"Evaluation Support for Mangrove Plantation in Sundarbans, South 24 Parganas, West Bengal"

Report no. 5: Final Evaluation Report

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1. INTRODUCTION

Sundarbans, the world's largest coastal mangrove forest is one of the natural wonders of the world. It was marked as UNESCO world heritage site in 1987. The forest lies in the wide delta on the Bay of Bengal formed by the perfect junction of the river Ganga, Brahmaputra and Meghna. Sundarbans Biosphere Reserve covers an area of 9,630 km^2. The Indian part is estimated to be about 4,110 km^2, out of which 1,700 km^2 is dominated by water bodies in the form of rivers, canals and creeks of width ranging from few metres to several kilometres. Recently in 2019, the Indian Sundarbans was accorded the status of '**Wetland of International Importance**' under the Ramsar Site. The Indian Sundarbans covering the south westernmost part of the delta constitutes over 60% of the country's total mangrove forest area and includes 90% of Indian mangrove species.

Sundarbans provides sustainable livelihoods to millions of people living in small villages surrounding the biosphere reserve, working as farmers, fisherman, honey gatherers and many others. The stretch of mangrove forests surrounding the biosphere reserve act as a biological shield to protect the people inhabiting there from massive storms, cyclones, tidal rise, sea water inundation and encroachment. As a result of climate change, the ecological quality of the forests is declining resulting in a consistent pattern of diminishing biodiversity along with the loss of species in the recent century. Loss of mangrove forest will put the surrounding poor coastal communities under high risk. Since the area is one of the most densely populated in the world, deforestation for fuel wood and other natural forest products is one of the major threats to the mangrove vegetation. The mangrove vegetation of Sundarbans as well as other parts of the world are highly affected due to anthropogenic activities, natural calamities, climate change etc. Cyclone '**Aila**', in 2009, caused extensive damage to livelihoods and mangrove vegetation in the Sundarbans and several areas of South 24 Parganas, West Bengal were severely affected. Recently, in May 2019, an **Extremely Severe Cyclonic Storm 'Fani'** hit Sundarbans. Sundarbans which is considered as one of the most vulnerable zones to be impacted by cyclones originating in the Bay of Bengal for its position, the storm 'Fani' also did not go down that lowly either. Though the ferocity of 'Fani' was predicted high, but steadily reduced its intensity after crashing on land, passed through the village destroying several homes and uprooting numerous trees, including many mangrove species. Afforestation, consciousness among the local community and concurrently providing the people with alternative income

generation scheme can lead the way to the conservation of mangroves in the Sundarbans so that in near future storms spare the delta region from more extensive damage.

The project "Restoration of Mangroves in Sundarbans through Afforestation, Integrated Mangrove-Shrimp Farming, Income Generation and Community Participation (2017–2020)" was taken up by 'Nature Environment and Wildlife Society (NEWS)' a conservation based NGO in 2017 with objectives to stabilize the mangrove ecosystems effectively and to improve the livelihood of the local coastal population through mangrove afforestation. The afforestation process (at two sites of Sundarbans) was monitored by Botanical Survey of India (BSI), Ministry of Environment, Forest and Climate Change, Government of India as a project entitled, "Evaluation Support for Mangrove Plantation in Sundarbans, South 24 Parganas, West Bengal".

Scientist/researcher assigned from BSI to evaluate the mangrove plantation:

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During the monitoring process, the BSI team undertook five survey tours to the plantation sites and submitted four reports after completion of respective surveys which are as follows.

i) Baseline Report for 2017 plantation
ii) Nursery visit for 2018 plantation and monitoring report of 2017 plantation
iii) Baseline report for 2018 plantation and evaluation report of 2017 existing plantation
iv) Midterm evaluation report for the total restoration sites and recommendations

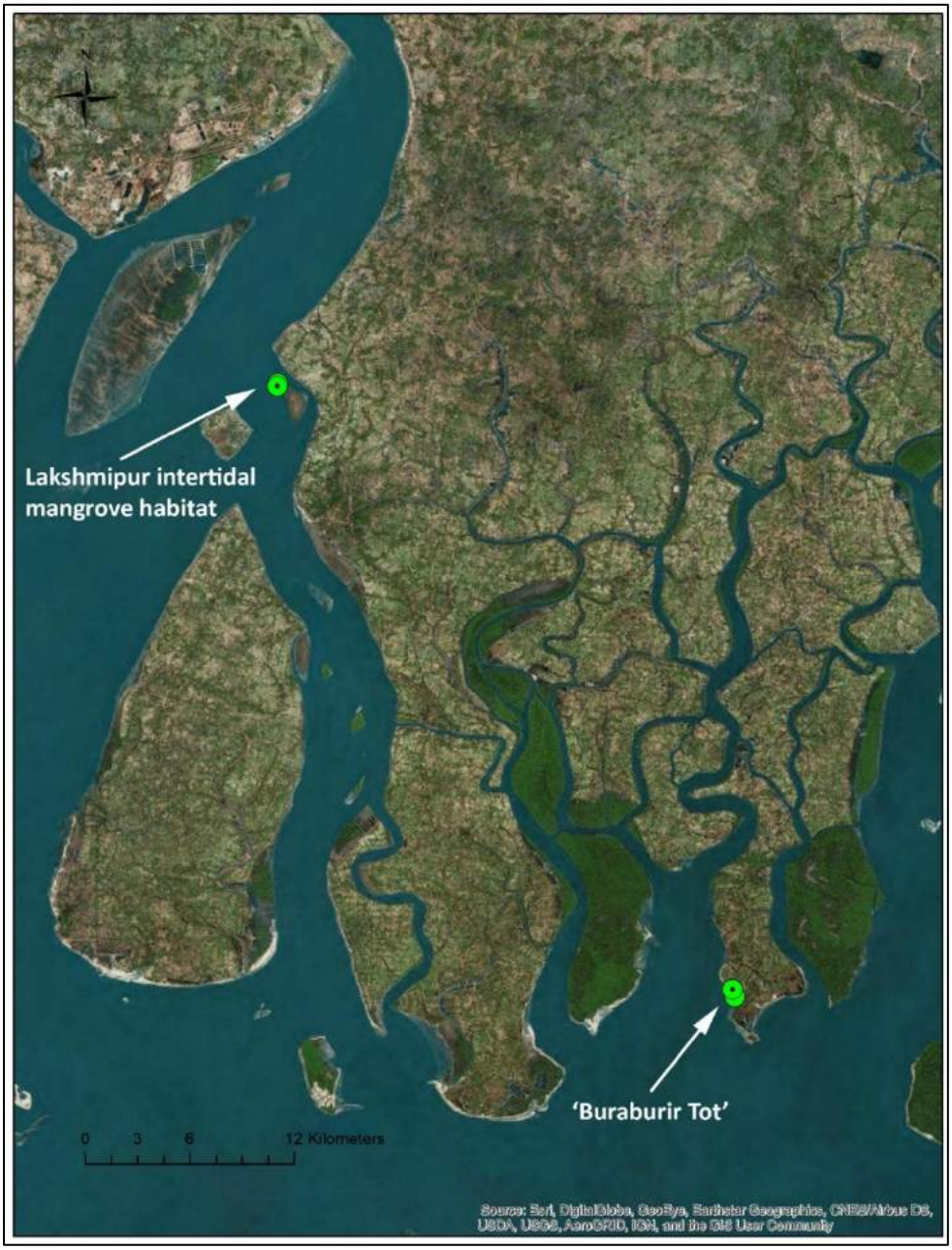
The present report is the final evaluation report of the restoration process done by NEWS under the project "Restoration of Mangroves in Sundarbans through Afforestation, Integrated Mangrove-Shrimp Farming, Income Generation and Community Participation (2017-2020)".

2. THE PLANTATION SITES

The sites selected by NEWS for afforestation of mangroves are as follows (Map 1).

I) 'Buraburir Tot', Gobardhanpur village, G.P. - G Plot, Block - Patharpratima, District - South 24 Parganas, West Bengal. This site is further subdivided into two subsites, viz. 'Buraburir Tot' (towards the sand dune) and 'Gobardhanpur' (towards the village) with two different nurseries.

II) Lakshmipur intertidal mangrove habitat, G.P. - Madhusudanpur, Block - Kakdwip, District - South 24 Parganas, West Bengal with one nursery.



3. EVALUATION OF THE MANGROVE PLANTATION AT 'BURABURIR TOT'

The plantation site is newly formed and a developing intertidal mangrove habitat which is exposed to sea. The tidal waves are low in the intertidal mangrove habitat due to presence of a sand dune as natural barrier in between the Bay of Bengal and the plantation site.

BSI team visited this site in March 2018, October 2018, January 2019, August 2019 and March 2020.

I. First survey:

- **Baseline Report for 2017 plantation**

In the first survey (March 2018) the team noticed that during high tide the site (with the planted mangroves) was submerged and planted saplings were exposed during the low tide. As per the data obtained from NEWS, seeds [20 sacks of seeds, 7000 seed per sack (approx.)] of *Avicennia alba* Blume [Beng.: Kalo Byne] were planted in 10 hectare (ha) area (out of 56 ha of the total proposed area for plantation) of the intertidal mangrove habitat. However it was later informed by NEWS that some seeds of *Avicennia marina* (Forssk.) Vierh. [Beng.: Peyara Byne] were also present along with the seeds of *A. alba* during 2017 plantation. To evaluate the growth rate/success rate of planted mangroves, the number, height of seedling/ saplings of each species at four spots (with 3 m radius) were noted and marked with GPS. Among these four spots, two were selected as permanent fixed points for monitoring during the subsequent visits. Besides, naturally regenerated seedlings/ saplings of *Aegialitis rotundifolia* Roxb. [Beng.: Tora], *Avicennia alba*, *Avicennia marina*, *Sonneratia alba* Sm. [Beng.: Ora] (misidentified as *S. griffithii* Kurz in earlier reports) and *Sonneratia caseolaris* (L.) Engl. [Beng.: Ora] were also observed at the plantation site and nearby area and their number and height were also noted. Saplings of *Bruguiera gymnorrhiza* (L.) Savigny [Kankra] were also found in the intertidal mangrove habitat which were earlier planted by the forest department. The women group ('Srijoni Mohila Badabon Committee') with 12–15 active members were found to be involved in plantation and laterally monitoring (survival rate study, study of growth, investigation of cause for mortality etc.) in the afforestation programme. They were well trained by NEWS and fully aware about the needs of afforestation of mangroves in the intertidal mangrove habitat. NEWS also supported the local community to develop livelihood and income augmentation (like backyard poultry farming).

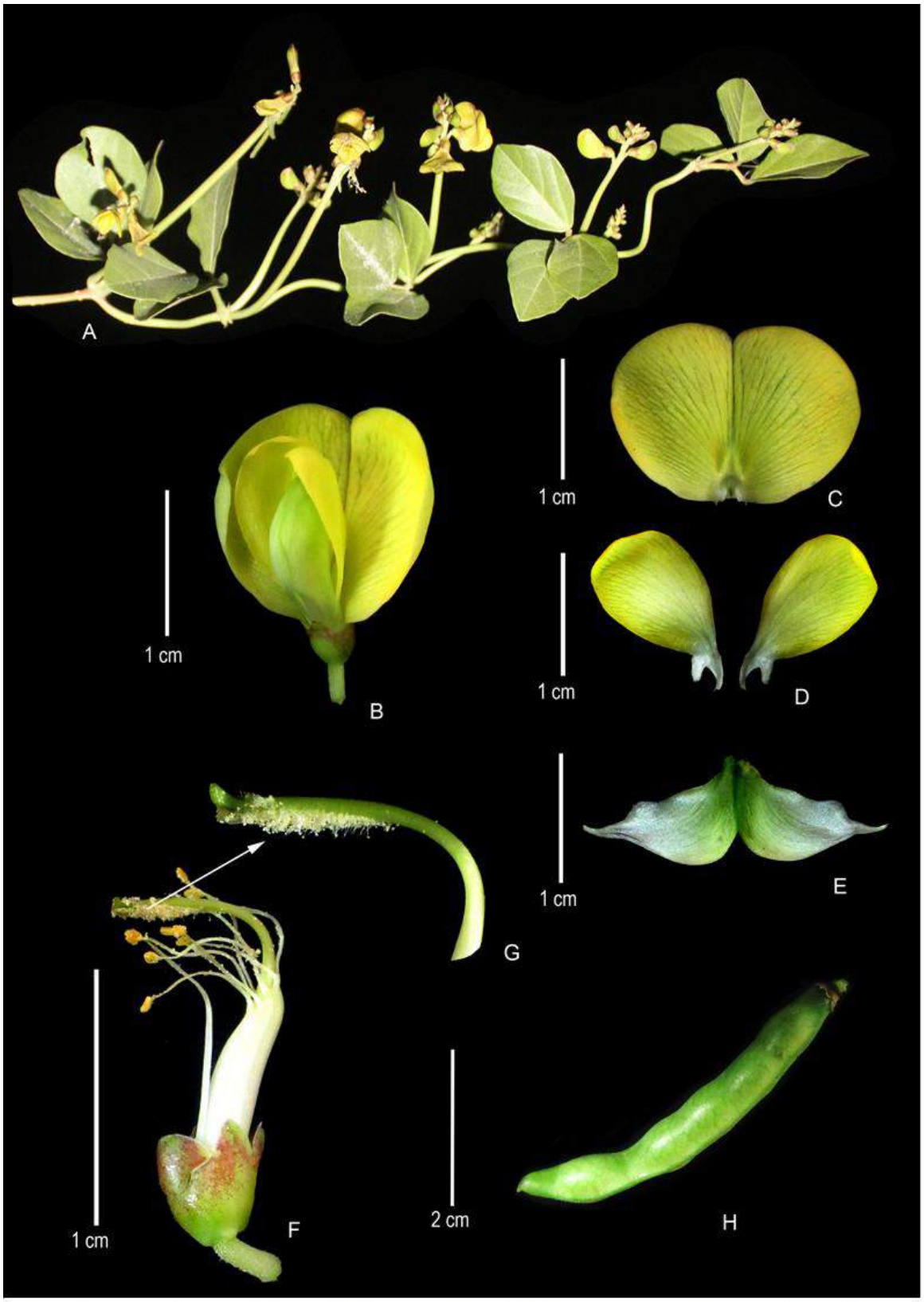
A: The site submerged during mid tide; B - D: Plantation site exposed during ebb; E: Evaluation of plantation during visit of BSI team; F. Naturally grown plants of *Avicennia marina* in the plantation site.

➢ **Other observations**

Several **mangrove associates** were also found in the sand dune and a few of these were good sand binders. As the sand dune plays a vital role in developing and maintaining the characters of the plantation site, information on these mangrove associates are also essential to monitor the overall plantation process. Therefore, a complete list of the existing flora (mangrove associates) of the area was also prepared during the first visit.

1. *Acanthus ilicifolius* L. (Acanthaceae)
2. *Aegialitis rotundifolia* Roxb. (Plumbaginaceae)
3. *Avicennia marina* (Forssk.) Vierh. (Avicenniaceae)
4. *Bruguiera gymnorrhiza* (L.) Savigny (Rhizophoraceae)
5. *Casuarina equsetifolia* L. (Casuarinaceae)
6. *Derris trifoliata* Lour. (Fabaceae)
7. *Excoecaria agallocha* L. (Euphorbiaceae)
8. *Launaea sarmentosa* (Willd.) Sch.Bip. ex Kuntze (Asteraceae)
9. *Ipomoea pes-caprae* (L.) R.Br. (Convolvulaceae)
10. *Opuntia dillenii* (Ker Gawl.) Haw. (Cactaceae)
11. *Pandanus odorifer* (Forssk.) Kuntze (Pandanaceae)
12. *Phyla nodiflora* (L.) Greene (Verbenaceae)
13. *Prosopis juliflora* (Sw.) DC. (Mimosaceae)
14. *Saccharum spontaneum* L. (Poaceae)
15. *Sesuvium portulacastrum* (L.) L. (Aizoaceae)
16. *Spinifex littoreus* (Burm.f.) Merr. (Poaceae)
17. *Suaeda maritima* (L.) Dumort. (Chenopodiaceae)
18. *Vigna marina* (Burm.) Merr. (Fabaceae)

Common sand binders like *Derris scandens*, *Ipomoea pes-capre*, *Launaea sarmentosa*, *Spinifex littoreus* etc. were found commonly along the sand dunes adjacent to the site. Psammophytes such as *Sesuvium portulacastrum*, *Suaeda maritima* were found commonly throughout the area. A good population of *Casuarina equisetifolia* was also observed in the area. Saplings of the notorious invasive alien species, *Prosopis juliflora* was also noticed in some places. *Vigna marina* was reported for the first time during the survey constituting a **new record for West Bengal**.



Vigna marina (Burm.) Merr.: A. Flowering twig; B. Flower; C. Standard petal; D. Wings; E. Keels; F. Calyx, androecium and gynoecium; G. Portion of style with hairy apical part; H. Pod. (*K. Karthigeyan & B. Bhattacharjee* 65107, CAL)

A: *Casuarina equisetifolia* - a dominant tree species; B. *Ipomoea pes-caprae* - a common trailer covering the sandy shores; C. *Launaea sarmentosa* - a common sand binder; D: Natural regeneration of *Aegialitis rotundifolia*; E. *Pandanus odorifer* - a common littoral species; F. *Bruguiera gymnorrhiza*.

A: *Saccharum spontaneum* - a common sand dune grass; B. *Sesuvium portulacastrum* - a common mangrove associate; C. *Suaeda maritima* - a common mangrove associate.

BSI team interacting with the members of 'Srijoni Mohila Badabon Committee'

A newly built backyard poultry house

II. Second survey:

- **Nursery visit for 2018 plantation**

During the second visit in October 2018 it was observed that plantation of mangroves was further extended by 18.3 ha. A mangrove nursery was established by the women group ('Srijoni Mohila Badabon Committee') with objective to develop simple and inexpensive method for producing seedlings for afforestation.

Total number of saplings planted for each species in the nursery are provided below.

i. *Avicennia marina* (Peyara byne) - 18,300
ii. *Avicennia alba* (Kalo byne) - 2,000
iii. *Aegialitis rotundifolia* (Tora) - 2,000
iv. *Bruguiera gymnorhiza* (Kankra) - 1,000
v. *Ceriops decandra* (Goran) - 500
vi. *Ceriops tagal* (Motth goran) - 500
vii. *Sonneratia apetala* (Keora) - 500
viii. *Rhizophora mucronata* (Garjan) - 200
TOTAL - 25,000 saplings

(*Rhizophora mucronata* Lam. [Beng.: Garjan] was earlier misidentified as *Rhizophora apiculata* Blume due to lack of minimal diagnostic characters at seedling stage and also because of the usage of the same vernacular name)

A total of 25,000 saplings were raised from the seeds purchased from the group of local community. These groups collected the seeds throughout the Sundarbans region. One of such group was 'Amlamethi Mohila group' which is a bunch of many small groups of 10–12 local women supervised by the leader of the group. Purchasing seeds from these local women groups further supported them financially.

The seeds purchased were provided to the women group at Buraburir tot ('Srijoni Mohila Badabon Committee') for nursery preparation. Seed germination took place within 10 days of imbibition which were then transferred to small jute bags made by the group members. Making jute bags and preparation of soil for plantation of seeds were efficiently done by the local women community. Seedlings were thereafter very carefully monitored and watered in the nursery by the women group regularly. Seedlings were then transferred along the edges of the mangrove swamps when they attained an average height of 2–3 inch

(after 1 month). The seedlings got submerged in the saline water during high tide which made them salt tolerant for natural adaptation. Finally, the saplings with height of c. 1 ft. were selected for transfer to the plantation site

A valid number of saplings only of *Avicennia marina* has been planted from the nursery to the main plantation area before the onset of winter. List of species alongside their numbers (as per the data provided by NEWS) of saplings planted from the nursery and direct seed or seedling plantation in 2018 is given below:

i. *Avicennia marina* (Peyara byne) - 15,000 saplings from nursery & 12 sacks of seed
ii. *Avicennia alba* (Kalo byne) - 28 sacks of seed
iii. *Aegialitis rotundifolia* (Tora) - 2,000 seedlings
iv. *Bruguiera gymnorhiza* (Kankra) - 2,000 seedlings
v. *Ceriops decandra* (Goran) - 500 seedlings
vi. *Ceriops tagal* (Motth goran) - 500 seedlings
vii. *Rhizophora mucronata* (Garjan) - 500 seedlings

❖ **Note:**

i. Sacks were of medium size holding capacity of approx. 2,000 seeds.
ii. *Avicennia marina* and *Avicennia alba* seeds were collected in sacks as they were small in size, stick together and difficult to count in numbers.
iii. Whereas in case of other species possible seedling collection was less in number and countable. Large number of seed collection in sacks was not possible due to unavailability.
iv. In the spot survey, *Avicennia marina* and *Avicennia alba* represented by quite a decent number of plants in the field whereas other newly planted species (excluding new natural regeneration) were quite less. This was because both the above-mentioned species have been planted in massive numbers in comparison to other species.
v. The remaining saplings present in the nursery was stocked for plantation during high spring tides when tidal actions would be high destroying young plants planted during the previous seasons. After winter fishing activities, crab collections furthermore increase due to rise in water level and such anthropogenic activities contribute in the destruction of planted saplings.

vi. The saplings established in nursery were mainly planted towards the central part of plantation area with lower elevation where the water level was higher than the remaining plantation area during the tide. The nursery raised saplings were preferred for plantation towards the central part because of the low survival capacity of the directly planted seeds/ propagules due to moderately strong tidal waves. Nursery saplings attaining a height of 30 cm were transferred to the plantation site which increases their maximum survivability in the high intertidal mangrove zone.

vii. Further, some nursery raised saplings were also planted along with the well-established plants of 2017 plantation.

- **Monitoring report of 2017 plantation**

  The area was dominated by *Avicennia marina* and it contributed in the increased mangrove plant population. In addition to the two permanent spots marked during the first survey, two more new spots were considered during the second survey.

- **Other observations**

  Propagules of 14 different species of mangrove and mangrove associates were recorded from the littoral zone of 'Buraburir Tot' during the survey.

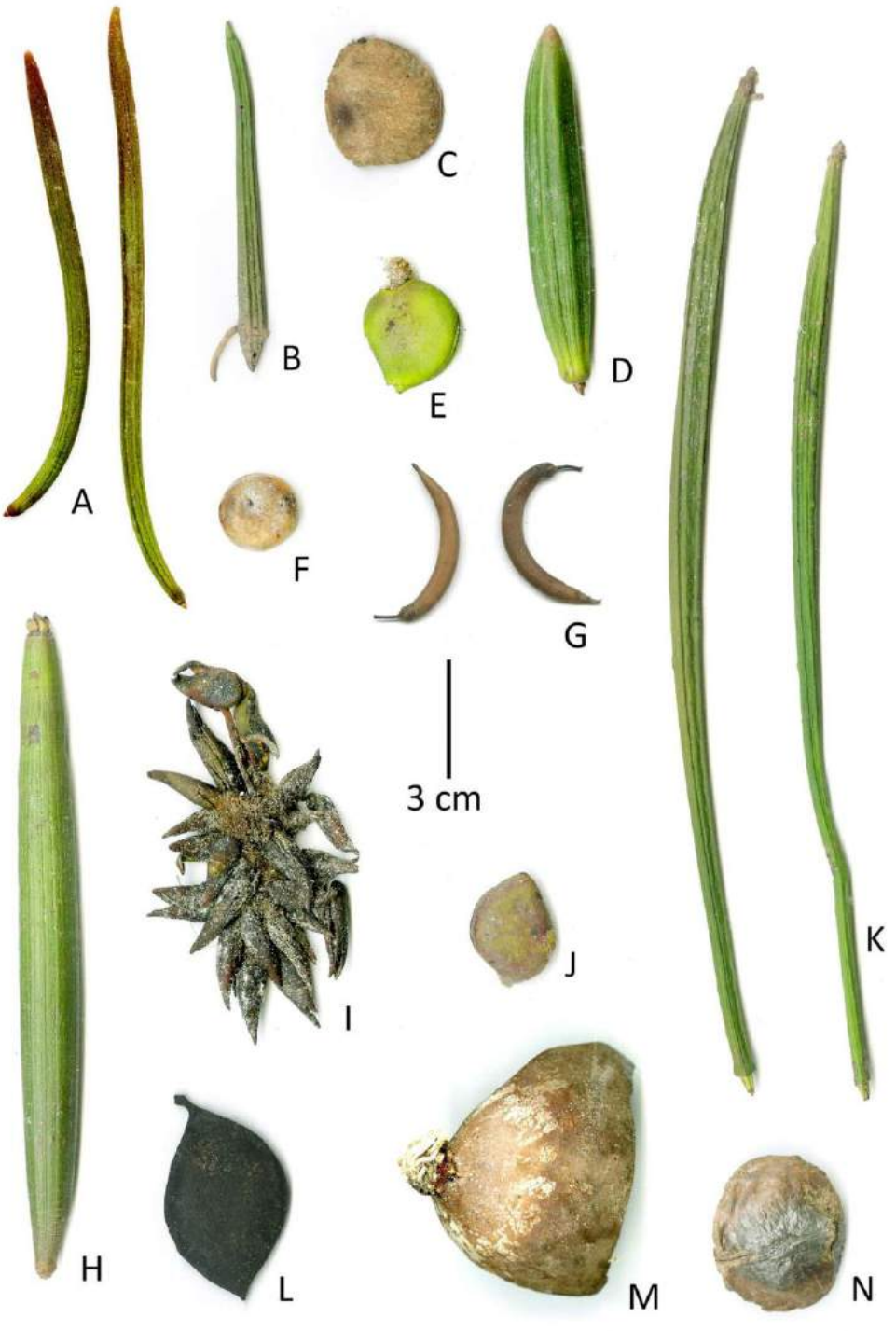
1. *Aegiceras corniculatum* (L.) Blanco (Primulaceae) [Beng.: Khalsi]
2. *Avicennia alba* Blume (Acanthaceae) [Beng.: Kalo Byne]
3. *Avicennia marina* (Forssk.) Vierh (Acanthacea) [Beng.: Peyara Byne]
4. *Avicennia officinalis* L. (Acanthaceae) [Beng.: Jat Byne]
5. *Bruguiera cylindrica* (L.) Blume (Rhizophoracea) [Beng.: Bakul Kankra]
6. *Bruguiera gymnorhiza* (L.) Savigny (Rhizophoracea) [Beng.: Kankra]
7. *Bruguiera sexangula* (Lour.) Poir. (Rhizophoracea) [Beng.: Kankra]
8. *Caesalpinia bonduc* (L.) Roxb. (Fabaceae) [Beng.: Nata Karanja]
9. *Ceriops decandra* (Griff.) W. Theob. (Rhizophoraceae) [Beng.: Jele Goran/ Goran]
10. *Ceriops tagal* (Perr.) C.B. Rob. (Rhizophoraceae) [Beng.: Motth goran]
11. *Derris trifoliata* Lour. (Fabaceae) [Beng.: Nayalata]
12. *Heritiera fomes* Buch.-Ham. (Sterculiaceae) [Beng.: Sundari]
13. *Sonneratia apetala* Buch.-Ham. (Lythraceae) [Beng.: Keora]
14. *Xylocarpus granatum* J.Koenig (Meliaceae) [Beng.: Dhudul]

A. Backyard Poultry Farming; B. Nursery at Gobardhanpur; C. Saplings ready for transplanting; D. Nursery visit by BSI person; E. Plantation by local women; F. Propagules ready for plantation,; G. Plantation site.

A. Plant survey at Gobardhanpur; B. Measuring the height of plants; C. Well grown sapling at Spot 2; D. Documentation of data by a BSI team member; E. A view of nursery at Gobardhanpur.

A. Nursery maintained by the 'Srijoni Mohila Badabon Committee' group; B.Saplings raised in the nursery; C. BSI team member interacting with members of 'Srijoni Mohila Badabon Committee'; D. BSI team members interacting with local people.

Mangrove nursery at ‘Boraburir Tot’



Propagules of – A. *Bruguiera cylindrica*; B. *Ceriops decandra*; C. *Derris trifoliata*; D. *Bruguiera sexangular*; E. *Avicennia officinalis*; F. *Sonneratia apetala*; G. *Aegiceras corniculatum*; H. *Bruguiera gymnorhiza*; I. *Avicennia alba*; J. *Avicennia marina*; K. *Ceriops tagal*; L. *Caesalpinia bonduc*; M. *Xylocarpus granatum*; N. *Heritiera fomes*.

III. Third survey:

- **Baseline report for 2018 plantation and evaluation report of 2017 existing plantation**

The third survey was undertaken by the BSI team in January 2019. Total area of plantation at the end of 2019 was 29 ha. During the survey the evaluation of mangrove plantation done by NEWS was made based on the survey in 11 new spots and 2 permanent spots (Spot A and B).

- Plants observed on the surveyed spots:

i. Spot 1:

Avicennia alba: 81 (new; 20–30 cms)

Avicennia marina: 8 (new; 20–30 cms)

- New plants were from direct seed sowing (no nursery plants).

ii. Spot 2:

Avicennia alba: 4 (old; 120 cms); 3 (new; 30 cms)

Avicennia marina: 8 (old; 100 cms); 3 (new; 20 cms)

- New plants were from direct seed sowing (no nursery plants).

iii. Spot 3:

Avicennia alba: 36 (new; 20– 40 cms)

Avicennia marina: 3 (old; 100 cms); 20 (new; 40–60 cms)

Aegialitis rotundifolia: 2 (new; 10 cms)

- New plants were from direct seed sowing (no nursery plants).

iv. Spot 4:

Avicennia alba: 3 (old; 100–120 cms); 2 (new; 20–35 cms)

Avicennia marina: 10 (old; 100–180 cms); 25 (new; 30–50 cms)

Aegialitis rotundifolia: 30 (natural; 20– 40 cms)

Sonneratia alba: 5 (natural; 160 cms)

- New plants were from direct seed sowing (no nursery plants).
- Many plants were growing naturally.

v. Spot 5

Avicennia alba: 4 (old; 130– 150 cms); 1 (new; 30 cms)

Avicennia marina: 30 (old; 120–150 cms); 6 (new; 30–60 cms)

Aegialitis rotundifolia: 1 (natural; 20 cms)

Sonneratia apetala: 2 (natural; 10–20 cms)

- New plants were from direct seed sowing (no nursery plants).

vi. Spot 6

Avicennia alba: 2 (old; 110–130 cms); 3 (new; 20–30 cms)

Avicennia marina: 28 (old; 130– 160 cms); 9 (new; 30–60 cms)

Aegialitis rotundifolia: 1 (natural; 10 cms)

- New plants were from direct seed sowing (no nursery plants).

vii. Spot 7

Avicennia alba: 3 (old; 90–110 cms); 15 (natural; 20–30 cms)

Avicennia marina: 29 (old; 70–110 cms); 5 (natural; 50–60 cms)

Avicennia officinalis: 1 (natural; 40 cms)

Aegialitis rotundifolia: 30 (natural; 10–30 cms)

Sonneratia apetala: 1 (natural; 80 cms)

- New plants were from direct seed sowing (no nursery plants).
- Many naturally grown plants occurred here.

viii. Spot 8

Avicennia marina: 2 (old; 70–100 cms); 15 [new (5 nursery plants, 10 directly from seeds); 30– 50 cms]

Aegialitis rotundifolia: 3 (natural; 10–20 cms)

Aegiceras corniculatum: 1 (natural; 10 cms)

ix. Spot 9

Avicennia alba: 5 (natural; 20 cms)

Avicennia marina: 3 (old; 110–130 cms); 35 [new (6 nursery plants, 29 directly from seeds); 30–50 cms]

Avicennia officinalis: 1 (natural; 40 cms)

Aegiceras corniculatum: 1 (natural; 10 cms)

x. Spot 10

Avicennia marina: 1 (old; 100 cms); 9 (new; all nursery plants, 40–48 cms); 7 (natural; 20 cms)

xi. Spot 11

Avicennia marina: 1 (old; 70 cms); 7 (new; all nursery plants; 20–30 cms); 7 (natural; 20–30 cms); 18 (new; all directly from seeds; 20–30 cms)

xii. Spot A (Permanent spot)

Avicennia alba: 2 (old; 110–130 cms); 3 (new; all directly from seeds; 25–30 cms)

Avicennia marina: 29 (old; 120–140 cms); 5 (new; all nursery plants; 30–45 cms)

xiii. Spot B (Permanent spot)

Avicennia alba: 1 (old; 90–110 cms); 1 (natural; 15 cms)

Avicennia marina: 6 (old; 70–110 cms); 3 (natural; 20–30 cms)

Surveyed spots at 'Buraburir Tot'

A - E. Evaluation of mangrove plantation at different spots of 'Buraburir Tot'

Spot survey showed that *A. marina* was the most dominating (up to 30 in number) and well grown (maximum height up to 180 cms) species in the plantation zone. Comparative study of the species planted in 2017 with their rate of survival in the two permanent spots were also provided in the third report.

Permanent spot A	**Name of the species**	**Time of survey**		**Rate of survival**
	Avicennia alba	March 2018	January 2019	
No. of plants		7	3	42.8%
Permanent spot B	**Name of the species**	**Time of survey**		**Rate of survival**
	Avicennia alba	March 2018	January 2019	
No. of plants		2	1	50%

IV. Fourth survey:

- **Midterm evaluation report for the total restoration sites and recommendations**

The fourth survey was undertaken in August, 2019 to evaluate the total restoration process till date and to provide a midterm evaluation report**.** As mentioned in the third report, the priority was given to survey in the central part of the plantation area along with study in some randomly selected spots to evaluate the status of the overall plantation. The following interpretations were made during the survey.

- Out of 56 ha of the total proposed area, 29 ha was found suitable and stabilised for mangrove plantation. In 2017, the plantation was done in c. 10 ha area, whereas the plantation in remaining 18.3 ha area was carried out in 2018 and by the end of 2019 maximum plantation area reached up to 29 ha.
- The Changes in salinity and pH of water was also recorded.

Date	**Salinity of water**		**pH of water**	
	Tide	Ebb	Tide	Ebb
29.03.2018	15 ppt	17 ppt	7.5	7.5
11.01.2019	27 ppt	29 ppt	7.5	7.5
04.08.2019	15 ppt	17 ppt	7	7

The pH of water (7 = neutral) measured during the present survey is slightly low than that of the prior visits, may be due to the monsoon.

- Plants observed on the surveyed spots:

i. Spot 1:

Avicennia alba: 15 (c. 80 cms; 7 planted, others natural)

Avicennia marina: 39 (c. 100 cms; 2 planted, others natural)

Aegialitis rotundifolia: 2 (c. 10cms; naturally regenerated)

Aegiceras corniculatum: 2 (c. 20 cms; naturally regenerated)

ii. Spot 2:

Avicennia alba: 12 (c. 80 cms; 4 planted, others natural)

Avicennia marina: 30 (c. 120 cms; 3 planted, others natural)

Aegialitis rotundifolia: 1 (10cms; naturally regenerated)

Aegiceras corniculatum: 2 (c. 20 cms; naturally regenerated)

iii. Spot 3:

Avicennia alba: 4 (c. 60 cms; 2 planted, others natural)

Avicennia marina: 25 (c. 60 cms; 2 planted, others natural)

Aegiceras corniculatum: 1 (20 cms; naturally regenerated)

iv. Spot 4:

Avicennia alba: 1 (c. 50 cms; naturally regenerated)

Avicennia marina: 12 (c. 50 cms; 5 planted, others natural)

v. Spot 5

Avicennia alba: 4 (c. 130 cms; 2 planted, others natural)

Avicennia marina: 28 (c. 120 cms; 12 planted, others natural)

Aegialitis rotundifolia: 1 (10 cms; natural regeneration)

vi. Spot 6

Avicennia alba: 3 (c. 120 cms; 2 planted)

Avicennia marina: 3 (c. 110 cms; all planted)

vii. Spot 7

Avicennia alba: 6 (c. 90 cms; 4 planted, others natural)

Avicennia marina: 10 (c. 90 cms; 8 planted, others natural)

Aegialitis rotundifolia: 2 (c. 20 cms; naturally regenerated)

Aegiceras corniculatum: 1 (10 cms; naturally regenerated)

viii. Spot 8

Avicennia alba: 9 (c.100 cms; 6 planted, others natural)

Avicennia marina: 42 (c. 90 cms; 20 planted, others natural)

ix. Spot 9

Avicennia alba: 8 (c. 220 cms; 3 planted, others natural)

Avicennia marina: 27 (c. 180 cms; 10 planted, others natural)

Avicennia officinalis : 1 (200 cms; naturally regenerated)

Aegialitis rotundifolia: 46 (c. 30cms; naturally regenerated)

x. Spot 10

Avicennia alba: 3 (c. 200 cms; 2 planted)

Avicennia marina: 26 (c. 180 cms; 12 planted, others natural)

Aegialitis rotundifolia: 2 (c. 30cms; naturally regenerated)

Sonneratia apetala: 3 (c. 40 cms; natural regeneration)

xi. Spot 11

Avicennia marina: 14 (c. 150 cms; 2 planted, others natural)

Aegialitis rotundifolia: 2 (c. 30 cms; naturally regenerated)

Aegiceras corniculatum: 2 (c. 20 cms; naturally regenerated)

A - C. Planted mangove saplings at 'Buraburir Tot'; D. Natural regenerat-
-ion from seeds; E. Spot-wise survey at 'Buraburir Tot'.

xii. Spot 12

Avicennia alba: 6 (c. 100 cms; 1 planted, others natural)

Avicennia marina: 27 (c. 150 cms; 17 planted, others natural)

Avicennia officinalis: 2 (c. 150 cms; naturally regenerated)

Aegiceras corniculatum: 2 (c. 20 cms; naturally regenerated)

xiii. Spot A (Permanent spot)

Avicennia alba: 3 [1 planted (180–195 cms); 1 planted (55 cms); 1 natural (40 cms)]

Avicennia marina: 30 [21 planted (150–180 cms; 3 planted (80–90 cms); 6 natural (15–20 cms)

xiv. Spot B (Permanent spot)

Avicennia alba: 4 [1 planted: (150–170 cms); 3 natural: (15–55 cms)]

Avicennia marina: 5 [3 planted: (150–180 cms); 2 natural: (12–15 cms)]

Note: During the 4th survey, the evaluation was done based on 12 new spots and 2 permanent spots (Spot A and B).

Majority of the nursery plants were planted in the central part of the plantation area as nursery plants attaining certain height could survive better than the direct seed plantation reducing the chance of mortality due to high silt deposition in that zone. To evaluate the total restoration process, a comparative study of the permanent spots was done to calculate the survival rate of the plants.

Comparative study of the permanent spots during the surveys

Permanent spot	March 2018		January 2019		August 2019	
	Name of the species with no. of individuals	**Heights of plants**	**Name of the species with no. of individuals**	**Heights of plants**	**Name of the species with no. of individuals**	**Heights of plants**
Spot A	*Avicennia alba*: 2	45–72 cms	*Avicennia alba*: 3 (old); 2 (new)	110–130 cms (old); 25–30 cms (new)	*A. alba*: 3	180–195 cms (1 planted); 55 cms (1 planted); 40 cms (natural)
	A. marina: 38	42–70 cms	*A. marina*: 29 (old); 5 (new)	120–140 cms (old); 30–45 cms (new)	*A. marina*: 30	150–180 cms (21 planted); 80-90 cms (3 planted); 15–20 cms (6 natural)

Survival percentage of planted mangroves at 'Spot A' till August 2019: 67.5 %

Total no. of plants observed in March 2018	Total no. of plants observed in January 2019	Total no. of plants observed in August 2019
40	39	27

Survival percentage of overall mangroves at 'Spot A' (including naturally regenerated plants) till August 2019: 82.5 %

Total no. of plants observed in March 2018	Total no. of plants observed in January 2019	Total no. of plants observed in August 2019
40	39	33

Permanent spot	March 2018		January 2019		August 2019	
	Name of the species with no. of individuals	Heights of plants	Name of the species with no. of individuals	Heights of plants	Name of the species with no. of individuals	Heights of plants
Spot B	*Avicennia alba*: 2	44 – 67 cms	*Avicennia alba*: 1 (old); 1 (natural)	90 – 110 cms (old); 15 cms (natural)	*A. alba*: 4	150 – 170 cms (1 planted); 15-55 cms (3 natural)
	A. marina: 8	45 – 74 cms	*A. marina*: 6 (old); 3 (natural)	70 – 110 cms; 20-30 cms (natural)	*A. marina*: 5	150 – 180 cms (3 planted); 12-15 cms (2 natural)

Survival percentage of planted mangroves at 'Spot B' till August 2019: 60 %

Total no. of plants observed in March 2018	Total no. of plants observed in March 2018	Total no. of plants observed in August 2019
10	7	6

Survival percentage of overall mangroves at 'Spot B' (including naturally regenerated plants) till August 2019: 90 %

Total no. of plants observed in March 2018	Total no. of plants observed in January 2019	Total no. of plants observed in August 2019
10	11	9

During survey at 'Buraburir Tot'

➢ **Conclusion:** It was observed that mangrove plantation process at 'Buraburir Tot' also strengthened the natural regeneration of plant notably accelerating the overall afforestation programme. Survival rates of planted and naturally regenerated plants were quite good as shown in the above tables.

V. Fifth survey:

➢ Final Evaluation

Final survey was done by BSI team in March, 2020 for final evaluation of the restoration process through mangrove plantation by NEWS. This time the team selected 12 spots (including 2 permanent spots).

Surveyed spots at 'Buraburir Tot'

❖ Plants observed on the surveyed spots:

i. **Spot 1:**

Avicennia marina: 13 [5 planted (200–210 cms); 8 natural (30–40 cms)]

Aegialitis rotundifolia: 9 (30–40 cms; natural)

Aegiceras corniculatum: 8 (90–10 cms; natural)

Sonneratia alba: 5 (270–280 cms; natural)

ii. **Spot 2:**

Avicennia alba: 14 [6 planted (165–170 cms); 8 natural (30–35 cms)]

Avicennia marina: 16 [8 planted (160–170 cms); 8 natural (50–60 cms)]

Aegialitis rotundifolia: 1 (30 cms; natural)

Aegiceras corniculatum: 8 (30–40 cms; natural)

iii. **Spot 3:**

Avicennia alba: 16 [8 planted (160–170 cms); 8 natural (30–40 cms)]

Avicennia marina: 17 [9 planted (150–160 cms); 8 natural (30–40 cms)]

Aegialitis rotundifolia: 1 (40 cms; planted)

Aegiceras corniculatum: 6 (20–30 cms; natural)

iv. **Spot 4:**

Avicennia marina: 9 (200–210 cms; planted)

Aegialitis rotundifolia: 2 (40–45 cms; natural)

Aegiceras corniculatum: 4 (30 cms; natural)

v. **Spot 5**

Avicennia marina: 15 (220–230 cms; planted)

Avicennia alba: 1 (240 cms; planted)

Aegialitis rotundifolia: 6 (40–45 cms; natural)

Aegiceras corniculatum: 2 (40–45 cms; natural)

vi. **Spot 6**

Avicennia alba: 11 (140–150 cms; planted)

Avicennia marina: 14 (180–195 cms; planted)

Aegiceras corniculatum: 2 (30–35 cms; natural)

vii. **Spot 7**

Avicennia alba: 13 (125–135 cms; planted)

Avicennia marina: 25 (140–155 cms; planted)

Avicennia officinalis: 1 (120 cms; natural)

Aegialitis rotundifolia: 2 (c. 20 cms; natural)

Aegiceras corniculatum: 3 (c. 30 cms; natural)

viii. **Spot 8**

Avicennia alba: 14 [5 planted (125–135 cms); 9 natural (30–35 cms)]

Avicennia marina: 35 (115–130 cms; planted)

ix. **Spot 9**

Avicennia alba: 2 [1 planted (90 cms); 1 natural (40 cms)]

Avicennia marina: 34 [28 planted (100–110 cms); 6 natural (50–55 cms)]

x. **Spot 10**

Avicennia alba: 2 [1 planted (95 cms); 2 natural (40–45 cms)]

Avicennia marina: 34 [20 planted (95–105 cms); 4 natural (45–50 cms)

xi. **Spot A (Permanent spot)**

Avicennia alba: 4 (2 planted: 240 cms, 95 cms; 2 natural: 45–55 cms)

Avicennia marina: 43 (20 planted: 210–225 cms; 3 planted: 130–140 cms; 20 natural: 35–62 cms)

Aegialitis rotundifolia: 15 (c. 40 cms; natural)

Aegiceras corniculatum: 3 (c. 40 cms; natural)

xii. **Spot B (Permanent spot)**

Avicennia alba: 4 [1 re-planted (90 cms); 3 natural (40–65 cms)]

Avicennia marina: 20 [1 planted (210 cms); 3 re-planted (90–95 cms); 16 natural (40–60 cms)]

During survey at ‘Buraburir Tot’

A - B. Planted mangroves in 2018; C - E. BSI team along with members of 'Srijoni Mohila Badabon Committee' and NEWS evaluating the mangroves plantation done by NEWS during 2017 and early 2018.

Comparative study of the permanent spots during the surveys

Permanent spots	March 2018		January 2019		August 2019		March 2020	
	Name of the species with no. of individuals	**Heights of plants**	**Name of the species with no. of individuals**	**Heights of plants**	**Name of the species with no. of individuals**	**Heights of plants**	**Name of the species with no. of individuals**	**Heights of plants**
Spot A	*Avicennia alba*: 2 *A. marina*: 38	45–72 cms 42–70 cms	*Avicennia alba*: 2 (old); 3 (new) *A. marina*: 29 (old); 5 (new)	110–130 cms (old); 25–30 cms (new) 120–140 cms (old); 30–45 cms (new)	*A. alba*: 3 *A. marina*: 30	180–195 cms (1 planted); 55 cms (1 planted); 40 cms (natural) 150–180 cms (21 planted); 80–90 cms (3 planted); 15–20 cms (6 natural)	*Avicennia alba*: 4 *Avicennia marina*: 43 *Aegialitis rotundifolia*: 15 *Aegiceras corniculatum:* 3	240 cms (1 planted); 95 cms (1 planted); 45–55 cms (2 natural) 210–225 cms (20 planted); 130–140 cms (3 planted); 35–62 cms (20 natural) c. 40 cms (all natural) c. 40 cms (all natural)

Survival percentage of planted mangroves at 'Spot A' since March 2018 to March 2020: 62.5 %

Total no. of plants observed in March 2018	Total no. of plants observed in January 2019	Total no. of plants observed in August 2019	Total no. of plants observed in March 2020
40	39	26	25

Survival percentage of overall mangroves at 'Spot A' (including naturally regenerated plants) since March 2018 to March 2020: 162.5 %

Total no. of plants observed in March 2018	Total no. of plants observed in January 2019	Total no. of plants observed in August 2019	Total no. of plants observed in March 2020
40	39	33	65

Permanent spots	March 2018		January 2019		August 2019		March 2020	
	Name of the species with no. of individuals	**Heights of plants**	**Name of the species with no. of individuals**	**Heights of plants**	**Name of the species with no. of individuals**	**Heights of plants**	**Name of the species with no. of individuals**	**Heights of plants**
Spot B	*Avicennia alba*: 2 *A. marina*: 8	44 – 67 cms 45 – 74 cms	*Avicennia alba*: 1 (old); 1 (natural) *A. marina*: 6 (old); 3 (natural)	90 – 110 cms (old); 15 cms (natural) 70 – 110 cms; 20-30 cms (natural)	*A. alba*: 4 *A. marina*: 5	150 – 170 cms (1 planted); 15-55 cms (3 natural) 150 – 180 cms (3 planted); 12-15 cms (2 natural)	*A. alba*: 4 *A. marina*: 20	90 cms (1 re-planted); 40–65 cms (3 natural) 210 cms (1 planted); 90–95 cms (3 re-planted); 40–60 cms (16 natural)

Survival percentage of planted mangroves at 'Spot B' since March 2018 to March 2020: 50 %

Total no. of plants observed in March 2018	Total no. of plants observed in January 2019	Total no. of plants observed in August 2019	Total no. of plants observed in March 2020
10	7	6	5

Survival percentage of overall mangroves at 'Spot B' (including naturally regenerated plants) since March 2018 to March 2020:

240 %

Total no. of plants observed in March 2018	Total no. of plants observed in January 2019	Total no. of plants observed in August 2019	Total no. of plants observed in March 2020
10	11	9	24

4. EVALUATION OF THE MANGROVE PLANTATION AT LAKSHMIPUR INTERTIDAL MANGROVE HABITAT

Like 'Buraburir Toth', the plantation site of intertidal mangrove habitat is newly formed, but its nature is entirely different than that of the former. The plantation site is a newly formed grassland covered by the species of salt tolerant wild rice *Porteresia coarctata* (Roxb.) Tateoka. *P. coarctata* act as pioneer species in the succession process of mangrove formation along the estuaries of India. *Porteresia* forms a vast population as mangrove associates throughout the root matrices of tree mangroves, binds the soil and prevents the coastline from erosion. During high tide, the plantation area (with the planted mangroves) is found immersed and planted saplings are visible only during the low tide. The mean elevation of this intertidal mangrove habitat is c. 1.4 m. The site is more or less plane (without significant slope) which helps the tidal water to flow in and out. The site is also prone to continuous threat of erosion as well as siltation.

BSI team visited this site in March 2018, October 2018, January 2019, August 2019 and March 2020.

I. First survey:

- **Baseline Report for 2017 plantation**

In the first survey (March 2018) the team noticed that the site was almost covered by *Porteresia coarctata,* a species of grass belonging to the family Poaceae. Apart from that a few saplings of naturally grown *Avicennia alba* was also observed in the site. Out of c. 12 ha of the selected area, the mangrove plantation was done in c. 4 ha area by NEWS which was found appropriate for plantation in the year 2017. As per the data obtained from NEWS, 8000 seeds of *Bruguiera gymnorhiza* (L.) Savigny [Kankra] and 4000 seeds of *Sonneratia apetala* Buch.-Ham. [Keora] were germinated at the nursery developed by the women group of Lakshmipur ('Lakshmishree Mohila badabon Committee") supported and trained by NEWS. Further, 9310 saplings and 2028 seeds of *Rhizophora mucronata* Lam. [Garjan] (earlier misidentified as *Rhizophora apiculata* Blume due to lack of minimal diagnostic characters at seedling stage and also for the same vernacular name) were sown at Lakshmipur intertidal mangrove habitat during 15th–17th September 2017 and 2415 saplings of *S. apetala* were planted on 12th October 2017. To evaluate the mangrove plantation, two spots of 3 metre radius were selected as permanent fixed points and marked

with GPS. The name of the species, number of seedlings/ saplings of each species and their height within those spots were recorded.

A. The site exposed during ebb; B. Planted saplings by NEWS; C. Sapling of *Rhizophora mucronata;* D. Naturally grown sapling of *Avicennia alba*; E. Evaluation of plantation during visit of BSI team; F. Sapling of *Sonneratia apetala*.

It was found that a group of 11 local women ('Lakshmishree Mohila badabon Committee") from the Lakshmipur village were selected and trained for the afforestation programme. They were encouraged to develop nursery for raising mangrove saplings with the seeds collected and supplied to them by the volunteers from NEWS. Training was also provided on the techniques involved in raising the mangrove saplings It was noted that the volunteers of the women group regularly monitor the saplings planted in the site. The group was also involved in creating awareness among the local community.

BSI team interacting with the members of the women group of Lakshmipur

II. Second survey:

- **Nursery visit for 2018 plantation**

During the second survey in October 2018 it was found that after 4 ha area of plantation during 2017, the mangrove plantation was done on 8.2 ha area in 2018 by NEWS. Replantation was frequently done in some patches due to destruction of saplings by different factors. During the visit it was observed that both the species (*Rhizophora mucronata*,

Sonneratia apetala) planted in 2017 were emerging satisfactorily. The plants were growing effectively but due to heavy siltation the plants were visually dwarf.

The nursery raised at Lakshmipur intertidal mangrove site was also surveyed. Around 13000 seeds of mixed species of mangrove viz., *Avicennia marina* [Beng.: Peyara Byne], *Ceriops decandra* [Beng.: Goran], *Rhizophora mucronata* [Beng.: Garjan**]** and *Bruguiera cylindrica* (L.) Blume [Beng.: Bakul Kankra] were purchased from local women group engaged in gathering seeds from different parts of Sundarbans. A total of 13 local women of 'Lakshmishree Mohila Badabon Committee' were actively engaged then in the nursery development. Trainings were also conducted to provide them assistance to develop the right techniques related to the nursery groundwork such as making jute bags, preparing soil mixture for the nursery, planting seeds, proper watering and transfer of the saplings in the intertidal region to accustom them in salt water before transferring to the selected site. Volunteers in group all over the year repeatedly monitor the saplings planted in the site to protect the growing plants from animal grazing and human interference due to fishing and crab hunting. They even imposed penalty for the trespassers who enter inside the plantation area with the help of local governing authorities. The women group was also enthusiastically associated in creating awareness among the villagers about the significance of mangrove and measures to protect their mangrove forests.

All the 13 women of 'Lakshmishree Mohila Badabon Committee' group were engaged in backyard poultry farming as an alternative livelihood. NEWS provided training and materials to construct chicken cages, chicks along with feed, training on production of chicken feed using local raw materials etc. The organically farmed eggs and chicken produced are in high demand list in metro cities.

A. Plantation site at Lakshmipur; B. Plantation site submerged during high tide; C. Survey at plantation site; D. 'Lakshmishree Mohila Badabon Committee' women group at the nursery; E & F. Sap--lings submerged during high tide at the nursery; G & H. Local women of the group preparing jute bags.

III. Third survey:

- **Baseline report for 2018 plantation**

Third survey was conducted during January 2019 after the plantation was completed by the end of 2018.

List of species along with numbers (as per the data provided by NEWS) of seeds/ seedlings/ saplings planted from the nursery in 2018 is given below:

Avicennia alba [Kalo byne] - 9 sacks of seed (approx.2000 seeds per sack)

Sonneratia apetala [Keora] - 9967 saplings from nursery

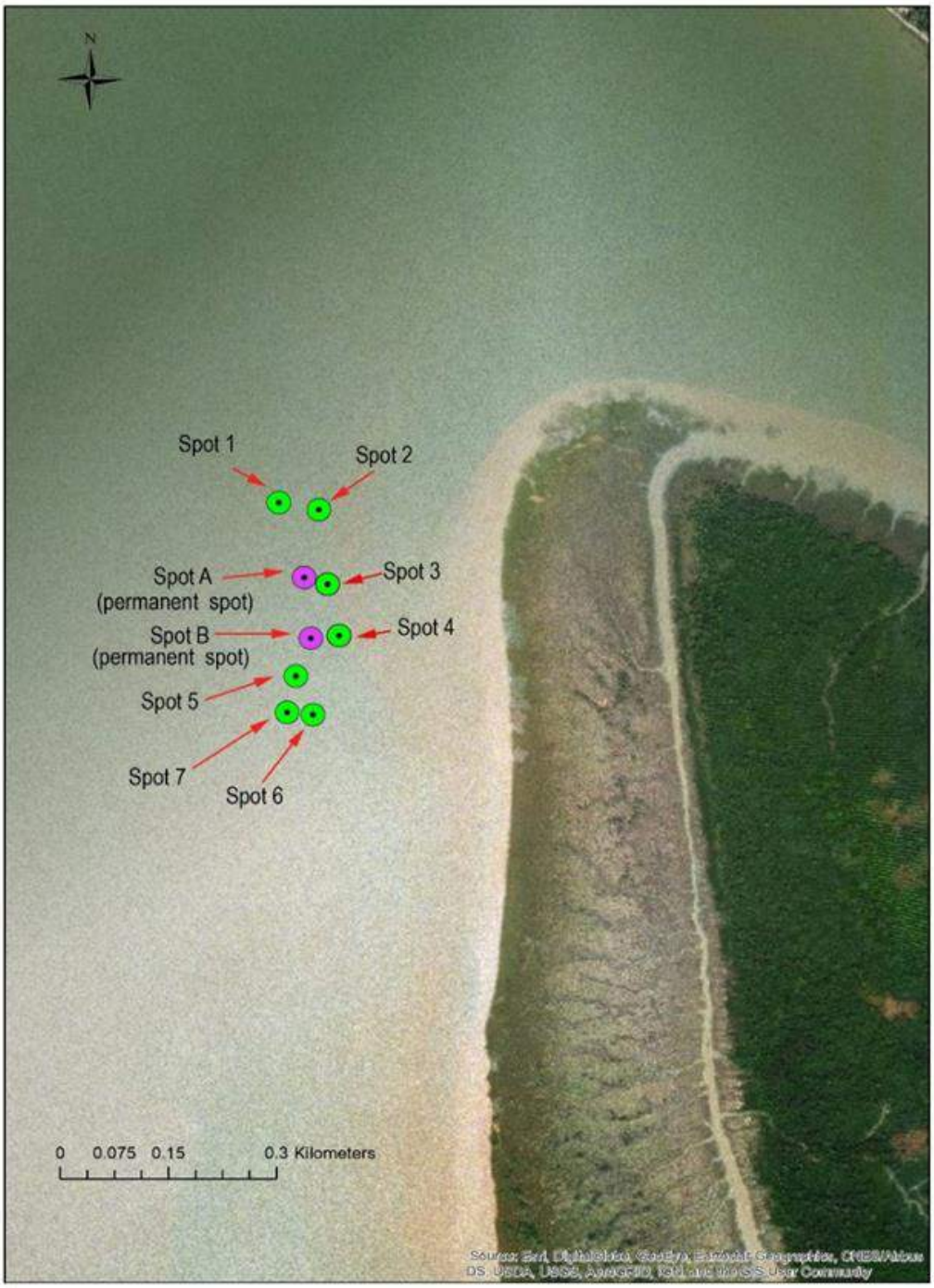
Rhizophora mucronata [Garjan] - 16950 direct seedlings

Earlier in 2017, 8000 seeds of *Bruguiera gymnorhiza* were planted in the nursery and reserved for plantation in 2018. In post monsoon months i.e., in August and September 2018, *c.* 7212 saplings of *B. gymnorhiza* grown in good condition in nursery were transferred to the main field.

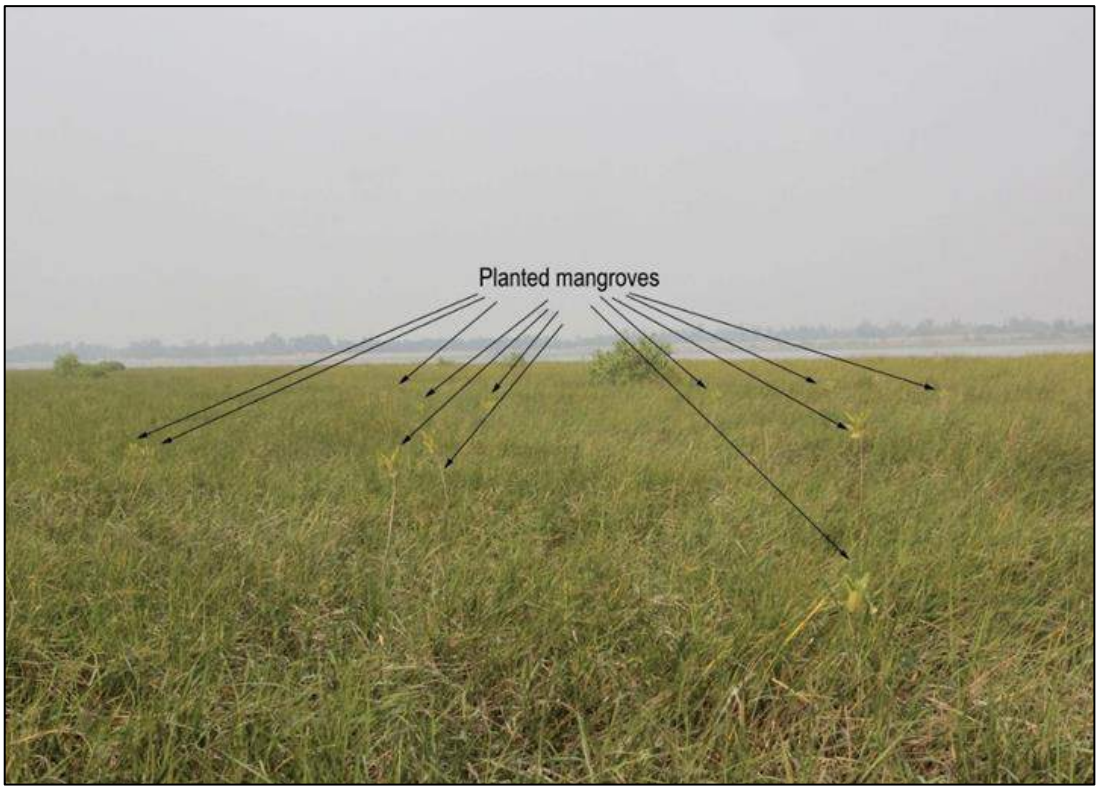
- **Evaluation report of 2017 existing plantation**

In January 2019, during the third survey, it was noted that both the species (*Sonneratia apetala, Rhizophora mucronata*) selected for 2017 plantation were growing satisfactorily. To evaluate the mangrove plantation, nine spots with three-meter radius were selected. As mentioned earlier, the site was covered by *Porteresia*

coarctata. Apart from *P. coarctata*, naturally grown saplings of *Acanthus ilicifolius* L. and *Avicennia alba* were also found in some places of the intertidal mangrove habitat.



Surveyed spots at Lakshmipur (submerged during high tide)



❖ Plants observed on the surveyed spots: (old plants of 2017 plantation and new plants of 2018 plantation either from direct seed or from nursery saplings)

i. Spot 1:

Avicennia alba : 5 (50–60 cms)

Rhizophora mucronata: 2 (50–60 cms)

- New plants; directly planted from the seeds (no nursery plant).

ii. Spot 2:

Rhizophora mucronata: 4 (70–80 cms)

Sonneratia apetala: 3 (30–35 cms)

- New plants; from direct seed sowing (no nursery plant).

iii. Spot 3:

Rhizophora mucronata: 4 (60–70 cms)

Sonneratia apetala: 7 (20–25 cms)

- New plants; from direct seed sowing (no nursery plant).

A, F. Evaluation of mangrove plantation at Lakshmipur intertidal mangrove habitat; B. Measuring length of a plant of *Sonneratia apetala* (2017 plantation); C. Plants of *S. apetala* (2017 plantation); D – E. Seedlings of *Rhizophora mucronata* (2018 plantation); F. Members of BSI and NEWS team engaged in evaluation of plantation at Lakshmipur.

iv. Spot 4:

Avicennia alba: 3 (new, 50–55 cms)

Rhizophora mucronata: 1 (old, 80 cms); 3 (new, 40–45 cms)

Sonneratia apetala: 3 (old, 110–120 cms)

- New plants are from direct seed sowing (no nursery plant).

v. Spot 5:

Rhizophora mucronata: 5 (old, 120–130 cms); 3 (new, 50–55 cms)

Sonneratia apetala: 2 (new, c. 20 cms)

- New plants are from direct seed sowing (no nursery plant).

vi. Spot 6:

Sonneratia apetala: 1 (natural, 180–190 cms); 3 (nursery plants, 20–25 cms)

Avicennia alba: 13 (new plants; from direct seed sowing; 20–25 cms)

vii. Spot 7:

Rhizophora mucronata: 5 (old, 90–100 cms)

Sonneratia apetala: 1 (old, 130 cms)

viii. Spot A:

Sonneratia apetala: 2 (old, 100–110 cms)

Rhizophora mucronata: 4 (old, 120–125 cms)

- one plant is found damaged due to accidental cutting.

ix. Spot B:

Avicennia alba: 2 (new; 20–25 cms)

Sonneratia apetala: 3 (old, 100–105 cms)

Rhizophora mucronata: 4 (old, 120–125 cms)

A physically damaged planted sapling

Permanent spots A	Name of the species	Time of survey		Rate of survival
		March 2018	January 2019	
	Sonneratia apetala			
No. of plants		3	2	66.6%
	Rhizophora mucronata			
No. of plants		5	3	60%
Permanent spots B	**Name of the species**	**Time of survey**		**Rate of survival**
		March 2018	January 2019	
	Sonneratia apetala			
No. of plants		4	3	75%
	Rhizophora mucronata			
No. of plants		5	4	80%

Note: 2 newly planted saplings of *A.alba* were also found at Spot B

- **Other observations:**

a) *Avicennia alba* seeds were collected in large number in sacks which were small in size, stick together and difficult to count.

b) Collection *Rhizophora mucronata* seeds in huge number is not possible due to unavailability of seeds naturally in comparison to *A. alba*.

c) *Bruguiera gymnorhiza* was not observed in the nine survey spots, but a few plants were found in other locations of the plantation area.

d) Rate of survival of the nursery raised saplings were certainly high in comparison to direct seed sowing. It was observed by many experts studying various mangrove afforestation programmes that crabs damage the sprouting seeds by eating the hypocotyle. The chemical reaction that takes place in the sprouting seeds emits a gaseous smell that attracts the crabs. Nursery raised saplings also develop well established root system that enhance their survivability in the degraded area which are under extensive saline conditions. Though the mortality of direct seed plantation

was high in comparison to nursery raised saplings, both direct seed sowing and nursery sapling plantation were done to minimize the cost as the cost of nursery raised sapling was high.

e) The nursery raised saplings of > 40 cm length were suggested to be preferred for plantation due to the nature of the plantation area (covered with *Porteresia coarctata*) which could increase their surviving capacity.

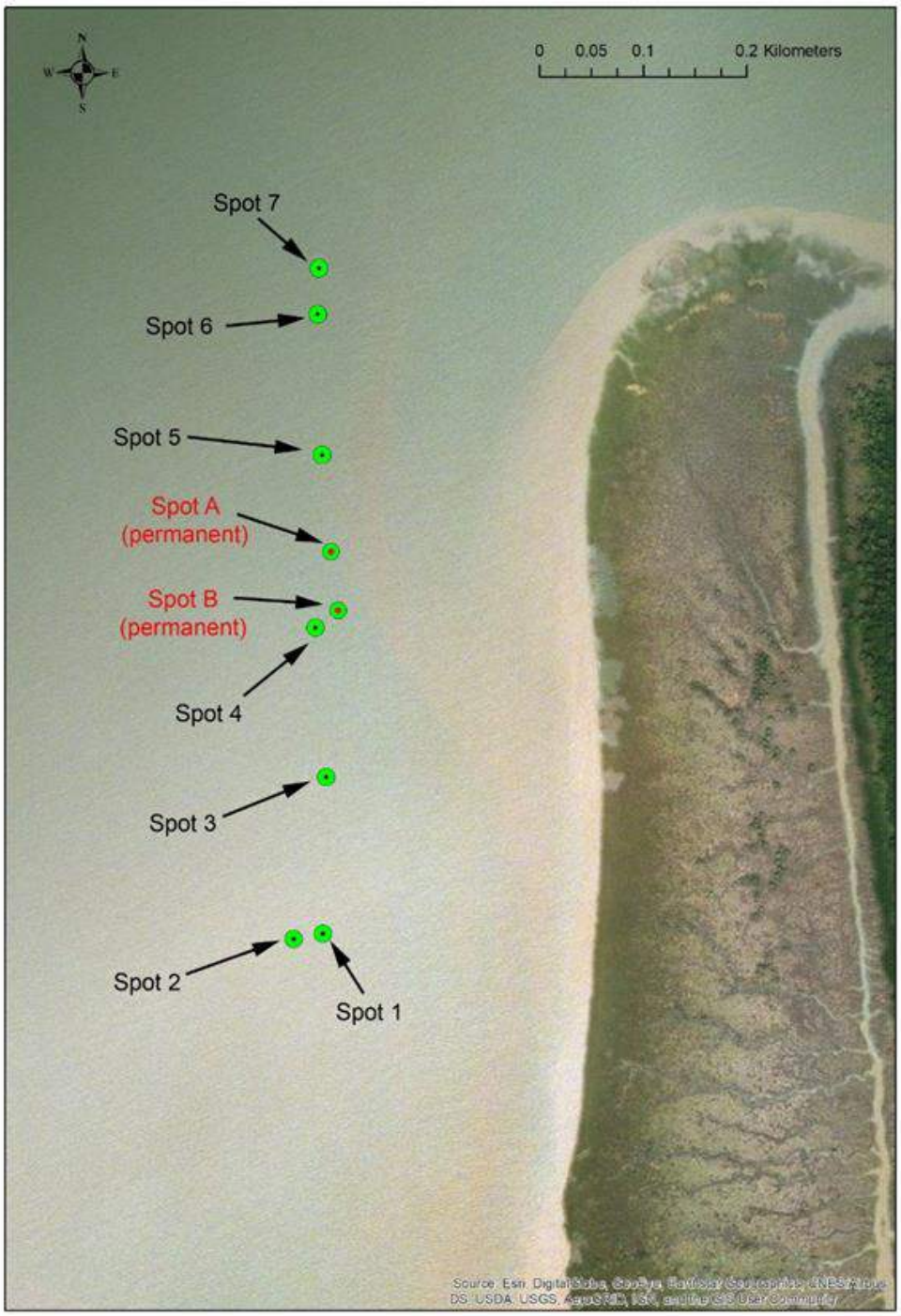
f) During this third survey, the **misidentification** of *Sonneratia alba* Sm. was detected (reported as *S. griffithii* Kurz in earlier reports). BSI team earlier observed the species in the plantation sites in seedling/ sapling stage and therefore, it was not possible to confirm its identity due to lack of flowers. Hence, BSI team had to follow the local name of the species by which it was known by the local people and field staff of NEWS. However, the detailed dissected photographs of floral parts taken by Mr. Paritosh Giri, one of the Field Officers of NEWS, helped BSI team to identify the species. Incidentally, before publishing this finding by BSI, Raghavan & al. (2019) published the similar finding and concluded that *S. griffithii* only occurs in Andaman & Nicobar Islands. Therefore, specimens/ plants from the Indian Sundarbans and Odisha, previously misidentified as *S. griffithii*, are actually *S. alba*.

Sonneratia alba: A. Plants in natural habitat; B. bud; C. Flower; D. Calyx lobe and part of gynoecium; F. Fruit; G. Fruit and sections of fruit (Photo: Paritosh Giri)

IV. Fourth survey:

- **Midterm evaluation report for the total restoration sites and recommendations**

The fourth survey was undertaken by BSI team in August 2019. During the survey data from nine spots (including two permanent spots) were taken.



Surveyed spots at Lakshmipur (submerged during high tide)

❖ Plants observed on the surveyed: (old plants of 2017 plantation & new plants of 2018 plantation either from direct seed or from nursery saplings)

i. Spot 1:

Rhizophora mucronata: 5 (90 cms)

Sonneratia apetala: 1 (110 cms)

ii. Spot 2:

Rhizophora mucronata: 7 (80 cms)

Sonneratia apetala: 4 (50 cms)

iii. Spot 3:

Rhizophora mucronata: 8 (80 cms)

iv. Spot 4:

Avicennia alba: 2 (1 planted, 50 cms; 1 natural, 10 cms)

Rhizophora mucronata: 3 (80 cms)

Sonneratia apetala: 1 (150 cms, natural)

v. Spot 5:

Avicennia alba: 1 (60 cms)

Rhizophora mucronata: 4 (70 cms)

vi. Spot 6:

Avicennia officinalis: 1 (70 cms, natural)

Rhizophora mucronata: 8 (100 cms)

Sonneratia apetala: 4 (90 cms)

vii. Spot 7:

Rhizophora mucronata: 6 (90 cms)

Sonneratia apetala: 4 (3 planted, 70 cms; 1 natural, 200 cms)

viii. Spot A:

Avicennia alba: 1 (natural, 30 cms)

Rhizophora mucronata: 3 (125–135 cms)

Sonneratia apetala: 3 [2 planted (120–130 cms); 1 natural (40 cms)]

ix. Spot B:

Avicennia alba: 3 [1 planted (60 cms); 2 natural (30–40 cms)]

Rhizophora mucronata: 3 (planted, 120–130 cms)

Sonneratia apetala: 3 [2 planted (115–120 cms); 1 natural (45 cms)

A, B, D. Planted mangrove saplings growing .at the Lakshmipur site; C, D. Measuring the height of planted saplings at Lakshmipur.

Comparative study of the permanent spots during the surveys

Permanent spot	March 2018		January 2019		August 2019	
	Name of the species with no. of individuals	**Heights of plants**	**Name of the species with no. of individuals**	**Heights of plants**	**Name of the species with no. of individuals**	**Heights of plants**
Spot A	*Rhizophora mucronata*: 5 (old)	65–75 cms	*R. mucronata*: 4 (old)	120–125 cms	*Avicennia alba:* 1 (natural) *R. mucronata*: 3 (old)	30 cms 125–135 cms
	Sonneratia apetala: 3 (old)	60–70 cms	*S. apetala*: 2 (old)	100–110 cms	*S. apetala*: 2 (planted), 1 (natural)	120–130 cms (2 planted); 40 cms (natural)

Survival percentage of planted mangroves at 'Spot A' till date: 62.5 %

Total no. of plants observed in March 2018	Total no. of plants observed in January 2019	Total no. of plants observed in August 2019
8	6	5

Survival percentage of overall mangroves at 'Spot A' (including naturally regenerated plants) till date: 87.5 %

Total no. of plants observed in March 2018	Total no. of plants observed in January 2019	Total no. of plants observed in August 2019
8	6	7

Permanent spot	March 2018		January 2019		August 2019	
	Name of the species with no. of individuals	**Heights of plants**	**Name of the species with no. of individuals**	**Heights of plants**	**Name of the species with no. of individuals**	**Heights of plants**
Spot B			*Avicennia alba:* 2 (new)	20–25 cms	*Avicennia alba:* 1 planted; 2 (natural)	60 cms (1 planted); 30–40 cms (2 natural)
	Rhizophora mucronata: 5 (old)	70–80 cms	*R. mucronata*: 4 (old)	120–125 cms	*R. mucronata* : 3 (planted)	120–130 cms
	Sonneratia apetala: 4 (old)	65–70 cms	*S. apetala*: 3 (old)	100–105 cms	*S. apetala*: 2 (planted), 1 (natural)	115–120 cms (2 planted); 45 cms (natural)

Survival percentage of planted mangroves at 'Spot B' till date: 66.66 %

Total no. of plants observed in March 2018	Total no. of plants observed in January 2019	Total no. of plants observed in August 2019
9	9	6

Survival percentage of overall mangroves at 'Spot B' (including naturally regenerated plants) till date: 100 %

Total no. of plants observed in March 2018	Total no. of plants observed in January 2019	Total no. of plants observed in August 2019
9	9	9

- **Observations**

The plantation of mangrove species in this site was started by NEWS in 2017 and in 2018, 8.3 ha area was newly planted. Two species were planted in 2017 viz., *Rhizophora mucronata* and *Sonneratia apetala*. Besides, populations of *P. coarctata* and a few naturally grown saplings of *Avicennia alba* and *Acanthus ilicifolius* were noticed. *Rhizophora mucronata* was the dominating species in this plantation site.

As it was observed at 'Buraburir Tot', similarly at Lakshmipur site survival rate of plants together with the naturally regenerated plants is equally satisfactory. At Lakshmipur which is a newly formed island, located in the western part of Indian Sundarbans undergo siltation from the fresh water carrying rivers. Deposition of sediments play a more dominant role in the island formation process.

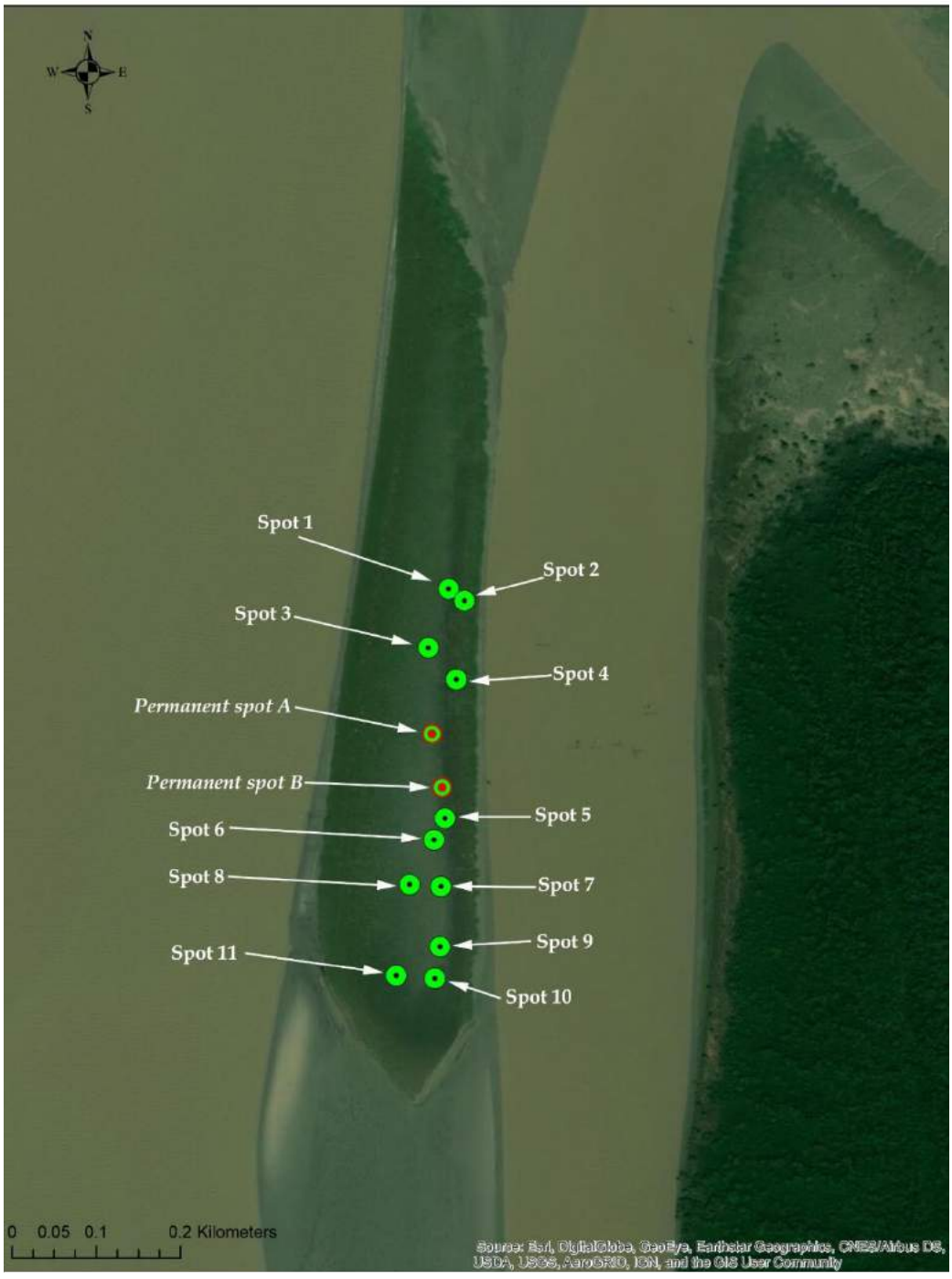
Sedimentation is a natural process of which an increase in sediments on the former top layer is established. Sedimentation causes land formation and does not result in any additional negative effect on trees. High sedimentation rate is causing an increase in the thickness of the upper soil layer. This process is known to be typical for mangrove ecosystems where it assures an essential import of nutrients. Moderate sedimentation rate can be positive for mangroves leading to enhanced growth of the trees. At Lakshmipur, *Rhizophora mucronata* plantation has been done in good numbers as they have complex aerial root structure phenomena. At the shallow water level, the effect of the drag force of aerial roots of *Rhizophora* sp. on the wave reduction increases but with the increase of water level, resulting in huge decrease in the rate of wave reduction (Mazda et al., 2006). *Rhizophora* plants due to their large amount of stilt roots, which appears less susceptible for forming a smothering layer of sediment and leave as such large root parts still capable of aeration. Mangrove plants shows adaptations to stress conditions in a similar way but some adaptations are species specific, including the increased vessel density for *Rhizophora* and the higher stomatal density for *Avicennia* spp. found in the siltation sites. It was noticed that the saplings were buried at least up to 3/4th of its height. It was suggested that selection of tall/mature saplings or well grown saplings from the nursery for plantation could be helpful in overcoming this disadvantage.

V. Fifth (final) survey:

- **Final Evaluation**

The fifth and the final survey was done by BSI team in March 2020 for final evaluation of the restoration process through mangrove plantation by NEWS. As per data provided by NEWS

total plantation area by the end of 2019 is 9.1 ha area. Proposed area for plantation was 12 ha. In 2017, 4 ha area was selected for plantation and successfully done. In 2018, 8.3 ha area was completed including replantation in some parts of the previous year plantation area. But due to erosion by the end of 2019 total area of mangrove plantation is 9.1 ha. This time the survey team selected 13 spots (including 2 permanent spots).



Surveyed spots at Lakshmipur

❖ Plants observed on the surveyed spots:

i. Spot 1:

Rhizophora mucronata: 2 (c. 110 cms; planted)

Sonneratia apetala: 4 (115–120 cms; planted)

ii. Spot 2:

Rhizophora mucronata: 6 (110–115 cms; planted)

Sonneratia apetala: 1 (120 cms; planted)

iii. Spot 3:

Avicennia alba: 1 (50 cms; re-planted)

Bruguiera gymnorhiza: 1 (70 cms; planted)

Rhizophora mucronata: 7 (90 cms; planted/ re-planted)

Sonneratia apetala: 3 (100–105 cms; planted)

iv. Spot 4:

Avicennia alba: 1 (80 cms; planted)

Rhizophora mucronata: 1 (100 cms; planted)

Sonneratia apetala: 9 (60–110 cms; planted/ re-planted)

v. Spot 5:

Rhizophora mucronata: 4 (50–60 cms; re-planted)

Sonneratia apetala: 5 (100 cms; planted)

vi. Spot 6:

Rhizophora mucronata: 7 (60–130 cms; planted/ re-planted)

Sonneratia apetala: 6 (80 cms; planted)

vii. Spot 7:

Avicennia alba: 13 (50–70 cms; planted/ re-planted)

Avicennia officinalis 1 (110 cms; natural)

Rhizophora mucronata: 3 (50–70 cms; planted/ re-planted)

Sonneratia apetala: 4 (180 cms; planted)

viii. Spot 8:

Rhizophora mucronata: 6 (60–90 cms; planted/ re-planted)

Sonneratia apetala: 3 (140–150 cms; planted)

ix. Spot 9:

Avicennia alba: 1 (50 cms; re-planted)

Rhizophora mucronata: 3 (80–90 cms; planted)

Sonneratia apetala: 7 (6 planted: 100–110 cms; 1 natural: c. 400 cms)

x. Spot 10:

Rhizophora mucronata: 3 (80 cms; planted)

Sonneratia apetala: 5 (4 planted: 190–200 cms; 1 natural: 350 cms)

xi. Spot 11:

Rhizophora mucronata: 4 (135–140 cms)

Sonneratia apetala: 1 (100 cms; planted)

xii. Spot A (Permanent spot):

Avicennia alba: 1 (80 cms; planted)

Rhizophora mucronata: 3 (90–110 cms; planted/ re-planted)

Sonneratia apetala: 7 (80–100 cms; planted/ re-planted)

xiii. Spot B (Permanent spot):

Avicennia alba: 2 (1 planted: 80 cms; 1 natural: 70 cms)

Rhizophora mucronata: 3 (80–160 cms; planted/re-planted)

Sonneratia apetala: 8 (75–100 cms; planted/re-planted)

Lakshmipur intertidal mangrove habitat

A, B, F. BSI team surveying different spots of plantation area; C. Naturally regenerated sapling of *Sonneratia apetala*; D. Roots of *Rhizophora mucronata*; E. Sapling of *R. mucronata* along with naturally regenerated saplings of *A. ilicifolius*; G. Plantation area with mangroves.

A & B. Member(s) of the survey team with women of 'Lakshmishree Mohila Badabon Committee'

Comparative study of the permanent spots during the surveys

Permanent spot	March 2018		January 2019		August 2019		March 2020	
	Name of the species with no. of individuals	**Heights of plants**	**Name of the species with no. of individuals**	**Heights of plants**	**Name of the species with no. of individuals**	**Heights of plants**	**Name of the species with no. of individuals**	**Heights of plants**
Spot A	*Rhizophora mucronata*: 5 (old)	65–75 cms	*R. mucronata*: 4 (old)	120–125 cms	*Avicennia alba:* 1	30 cms (natural)	*Avicennia alba:* 1	80 cms (planted)
	Sonneratia apetala: 3 (old)	60–70 cms	*S. apetala*: 2 (old)	100–110 cms	*R. mucronata*: 3	125–135 cms (planted)	*R. mucronata*: 3	90–110 cms (planted/ re-planted)
					S. apetala: 3	120–130 cms (2 planted); 40 cms (1 natural)	*S. apetala*: 7	80–100 cms (planted/ re-planted)

Survival percentage of planted mangroves at 'Spot A' since March 2018 to March 2020: 137.5 %*

Total no. of plants observed in March 2018	Total no. of plants observed in January 2019	Total no. of plants observed in August 2019	Total no. of plants observed in March 2020
8	6	5	11

*It should be noted that the number of planted mangroves includes some re-planted saplings and thus, the survival percentage appears to be high.

Survival percentage of overall mangroves at 'Spot A' (including naturally regenerated plants) since March 2018 to March 2020: 137.5 %

Total no. of plants observed in March 2018	Total no. of plants observed in January 2019	Total no. of plants observed in August 2019	Total no. of plants observed in March 2020
8	6	7	11

Permanent spot	March 2018		January 2019		August 2019		March 2020	
	Name of the species with no. of individuals	**Heights of plants**	**Name of the species with no. of individuals**	**Heights of plants**	**Name of the species with no. of individuals**	**Heights of plants**	**Name of the species with no. of individuals**	**Heights of plants**
Spot B			*Avicennia alba:* 2	20–25 cms	*A. alba:* 3	60 cms (1 planted); 30–40 cms (2 natural)	*A. alba:* 2	80 cms (1 planted); 70 cms (1 natural)
	Rhizophora mucronata: 5 (old)	70 – 80 cms	*R. mucronata*: 4	120–125 cms	*R. mucronata*: 3	120 – 130 cms (planted)	*R. mucronata*: 3	80–160 cms (planted/re-planted)
	Sonneratia apetala: 4 (old)	65 – 70 cms	*S. apetala*: 3 (old)	100–105 cms	*S. apetala*: 3	115 – 120 cms (2 planted); 45 cms (1 natural)	*S. apetala*: 8	75–100 cms (planted/re-planted)

Survival percentage of planted mangroves at 'Spot B' since March 2018 to March 2020: 133.3 %*

Total no. of plants observed in March 2018	Total no. of plants observed in January 2019	Total no. of plants observed in August 2019	Total no. of plants observed in March 2020
9	9	6	12

*It should be noted that the number of planted mangroves includes some re-planted saplings and thus, the survival percentage appears to be high.

Survival percentage of overall mangroves at 'Spot B' (including naturally regenerated plants) since March 2018 to March 2020:

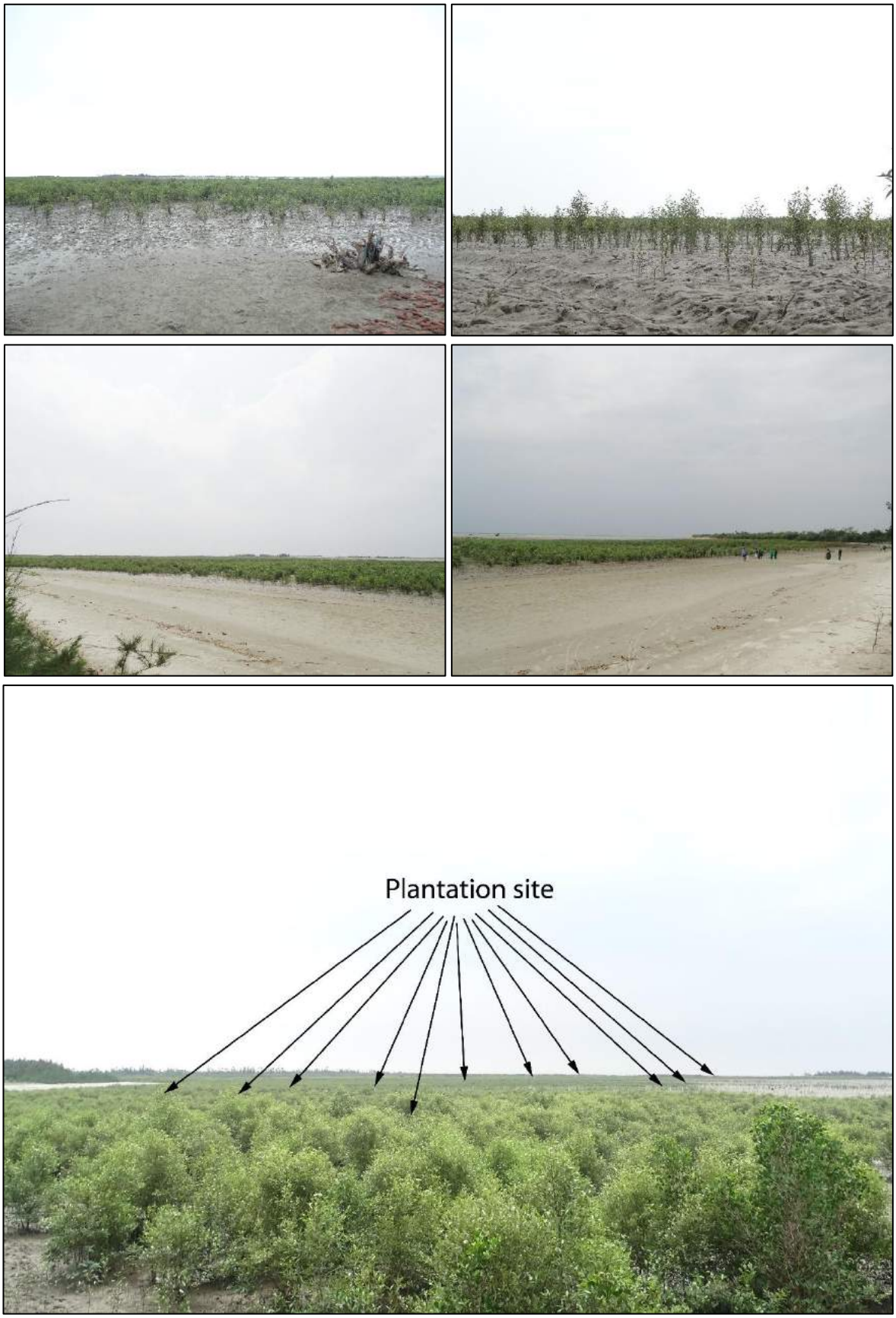
144.4 %

Total no. of plants observed in March 2018	Total no. of plants observed in January 2019	Total no. of plants observed in August 2019	Total no. of plants observed in March 2020
9	9	9	13

5. CONCLUSION:

The overall restoration process at ‘Buraburir Tot’ is found to be very successful. The difference of mangrove vegetation at the plantation site from March 2018 to March 2020 is clearly visible from the GIS maps (showed under fifth survey) and photographs taken during the evaluation process which justifies the effective afforestation program carried out by NEWS. The same has also been interpreted from the data recorded from different spots (including permanent spots) during the surveys. The survival percentage of planted mangrove at ‘Boraburir Tot’ varies between 50–62.5 %, whereas it is between 162.5–240 % for overall restoration (including naturally regenerated mangroves).

Plantation area in March 2018



Plantation area in March 2020

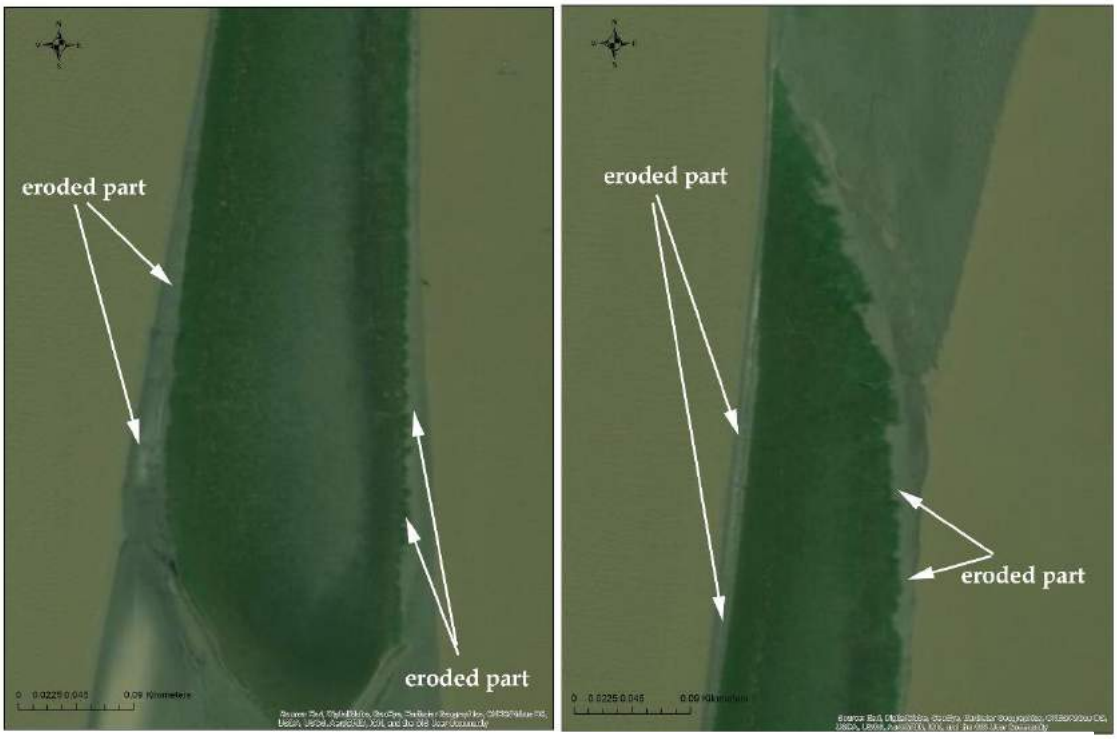
Plantation area of 'Buraburir Tot' in March 2018

Plantation area of 'Buraburir Tot' in March 2020

Similarly, the overall restoration process at ‘Lakshmipur intertidal mangrove habitat’ is also successful, but comparatively to a smaller extent when compared with ‘Buraburir Tot’. In Sundarbans it is already known that mangrove forest formation from siltation nearly equals to the loss of mangrove forests by erosion. It has been prominent during the last visit that due to tidal erosion in intertidal mangrove habitat of Lakshmipur (at edges), certain area with planted mangroves have been eroded. This is perhaps due to the fluctuating water flow of the river affected by anthropogenic activities along with rising sea level. Another factor which has affected somehow the overall plantation process is very high siltation. Further, the plantation site is covered by naturally grown mangrove grass *Porteresia coarctata* which has played both positive as well as negative impact on the complete plantation process. It protected the uprooting of planted mangroves by the tidal waves and flow of the river, but simultaneously assisted high siltation causing mortality and retarded growth of some of the planted saplings. However, NEWS carried out re-plantation frequently to overcome these difficulties. At present, with well-established plants and re-planted saplings, the overall plantation process at Lakhimpur appears to be effective with visible improvement. The survival percentage of planted mangrove at ‘Lakshmipur intertidal mangrove habitat’ varies between 133.3–137.55 % (including re-planted saplings), whereas it is between 137.5–144.4 % for overall restoration (including naturally regenerated mangroves).

Plantation site of Lakshmipur intertidal mangrove habitat in March 2018

Plantation site of Lakshmipur intertidal mangrove habitat in March 2020



GIS maps showing some affected parts of plantation site of Lakshmipur intertidal mangrove habitat due to erosion

Erosion of land at western part of Lakshmipur intertidal mangrove habitat

Dying saplings at Lakshmipur intertidal mangrove habitat probably due to high siltation

The most notable point of this overall restoration process at ‘Buraburir Tot’ and ‘Lakshmipur intertidal mangrove habitat’ is the increase in floral and faunal diversity supporting the enhancement of the ecosystem and its services. Several species of birds, animals and insects are nowadays frequently visible at the plantation sites. Numbers of Horseshoe crab (considered as ‘Living fossil’), Fiddler crab have been increased at ‘Buraburir Tot’ along with many other species of crabs, shrimps, small fishes and other marine organisms.

Some parts of the plantation area of ‘Buraburir Tot’ showing: A. Horse shoe crab; B. Fiddler crab; C. Red Ghost Crab; D. Mud crab; E. Common Mudskipper fish; F. Colony of molluscs.

Some parts of the plantation area of ‘Buraburir Tot’ showing: A. Kingfisher; B. Curlew; C. Pond Heron; D. Little black Cormorant; E. Ashy Drongo; F. Black Drongo; G. Sea Gull; H. Green bee eater.

Some parts of the plantation area of 'Lakshmipur intertidal mangrove habitat' showing: A. Increased population of mud crab; B. An unidentified species of crab; C. Paddler Crab; D. Bird's nest.

Crabs are keystone species in the mangrove forests and the population of crabs at Lakshmipur intertidal mangrove habitat has increased significantly. This means the presence of this animal in the community makes it possible for many other species to survive there. The crabs complete their larval stage in the water underneath mangroves. Once they are mature, they creep on the mangroves and feed on the leaves. They grow in large numbers and are crucial in the processing of the leaf litter. They also burrow the soil. The micro-topography of the bottom will be improved and the soil becomes aerated. This decline the sulphide levels in the soil and positively influence the productivity of the trees.

6. REMARKS/ RECOMMENDATIONS

- Restoration in both the sites is still in developing conditions and for well establishing the mangroves at these sites requires 4 to 5 years of further monitoring and re-plantation (where necessary). The women groups who are skilled in mangrove afforestation in these two sites should be encouraged to continue the monitoring and maintenance of the plantation sites.
- NEWS has already initiated the empowerment of women in Sundarbans through backward poultry farming to strengthen the ecosystem conservation. The women groups were provided with chicks and poultry feeds at the initiation stage of this project. Obtaining chicks are very important in backyard poultry farming for auto regeneration of the flock. Natural hatching process is quite laborious and time consuming. Various reports thus clearly indicate a shift from traditional practice of natural hatching towards artificial hatching by incubators. After face to face discussion with the local women group during the survey it has been noted that they require incubators for hatching eggs to increase the number of poultry chicks. Without taking any measures for this problem the objective of this project to provide alternative income generation cannot be attained. It may also affect the community participation in mangrove restoration.
- Some other strong alternative livelihood options are also required for the development of these remote areas so that the people engaged in restoration process can develop awareness among the villagers about the alternative livelihood options without disturbing the mangroves, which will ensure the long term protection of these newly formed mangrove forests.

- The presence of highly invasive alien species, viz. *Prosopis juliflora* was noted at the sand dune and nearby area of the plantation site of 'Buraburir Tot' during the first survey (also mentioned in the first report). The population of this species is increasing highly and if proper management measures are not taken with help of forest department and local community, it will severely affect the biodiversity of the area.

Prosopis juliflora – one of the world's worst invasive plant species is in flowering/ fruiting stage at 'Buraburir Tot'

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