: **LULC Classification** Agricultural land Barrenland River Settlement and homestead vegetatior Stagnant water body

Raster data:

File name: Elevation

Ground Sampling Distance (spatial resolution):10 m by 10m

File format: Tagged Image File Format (TIF)

Extend

__23.8882068387361_Top

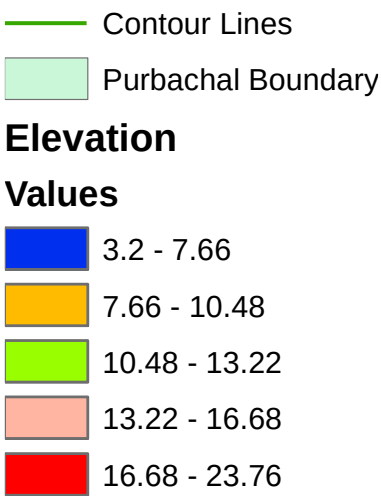
__23.817453083264__Bottom

__90.4460990152641_Left

___90.5489879425441_Right

Pixel depth:8 bit

Legends of elevation



ANNEXURE-II

GRAIN SIZE ANALYSIS OF BOREHOLES DATA

GRAIN SIZE ANALYSIS DATA OF 15 BHOREHOLES											
BH0100						BH0200					
Lon:	90.474448					Lon:	90.493711				
Lat:	23.845059					Lat:	23.858369				
Elevation:	8.686					Elevation:	14.985				
Depth from (m)	Depth to (m)	Sand	Silty	Clay	SPT	Depth from (m)	Depth to (m)	Sand	Silty	Clay	SPT
0.00	1.50	37.01	44.96	17.40	11	0.00	1.50	14.60	61.68	22.66	14
1.50	3.00	36.94	47.83	14.81	25	1.50	3.00	33.31	30.93	35.31	12
3.00	4.50	33.62	47.92	17.75	12	3.00	4.50	53.98	32.95	12.86	12
4.50	6.00	51.16	43.08	5.08	6	4.50	6.00	69.26	24.02	5.53	14
6.00	7.50	64.20	31.30	4.10	7	6.00	7.50	56.79	33.70	9.33	18
7.50	9.00	74.55	23.20	1.50	9	7.50	9.00	63.03	28.44	8.42	25
9.00	10.50	61.30	37.17	1.19	19	9.00	10.50	52.89	33.13	13.83	28
10.50	12.00	65.20	31.40	2.70	18	10.50	12.00	58.88	28.33	12.93	46
12.00	13.50	72.10	25.70	1.60	20	12.00	13.50	54.71	29.17	15.61	41
13.50	15.00	73.04	24.76	1.76	26	13.50	15.00	65.25	22.08	12.45	53
15.00	16.50	77.00	20.00	2.58	44	15.00	16.50	71.42	16.87	11.42	60
16.50	18.00	70.25	26.65	2.65	56	16.50	18.00	75.29	15.35	8.90	50
18.00	19.50	76.35	20.50	2.75	54	18.00	19.50	72.37	15.39	11.18	50
19.50	21.00	69.90	25.50	4.20	81	19.50	21.00	76.09	14.72	8.89	52
21.00	22.50	79.25	19.17	1.33	60	21.00	22.50	77.01	12.47	10.16	51
22.50	24.00	74.75	22.02	2.53	53	22.50	24.00	73.75	14.61	11.38	50
24.00	25.50	73.62	22.14	3.49	57	24.00	25.50	77.64	14.66	7.43	56
25.50	27.00	65.00	33.43	0.86	51	25.50	27.00	76.74	17.25	5.76	50
27.00	28.50	62.20	34.40	2.40	52	27.00	28.50	75.75	15.73	8.36	58
28.50	30.00	85.70	11.80	2.00	57	28.50	30.00	78.40	13.31	8.10	62
30.00	31.50	85.83	13.08	1.00	52	30.00	31.50	74.22	17.84	7.58	52
31.50	33.00	82.34	15.73	1.60	57	31.50	33.00	74.28	17.91	7.52	56
33.00	34.50	65.60	29.00	5.00	67	33.00	34.50	72.27	15.60	8.78	53
34.50	36.00	89.90	8.70	0.60	50	34.50	36.00	74.99	14.97	9.72	51
36.00	37.50	75.00	21.00	3.85	50	36.00	37.50	73.69	15.55	10.41	59
37.50	39.00	81.40	15.20	2.60	69	37.50	39.00	74.34	17.48	7.90	50
39.00	40.50	76.10	20.50	3.00	5	39.00	40.50	71.06	19.56	8.96	50
40.50	42.00	50.13	38.84	10.64	50	40.50	42.00	69.32	18.35	11.93	51
42.00	43.50	67.66	19.03	10.72	50	42.00	43.50	73.03	21.42	5.26	52
43.50	45.00	72.16	18.03	9.56	50	43.50	45.00	70.38	19.88	9.31	54
45.00	48.00	78.54	20.67	0.67	56	45.00	48.00	64.29	19.50	7.88	50
48.00	51.00	67.27	21.69	10.90	63	48.00	51.00	57.43	19.30	8.33	57
51.00	54.00	72.89	22.65	4.09	56	51.00	54.00	68.44	22.68	8.28	50
54.00	57.00	31.92	48.05	19.56	61	54.00	57.00	67.23	26.14	6.26	50
57.00	60.00	72.28	24.85	2.57	63	57.00	60.00	61.95	20.71	10.07	50
60.00	63.00	66.77	31.35	1.18	70	60.00	63.00	56.85	19.84	13.08	58
63.00	66.00	70.00	25.33	4.00	58	63.00	66.00	62.98	15.33	14.19	60
66.00	69.00	58.83	29.41	11.39	50	66.00	69.00	64.23	14.57	13.66	54

Annexure -II

GRAIN SIZE ANALYSIS DATA OF 15 BHOREHOLES

BH0300						BH0400					
Lon:	90.539674					Lon:	90.515088				
Lat:	23.84161					Lat:	23.833127				
Elevation:	10.801					Elevation:	9.321				
Depth from (m)	**Depth to**	**Sand**	**Silty**	**Clay**	**SPT**	**Depth from (m)**	**Depth to**	**Sand**	**Silty**	**Clay**	**SPT**
0.00	1.50	53.63	61.68	22.66	9	0.00	1.50	53.63	61.68	22.66	4
1.50	3.00	56.92	30.93	35.31	7	1.50	3.00	56.92	30.93	35.31	4
3.00	4.50	15.66	32.95	12.86	3	3.00	4.50	15.66	32.95	12.86	7
4.50	6.00	2.04	24.02	5.53	5	4.50	6.00	2.04	24.02	5.53	9
6.00	7.50	16.96	33.70	9.33	3	6.00	7.50	16.96	33.70	9.33	12
7.50	9.00	20.70	28.44	8.42	2	7.50	9.00	20.70	28.44	8.42	8
9.00	10.50	18.52	33.13	13.08	4	9.00	10.50	18.52	33.13	13.08	7
10.50	12.00	10.24	28.33	12.93	6	10.50	12.00	10.24	28.33	12.93	14
12.00	13.50	3.25	29.17	15.61	17	12.00	13.50	3.25	29.17	15.61	16
13.50	15.00	5.27	22.08	12.95	19	13.50	15.00	5.27	22.08	12.95	20
15.00	16.50	3.68	16.87	11.42	16	15.00	16.50	3.68	16.87	11.42	19
16.50	18.00	7.63	15.35	8.90	18	16.50	18.00	7.63	15.35	8.90	21
18.00	19.50	16.22	15.39	11.18	14	18.00	19.50	16.22	15.39	11.18	18
19.50	21.00	10.44	14.72	8.89	11	19.50	21.00	10.44	14.72	8.89	15
21.00	22.50	70.40	12.47	10.16	24	21.00	22.50	70.40	12.47	10.16	17
22.50	24.00	67.83	14.61	11.38	26	22.50	24.00	67.83	14.61	11.38	20
24.00	25.50	71.86	14.66	7.43	31	24.00	25.50	71.86	14.66	7.43	52
25.50	27.00	68.03	17.25	5.76	43	25.50	27.00	68.03	17.25	5.76	56
27.00	28.50	72.79	15.73	8.36	50	27.00	28.50	72.79	15.73	8.36	42
28.50	30.00	70.66	13.31	8.10	49	28.50	30.00	70.66	13.31	8.10	48
30.00	31.50	70.32	17.84	7.58	50	30.00	31.50	70.32	17.84	7.58	50
31.50	33.00	68.05	17.91	7.52	42	31.50	33.00	68.05	17.91	7.52	50
33.00	34.50	65.89	15.60	8.78	47	33.00	34.50	65.89	15.60	8.78	50
34.50	36.00	63.41	14.97	9.72	57	34.50	36.00	63.41	14.97	9.72	50
36.00	37.50	70.70	15.55	10.41	53	36.00	37.50	70.70	15.55	10.41	50
37.50	39.00	74.34	17.48	7.90	54	37.50	39.00	74.34	17.48	7.90	55
39.00	40.50	71.06	19.56	8.96	50	39.00	40.50	71.06	19.56	8.96	51
40.50	42.00	69.32	18.35	11.93	52	40.50	42.00	69.32	18.35	11.93	52
42.00	43.50	73.03	21.42	5.26	50	42.00	43.50	73.03	21.42	5.26	50
43.50	45.00	70.38	19.88	9.31	50	43.50	45.00	70.38	19.88	9.31	52
45.00	48.00	72.25	19.50	7.88	85	45.00	48.00	72.25	19.50	7.88	50
48.00	51.00	71.78	19.30	8.33	52	48.00	51.00	71.78	19.30	8.33	51
51.00	54.00	68.44	22.68	8.28	54	51.00	54.00	68.44	22.68	8.28	
54.00	57.00	67.23	26.14	6.26	51	54.00	57.00	67.23	26.14	6.26	
57.00	60.00	68.83	20.71	10.07	52	57.00	60.00	68.83	20.71	10.07	
60.00	63.00	66.88	19.84	13.08		60.00	63.00	66.88	19.84	13.08	
63.00	66.00	69.98	15.33	14.19		63.00	66.00	69.98	15.33	14.19	
66.00	69.00	71.37	14.57	13.66		66.00	69.00	71.37	14.57	13.66	

Annexure -II

GRAIN SIZE ANALYSIS DATA OF 15 BHOREHOLES

BH0500						BH0600					
Lon:	90.494174					Lon:	90.482956				
Lat:	23.834752					Lat:	23.832281				
Elevation:	5.693					Elevation:	5.836				
Depth from (m)	**Depth to**	**Sand**	**Silty**	**Clay**	**SPT**	**Depth from (m)**	**Depth to**	**Sand**	**Silty**	**Clay**	**SPT**
0.00	1.50	53.63	61.68	22.66	7	0.00	1.50	53.63	61.68	22.66	3
1.50	3.00	56.92	30.93	35.31	18	1.50	3.00	56.92	30.93	35.31	2
3.00	4.50	15.66	32.95	12.86	7	3.00	4.50	15.66	32.95	12.86	3
4.50	6.00	2.04	24.02	5.53	4	4.50	6.00	2.04	24.02	5.53	12
6.00	7.50	16.96	33.70	9.33	2	6.00	7.50	16.96	33.70	9.33	2
7.50	9.00	20.70	28.44	8.42	13	7.50	9.00	20.70	28.44	8.42	2
9.00	10.50	18.52	33.13	13.08	21	9.00	10.50	18.52	33.13	13.08	2
10.50	12.00	10.24	28.33	12.93	31	10.50	12.00	10.24	28.33	12.93	4
12.00	13.50	3.25	29.17	15.61	24	12.00	13.50	3.25	29.17	15.61	3
13.50	15.00	5.27	22.08	12.95	28	13.50	15.00	5.27	22.08	12.95	4
15.00	16.50	3.68	16.87	11.42	32	15.00	16.50	3.68	16.87	11.42	2
16.50	18.00	7.63	15.35	8.90	37	16.50	18.00	7.63	15.35	8.90	16
18.00	19.50	16.22	15.39	11.18	52	18.00	19.50	16.22	15.39	11.18	13
19.50	21.00	10.44	14.72	8.89	53	19.50	21.00	10.44	14.72	8.89	15
21.00	22.50	70.40	12.47	10.16	52	21.00	22.50	70.40	12.47	10.16	17
22.50	24.00	67.83	14.61	11.38	54	22.50	24.00	67.83	14.61	11.38	64
24.00	25.50	71.86	14.66	7.43	51	24.00	25.50	71.86	14.66	7.43	53
25.50	27.00	68.03	17.25	5.76	54	25.50	27.00	68.03	17.25	5.76	60
27.00	28.50	72.79	15.73	8.36	57	27.00	28.50	72.79	15.73	8.36	65
28.50	30.00	70.66	13.31	8.10	52	28.50	30.00	70.66	13.31	8.10	65
30.00	31.50	70.32	17.84	7.58	54	30.00	31.50	70.32	17.84	7.58	60
31.50	33.00	68.05	17.91	7.52	60	31.50	33.00	68.05	17.91	7.52	74
33.00	34.50	65.89	15.60	8.78		33.00	34.50	65.89	15.60	8.78	
34.50	36.00	63.41	14.97	9.72		34.50	36.00	63.41	14.97	9.72	
36.00	37.50	70.70	15.55	10.41		36.00	37.50	70.70	15.55	10.41	
37.50	39.00	74.34	17.48	7.90		37.50	39.00	74.34	17.48	7.90	
39.00	40.50	71.06	19.56	8.96		39.00	40.50	71.06	19.56	8.96	
40.50	42.00	69.32	18.35	11.93		40.50	42.00	69.32	18.35	11.93	
42.00	43.50	73.03	21.42	5.26		42.00	43.50	73.03	21.42	5.26	
43.50	45.00	70.38	19.88	9.31		43.50	45.00	70.38	19.88	9.31	
45.00	48.00	72.25	19.50	7.88		45.00	48.00	72.25	19.50	7.88	
48.00	51.00	71.78	19.30	8.33		48.00	51.00	71.78	19.30	8.33	
51.00	54.00	68.44	22.68	8.28		51.00	54.00	68.44	22.68	8.28	
54.00	57.00	67.23	26.14	6.26		54.00	57.00	67.23	26.14	6.26	
57.00	60.00	68.83	20.71	10.07		57.00	60.00	68.83	20.71	10.07	
60.00	63.00	66.88	19.84	13.08		60.00	63.00	66.88	19.84	13.08	
63.00	66.00	69.98	15.33	14.19		63.00	66.00	69.98	15.33	14.19	
66.00	69.00	71.37	14.57	13.66		66.00	69.00	71.37	14.57	13.66	

Annexure -II

GRAIN SIZE ANALYSIS DATA OF 15 BOREHOLES

BH0700						BH0800					
Lon:	90.478076					Lon:	90.488866				
Lat:	23.855484					Lat:	23.867454				
Elevation:	11.335					Elevation:	12.603				
Depth from (m)	**Depth to**	**Sand**	**Silty**	**Clay**	**SPT**	**Depth from (m)**	**Depth to**	**Sand**	**Silty**	**Clay**	**SPT**
0.00	1.50	53.63	61.68	22.66	6	0.00	1.50	53.63	61.68	22.66	18
1.50	3.00	56.92	30.93	35.31	16	1.50	3.00	56.92	30.93	35.31	28
3.00	4.50	15.66	32.95	12.86	9	3.00	4.50	15.66	32.95	12.86	24
4.50	6.00	2.04	24.02	5.53	5	4.50	6.00	2.04	24.02	5.53	7
6.00	7.50	16.96	33.70	9.33	2	6.00	7.50	16.96	33.70	9.33	8
7.50	9.00	20.70	28.44	8.42	3	7.50	9.00	20.70	28.44	8.42	7
9.00	10.50	18.52	33.13	13.08	3	9.00	10.50	18.52	33.13	13.08	9
10.50	12.00	10.24	28.33	12.93	3	10.50	12.00	10.24	28.33	12.93	10
12.00	13.50	3.25	29.17	15.61	4	12.00	13.50	3.25	29.17	15.61	32
13.50	15.00	5.27	22.08	12.95	32	13.50	15.00	5.27	22.08	12.95	36
15.00	16.50	3.68	16.87	11.42	50	15.00	16.50	3.68	16.87	11.42	38
16.50	18.00	7.63	15.35	8.90	52	16.50	18.00	7.63	15.35	8.90	41
18.00	19.50	16.22	15.39	11.18	53	18.00	19.50	16.22	15.39	11.18	45
19.50	21.00	10.44	14.72	8.89	50	19.50	21.00	10.44	14.72	8.89	48
21.00	22.50	70.40	12.47	10.16	70	21.00	22.50	70.40	12.47	10.16	50
22.50	24.00	67.83	14.61	11.38	64	22.50	24.00	67.83	14.61	11.38	50
24.00	25.50	71.86	14.66	7.43	55	24.00	25.50	71.86	14.66	7.43	51
25.50	27.00	68.03	17.25	5.76	50	25.50	27.00	68.03	17.25	5.76	52
27.00	28.50	72.79	15.73	8.36	72	27.00	28.50	72.79	15.73	8.36	56
28.50	30.00	70.66	13.31	8.10	62	28.50	30.00	70.66	13.31	8.10	50
30.00	31.50	70.32	17.84	7.58		30.00	31.50	70.32	17.84	7.58	
31.50	33.00	68.05	17.91	7.52		31.50	33.00	68.05	17.91	7.52	
33.00	34.50	65.89	15.60	8.78		33.00	34.50	65.89	15.60	8.78	
34.50	36.00	63.41	14.97	9.72		34.50	36.00	63.41	14.97	9.72	
36.00	37.50	70.70	15.55	10.41		36.00	37.50	70.70	15.55	10.41	
37.50	39.00	74.34	17.48	7.90		37.50	39.00	74.34	17.48	7.90	
39.00	40.50	71.06	19.56	8.96		39.00	40.50	71.06	19.56	8.96	
40.50	42.00	69.32	18.35	11.93		40.50	42.00	69.32	18.35	11.93	
42.00	43.50	73.03	21.42	5.26		42.00	43.50	73.03	21.42	5.26	
43.50	45.00	70.38	19.88	9.31		43.50	45.00	70.38	19.88	9.31	
45.00	48.00	72.25	19.50	7.88		45.00	48.00	72.25	19.50	7.88	
48.00	51.00	71.78	19.30	8.33		48.00	51.00	71.78	19.30	8.33	
51.00	54.00	68.44	22.68	8.28		51.00	54.00	68.44	22.68	8.28	
54.00	57.00	67.23	26.14	6.26		54.00	57.00	67.23	26.14	6.26	
57.00	60.00	68.83	20.71	10.07		57.00	60.00	68.83	20.71	10.07	
60.00	63.00	66.88	19.84	13.08		60.00	63.00	66.88	19.84	13.08	
63.00	66.00	69.98	15.33	14.19		63.00	66.00	69.98	15.33	14.19	
66.00	69.00	71.37	14.57	13.66		66.00	69.00	71.37	14.57	13.66	

Annexure -II

GRAIN SIZE ANALYSIS DATA OF 15 BOREHOLES												
BH0900						BH1000						
Lon:	90.51441					Lon:	90.495626					
Lat:	23.864582					Lat:	23.8454					
Elevation:	13.12					Elevation:	7.621					
Depth from (m)	**Depth to**	**Sand**	**Silty**	**Clay**	**SPT**	**Depth from (m)**	**Depth to**	**Sand**	**Silty**	**Clay**	**SPT**
0.00	1.50	53.63	61.68	22.66	5	0.00	1.50	15.12	60.80	21.70	13
1.50	3.00	56.92	30.93	35.31	8	1.50	3.00	34.10	29.60	36.10	14
3.00	4.50	15.66	32.95	12.86	7	3.00	4.50	53.90	31.58	13.50	11
4.50	6.00	2.04	24.02	5.53	9	4.50	6.00	70.80	23.60	6.30	15
6.00	7.50	16.96	33.70	9.33	12	6.00	7.50	55.26	34.81	10.30	17
7.50	9.00	20.70	28.44	8.42	15	7.50	9.00	62.10	29.65	9.45	24
9.00	10.50	18.52	33.13	13.08	17	9.00	10.50	50.20	30.20	12.50	27
10.50	12.00	10.24	28.33	12.93	20	10.50	12.00	60.23	29.50	11.50	47
12.00	13.50	3.25	29.17	15.61	24	12.00	13.50	55.20	30.70	14.20	40
13.50	15.00	5.27	22.08	12.95	26	13.50	15.00	66.23	23.58	13.87	54
15.00	16.50	3.68	16.87	11.42	15	15.00	16.50	70.20	17.60	12.58	56
16.50	18.00	7.63	15.35	8.90	16	16.50	18.00	76.36	16.80	9.25	49
18.00	19.50	16.22	15.39	11.18	17	18.00	19.50	73.26	16.20	12.25	49
19.50	21.00	10.44	14.72	8.89	16	19.50	21.00	75.36	15.25	9.20	51
21.00	22.50	70.40	12.47	10.16	19	21.00	22.50	77.98	11.36	12.54	52
22.50	24.00	67.83	14.61	11.38	50	22.50	24.00	72.36	15.23	12.36	49
24.00	25.50	71.86	14.66	7.43	52	24.00	25.50	78.25	15.20	8.36	55
25.50	27.00	68.03	17.25	5.76	51	25.50	27.00	75.26	18.25	5.69	50
27.00	28.50	72.79	15.73	8.36	53	27.00	28.50	76.30	14.25	8.66	59
28.50	30.00	70.66	13.31	8.10	54	28.50	30.00	79.26	12.36	8.90	61
30.00	31.50	70.32	17.84	7.58	50	30.00	31.50	75.26	18.25	9.36	53
31.50	33.00	68.05	17.91	7.52		31.50	33.00	75.26	18.65	8.50	57
33.00	34.50	65.89	15.60	8.78		33.00	34.50	70.20	14.26	8.72	52
34.50	36.00	63.41	14.97	9.72		34.50	36.00	75.29	15.98	10.20	52
36.00	37.50	70.70	15.55	10.41		36.00	37.50	74.69	16.58	11.26	60
37.50	39.00	74.34	17.48	7.90		37.50	39.00	75.44	18.69	8.21	49
39.00	40.50	71.06	19.56	8.96		39.00	40.50	70.26	18.26	7.25	52
40.50	42.00	69.32	18.35	11.93		40.50	42.00	70.36	19.87	12.36	50
42.00	43.50	73.03	21.42	5.26		42.00	43.50	74.25	20.36	6.80	51
43.50	45.00	70.38	19.88	9.31		43.50	45.00	71.15	20.87	10.25	55
45.00	48.00	72.25	19.50	7.88		45.00	48.00	65.36	20.30	8.26	49
48.00	51.00	71.78	19.30	8.33		48.00	51.00	58.36	20.36	9.26	56
51.00	54.00	68.44	22.68	8.28		51.00	54.00	70.36	21.50	9.30	51
54.00	57.00	67.23	26.14	6.26		54.00	57.00	66.36	25.94	7.60	51
57.00	60.00	68.83	20.71	10.07		57.00	60.00	60.36	19.96	11.30	52
60.00	63.00	66.88	19.84	13.08		60.00	63.00	55.69	20.36	15.60	57
63.00	66.00	69.98	15.33	14.19		63.00	66.00	61.36	16.58	14.98	61
66.00	69.00	71.37	14.57	13.66		66.00	69.00	66.35	12.58	14.36	55

Annexure -II

GRAIN SIZE ANALYSIS DATA OF 15 BHOREHOLES												
BH1100						BH1200						
Lon:	90.517367					Lon:	90.507759					
Lat:	23.848752					Lat:	23.854795					
Elevation:	18.258					Elevation:	12.503					
Depth from (m)	Depth to	Sand	Silty	Clay	SPT	Depth from (m)	Depth to	Sand	Silty	Clay	SPT
0.00	1.50	15.36	60.25	21.36	13	0.00	1.50	0.00	0.00	0.00	11
1.50	3.00	32.60	29.69	34.30	11	1.50	3.00	0.00	0.00	0.00	25
3.00	4.50	52.36	31.85	11.25	13	3.00	4.50	0.00	0.00	0.00	12
4.50	6.00	69.26	24.96	6.80	13	4.50	6.00	51.16	43.08	5.08	12
6.00	7.50	55.28	34.75	10.36	17	6.00	7.50	64.20	31.30	4.10	11
7.50	9.00	64.36	29.45	9.25	24	7.50	9.00	74.55	23.20	1.50	12
9.00	10.50	53.26	32.85	14.25	27	9.00	10.50	61.30	37.17	1.19	19
10.50	12.00	59.67	27.45	13.60	47	10.50	12.00	65.20	31.40	2.70	18
12.00	13.50	55.26	30.30	14.58	42	12.00	13.50	72.10	25.70	1.60	20
13.50	15.00	66.36	21.25	14.90	54	13.50	15.00	73.04	24.76	1.76	26
15.00	16.50	70.23	17.25	10.94	59	15.00	16.50	77.00	20.00	2.58	44
16.50	18.00	74.36	16.87	9.50	49	16.50	18.00	70.25	26.65	2.65	56
18.00	19.50	73.26	14.87	12.36	52	18.00	19.50	76.35	20.50	2.75	54
19.50	21.00	75.36	13.25	9.60	51	19.50	21.00	69.90	25.50	4.20	81
21.00	22.50	78.26	13.68	11.26	50	21.00	22.50	79.25	19.17	1.33	60
22.50	24.00	74.36	15.87	13.40	52	22.50	24.00	74.75	22.02	2.53	53
24.00	25.50	78.98	13.56	7.20	57	24.00	25.50	73.62	22.14	3.49	57
25.50	27.00	75.36	18.68	5.94	49	25.50	27.00	65.00	33.43	0.86	51
27.00	28.50	76.26	16.58	9.36	59	27.00	28.50	62.20	34.40	2.40	52
28.50	30.00	79.26	14.25	9.45	61	28.50	30.00	85.70	11.80	2.00	57
30.00	31.50	75.69	18.80	8.65	51	30.00	31.50	85.83	13.08	1.00	52
31.50	33.00	75.26	18.58	8.69	55	31.50	33.00	82.34	15.73	1.60	57
33.00	34.50	71.36	16.80	9.78	52	33.00	34.50	65.60	29.00	5.00	67
34.50	36.00	75.25	15.80	10.37	52	34.50	36.00	89.90	8.70	0.60	50
36.00	37.50	74.12	16.58	11.29	60	36.00	37.50	75.00	21.00	3.85	50
37.50	39.00	74.98	16.77	8.20	49	37.50	39.00	81.40	15.20	2.60	69
39.00	40.50	70.23	20.80	9.30	52	39.00	40.50	76.10	20.50	3.00	5
40.50	42.00	70.36	18.20	14.30	52	40.50	42.00	50.13	38.84	10.64	50
42.00	43.50	72.23	20.36	6.80	53	42.00	43.50	67.66	19.03	10.72	50
43.50	45.00	70.60	20.90	10.20	55	43.50	45.00	72.16	18.03	9.56	50
45.00	48.00	65.20	20.90	8.60	49	45.00	48.00	78.54	20.67	0.67	56
48.00	51.00	58.36	20.60	9.30	55	48.00	51.00	67.27	21.69	10.90	63
51.00	54.00	69.23	21.30	9.26	49	51.00	54.00	72.89	22.65	4.09	56
54.00	57.00	68.23	27.40	7.26	51	54.00	57.00	31.92	48.05	19.56	61
57.00	60.00	60.36	21.39	11.80	51	57.00	60.00	72.28	24.85	2.57	63
60.00	63.00	57.25	20.90	14.80	59	60.00	63.00	66.77	31.35	1.18	70
63.00	66.00	63.25	16.40	15.20	59	63.00	66.00	70.00	25.33	4.00	58
66.00	69.00	65.36	15.60	14.80	55	66.00	69.00	58.83	29.41	11.39	50

Annexure -II

GRAIN SIZE ANALYSIS DATA OF 15 BHOREHOLES												
BH1300						BH1400					
Lon:	90.508076					Lon:	90.526193				
Lat:	23.84354					Lat:	23.841087				
Elevation:	14.869					Elevation:	14.004				
Depth from (m)	Depth to	Sand	Silty	Clay	SPT	Depth from (m)	Depth to	Sand	Silty	Clay	SPT
0.00	1.50	0.00	0.00	0.00	11	0.00	1.50	0.00	0.00	0.00	11
1.50	3.00	0.00	0.00	0.00	25	1.50	3.00	0.00	0.00	0.00	25
3.00	4.50	0.00	0.00	0.00	12	3.00	4.50	0.00	0.00	0.00	12
4.50	6.00	51.16	43.08	5.08	13	4.50	6.00	51.16	43.08	5.08	10
6.00	7.50	64.20	31.30	4.10	11	6.00	7.50	64.20	31.30	4.10	12
7.50	9.00	74.55	23.20	1.50	18	7.50	9.00	74.55	23.20	1.50	14
9.00	10.50	61.30	37.17	1.19	19	9.00	10.50	61.30	37.17	1.19	19
10.50	12.00	65.20	31.40	2.70	18	10.50	12.00	65.20	31.40	2.70	18
12.00	13.50	72.10	25.70	1.60	20	12.00	13.50	72.10	25.70	1.60	20
13.50	15.00	73.04	24.76	1.76	26	13.50	15.00	73.04	24.76	1.76	26
15.00	16.50	77.00	20.00	2.58	44	15.00	16.50	77.00	20.00	2.58	44
16.50	18.00	70.25	26.65	2.65	56	16.50	18.00	70.25	26.65	2.65	56
18.00	19.50	76.35	20.50	2.75	54	18.00	19.50	76.35	20.50	2.75	54
19.50	21.00	69.90	25.50	4.20	81	19.50	21.00	69.90	25.50	4.20	81
21.00	22.50	79.25	19.17	1.33	60	21.00	22.50	79.25	19.17	1.33	60
22.50	24.00	74.75	22.02	2.53	53	22.50	24.00	74.75	22.02	2.53	53
24.00	25.50	73.62	22.14	3.49	57	24.00	25.50	73.62	22.14	3.49	57
25.50	27.00	65.00	33.43	0.86	51	25.50	27.00	65.00	33.43	0.86	51
27.00	28.50	62.20	34.40	2.40	52	27.00	28.50	62.20	34.40	2.40	52
28.50	30.00	85.70	11.80	2.00	57	28.50	30.00	85.70	11.80	2.00	57
30.00	31.50	85.83	13.08	1.00	52	30.00	31.50	85.83	13.08	1.00	52
31.50	33.00	82.34	15.73	1.60	57	31.50	33.00	82.34	15.73	1.60	57
33.00	34.50	65.60	29.00	5.00	67	33.00	34.50	65.60	29.00	5.00	67
34.50	36.00	89.90	8.70	0.60	50	34.50	36.00	89.90	8.70	0.60	50
36.00	37.50	75.00	21.00	3.85	50	36.00	37.50	75.00	21.00	3.85	50
37.50	39.00	81.40	15.20	2.60	69	37.50	39.00	81.40	15.20	2.60	69
39.00	40.50	76.10	20.50	3.00	5	39.00	40.50	76.10	20.50	3.00	5
40.50	42.00	50.13	38.84	10.64	50	40.50	42.00	50.13	38.84	10.64	50
42.00	43.50	67.66	19.03	10.72	50	42.00	43.50	67.66	19.03	10.72	50
43.50	45.00	72.16	18.03	9.56	50	43.50	45.00	72.16	18.03	9.56	50
45.00	48.00	78.54	20.67	0.67	56	45.00	48.00	78.54	20.67	0.67	56
48.00	51.00	67.27	21.69	10.90	63	48.00	51.00	67.27	21.69	10.90	63
51.00	54.00	72.89	22.65	4.09	56	51.00	54.00	72.89	22.65	4.09	56
54.00	57.00	31.92	48.05	19.56	61	54.00	57.00	31.92	48.05	19.56	61
57.00	60.00	72.28	24.85	2.57	63	57.00	60.00	72.28	24.85	2.57	63
60.00	63.00	66.77	31.35	1.18	70	60.00	63.00	66.77	31.35	1.18	70
63.00	66.00	70.00	25.33	4.00	58	63.00	66.00	70.00	25.33	4.00	58
66.00	69.00	58.83	29.41	11.39	50	66.00	69.00	58.83	29.41	11.39	50

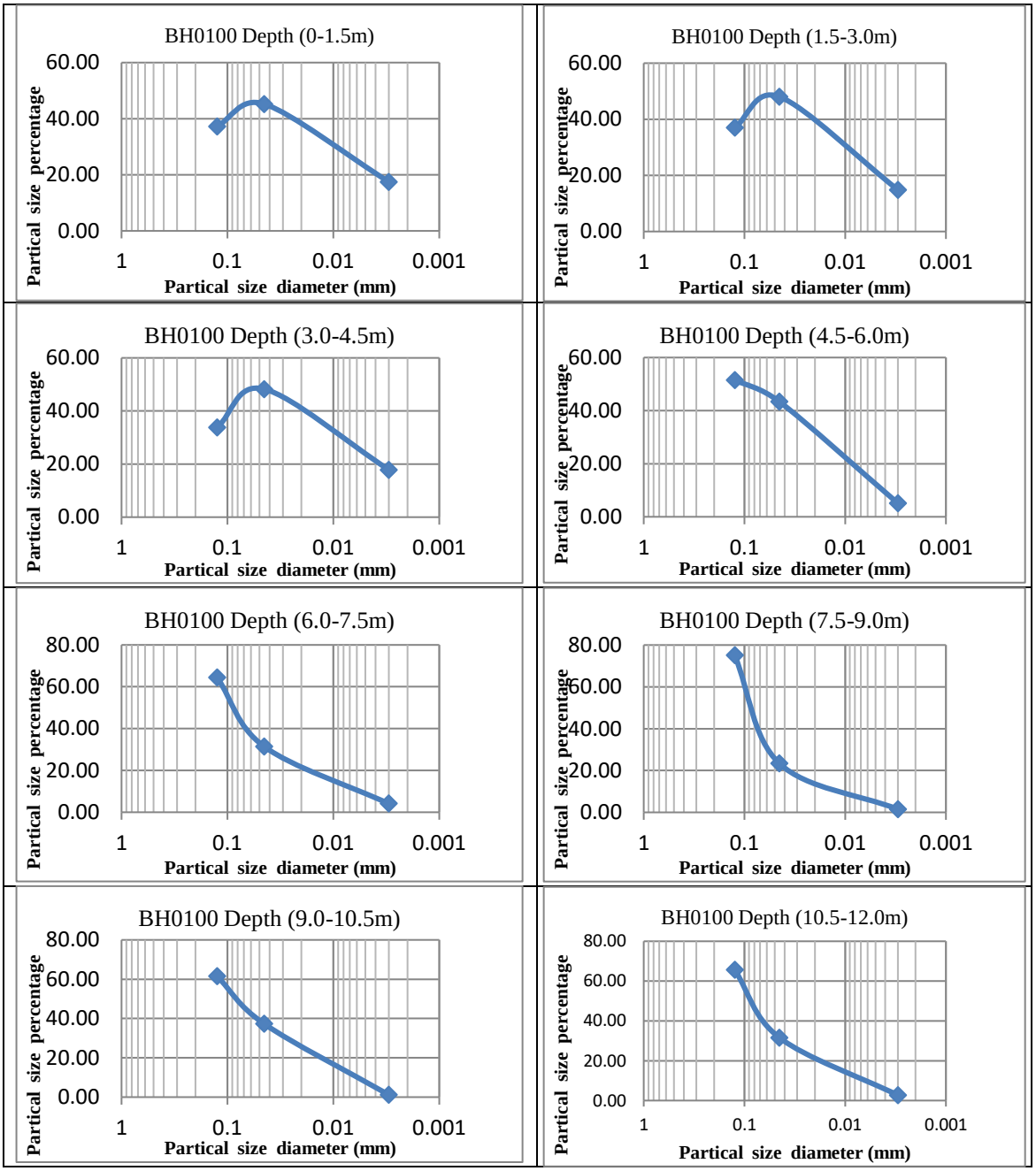
Annexure -II

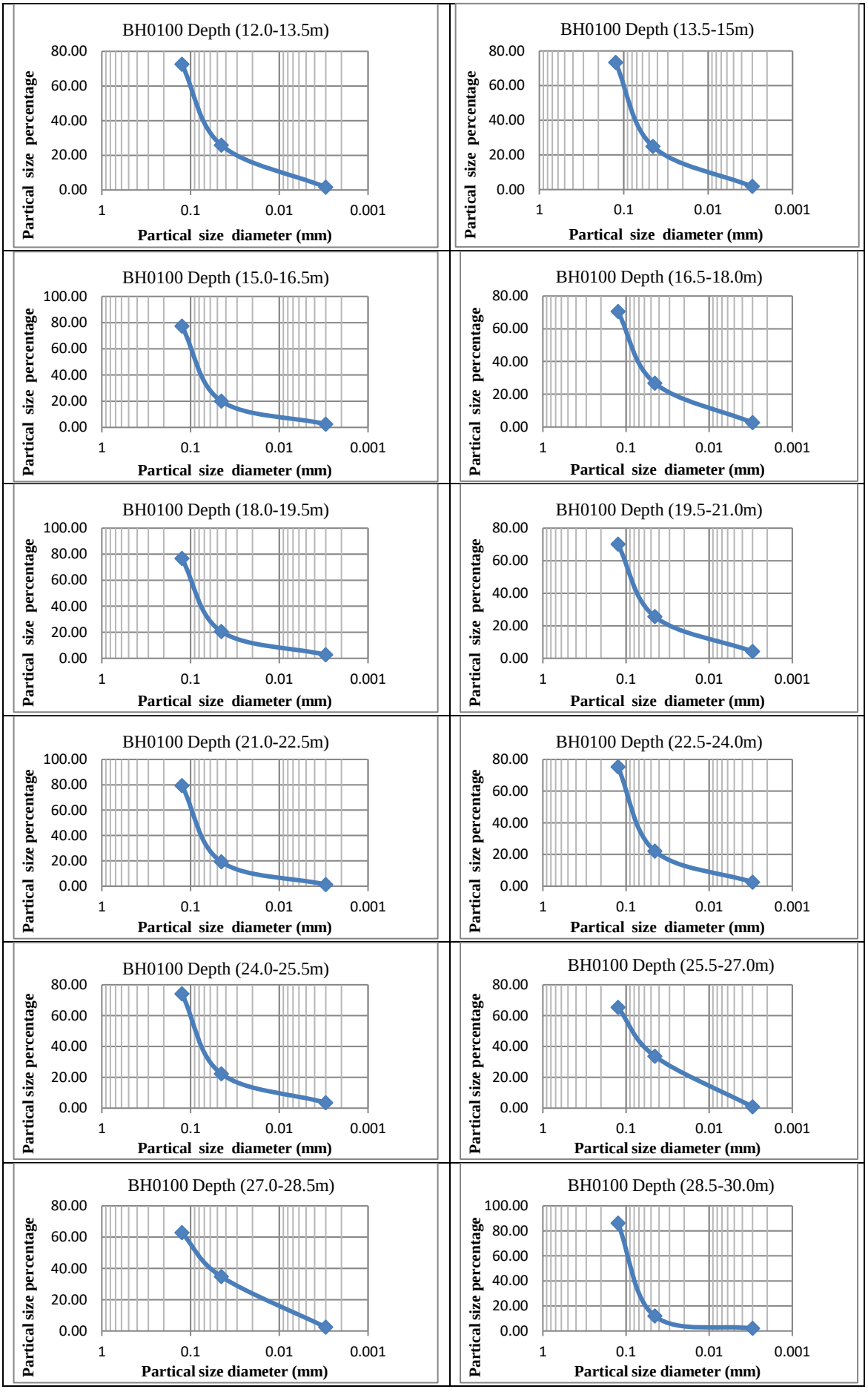
GRAIN SIZE ANALYSIS DATA OF 15 BHOREHOLES

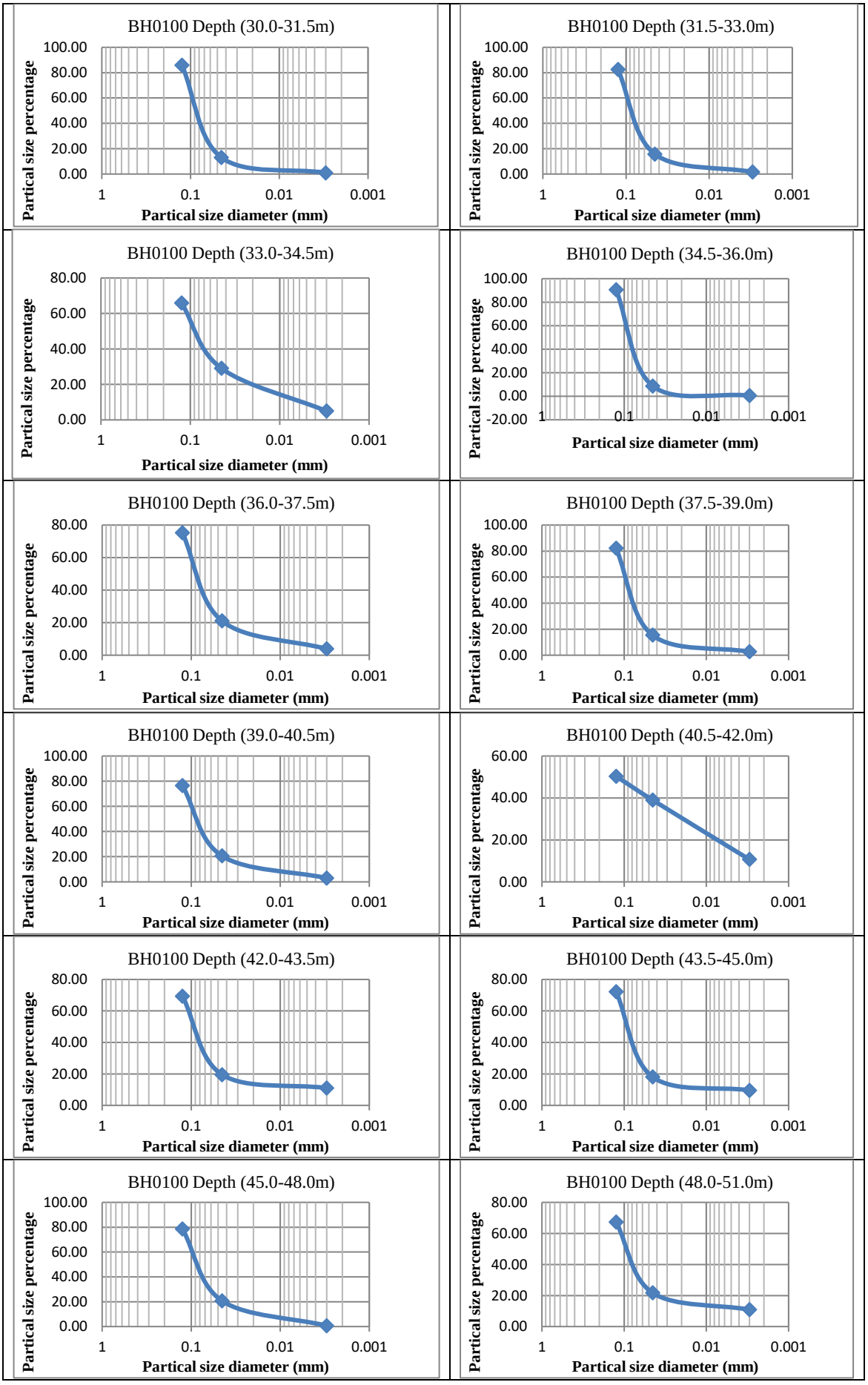
BH1500					
Lon:	90.531136				
Lat:	23.851233				
Elevation:	12.295				
Depth from (m)	**Depth to**	**Sand**	**Silty**	**Clay**	**SPT**
0.00	1.50	0.00	0.00	0.00	11
1.50	3.00	0.00	0.00	0.00	25
3.00	4.50	0.00	0.00	0.00	12
4.50	6.00	51.16	43.08	5.08	12
6.00	7.50	64.20	31.30	4.10	14
7.50	9.00	74.55	23.20	1.50	11
9.00	10.50	61.30	37.17	1.19	19
10.50	12.00	65.20	31.40	2.70	18
12.00	13.50	72.10	25.70	1.60	20
13.50	15.00	73.04	24.76	1.76	26
15.00	16.50	77.00	20.00	2.58	44
16.50	18.00	70.25	26.65	2.65	56
18.00	19.50	76.35	20.50	2.75	54
19.50	21.00	69.90	25.50	4.20	81
21.00	22.50	79.25	19.17	1.33	60
22.50	24.00	74.75	22.02	2.53	53
24.00	25.50	73.62	22.14	3.49	57
25.50	27.00	65.00	33.43	0.86	51
27.00	28.50	62.20	34.40	2.40	52
28.50	30.00	85.70	11.80	2.00	57
30.00	31.50	85.83	13.08	1.00	52
31.50	33.00	82.34	15.73	1.60	57
33.00	34.50	65.60	29.00	5.00	67
34.50	36.00	89.90	8.70	0.60	50
36.00	37.50	75.00	21.00	3.85	50
37.50	39.00	81.40	15.20	2.60	69
39.00	40.50	76.10	20.50	3.00	5
40.50	42.00	50.13	38.84	10.64	50
42.00	43.50	67.66	19.03	10.72	50
43.50	45.00	72.16	18.03	9.56	50
45.00	48.00	78.54	20.67	0.67	56
48.00	51.00	67.27	21.69	10.90	63
51.00	54.00	72.89	22.65	4.09	56
54.00	57.00	31.92	48.05	19.56	61
57.00	60.00	72.28	24.85	2.57	63
60.00	63.00	66.77	31.35	1.18	70
63.00	66.00	70.00	25.33	4.00	58
66.00	69.00	58.83	29.41	11.39	50

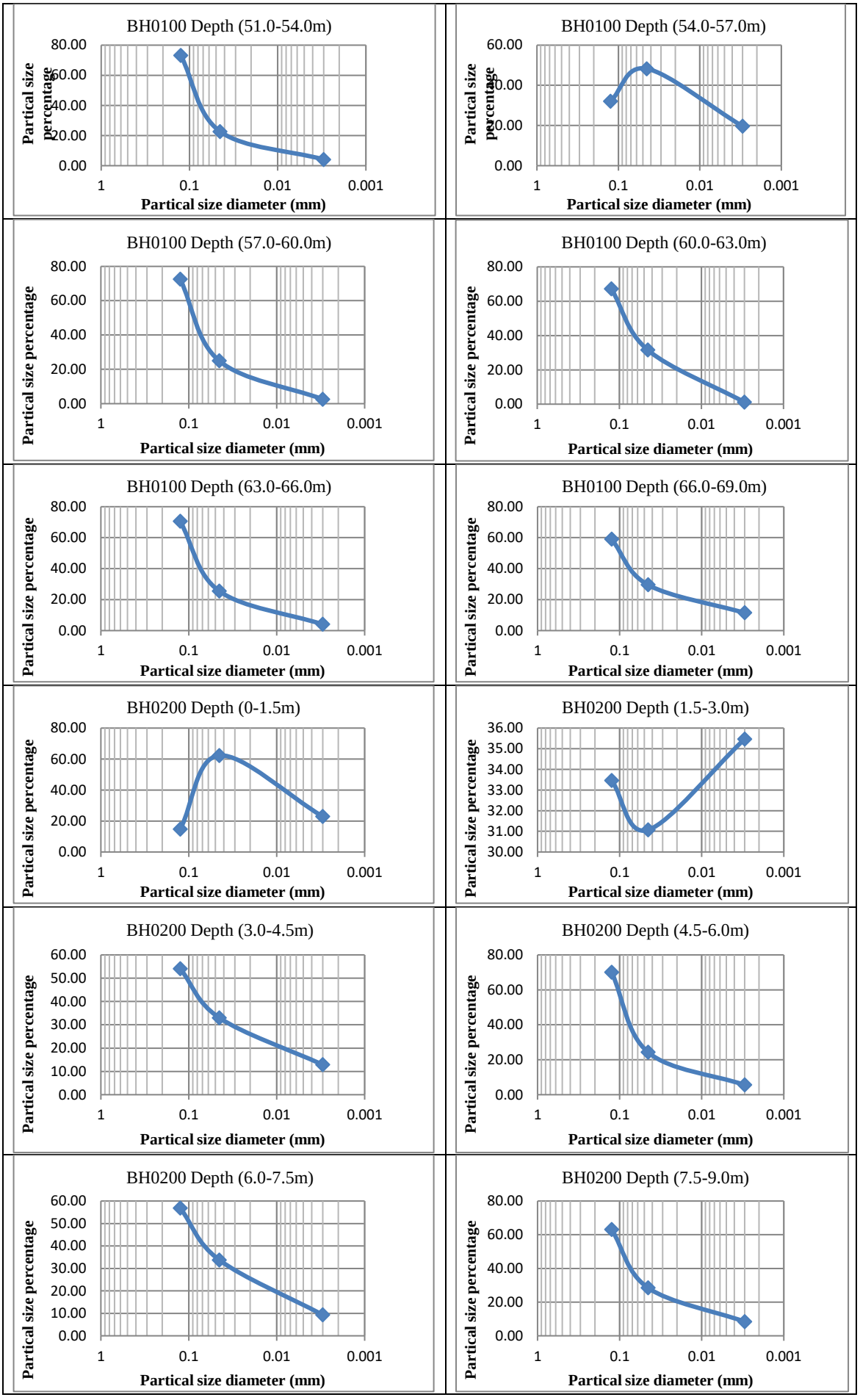
ANNEXURE-III

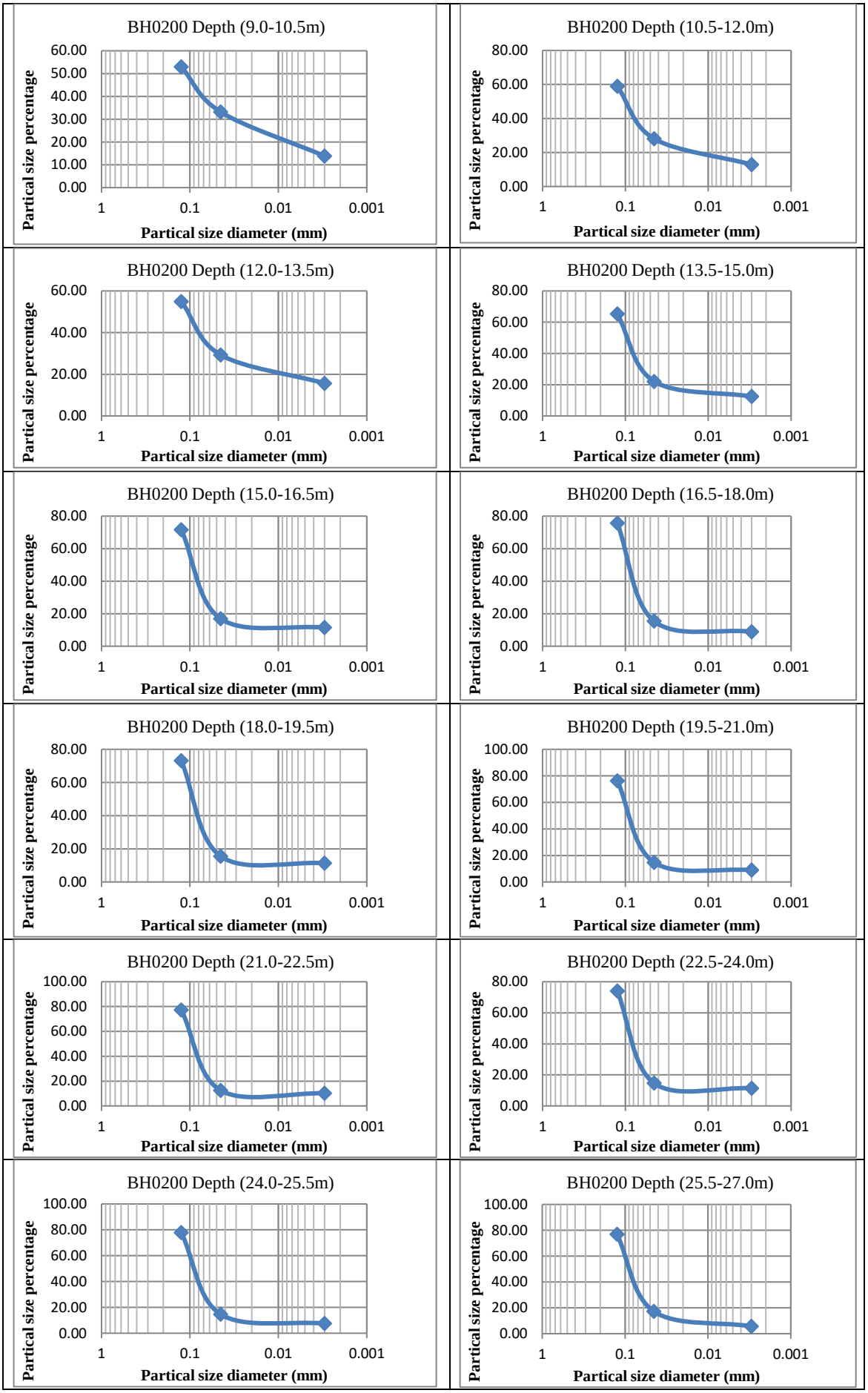
SIEVE ANALYSIS RESULTS OF BOREHOLE

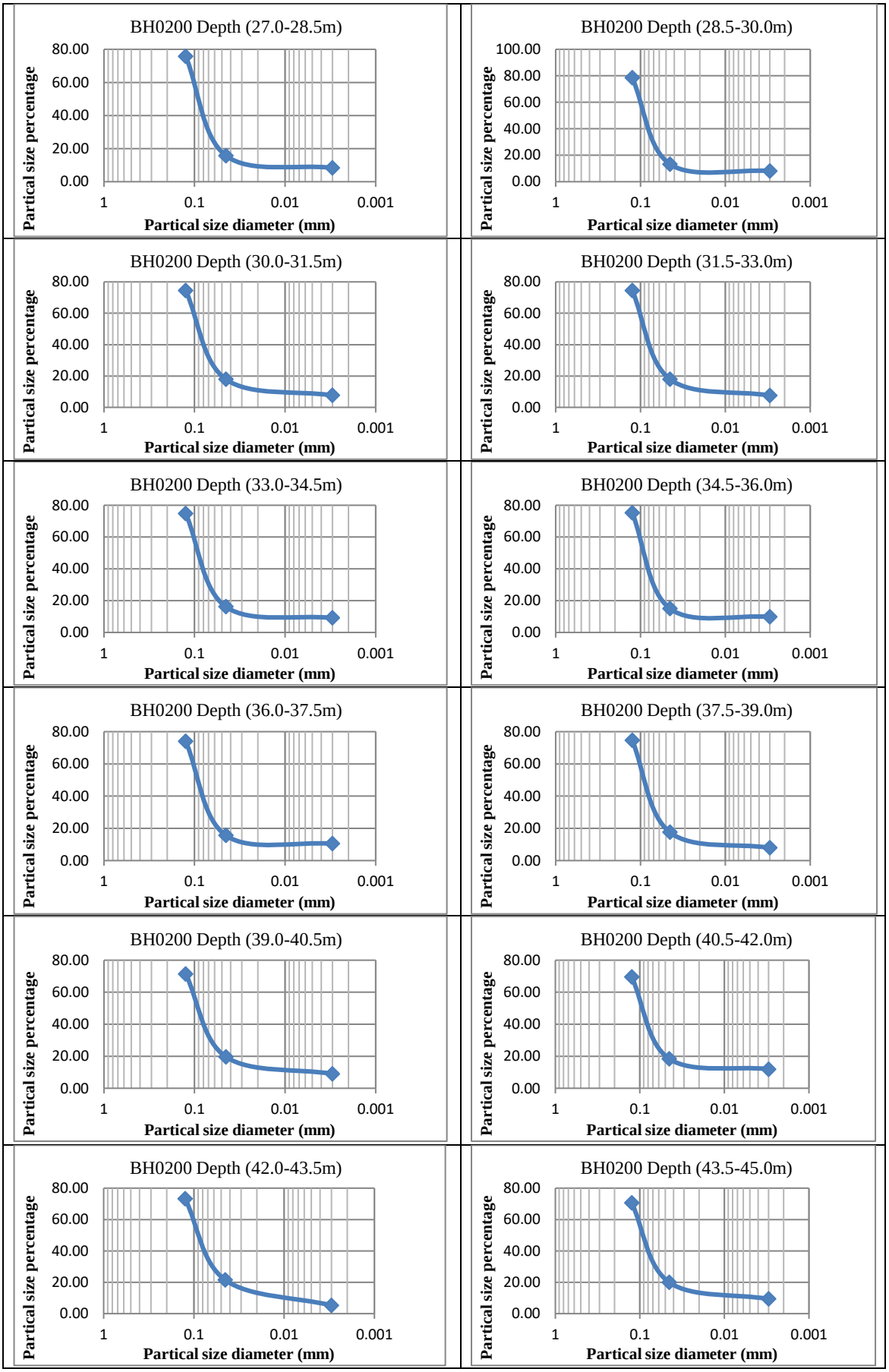

BH0100 Depth (0-1.5m)
Partical size percentage
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0100 Depth (1.5-3.0m)
Partical size percentage
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0100 Depth (3.0-4.5m)
Partical size percentage
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0100 Depth (4.5-6.0m)
Partical size percentage
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0100 Depth (6.0-7.5m)
Partical size percentage
80.00
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0100 Depth (7.5-9.0m)
Partical size percentage
80.00
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0100 Depth (9.0-10.5m)
Partical size percentage
80.00
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0100 Depth (10.5-12.0m)
Partical size percentage
80.00
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)

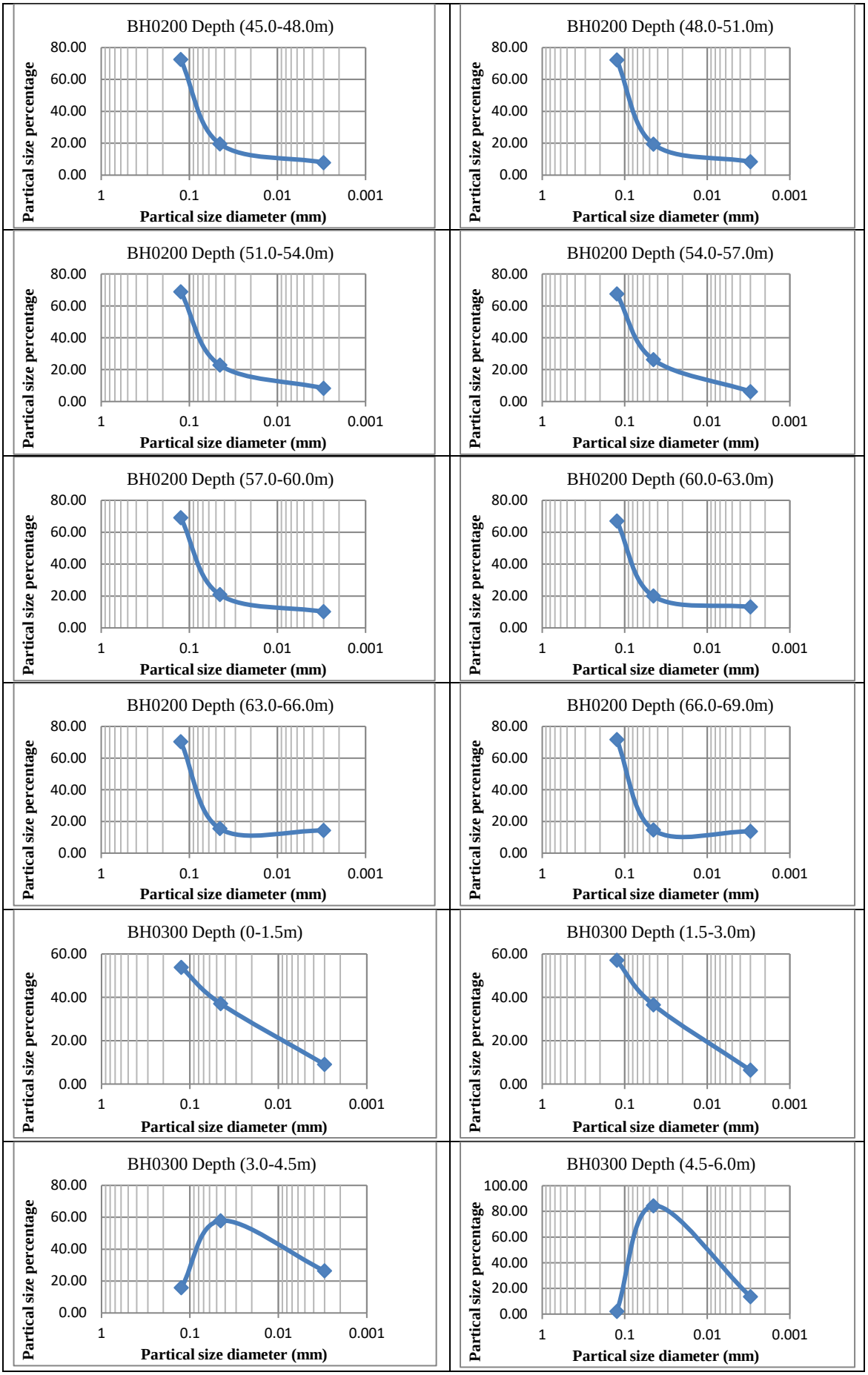

BH0100 Depth (12.0-13.5m)
Partical size percentage
80.00
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0100 Depth (13.5-15m)
Partical size percentage
80.00
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0100 Depth (15.0-16.5m)
Partical size percentage
100.00
80.00
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0100 Depth (16.5-18.0m)
Partical size percentage
80.00
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0100 Depth (18.0-19.5m)
Partical size percentage
100.00
80.00
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0100 Depth (19.5-21.0m)
Partical size percentage
80.00
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0100 Depth (21.0-22.5m)
Partical size percentage
100.00
80.00
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0100 Depth (22.5-24.0m)
Partical size percentage
80.00
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0100 Depth (24.0-25.5m)
Partical size percentage
80.00
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0100 Depth (25.5-27.0m)
Partical size percentage
80.00
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0100 Depth (27.0-28.5m)
Partical size percentage
80.00
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0100 Depth (28.5-30.0m)
Partical size percentage
100.00
80.00
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)

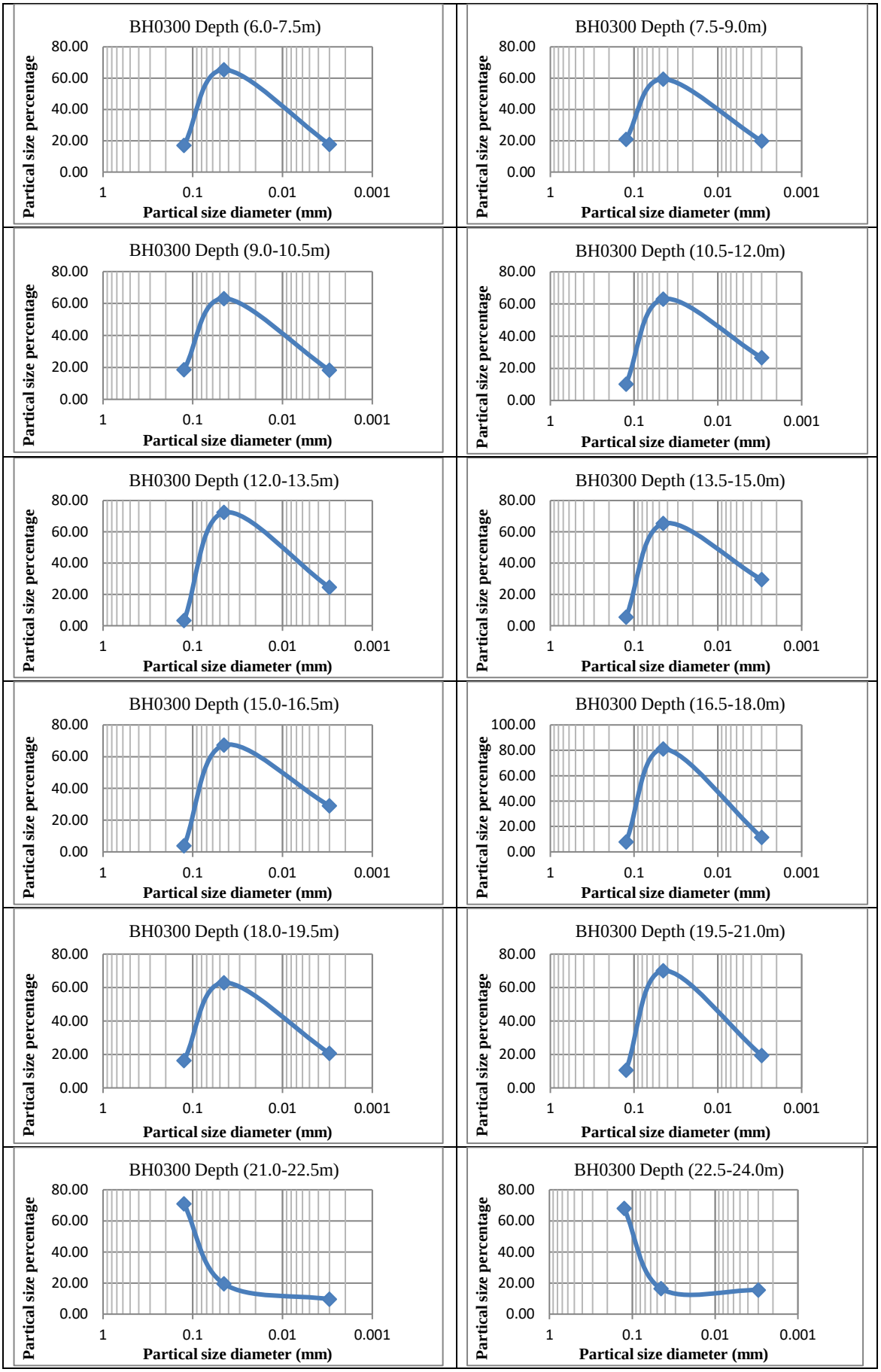

BH0100 Depth (30.0-31.5m)
BH0100 Depth (31.5-33.0m)
BH0100 Depth (33.0-34.5m)
BH0100 Depth (34.5-36.0m)
BH0100 Depth (36.0-37.5m)
BH0100 Depth (37.5-39.0m)
BH0100 Depth (39.0-40.5m)
BH0100 Depth (40.5-42.0m)
BH0100 Depth (42.0-43.5m)
BH0100 Depth (43.5-45.0m)
BH0100 Depth (45.0-48.0m)
BH0100 Depth (48.0-51.0m)
Partical size percentage
Partical size diameter (mm)
1
0.1
0.01
0.001

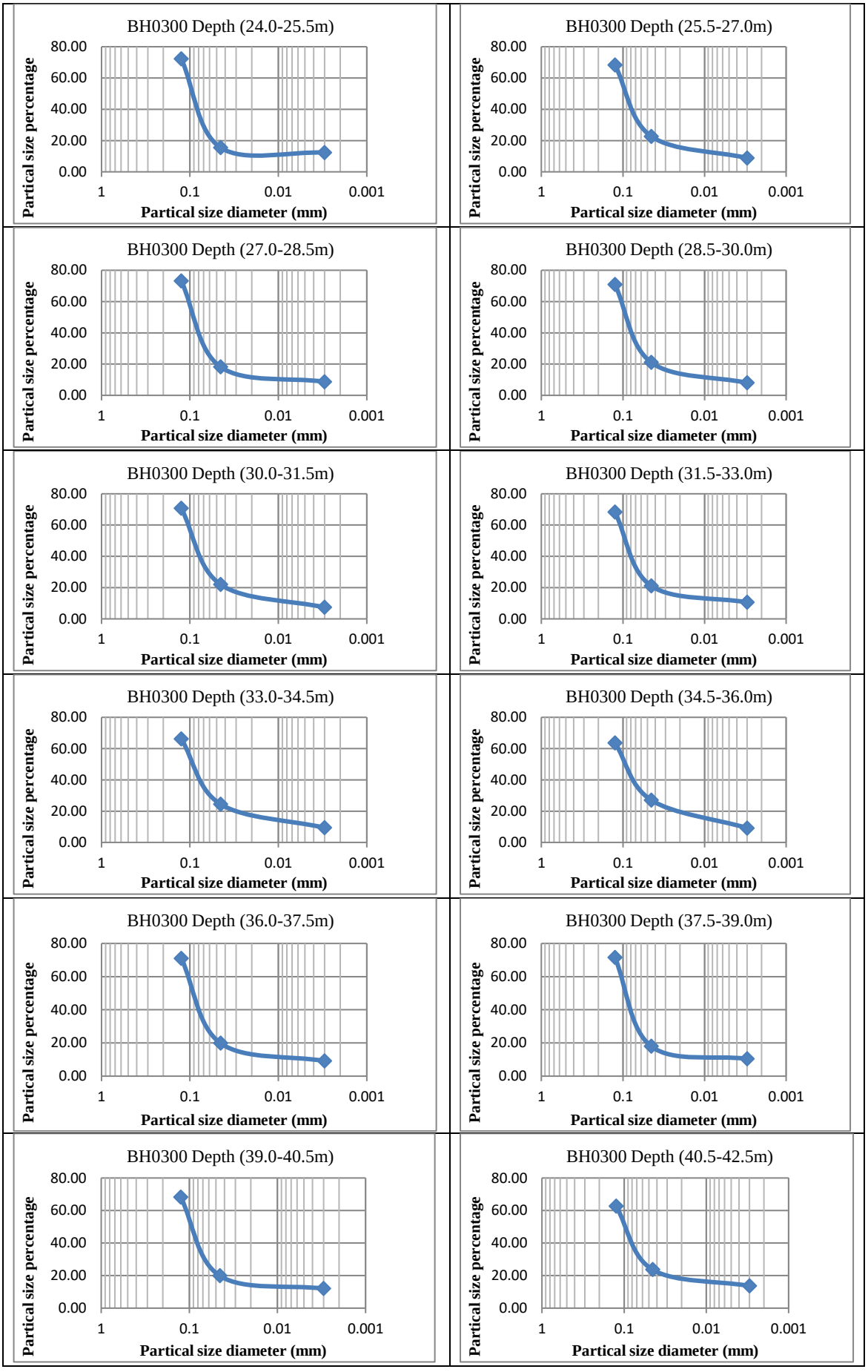

BH0100 Depth (51.0-54.0m)
Partical size percentage
80.00
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0100 Depth (54.0-57.0m)
Partical size percentage
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0100 Depth (57.0-60.0m)
Partical size percentage
80.00
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0100 Depth (60.0-63.0m)
Partical size percentage
80.00
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0100 Depth (63.0-66.0m)
Partical size percentage
80.00
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0100 Depth (66.0-69.0m)
Partical size percentage
80.00
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0200 Depth (0-1.5m)
Partical size percentage
80.00
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0200 Depth (1.5-3.0m)
Partical size percentage
36.00
35.00
34.00
33.00
32.00
31.00
30.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0200 Depth (3.0-4.5m)
Partical size percentage
60.00
50.00
40.00
30.00
20.00
10.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0200 Depth (4.5-6.0m)
Partical size percentage
80.00
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0200 Depth (6.0-7.5m)
Partical size percentage
60.00
50.00
40.00
30.00
20.00
10.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0200 Depth (7.5-9.0m)
Partical size percentage
80.00
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)

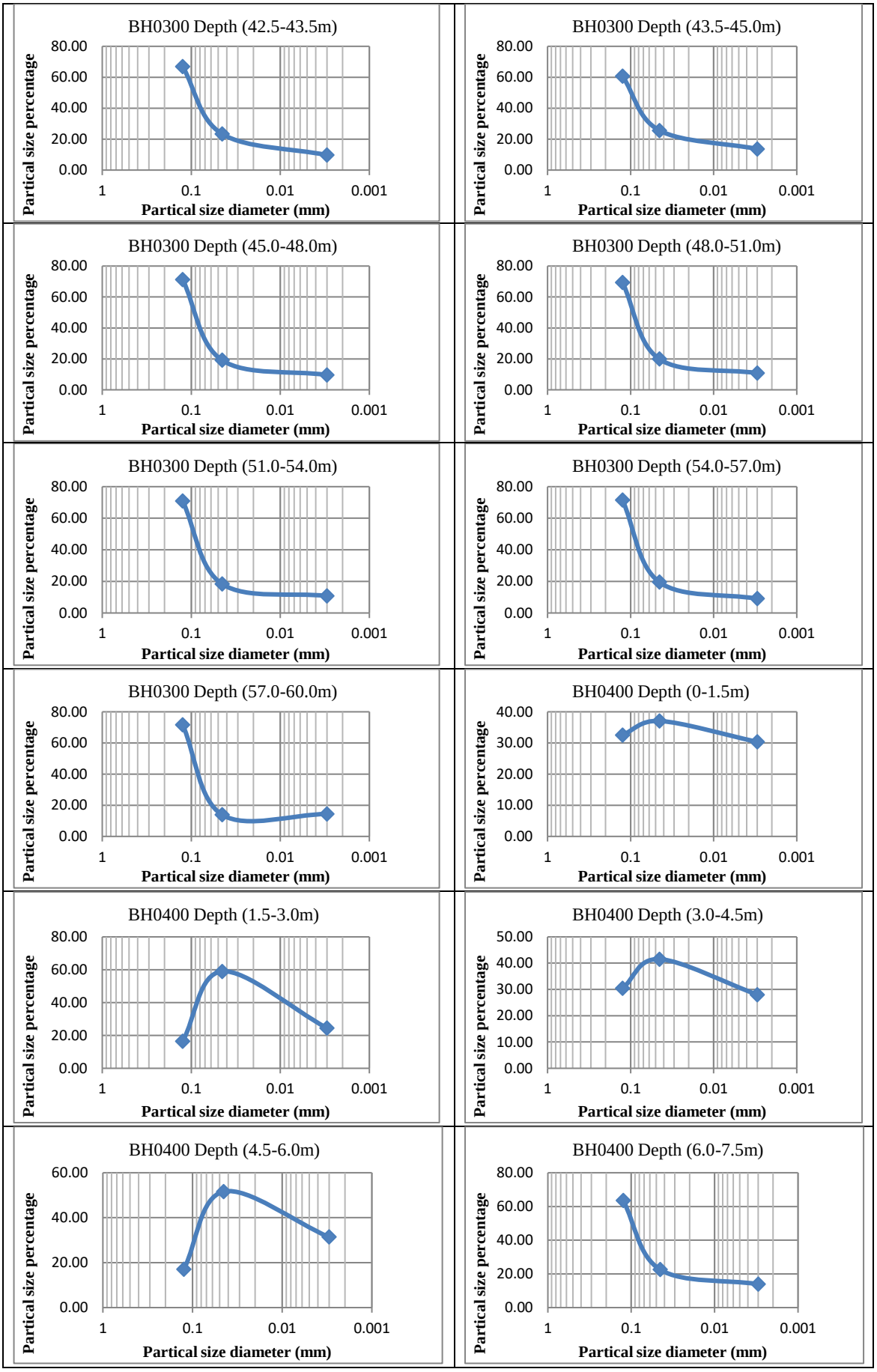

BH0200 Depth (9.0-10.5m)
Partical size percentage
60.00
50.00
40.00
30.00
20.00
10.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0200 Depth (10.5-12.0m)
Partical size percentage
80.00
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0200 Depth (12.0-13.5m)
Partical size percentage
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0200 Depth (13.5-15.0m)
Partical size percentage
80.00
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0200 Depth (15.0-16.5m)
Partical size percentage
80.00
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0200 Depth (16.5-18.0m)
Partical size percentage
80.00
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0200 Depth (18.0-19.5m)
Partical size percentage
80.00
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0200 Depth (19.5-21.0m)
Partical size percentage
100.00
80.00
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0200 Depth (21.0-22.5m)
Partical size percentage
100.00
80.00
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0200 Depth (22.5-24.0m)
Partical size percentage
80.00
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0200 Depth (24.0-25.5m)
Partical size percentage
100.00
80.00
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0200 Depth (25.5-27.0m)
Partical size percentage
100.00
80.00
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)

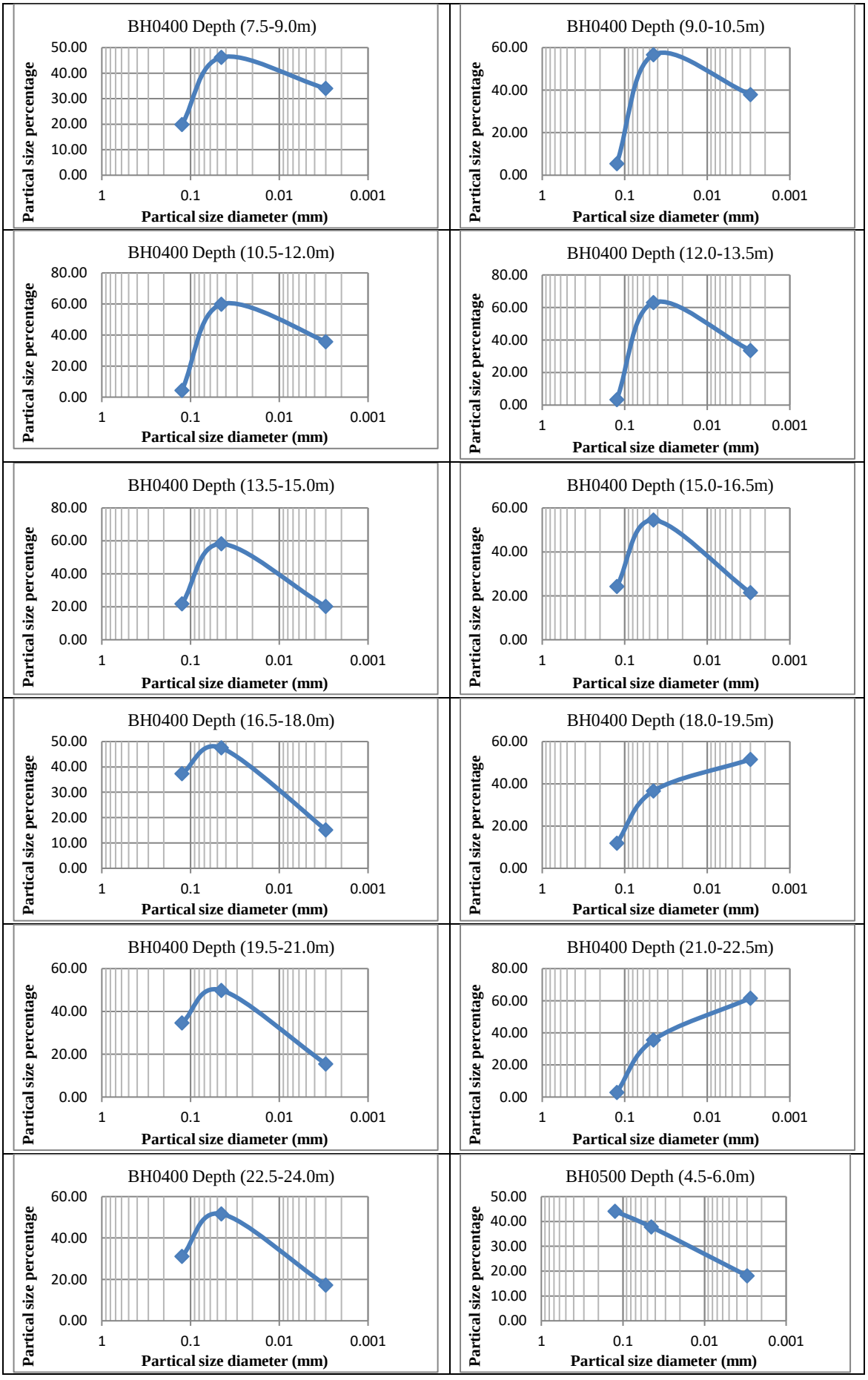

BH0200 Depth (27.0-28.5m)
BH0200 Depth (28.5-30.0m)
BH0200 Depth (30.0-31.5m)
BH0200 Depth (31.5-33.0m)
BH0200 Depth (33.0-34.5m)
BH0200 Depth (34.5-36.0m)
BH0200 Depth (36.0-37.5m)
BH0200 Depth (37.5-39.0m)
BH0200 Depth (39.0-40.5m)
BH0200 Depth (40.5-42.0m)
BH0200 Depth (42.0-43.5m)
BH0200 Depth (43.5-45.0m)
Partical size percentage
Partical size diameter (mm)
80.00
60.00
40.00
20.00
0.00
100.00
1
0.1
0.01
0.001

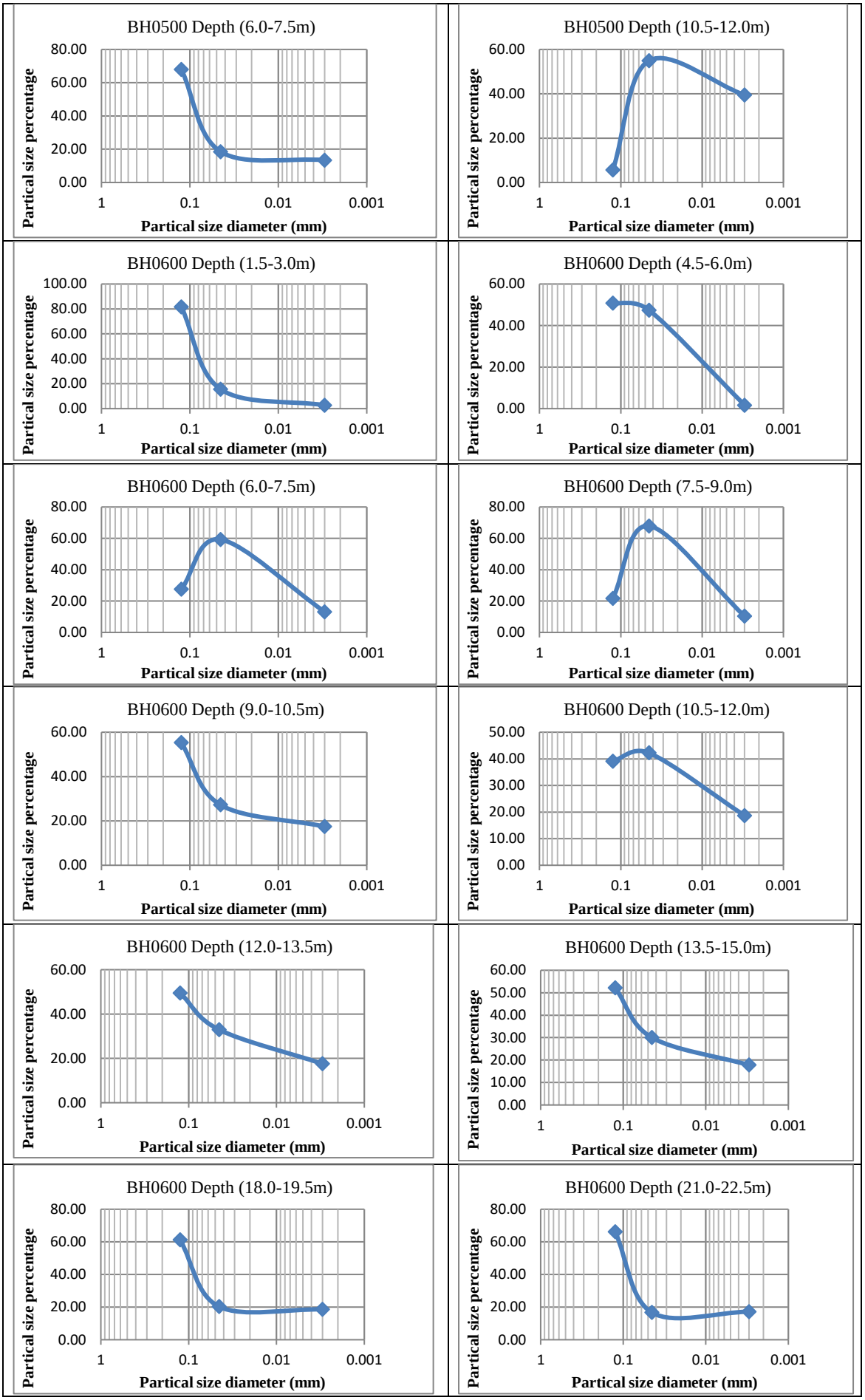

BH0200 Depth (45.0-48.0m)
BH0200 Depth (48.0-51.0m)
BH0200 Depth (51.0-54.0m)
BH0200 Depth (54.0-57.0m)
BH0200 Depth (57.0-60.0m)
BH0200 Depth (60.0-63.0m)
BH0200 Depth (63.0-66.0m)
BH0200 Depth (66.0-69.0m)
BH0300 Depth (0-1.5m)
BH0300 Depth (1.5-3.0m)
BH0300 Depth (3.0-4.5m)
BH0300 Depth (4.5-6.0m)
Partical size percentage
Partical size diameter (mm)
80.00
60.00
40.00
20.00
0.00
100.00
1
0.1
0.01
0.001


BH0300 Depth (6.0-7.5m)
BH0300 Depth (7.5-9.0m)
BH0300 Depth (9.0-10.5m)
BH0300 Depth (10.5-12.0m)
BH0300 Depth (12.0-13.5m)
BH0300 Depth (13.5-15.0m)
BH0300 Depth (15.0-16.5m)
BH0300 Depth (16.5-18.0m)
BH0300 Depth (18.0-19.5m)
BH0300 Depth (19.5-21.0m)
BH0300 Depth (21.0-22.5m)
BH0300 Depth (22.5-24.0m)
Partical size percentage
Partical size diameter (mm)
80.00
60.00
40.00
20.00
0.00
100.00
1
0.1
0.01
0.001


BH0300 Depth (24.0-25.5m)
BH0300 Depth (25.5-27.0m)
BH0300 Depth (27.0-28.5m)
BH0300 Depth (28.5-30.0m)
BH0300 Depth (30.0-31.5m)
BH0300 Depth (31.5-33.0m)
BH0300 Depth (33.0-34.5m)
BH0300 Depth (34.5-36.0m)
BH0300 Depth (36.0-37.5m)
BH0300 Depth (37.5-39.0m)
BH0300 Depth (39.0-40.5m)
BH0300 Depth (40.5-42.5m)
Partical size percentage
80.00
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)


BH0300 Depth (42.5-43.5m)
BH0300 Depth (43.5-45.0m)
BH0300 Depth (45.0-48.0m)
BH0300 Depth (48.0-51.0m)
BH0300 Depth (51.0-54.0m)
BH0300 Depth (54.0-57.0m)
BH0300 Depth (57.0-60.0m)
BH0400 Depth (0-1.5m)
BH0400 Depth (1.5-3.0m)
BH0400 Depth (3.0-4.5m)
BH0400 Depth (4.5-6.0m)
BH0400 Depth (6.0-7.5m)
Partical size percentage
Partical size diameter (mm)
1
0.1
0.01
0.001


BH0400 Depth (7.5-9.0m)
Partical size percentage
50.00
40.00
30.00
20.00
10.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0400 Depth (9.0-10.5m)
Partical size percentage
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0400 Depth (10.5-12.0m)
Partical size percentage
80.00
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0400 Depth (12.0-13.5m)
Partical size percentage
80.00
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0400 Depth (13.5-15.0m)
Partical size percentage
80.00
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0400 Depth (15.0-16.5m)
Partical size percentage
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0400 Depth (16.5-18.0m)
Partical size percentage
50.00
40.00
30.00
20.00
10.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0400 Depth (18.0-19.5m)
Partical size percentage
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0400 Depth (19.5-21.0m)
Partical size percentage
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0400 Depth (21.0-22.5m)
Partical size percentage
80.00
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0400 Depth (22.5-24.0m)
Partical size percentage
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0500 Depth (4.5-6.0m)
Partical size percentage
50.00
40.00
30.00
20.00
10.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)


BH0500 Depth (6.0-7.5m)
Partical size percentage
80.00
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0500 Depth (10.5-12.0m)
Partical size percentage
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0600 Depth (1.5-3.0m)
Partical size percentage
100.00
80.00
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0600 Depth (4.5-6.0m)
Partical size percentage
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0600 Depth (6.0-7.5m)
Partical size percentage
80.00
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0600 Depth (7.5-9.0m)
Partical size percentage
80.00
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0600 Depth (9.0-10.5m)
Partical size percentage
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0600 Depth (10.5-12.0m)
Partical size percentage
50.00
40.00
30.00
20.00
10.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0600 Depth (12.0-13.5m)
Partical size percentage
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0600 Depth (13.5-15.0m)
Partical size percentage
60.00
50.00
40.00
30.00
20.00
10.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0600 Depth (18.0-19.5m)
Partical size percentage
80.00
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)
BH0600 Depth (21.0-22.5m)
Partical size percentage
80.00
60.00
40.00
20.00
0.00
1
0.1
0.01
0.001
Partical size diameter (mm)

Annexure-IV

LITHO-STRATIGRAPHY DATA OF BOREHOLES

LITHOLOGICAL DATA OF 15 BOREHOLES (Annexure-IV)

BH0100		
Depth From (m)	**Depth To (m)**	**Lithology**
0	7.5	Silty Clay
7.5	39.5	Medium to Fine Sand
39.5	69.00	Very Fine to Fine Sand

BH0200		
Depth From (m)	**Depth To (m)**	**Lithology**
0	3	Silty Clay
3	4.5	Medium to Fine Sand
4.5	69.0	Very Fine to Fine Sand

BH0300		
Depth From (m)	**Depth To (m)**	**Lithology**
0	3	Artificial Filling (AF)
3	21.34	Organic clay
21.34	69	Very Fine to Fine Sand

BH0400		
Depth From (m)	**Depth To (m)**	**Lithology**
0	3	Artificial Filling (AF)
3	25.90	Organic clay
25.9	51	Very Fine to Fine Sand
51	69.00	Medium to Fine Sand

BH0500		
Depth From (m)	**Depth To (m)**	**Lithology**
0	4.5	Artificial Filling (AF)
4.5	7.50	Organic clay
7.5	19.5	Very Fine to Fine Sand
19.5	69.00	Medium to Fine Sand

BH0600		
Depth From (m)	**Depth To (m)**	**Lithology**
0	4.5	Artificial Filling (AF)
4.5	15.25	Organic clay
15.25	22.5	Sandy Clay
22.5	69.00	Medium to Fine Sand

BH0700		
Depth From (m)	**Depth To (m)**	**Lithology**
0	6.0	Artificial Filling (AF)
6	13.5	Organic clay
13.5	69	Medium to Fine Sand

BH0800		
Depth From (m)	**Depth To (m)**	**Lithology**
0	4.5	Silty Clay
4.5	9.0	Sandy Clay
9	69	Very Fine to Fine Sand

BH0900		
Depth From (m)	**Depth To (m)**	**Lithology**
0	21	Silty Clay
21	69	Medium to Fine Sand

BH1000		
Depth From (m)	**Depth To (m)**	**Lithology**
0	10.5	Silty Clay
10.5	69	Very Fine to Fine Sand

BH1100		
Depth From (m)	**Depth To (m)**	**Lithology**
0	4.5	Silty Clay
4.5	37.5	Medium to Fine Sand
37.5	69	Very Fine to Fine Sand

BH1200		
Depth From (m)	**Depth To (m)**	**Lithology**
0	4.5	Silty Clay
4.5	42.0	Medium to Fine Sand
42	69	Very Fine to Fine Sand

BH1300		
Depth From (m)	**Depth To (m)**	**Lithology**
0	3.5	Silty Clay
3.5	33.0	Medium to Fine Sand
33	69	Very Fine to Fine Sand

BH1400		
Depth From (m)	**Depth To (m)**	**Lithology**
0	4.25	Silty Clay
4.25	36.0	Medium to Fine Sand
36	69	Very Fine to Fine Sand

BH1500		
Depth From (m)	**Depth To (m)**	**Lithology**
0	4.5	Silty Clay
4.5	43.5	Medium to Fine Sand
43.5	69	Very Fine to Fine Sand

SIMULATED LITHOLOGICAL DATA OF 15 BOREHOLES(Annexure-IV)

BH0101		
Depth From (m)	Depth To (m)	Lithology
0	8.25	Silty Clay
8.25	35.50	Very Fine to Fine Sand
35.5	69	Medium to Fine Sand

BH0201		
Depth From (m)	Depth To (m)	Lithology
0	4.25	Silty Clay
4.25	40.00	Medium to Fine Sand
40	69	Very Fine to Fine Sand

BH0301		
Depth From	Depth To	Lithology
0	4.75	Artificial Filling (AF)
4.75	25	Organic Clay
25	69.00	Very Fine to Fine Sand

BH0401		
Depth From (m)	Depth To (m)	Lithology
0	4.25	Artificial Filling (AF)
4.25	26.5	Silty Clay
26.5	42.00	Very Fine to Fine Sand
42	69	Medium to Fine Sand

BH0501		
Depth From (m)	Depth To (m)	Lithology
0	5.25	Artificial Filling (AF)
5.25	10.25	Organic clay
10.25	35.00	Very Fine to Fine Sand
35	69	Medium to Fine Sand

BH0601		
Depth From (m)	Depth To (m)	Lithology
0	5.5	Artificial Filling (AF)
5.5	18	Organic clay
18	24	Sandy Clay
24	69	Medium to Fine Sand

BH0701		
Depth From (m)	Depth To (m)	Lithology
0	7.5	Artificial Filling (AF)
7.5	16	Organic clay
16.25	69	Medium to Fine Sand

BH0801		
Depth From (m)	Depth To (m)	Lithology
0	5.25	Silty Clay
5.25	12	Sandy Clay
12	69	Very Fine to Fine Sand

BH0901		
Depth From (m)	Depth To (m)	Lithology
0	19	Silty Clay
19	69	Medium to Fine Sand

BH1001		
Depth From (m)	Depth To (m)	Lithology
0	9.25	Silty Clay
9.25	40	Very Fine to Fine Sand
40	69	Medium to Fine Sand

BH1101		
Depth From (m)	Depth To (m)	Lithology
0	5.25	Silty Clay
5.25	40	Medium to Fine Sand
40	69	Very Fine to Fine Sand

BH1201		
Depth From (m)	Depth To (m)	Lithology
0	4.25	Silty Clay
4.25	45.00	Medium to Fine Sand
45	69	Very Fine to Fine Sand

H1301		
Depth From (m)	Depth To (m)	Lithology
0	4.75	Silty Clay
4.75	42	Medium to Fine Sand
42	69	Very Fine to Fine Sand

BH1401		
Depth From (m)	Depth To (m)	Lithology
0	4.15	Silty Clay
4.15	39	Medium to Fine Sand
39	69	Very Fine to Fine Sand

BH1501		
Depth From (m)	Depth To (m)	Lithology
0	5.25	Silty Clay
5.25	44.5	Medium to Fine Sand
44.5	69	Very Fine to Fine Sand

STRATIGRAPHY FORMATION DATA OF 15 BOREHOLES(Annexure-IV)

BH0100		
Depth From (m)	**Depth To (m)**	**Stratigraphy Formation**
0.0	0.0	Artificial Filling (AF)
0.0	0.0	Organic Clay
0.0	7.5	Madhupur Red Clay
7.5	69.0	Dupi Tila Sand

BH0200		
Depth From (m)	**Depth To (m)**	**Stratigraphy Formation**
0.0	0.0	Artificial Filling (AF)
0.0	0.0	Organic Clay
0.0	3.0	Madhupur Red Clay
3.0	69.0	Dupi Tila Sand

BH0300		
Depth From (m)	**Depth To (m)**	**Stratigraphy Formation**
0.0	3.0	Artificial Filling (AF)
3.0	21.34	Organic Clay
21.34	21.34	Madhupur Red Clay
21.34	69.0	Dupi Tila Sand

BH0400		
Depth From (m)	**Depth To (m)**	**Stratigraphy Formation**
0.0	3.0	Artificial Filling (AF)
3.0	25.9	Organic Clay
25.9	25.9	Madhupur Red Clay
25.9	69.0	Dupi Tila Sand

BH0500		
Depth From (m)	**Depth To (m)**	**Stratigraphy Formation**
0.0	4.5	Artificial Filling (AF)
4.5	7.5	Organic Clay
7.5	7.5	Madhupur Red Clay
7.5	69.0	Dupi Tila Sand

BH0600		
Depth From (m)	**Depth To (m)**	**Stratigraphy Formation**
0.00	4.50	Artificial Filling (AF)
4.50	15.25	Organic Clay
15.25	15.25	Madhupur Red Clay
15.25	69.00	Dupi Tila Sand

BH0700		
Depth From (m)	**Depth To (m)**	**Stratigraphy Formation**
0.0	6.0	Artificial Filling (AF)
6.0	13.5	Organic Clay
13.5	13.5	Madhupur Red Clay
13.5	69.0	Dupi Tila Sand

BH0800		
Depth From (m)	**Depth To (m)**	**Stratigraphy Formation**
0.0	0.0	Artificial Filling (AF)
0.0	0.0	Organic Clay
0.0	4.5	Madhupur Red Clay
4.5	69.0	Dupi Tila Sand

BH0900		
Depth From (m)	**Depth To (m)**	**Stratigraphy Formation**
0.0	0.0	Artificial Filling (AF)
0.0	0.0	Organic Clay
0.0	21.0	Madhupur Red Clay
21.0	69.0	Dupi Tila Sand

BH1000		
Depth From (m)	**Depth To (m)**	**Stratigraphy Formation**
0.0	0.0	Artificial Filling (AF)
0.0	0.0	Organic Clay
0.0	10.5	Madhupur Red Clay
10.5	69.0	Dupi Tila Sand

BH1100		
Depth From (m)	**Depth To (m)**	**Stratigraphy Formation**
0.0	0.0	Artificial Filling (AF)
0.0	0.0	Organic Clay
0.0	4.5	Madhupur Red Clay
4.5	69.0	Dupi Tila Sand

BH1200		
Depth From (m)	**Depth To (m)**	**Stratigraphy Formation**
0.0	0.0	Artificial Filling (AF)
0.0	0.0	Organic Clay
0.0	4.5	Madhupur Red Clay
4.5	69.0	Dupi Tila Sand

BH1300		
Depth From (m)	**Depth To (m)**	**Stratigraphy Formation**
0.0	0.0	Artificial Filling (AF)
0.0	0.0	Organic Clay
0.0	3.5	Madhupur Red Clay
3.5	69.0	Dupi Tila Sand

BH1400		
Depth From (m)	**Depth To (m)**	**Stratigraphy Formation**
0.0	0.0	Artificial Filling (AF)
0.0	0.0	Organic Clay
0.0	4.3	Madhupur Red Clay
4.25	69.0	Dupi Tila Sand

BH1500		
Depth From (m)	**Depth To (m)**	**Stratigraphy Formation**
0.0	0.0	Artificial Filling (AF)
0.0	0.0	Organic Clay
0.0	4.5	Madhupur Red Clay
4.5	69.0	Dupi Tila Sand

SIMULATED STRATIGRAPHY FORMATION DATA OF 15 BOREHOLE(Annexure-IV)

BH0101		
Depth From (m)	**Depth To (m)**	**Stratigraphy Formation**
0.00	0.00	Artificial Filling (AF)
0.00	0.00	Organic Clay
0.00	8.25	Madhupur Red Clay
8.25	69.00	Dupi Tila Sand

BH0201		
Depth From (m)	**Depth To (m)**	**Stratigraphy Formation**
0.00	0.00	Artificial Filling (AF)
0.00	0.00	Organic Clay
0.00	4.25	Madhupur Red Clay
4.25	69.00	Dupi Tila Sand

BH0301		
Depth From (m)	**Depth To (m)**	**Stratigraphy Formation**
0.0	4.8	Artificial Filling (AF)
4.8	25.0	Organic Clay
25.0	25.0	Madhupur Red Clay
25.0	69.0	Dupi Tila Sand

BH0401		
Depth From (m)	**Depth To (m)**	**Stratigraphy Formation**
0.00	4.25	Artificial Filling (AF)
4.25	4.25	Organic Clay
4.25	26.50	Madhupur Red Clay
26.50	69.00	Dupi Tila Sand

BH0501		
Depth From (m)	**Depth To (m)**	**Stratigraphy Formation**
0.00	5.25	Artificial Filling (AF)
5.25	10.25	Organic Clay
10.25	10.25	Madhupur Red Clay
10.25	69.00	Dupi Tila Sand

BH0601		
Depth From (m)	**Depth To (m)**	**Stratigraphy Formation**
0.0	5.5	Artificial Filling (AF)
5.5	18.0	Organic Clay
18.0	18.0	Madhupur Red Clay
19.0	69.0	Dupi Tila Sand

BH0701		
Depth From (m)	**Depth To (m)**	**Stratigraphy Formation**
0.0	7.5	Artificial Filling (AF)
7.5	16.0	Organic Clay
16.0	16.0	Madhupur Red Clay
16.0	69.0	Dupi Tila Sand

BH0801		
Depth From (m)	**Depth To (m)**	**Stratigraphy Formation**
0.00	0.00	Artificial Filling (AF)
0.00	0.00	Organic Clay
0.00	5.25	Madhupur Red Clay
5.25	69.00	Dupi Tila Sand

BH0901		
Depth From (m)	**Depth To (m)**	**Stratigraphy Formation**
0.00	0.00	Artificial Filling (AF)
0.00	0.00	Organic Clay
0.00	19.00	Madhupur Red Clay
19.00	69.00	Dupi Tila Sand

BH1001		
Depth From (m)	**Depth To (m)**	**Stratigraphy Formation**
0.00	0.00	Artificial Filling (AF)
0.00	0.00	Organic Clay
0.00	9.25	Madhupur Red Clay
9.25	69.00	Dupi Tila Sand

BH1101		
Depth From (m)	**Depth To (m)**	**Stratigraphy Formation**
0.00	0.00	Artificial Filling (AF)
0.00	0.00	Organic Clay
0.00	5.25	Madhupur Red Clay
5.25	69.00	Dupi Tila Sand

BH1201		
Depth From (m)	**Depth To (m)**	**Stratigraphy Formation**
0.00	0.00	Artificial Filling (AF)
0.00	0.00	Organic Clay
0.00	4.25	Madhupur Red Clay
4.25	69.00	Dupi Tila Sand

BH1301		
Depth From (m)	**Depth To (m)**	**Stratigraphy Formation**
0.00	0.00	Artificial Filling (AF)
0.00	0.00	Organic Clay
0.00	4.75	Madhupur Red Clay
4.75	69.00	Dupi Tila Sand

BH1401		
Depth From (m)	**Depth To (m)**	**Stratigraphy Formation**
0.00	0.00	Artificial Filling (AF)
0.00	0.00	Organic Clay
0.00	4.15	Madhupur Red Clay
4.15	69.00	Dupi Tila Sand

BH1501		
Depth From (m)	**Depth To (m)**	**Stratigraphy Formation**
0.00	0.00	Artificial Filling (AF)
0.00	0.00	Organic Clay
0.00	4.75	Madhupur Red Clay
4.75	69.00	Dupi Tila Sand