

Competitive Research Grant
Sub-Project Completion Report

on

**Management of acid soils for sustainable crop
production in Madhupur Tract and Northern &
Eastern Piedmont Plains**

Project Duration

May 2017 to September 2018

**Department of Soil Science,
Bangladesh Agricultural University
Mymensingh**



Submitted to
Project Implementation Unit-BARC, NATP 2
Bangladesh Agricultural Research Council
Farmgate, Dhaka-1215



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Acronyms

AEZ	Agroecological Zone
BAU	Bangladesh Agricultural University
CV	Co-efficient of Variation
Lime1	Dololime @ 1 t/ha
Lime2	Dololime @ 2 t/ha
OM1	Cowdung
OM2	Poultry manure
ppm	Parts per million
RCBD	Randomized Complete Block Design
SE	Standard error of means
T. aman	Transplanted aman

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Executive Summary

The sub-project belongs to the research area, Natural Resources (Land and Soil Resources) under the thematic area, 'Ecologically Unfavorable Land and Soil Management. The goal of this project was to improve the crop productivity in the acid prone areas of Madhupur Tract and Northern & Eastern Piedmont Plains for sustaining food security. This is a 17 months project from May 2017 to September 2018. The sub-project has two main objectives: i) to determine lime and organic manure requirement to attain suitable pH for field crop production and ii) to evaluate the effect of lime and organic matter amendment on yield and nutrient uptake of major crops of the cropping patterns. The project activities were started from 09 May 2017. In this reporting period, major activities were focused on soil sample collection, chemical analysis of soil and plant samples, field experiment setup, and harvesting and data recording of crops. Project manpower, one Lab Technician, one Part-time Accountant and one MS student were appointed. Required laboratory spaces were prepared for project activities. Two sites were selected for field experiments one in Nalitabari and the another one in Fulbaria Upazila covering acid soils of AEZ 22 (Northern and Eastern Piedmont Plains) and AEZ 28 (Madhupur Tract), respectively. Soil samples were collected at 0-15 cm depth from two AEZs covering two upazilas. Soil samples were analyzed for soil pH, texture, organic carbon and nutrients status (N, P, K& S). Considering the pH values of the soil samples collected, one site was selected for each upazila for conducting field experiment with different cropping patterns. Three cropping patterns viz. T. Aman rice - Wheat - Mungbean, T. Aman rice -Maize - Fallow and T. Aman rice -Mustard - Boro were followed for field experiments. All the crops were harvested at maturity and then data were recorded. Then plant samples were analyzed for N, P, K and S contents. All crops showed reductions in grain/seed and straw/stover yields in acid prone areas of Nalitabari and Fulbaria. On the other hand, application of lime showed an increase in grain/seed and straw/stover yields of crops in three cropping patterns. Additionally, organic manure alone or in combination with lime considerably increased yields of all crops. It might be concluded that addition of lime and organic manure to acid soils is beneficial for achieving sustainable crop productivity in the areas of Madhupur Tract and Northern & Eastern Piedmont Plains.

CRG Sub-Project Completion Report (PCR)

A. Sub-project Description

1. Title of the CRG sub-project: Management of acid soils for sustainable crop production in Madhupur Tract and Northern & Eastern Piedmont Plains
2. Implementing organization: Bangladesh Agricultural University
3. Name and full address with phone, cell and E-mail of PI / Co – P (s):
Principal Investigator: Dr. Md. Anamul Hoque
Professor
Department of Soil Science
Bangladesh Agricultural University, Mymensingh-2202
Cell: 01741-390715
Email: anamul71@yahoo.com
4. Sub-project budget (Tk):
4.1 Total: approved Budget (Taka) 24,81,575.00
4.2 Revised (if any): N/A
5. Duration of the sub-project:
5.1 Start date (based on LoA signed) : 09 May 2017
5.2 End date : 30 September 2018
6. Justification of undertaking the sub-project:

Land degradation is a major threat to food and environmental security of Bangladesh. In this regard, acid soils are an important issue because of its adverse effect on soil fertility and crop productivity. Geomorphologically acid sulphate soils, peat soils, acid basin clays, terrace soils, piedmont soils and hill soils are slightly acidic to strongly acidic in nature. Considering 30 agro-ecological zones (AEZ) of the country, strongly acid soils occur in Old Himalayan Piedmont Plain (AEZ 1), Lower Purnabhaha Flodplain (AEZ 6), Ganges Tidal Floodplains containing acid sulphate soils (AEZ 13), Gopalganj-Khulna Bils containing peat soils (AEZ 14), Arial Bil (AEZ 15), Sylhet Basin (AEZ 21), Northern and Eastern Piedmont Plains (AEZ 22), Chittagong Coastal Plains having acid sulphate soils (AEZ 23), Level Barind Tract (AEZ 25), North Eastern Barind Tract (AEZ 27), Madhupur Tract (AEZ 28), and Northern and Eastern Hills (AEZ 29). It is estimated that soils of 0.25 Mha lands across the country are very strongly acidic (pH <4.5), 3.71 Mha lands are strongly acidic (pH 4.5-5.5), and 2.74 Mha lands are slightly acidic (pH 5.6-6.5) (SRDI GIS map, 2010). Acid soils may constraint crop production in more than 30% of lands of Bangladesh.

Acid soils possess toxic concentrations of Al^{3+} , Fe^{3+} and Mn^{2+} , lower concentrations of P and low availability of bases which together cause reduction in crop yield. Legumes are highly affected due to soil acidity. Acidity limits both survival and persistence of nodule bacteria in soil, and the process of nodulation itself. Acidic soils

(pH<5.5) affects plant growth directly or indirectly by influencing the availability of plant nutrients, particularly phosphorus, secondary nutrients (Ca, Mg) and micronutrients (Mo, B and Zn), reducing microbial activity and creating toxicity of Fe and Mn (Al in some cases) (Havlin *et al*, 2016). Soil acidification may intensify and affect crop production if effective management strategies for amelioration are not implemented (Rossel and Mc Bratney, 2001).

Optimum crop growth and efficient use of organic and inorganic fertilizers in acid soils require an addition of lime to eliminate the toxic effects of Fe, Al, H and Mn. Liming is needed to achieve a soil pH at which available Fe, Al or Mn levels are no longer toxic. Regular application of well decomposed organic matter in acid soils is useful to prevent sudden fluctuation of soil pH as it improves the buffer capacity of soils. Moreover, it increases the availability of P and reduces the toxicity of Fe and Al in acid soils. The main reason why organic matter raises soil pH is due to the presence of calcium and magnesium elements in it and its buffer capacity because of forming complexes with Al and Fe in acid soils. Organic matter offers many negatively charged sites to bind H^+ in an acidic soil, or from which to release H^+ in a basic soil, in both cases pushing soil solution towards neutral. The application of composted lime treated organic matter to a slightly acidic soil increased soil pH to between 6.7 and 7.3 pH (Bickelhaupt, 1989). In a comparative study, organic manures and NPK fertilizer in acid soil significantly increased soil available P, pH, organic C and cation exchange capacity (Adeniyani *et al*, 2011). Kheyrodin and Antoun (2012) found that organic matter increased significantly soil P, Ca and Mg contents in the 15–30 cm depth. Combined lime and organic fertilizer had a significant effect on the yield and yield contributing characters. The improvement was attributed to the integrated effect of the amendments by improving soil pH, microbial activity, nutrient release from organic matter decomposition and improved soil structure as well. Sporadic works have been conducted on the effect of liming and organic amendments on crop productivity. Bodruzzaman (2009) demonstrated increased yield of wheat (35%) and maize (38%) due to application of 1 t lime/ha over no lime application. The effects of lime and organic matter are also to be known in acid soils of Madhupur Tract and Northern & Eastern Piedmont Plains of Bangladesh. However, sufficient data are not available on the management of acid soils in Madhupur Tract and Northern & Eastern Piedmont Plains of Bangladesh. Therefore, the proposed project was undertaken to investigate the management of acid soils in Terrace and Piedmont soils of Madhupur Tract and Northern & Eastern Piedmont Plains of Bangladesh for sustainable crop production.

7. Sub-project goal: Improvement of crop productivity in the acid prone areas of Madhupur Tract and Northern & Eastern Piedmont Plains for sustaining food security

8. Sub-project objective (s):
- i) To determine lime and organic manure requirement to attain suitable pH for field crop production.
 - ii) To evaluate the effect of lime and organic matter amendment on yield and nutrient uptake of major crops of the cropping patterns.
9. Implementing location (s):
- Field experiments:** Farmers' fields at Bisgiripara village, Ramchandrakura Union of Nalitabari Upazila under AEZ 22 (Northern and Eastern Piedmont Plains), and Nischintopur village, Bakta Union of Fulbaria Upazila under AEZ 28 (Madhupur Tract)
- Lab. analysis:** Department of Soil Science, Bangladesh Agricultural University, Mymensingh.

10. Methodology in brief:

Both laboratory and field studies were carried out for the project. However, the following approaches and methodologies were used to achieve the objectives of the proposed research project.

Expt. 1: Delineation of soil pH, soil texture, organic carbon and nutrient status in terrace and piedmont soils
Initial soil samples were collected based on land type and soil texture from two AEZs representing terrace (AEZ 28, Madhupur Tract) and piedmont (AEZ 22, Northern and Eastern Piedmont Plains) soils of intensively cropped areas. GPS (Global positioning system) reading was recorded on every site of sample collection. A total of 45 composite soil samples were collected from the two AEZs covering two upazilas (Nalitabari and Fulbaria), 2 unions/upazila, 2 villages/union, 5 sampling spots/village and 3 samples/spot (composite). Soil samples from each spot were collected at 0-15 cm depth. Soil samples were analyzed for soil pH, texture, organic carbon and nutrient status (N, P, K& S).

Expt. 2: Field experiments to evaluate the effect of lime and organic matter amendment on yield and nutrient uptake of major crops (cereals)

Locations: Piedmont soils - AEZ 22 (Northern and Eastern Piedmont Plains)

Terrace soils - AEZ 28 (Madhupur Tract)

Sites: Bisgiripara village of Ramchandrakura Union under Nalitabari Upazila

Nischintopur village of Bakta Union under Fulbaria Upazila

Crops:

Cereals - T. Aman rice, Boro rice, Wheat, Maize

Pulse - Mungbean

Oilseed - Mustard

Cropping patterns (for both sites):

T. Aman rice -Wheat -Mungbean

T. Aman rice -Maize - Fallow

T. Aman rice -Mustard - Boro

Treatments (for both sites):

- T₁: Control
 T₂: Lime1
 T₃: Lime2
 T₄: OM1
 T₅: OM2
 T₆: Lime1 OM1
 T₇: Lime1 OM2
 T₈: Lime2 OM1
 T₉: Lime2 OM2

N.B.: Lime1: Dololime @ 1 t/ha; Lime2: Dololime @ 2 t ha⁻¹; OM1: Cowdung @5 t⁻¹; OM2: Poultry manure @3 t⁻¹.

The first crop only received these treatments; their residual effects were noticed on the next crop(s) for the cropping pattern experiments.

Addition of nutrients: N, P, K, S, Zn & B (recommended and equal rates for all plots for all crops according to FRG, BARC-2012)

Table A: Fertilizer recommendation for the crops (AEZ-28) according to FRG-2012

Nutrients(kg ha ⁻¹)	Wheat	Mungbean	T. Aman	Maize	Mustard	Boro
N	120	18	90	255	90	150
P	30	27	10	75	27	20
K	60	36	35	80	32	65
S	10	18	8	36	10	12
Zn	1.3	2	-	10	2.5	1.3
B	0.6	1	1	1.4	0.6	-

Table B: Fertilizer recommendation for the crops (AEZ-22) according to FRG-2012

Nutrients(kg ha ⁻¹)	Wheat	Mungbean	T. Aman	Maize	Mustard	Boro
N	120	18	90	255	90	150
P	30	18	10	75	27	20
K	60	24	35	120	32	66
S	15	12	8	52	15	18
Zn	1.3	2	1	4	1	1.3
B	-	1.2	-	1.4	1	-

Design: Randomized Complete Block Design (RCBD)

Crop Harvesting and Data Collection: The crops were harvested at maturity. Yield contributing characters, and grain and straw yields were recorded. Plant samples were kept for chemical analysis.

11. Results and discussion:

Soil properties

A total of 45 soil samples were collected from Nalitabari (AEZ 22) and Fulbaria (AEZ 28) Upazilas. Soil samples were dried, ground, sieved and got ready for analysis. All the soil samples were analyzed for soil texture, soil pH, organic carbon, total N, and available P, K & S.

Particle size distribution and soil texture

Among the soils of Nalitabari upzila, sandy loam was the dominating texture. Out of 25 soils, 12 were sandy loam and 9 were loam. However, in Fulbaria upazila, the silt loam texture was prominent. Out of 20 soils, 15 were silt loam.

Soil pH, organic carbon and total N status of soils

Data on soil pH, organic carbon and total N have been reported in Table 1. The pH of soils demonstrated that all the soils comprised pH values less than 5 except one soil of Fulbaria location whose pH was 5.11. This indicates that the soils studied were strongly acidic in nature. Organic carbon status of soil varied from 0.502 to 1.351% in Nalitabari location whereas it ranged from 0.502 to 1.236% in Fulbaria. The total N of Nalitabari site ranged from 0.067 to 10.123% while in Fulbaria site the values varied from 0.078 to 0.157%.

Available P, K and S status of soils

The available P, K and S status of soils under study are presented in Table 2. The available P, K and S contents of soils varied from soil to soil in both Nalitabari and Fulbaria locations. The P status of soils was a bit low due to strong acidity. In Nalitabari location, out of 25 soils, 15 soils showed P values less than critical level of 10 ppm indicating P deficiency. However, in Fulbaria location, all the soils except three samples demonstrated P values less than 10 ppm. The K status of soils was also low in both locations ranging from 15.10 to 92.55 ppm in Nalitabari site whereas 16.08 to 98.43 ppm in Fulbaria site. Regarding the S status, 10 soils of Nalitabari and 8 soils of Fulbaria Upazila showed S values of less than 10 ppm indicating P deficiency.

Lime recommendation

Based on soil pH values, two doses of lime were decided for field experiments such as Dololime 1 t ha⁻¹ and Dololime 2 t ha⁻¹.

Site Selection

Since all the soils studied were strongly acidic, Bisgiripara Village of Ramchandrakura Union under Nalitabari Upazila and Nishchintopur Village of Bakta Union under Fulbaria Upazila were selected for field trials.

Table 1. Soil pH, organic carbon and total N of the soils under study (Background data)

Locations/Soils	pH	% Organic Carbon	Total N (%)
Nalitabari			
1	4.66±0.057	0.888±0.141	0.123±0.018
2	4.78±0.028	0.772±0.014	0.073±0.010
3	4.42±0.141	0.850±0.042	0.095±0.007
4	4.53±0.099	0.927±0.004	0.118±0.011
5	4.42±0.106	0.927±0.010	0.106±0.007
6	4.18±0.113	0.618±0.006	0.084±0.006
7	4.23±0.141	0.618±0.003	0.067±0.20
8	4.12±0.170	0.502±0.005	0.056±0.006
9	3.98±0.028	0.811±0.016	0.095±0.014
10	4.11±0.078	1.004±0.006	0.106±0.011
11	3.99±0.042	0.734±0.006	0.090±0.014
12	3.81±0.064	0.888±0.003	0.095±0.007
13	4.02±±0.092	0.695±0.007	0.101±0.009
14	3.89±0.127	0.772±0.003	0.067±0.001
15	3.88±0.028	0.811±0.008	0.084±0.006
16	4.01±0.057	0.927±0.010	0.112±00.017
17	4.13±0.042	0.811±0.016	0.101±0.006
18	4.12±0.099	0.811±0.006	0.106±0.004
19	4.11±0.156	0.850±0.014	0.106±0.006
20	3.96±0.057	1.004±0.004	0.106±0.004
21	4.10±0.071	0.811±0.003	0.118±0.003
22	3.99±0.042	0.850±0.014	0.118±0.007
23	3.93±0.042	1.351±0.028	0.129±0.004
24	4.47±0.099	0.734±0.006	0.067±0.004
25	4.26±0.085	1.236±0.014	0.140±0.014
26	4.54±0.170	1.043±0.014	0.067±0.004
Fulbaria			
27	4.62±0.078	0.850±0.028	0.078±0.003
28	4.89±0.127	0.579±0.014	0.078±0.010
29	4.60±0.141	0.772±0.005	0.129±0.018
30	4.59±0.127	1.274±0.014	0.129±0.013
31	4.52±0.085	0.734±0.008	0.095±0.007
32	4.56±0.057	0.734±0.014	0.084±0.006
33	4.31±0.120	0.734±0.006	0.095±0.004
34	3.96±0.057	0.618±0.011	0.078±0.006
35	4.43±0.071	1.236±0.020	0.140±0.007
36	4.75±0.071	1.081±0.028	0.140±0.004
37	4.97±0.049	1.274±0.014	0.134±0.006
38	4.62±0.106	1.081±0.014	0.140±0.006
39	4.92±0.113	0.850±0.007	0.134±0.004
40	4.86±0.198	0.502±0.014	0.084±0.004
41	4.63±0.042	1.236±0.051	0.151±0.006
42	4.68±0.113	1.004±0.057	0.157±0.157
43	4.43±0.134	1.081±0.014	0.129±0.013

44	5.11±0.156	0.850±0.014	0.101±0.010
45	4.48±0.113	0.850±0.028	0.112±0.003

Data are the means of three replicates (n =3)

Table 2. Available P, K and S status of soils under study(Background data)

Locations/Soils	Available P (ppm)	Available K (ppm)	Available S (ppm)
Nalitabari			
1	6.93	22.94	1.67
2	6.48	17.06	3.13
3	12.77	20.98	8.96
4	15.66	38.63	18.54
5	7.38	18.04	6.67
6	6.80	22.94	26.46
7	10.27	15.10	7.50
8	6.93	15.10	22.71
9	12.90	25.88	7.29
10	30.74	45.49	33.75
11	7.70	19.02	17.08
12	55.46	44.51	25.63
13	3.21	20.00	12.71
14	3.27	17.06	16.46
15	8.54	17.06	6.04
16	5.65	34.71	13.96
17	16.30	61.18	8.13
18	10.46	29.80	35.00
19	5.52	27.84	7.08
20	8.54	33.73	28.75
21	4.24	27.84	22.92
22	9.69	25.88	13.75
23	5.33	29.80	18.13
24	25.16	92.55	13.75
25	22.66	35.69	6.04
Fulbaria			
26	16.62	25.88	14.17
27	7.77	16.08	3.96
28	7.70	28.82	23.54
29	6.68	20.00	4.38
30	7.77	23.92	4.38
31	3.92	90.59	8.54
32	7.38	98.43	8.13
33	5.84	20.98	15.00
34	5.46	44.51	11.67
35	2.37	32.75	53.54
36	5.46	28.82	13.75
37	7.89	26.86	25.00
38	6.74	27.84	7.92
39	4.30	28.82	17.92
40	10.59	20.00	20.00

41	8.28	33.73	9.58
42	5.33	28.82	12.08
43	11.87	27.84	12.29
44	7.51	22.94	12.92
45	9.56	25.88	8.75

Growth and crop yields in T. Aman rice - Wheat - Mungbean cropping pattern

Seedlings of T. Aman rice cv. BINA dhan7 were transplanted in Nalitabari Upazila and those of BRRI dhan71 were transplanted in Fulbaria Upazila. Seeds of wheat cv. BARI Gom-30 and mungbean cv. BARI Mung-6 were sown in the both Nalitabari and Fulbaria experimental locations. T. aman rice, wheat and mungbean were harvested at maturity. The data on yield components, grain and straw yields were recorded. Most cases, plants grown in acid soils without lime and organic manure treatments caused significant decreases in growth, yield contributing characters (data not shown) and grain and straw yields of T. aman rice and wheat, and grain yield of mungbean whereas addition of lime or organic manure to acid soils significantly increased grain and straw yields of crops (Tables 3-4). Application of lime and manure did not increase significantly straw yields of T. aman rice in Fulbaria Upazila. However, the effect of lime was more effective in increasing yield of crops than that of organic manure. Combined application of lime and organic manure also significantly improved the grain and straw yields of crops.

Growth and crop yields in T. Aman rice -Maize – Fallow cropping pattern

Seedlings of T. Aman rice cv. BINA dhan7 were transplanted in Nalitabari Upazila and those of BRRI dhan71 were transplanted in Fulbaria Upazila. Seeds of maize cv. BARI Hybrid Maize-9 were sown in both locations. Except straw yield of T. aman rice in Fulbaria, addition of lime or organic manure to acid soils significantly increased grain and straw yields of T. aman rice (Tables 5-6). Except stover yield of maize in Nalitabari, application of lime or organic manure significantly increased grain and stover yields in acid soils. Combined application of lime and organic manure significantly improved the grain and straw/stover yields of T.aman rice and maize.

Growth and crop yields in T. Aman rice -Mustard – Boro rice cropping pattern

Seedling of T. aman rice cv. BINA dhan7 in Nalitabari and BRRI dhan71 in Fulbaria were transplanted for adopting cropping pattern T. Aman rice -Mustard - Boro rice. Seedlings of boro rice cv. BRRI dhan28 were transplanted in both locations. Seeds of mustard cv. BARI Sorisha14 were also sown in both locations. Results showed that plants grown in acid soils without lime and organic manure treatments caused significant decreases in growth, yield contributing characters (data not shown), and grain/seed and straw/stover yields of most crops. On the other hand, addition of lime or organic manure to acid soils significantly increased grain/seed and straw/stover yields of all crops (Tables 7-8). In T. Aman rice -Mustard - Boro rice cropping pattern, the effect of lime was also more effective than that of organic manure. Furthermore, combined application of lime and organic manure remarkably improved the grain/seed and straw/stover yields of all crops.

Table 3: Effect of lime and organic matter amendment on the growth and yield of T. Aman rice - Wheat - Mungbean cropping pattern in acid prone area of Nalitabari

Treatment	T - Aman rice		Wheat		Mungbean
	Grain yield (t ha ⁻¹)	Straw yield (t ha ⁻¹)	Grain yield (t ha ⁻¹)	Straw yield (t ha ⁻¹)	Grain yield (t ha ⁻¹)
T ₁ : Control	4.24f	4.51d	2.17f	3.11e	0.60f
T ₂ : Lime 1	4.36e	4.67bcd	2.97c	4.16c	1.03cd
T ₃ : Lime 2	4.39e	4.62cd	3.07bc	4.28bc	1.13c
T ₄ : OM1	4.4e	4.7bcd	2.39e	3.41de	0.84e
T ₅ : OM2	4.73c	4.78abc	2.62d	3.7d	0.90de
T ₆ : Lime1 OM1	4.23f	4.58cd	3.12bc	4.35abc	1.33b
T ₇ : Lime1 OM2	4.81a	4.9ab	3.16abc	4.5abc	1.43ab
T ₈ : Lime2 OM1	4.77b	4.98a	3.23ab	4.68ab	1.48ab
T ₉ : Lime2 OM2	4.54d	4.73abc	3.35a	4.79a	1.57a
SE(±)	0.016	0.112	0.095	0.201	0.046
CV(%)	4.3	4.9	4.0	5.9	4.4

Same letter in a column represents insignificant difference at $p < 0.05$.

Table 4: Effect of lime and organic matter amendment on the growth and yield of T. Aman rice - Wheat - Mungbean cropping pattern in acid prone area of Fulbaria

Treatment	T-Aman rice		Wheat		Mungbean
	Grain yield (t ha ⁻¹)	Straw yield (t ha ⁻¹)	Grain yield (t ha ⁻¹)	Straw yield (t ha ⁻¹)	Grain yield (t ha ⁻¹)
T ₁ : Control	5.02g	5.20	2.1f	3.26e	0.53g
T ₂ : Lime 1	5.09f	5.66	2.92d	4.11c	0.91de
T ₃ : Lime 2	5.20e	5.59	3.03cd	4.35bc	1.00d
T ₄ : OM1	5.30c	5.77	2.42c	3.62d	0.74f
T ₅ : OM2	5.42b	5.47	2.56e	3.76d	0.80ef
T ₆ : Lime1 OM1	5.10f	5.17	3.16bc	4.4bc	1.17c
T ₇ : Lime1 OM2	5.46a	4.85	3.24ab	4.54ab	1.26bc
T ₈ : Lime2 OM1	5.31c	5.44	3.28ab	4.62ab	1.30ab
T ₉ : Lime2 OM2	5.27d	5.24	3.38a	4.72a	1.39a
SE(±)	0.006	0.315	0.073	0.139	0.034
CV(%)	4.7	7.2	3.1	4.1	3.8

Same letter in a column represents insignificant difference at $p < 0.05$.

Table 5: Effect of lime and organic matter amendment on the growth and yield of T. Aman rice -Maize - Fallow cropping pattern in acid prone area of Nalitabari

Treatment	T-Aman rice		Maize		Fallow
	Grain yield (t ha ⁻¹)	Straw yield (t ha ⁻¹)	Grain yield (t ha ⁻¹)	Stover yield (t ha ⁻¹)	
T ₁ : Control	4.27f	4.59cd	5.28e	8.13	
T ₂ : Lime 1	4.4e	4.52d	7.16c	10.2	
T ₃ : Lime 2	4.42e	4.63bcd	7.28bc	10.4	
T ₄ : OM1	4.43e	4.59cd	6.15d	8.97	
T ₅ : OM2	4.76c	4.89ab	6.48d	9.50	
T ₆ : Lime1 OM1	4.26f	4.71abcd	7.62bc	10.7	
T ₇ : Lime1 OM2	4.84a	4.91a	7.78b	10.9	
T ₈ : Lime2 OM1	4.79b	4.84abc	7.75b	10.9	
T ₉ : Lime2 OM2	4.57d	4.73abcd	8.38a	11.6	
SE(±)	0.015	0.115	0.237	0.280	
CV(%)	4.1	4.0	4.1	6.4	

Same letter in a column represents insignificant difference at $p < 0.05$.

Table 6: Effect of lime and organic matter amendment on the growth and yield of T. Aman rice -Maize - Fallow cropping pattern in acid prone area of Fulbaria

Treatment	T-Aman rice		Maize		Fallow
	Grain yield (t ha ⁻¹)	Straw yield (t ha ⁻¹)	Grain yield (t ha ⁻¹)	Stover yield (t ha ⁻¹)	
T ₁ : Control	5.01g	5.08	5.52e	8.56f	
T ₂ : Lime 1	5.08f	5.56	7.27c	10.49cd	
T ₃ : Lime 2	5.18e	5.35	7.44bc	11.02bc	
T ₄ : OM1	5.29c	5.38	6.33d	9.47c	
T ₅ : OM2	5.38b	5.52	6.64d	9.98de	
T ₆ : Lime1 OM1	5.07f	5.33	7.57bc	11.14abc	
T ₇ : Lime1 OM2	5.44a	4.63	7.75ab	11.29ab	
T ₈ : Lime2 OM1	5.28c	5.20	7.89ab	11.3ab	
T ₉ : Lime2 OM2	5.25d	5.39	8.15a	11.82a	
SE(±)	0.007	0.468	0.195	0.298	
CV(%)	4.7	10.9	3.3	3.5	

Same letter in a column represents insignificant difference at $p < 0.05$.

Table 7: Effect of lime and organic matter amendment on the growth and yield of T. Aman rice -Mustard - Boro cropping pattern in acid prone area of Nalitabari

Treatment	T-Aman rice		Mustard		Boro rice	
	Grain yield (t ha ⁻¹)	Straw yield (t ha ⁻¹)	Seed yield (t ha ⁻¹)	Stover yield (t ha ⁻¹)	Grain yield (t ha ⁻¹)	Straw yield (t ha ⁻¹)
T ₁ : Control	4.24h	4.47cd	1.25f	2.62g	4.17c	4.48c
T ₂ : Lime 1	4.42f	4.69abc	1.52c	3.41d	5.93a	6.43a
T ₃ : Lime 2	4.44e	4.57bcd	1.61b	3.65c	6.12a	6.7a
T ₄ : OM1	4.44e	4.67abc	1.33e	2.84f	5.23b	5.72b
T ₅ : OM2	4.77c	4.8ab	1.42d	3.12e	5.44b	5.89b
T ₆ : Lime1 OM1	4.29g	4.37d	1.61b	3.67bc	5.84a	6.42a
T ₇ : Lime1 OM2	4.86a	4.86a	1.67ab	3.83ab	6.07a	6.63a
T ₈ : Lime2 OM1	4.82b	4.83a	1.66ab	3.8abc	6.11a	6.61a
T ₉ : Lime2 OM2	4.59d	4.63abc	1.71a	3.87a	6.22a	6.77a
SE(±)	0.006	0.107	0.031	0.075	0.174	0.220
CV(%)	6.2	4.8	3.5	4.7	5.8	4.4

Same letter in a column represents insignificant difference at $p < 0.05$.

Table 8: Effect of lime and organic matter amendment on the growth and yield of T. Aman rice -Mustard - Boro cropping pattern in acid prone area of Fulbaria

Treatment	T-Aman rice		Mustard		Boro rice	
	Grain yield (t ha ⁻¹)	Straw yield (t ha ⁻¹)	Seed yield (t ha ⁻¹)	Stover yield (t ha ⁻¹)	Grain yield (t ha ⁻¹)	Straw yield (t ha ⁻¹)
T ₁ : Control	4.99h	5.06	1.17d	2.87e	3.94c	4.76b
T ₂ : Lime 1	5.06g	5.19	1.45bc	3.5bc	5.21ab	6.23a
T ₃ : Lime 2	5.16f	5.38	1.62ab	3.7ab	5.48a	6.44a
T ₄ : OM1	5.27c	5.40	1.36cd	3.18d	4.76b	5.5ab
T ₅ : OM2	5.37b	5.49	1.4c	3.37cd	4.80b	5.69ab
T ₆ : Lime1 OM1	5.06g	5.13	1.55abc	3.7ab	5.39a	6.2a
T ₇ : Lime1 OM2	5.42a	5.51	1.62ab	3.85a	5.51a	6.23a
T ₈ : Lime2 OM1	5.26d	5.62	1.64ab	3.86a	5.63a	6.33a
T ₉ : Lime2 OM2	5.23e	5.34	1.68a	3.91a	5.67a	6.45a
SE(±)	0.002	0.176	0.093	0.110	0.210	0.440
CV(%)	3.7	4.0	7.6	3.8	5.0	9.1

Same letter in a column represents insignificant difference at $p < 0.05$.

Nutrients uptake by crops in T. Aman rice - Wheat - Mungbean cropping pattern

N, P, K and S contents in grain or straw of T. aman rice, wheat and mungbean were determined (Appendix I-VI) and then nutrient uptake by crops was calculated (Tables 9-14). In both acid-prone Nalitabari and Fulbaria locations, nutrient uptake by T. aman rice, wheat and mungbean was significantly increased in response to addition of lime and organic manures. Plants grown in acid soils without lime and organic manure showed significant decreases in nutrient uptake. Application of lime or organic manure alone significantly increased nutrient uptake by crops. In most cases, the effect of lime was more pronounced than that of organic manure. Combined application of lime and organic manure also significantly increased nutrient uptake by T.aman rice, wheat and mungbean crops (Tables 9-14).

Table 9: Effect of lime and organic matter amendment on total nutrient uptake by T. aman rice in T. Aman rice - Wheat - Mungbean cropping pattern in acid prone area of Nalitabari

Treatment	N uptake (kg ha ⁻¹)	P uptake (kg ha ⁻¹)	K uptake (kg ha ⁻¹)	S uptake (kg ha ⁻¹)
T ₁ : Control	56.75g	14.26f	61.44d	19.55e
T ₂ : Lime 1	63.9f	17.52e	69.0bc	22.0d
T ₃ : Lime 2	65.81e	18.67cd	70.11bc	22.89c
T ₄ : OM1	66.69e	17.15e	68.21c	22.67c
T ₅ : OM2	73.94c	19.04c	71.99b	24.7b
T ₆ : Lime1 OM1	69.04d	18.32d	70.19bc	24.5b
T ₇ : Lime1 OM2	77.81ab	21.88a	78.12a	29.09a
T ₈ : Lime2 OM1	78.12a	21.08b	78.89a	28.69a
T ₉ : Lime2 OM2	77.08b	21.01b	76.49a	29.14a
SE(±)	0.448	0.188	1.33	0.255
CV(%)	2.79	2.23	2.28	3.26

Same letter in a column represents insignificant difference at $p < 0.05$.

Table 10: Effect of lime and organic matter amendment on total nutrient uptake by wheat in T. Aman rice - Wheat - Mungbean cropping pattern in acid prone area of Nalitabari

Treatment	N uptake (kg ha ⁻¹)	P uptake (kg ha ⁻¹)	K uptake (kg ha ⁻¹)	S uptake (kg ha ⁻¹)
T ₁ : Control	47.1g	6.63g	52.85f	8.91g
T ₂ : Lime 1	67.76de	10.93e	73.41de	13.9de
T ₃ : Lime 2	72.24cd	12.11d	76.04cd	15.69c
T ₄ : OM1	55.87f	8.91f	59.7f	10.24f
T ₅ : OM2	62.66e	10.1e	67.74e	12.67e
T ₆ : Lime1 OM1	76.44bc	13.02c	81.89bc	14.89cd
T ₇ : Lime1 OM2	79.12ab	14.18b	85.54ab	15.24c
T ₈ : Lime2 OM1	81.33ab	14.68b	88.57ab	17.62b
T ₉ : Lime2 OM2	84.15a	15.93a	92.08a	19.43a
SE(±)	2.45	0.418	3.43	0.588
CV(%)	4.30	4.31	5.58	5.05

Same letter in a column represents insignificant difference at $p < 0.05$.

Table 11: Effect of lime and organic matter amendment on nutrient uptake by mungbean grain in T. Aman rice - Wheat- Mungbean cropping pattern in acid prone area of Nalitabari

Treatment	N uptake (kg ha ⁻¹)	P uptake (kg ha ⁻¹)	K uptake (kg ha ⁻¹)	S uptake (kg ha ⁻¹)
T ₁ : Control	21.77i	2.40i	8.52i	2.40i
T ₂ : Lime 1	38.62f	5.47f	15.28f	4.85f
T ₃ : Lime 2	42.86e	6.56e	16.74e	5.88e
T ₄ : OM1	30.76h	3.84h	12.45h	3.59h
T ₅ : OM2	33.65g	4.34g	13.75g	4.25g
T ₆ : Lime1 OM1	50.45d	7.43d	20.31d	6.9d
T ₇ : Lime1 OM2	54.75c	8.41c	21.96c	7.56c
T ₈ : Lime2 OM1	57.67b	8.85b	23.01b	7.97b
T ₉ : Lime2 OM2	61.67a	9.6a	25.02a	8.81a
SE(±)	0.857	0.157	0.348	0.139
CV(%)	2.41	3.04	2.44	2.91

Same letter in a column represents insignificant difference at $p < 0.05$.

Table 12: Effect of lime and organic matter amendment on total nutrient uptake by T. aman rice in T. Aman rice - Wheat - Mungbean cropping pattern in acid prone area of Fulbaria

Treatment	N uptake (kg ha ⁻¹)	P uptake (kg ha ⁻¹)	K uptake (kg ha ⁻¹)	S uptake (kg ha ⁻¹)
T ₁ : Control	66.87f	16.74e	71.2b	22.93e
T ₂ : Lime 1	75.28e	20.77d	83.05a	26.1d
T ₃ : Lime 2	78.27d	22.28bc	84.35a	27.33cd
T ₄ : OM1	80.73cd	20.8d	83.33a	27.53cd
T ₅ : OM2	84.7b	21.81cd	82.47a	28.3c
T ₆ : Lime1 OM1	81.89c	21.49cd	80.4a	28.73c
T ₇ : Lime1 OM2	85.52b	23.41ad	79.77a	31.24b
T ₈ : Lime2 OM1	86.5ab	23.28ad	86.62a	31.67ab
T ₉ : Lime2 OM2	88.44a	23.87a	85.52a	33.13a
SE(±)	1.25	0.636	3.97	0.813
CV(%)	3.9	3.61	5.93	3.49

Same letter in a column represents insignificant difference at $p < 0.05$.

Table 13: Effect of lime and organic matter amendment on total nutrient uptake by wheat in T. Aman rice - Wheat - Mungbean cropping pattern in acid prone area of Fulbaria

Treatment	N uptake (kg ha ⁻¹)	P uptake (kg ha ⁻¹)	K uptake (kg ha ⁻¹)	S uptake (kg ha ⁻¹)
T ₁ : Control	46.39g	6.57h	54.63f	8.96g
T ₂ : Lime 1	66.69d	10.76e	72.47cd	13.7d
T ₃ : Lime 2	71.91c	12.07d	76.91c	15.73c
T ₄ : OM1	57.28f	9.14g	62.89e	10.64f
T ₅ : OM2	61.89e	9.98f	68.47d	12.66e
T ₆ : Lime1 OM1	77.36b	13.18c	82.75b	15.06c
T ₇ : Lime1 OM2	80.67ab	14.46b	86.53ab	15.49c
T ₈ : Lime2 OM1	81.99a	14.8b	87.8ab	17.63b
T ₉ : Lime2 OM2	84.55a	16.01a	91.23a	19.39a
SE(±)	1.81	0.317	2.39	0.418
CV(%)	3.18	3.27	3.85	3.56

Same letter in a column represents insignificant difference at $p < 0.05$.

Table 14: Effect of lime and organic matter amendment on nutrient uptake by mungbean grain in T. Aman rice - Wheat - Mungbean cropping pattern in acid prone area of Fulbaria

Treatment	N uptake (kg ha⁻¹)	P uptake (kg ha⁻¹)	K uptake (kg ha⁻¹)	S uptake (kg ha⁻¹)
T ₁ : Control	19.18i	2.12i	7.42i	2.17i
T ₂ : Lime 1	34.12f	4.85f	13.56f	4.28f
T ₃ : Lime 2	37.80e	5.82e	14.90e	5.19e
T ₄ : OM1	27.14h	3.44h	10.95h	3.17h
T ₅ : OM2	29.69g	3.83g	12.08g	3.75g
T ₆ : Lime1 OM1	44.57d	6.57d	18.02d	6.09d
T ₇ : Lime1 OM2	48.26c	7.47c	19.40c	6.67c
T ₈ : Lime2 OM1	50.96b	7.82b	20.41b	7.03b
T ₉ : Lime2 OM2	54.48a	8.50a	22.24a	7.77a
SE(±)	0.790	0.145	0.320	0.127
CV(%)	2.52	3.17	2.55	3.04

Same letter in a column represents insignificant difference at $p < 0.05$.

Nutrients uptake by crops in T. Aman rice -Maize – Fallow cropping pattern

We measured N, P, K and S contents (Appendix VII-X) whether addition of lime or organic manure to acid soils influenced nutrient uptake by T. aman rice and maize (Tables 15-18). In both Nalitabari and Fulbaria locations, nutrient uptake by T. aman rice and maize was significantly increased in response to lime and organic manure. Plants grown in acid soils without lime and organic manure showed significant reductions in nutrient uptake. Application of lime or organic manure alone significantly increased nutrient uptake by T. aman rice and maize. Combined application of lime and organic manure also significantly increased nutrient uptake by T. aman rice and maize (Tables 15-18).

Table 15: Effect of lime and organic matter amendment on total nutrient uptake by T. aman rice in T. Aman rice -Maize - Fallow cropping pattern in acid prone area of Nalitabari

Treatment	N uptake (kg ha ⁻¹)	P uptake (kg ha ⁻¹)	K uptake (kg ha ⁻¹)	S uptake (kg ha ⁻¹)
T ₁ : Control	57.4f	14.44f	62.44e	19.8f
T ₂ : Lime 1	63.8e	17.39e	67.33cd	21.81e
T ₃ : Lime 2	66.14d	18.75d	70.33bc	22.99d
T ₄ : OM1	66.59d	17.06e	66.98d	22.5d
T ₅ : OM2	74.7b	19.29c	73.38b	25.04c
T ₆ : Lime1 OM1	69.9c	18.62d	71.9b	24.9c
T ₇ : Lime1 OM2	78.27a	21.99a	78.38a	29.24a
T ₈ : Lime2 OM1	77.84a	20.89b	77.31a	28.41b
T ₉ : Lime2 OM2	77.32a	21.05b	76.51a	29.2a
SE(±)	0.501	0.215	1.42	0.293
CV(%)	2.88	3.4	2.43	3.44

Same letter in a column represents insignificant difference at $p < 0.05$.

Table 16: Effect of lime and organic matter amendment on total nutrient uptake by maize in T. Aman rice - Maize - Fallow cropping pattern in acid prone area of Nalitabari

Treatment	N uptake (kg ha ⁻¹)	P uptake (kg ha ⁻¹)	K uptake (kg ha ⁻¹)	S uptake (kg ha ⁻¹)
T ₁ : Control	99.88g	19.5g	104.86g	26.44f
T ₂ : Lime 1	141.3de	29.86e	146.27de	36.62d
T ₃ : Lime 2	148.04d	33.02d	152.83cd	38.28d
T ₄ : OM1	121.38f	25.04f	127.87f	31.4e
T ₅ : OM2	132.32e	29.0e	138.25e	33.61e
T ₆ : Lime1 OM1	164.99c	35.63c	161.34bc	40.81c
T ₇ : Lime1 OM2	176.35d	39.06b	167.26b	41.82bc
T ₈ : Lime2 OM1	175.73d	38.2b	167.77b	43.37b
T ₉ : Lime2 OM2	192.75a	43.44a	184.15a	47.1a
SE(±)	4.57	0.958	4.27	1.13
CV(%)	3.72	3.61	3.49	3.68

Same letter in a column represents insignificant difference at $p < 0.05$.

Table 17: Effect of lime and organic matter amendment on total nutrient uptake by T. aman rice in T. Aman rice -Maize - Fallow cropping pattern in acid prone area of Fulbaria

Treatment	N uptake (kg ha ⁻¹)	P uptake (kg ha ⁻¹)	K uptake (kg ha ⁻¹)	S uptake (kg ha ⁻¹)
T ₁ : Control	66.31f	16.56d	69.86d	22.67f
T ₂ : Lime 1	74.71e	20.57c	81.76b	25.83e
T ₃ : Lime 2	77.25de	21.83bc	81.43b	26.77de
T ₄ : OM1	79.16cd	20.23c	78.87c	26.66de
T ₅ : OM2	84.48b	21.81bc	82.93b	28.31cd
T ₆ : Lime1 OM1	82.06bc	21.68bc	82.23b	28.98bcd
T ₇ : Lime1 OM2	84.36b	22.9ab	76.88c	30.59bc
T ₈ : Lime2 OM1	85.22ab	22.77ab	83.47b	30.94b
T ₉ : Lime2 OM2	88.71a	24.11a	87.38a	33.45a
SE(±)	1.70	0.802	1.63	1.07
CV(%)	2.60	4.59	4.57	4.62

Same letter in a column represents insignificant difference at $p < 0.05$.

Table 18: Effect of lime and organic matter amendment on total nutrient uptake by maize in T. Aman rice - Maize - Fallow cropping pattern in acid prone area of Fulbaria

Treatment	N uptake (kg ha ⁻¹)	P uptake (kg ha ⁻¹)	K uptake (kg ha ⁻¹)	S uptake (kg ha ⁻¹)
T ₁ : Control	104.55h	20.45g	110.32f	27.72h
T ₂ : Lime 1	143.94e	30.49e	149.84d	37.37e
T ₃ : Lime 2	152.91d	34.43d	161.21c	39.77d
T ₄ : OM1	125.76g	26.1f	134.46e	32.67g
T ₅ : OM2	136.57f	30.12e	144.73d	34.83f
T ₆ : Lime1 OM1	165.99c	36.26c	166.14bc	41.36c
T ₇ : Lime1 OM2	177.51b	39.72b	171.77b	42.35c
T ₈ : Lime2 OM1	179.87b	39.3b	173.51b	44.52b
T ₉ : Lime2 OM2	190.0a	43.4a	186.25a	46.76a
SE(±)	3.09	0.636	3.71	0.744
CV(%)	2.47	2.34	2.93	2.36

Same letter in a column represents insignificant difference at $p < 0.05$.

Nutrients uptake by crops in T. Aman rice -Mustard - Boro rice cropping pattern

N, P, K and S contents in grain and straw of T. aman rice, mustard and boro ricewere also determined (Appendix XI-XVI). In both acid-prone locations, significant variations were observed in nutrient uptake by crops in response to lime and organic manure addition. Plants grown in acid soils without lime and organic manure showed significant reductions in nutrient uptake. Application of lime or organic manure alone significantly increased nutrient uptake by crops. Combined application of lime and organic manure considerably and significantly increased nutrient uptake by T. aman rice, mustard and boro rice (Tables 19-24).

Table 19: Effect of lime and organic matter amendment on total nutrient uptake by T. aman rice in T. Aman rice -Mustard - Boro cropping pattern in acid prone area of Nalitabari

Treatment	N uptake (kg ha ⁻¹)	P uptake (kg ha ⁻¹)	K uptake (kg ha ⁻¹)	S uptake (kg ha ⁻¹)
T ₁ : Control	56.72g	14.24h	61.05d	19.51g
T ₂ : Lime 1	64.6f	17.69f	69.42c	22.21f
T ₃ : Lime 2	66.16e	18.69d	69.66c	22.92e
T ₄ : OM1	66.98e	17.19g	67.93c	22.7e
T ₅ : OM2	74.57c	19.19c	72.4b	24.88c
T ₆ : Lime1 OM1	68.92d	18.11e	67.88c	24.2d
T ₇ : Lime1 OM2	78.31a	21.93a	77.8a	29.18a
T ₈ : Lime2 OM1	78.07ab	20.92b	77.21a	28.45b
T ₉ : Lime2 OM2	77.25b	20.91b	75.28a	29.01a
SE(±)	0.390	0.16	1.25	0.23
CV(%)	3.68	4.05	2.16	3.10

Same letter in a column represents insignificant difference at $p < 0.05$.

Table 20: Effect of lime and organic matter amendment on total nutrient uptake by mustard in T. Aman rice - Mustard - Boro cropping pattern in acid prone area of Nalitabari

Treatment	N uptake (kg ha ⁻¹)	P uptake (kg ha ⁻¹)	K uptake (kg ha ⁻¹)	S uptake (kg ha ⁻¹)
T ₁ : Control	40.87g	17.04g	42.02g	23.13g
T ₂ : Lime 1	53.12d	22.91d	57.72d	30.09d
T ₃ : Lime 2	58.29c	25.1c	62.33c	32.15c
T ₄ : OM1	45.25f	19.24f	48.64f	25.84f
T ₅ : OM2	50.28e	21.49e	53.06e	27.98e
T ₆ : Lime1 OM1	59.91c	25.69c	62.56c	32.71c
T ₇ : Lime1 OM2	64.52b	27.67b	66.0b	34.49b
T ₈ : Lime2 OM1	64.81b	28.24b	65.89b	34.38b
T ₉ : Lime2 OM2	67.92a	29.47a	68.97a	35.99a
SE(±)	1.15	0.50	1.23	0.623
CV(%)	2.51	2.53	2.58	2.48

Same letter in a column represents insignificant difference at $p < 0.05$.

Table 21: Effect of lime and organic matter amendment on total nutrient uptake by boro rice in T. Aman rice - Mustard - Boro cropping pattern in acid prone area of Nalitabari

Treatment	N uptake (kg ha ⁻¹)	P uptake (kg ha ⁻¹)	K uptake (kg ha ⁻¹)	S uptake (kg ha ⁻¹)
T ₁ : Control	55.52g	13.29h	78.65f	19.31g
T ₂ : Lime 1	90.03de	23.88e	123.2d	36.88d
T ₃ : Lime 2	97.5c	26.63d	134.66bc	42.68c
T ₄ : OM1	82.83f	20.0g	108.35e	29.96f
T ₅ : OM2	86.47ef	21.85f	116.98de	33.32e
T ₆ : Lime1 OM1	96.18cd	26.16d	126.49cd	38.31d
T ₇ : Lime1 OM2	101.06bc	29.08c	135.12bc	42.93c
T ₈ : Lime2 OM1	104.2b	30.96b	140.42ab	46.23b
T ₉ : Lime2 OM2	110.53a	33.55a	145.44a	49.08a
SE(±)	2.91	0.843	4.28	1.28
CV(%)	3.89	4.12	4.25	4.17

Same letter in a column represents insignificant difference at $p < 0.05$.

Table 22: Effect of lime and organic matter amendment on total nutrient uptake by T. aman rice in T. Aman rice -Mustard - Boro cropping pattern in acid prone area of Fulbaria

Treatment	N uptake (kg ha ⁻¹)	P uptake (kg ha ⁻¹)	K uptake (kg ha ⁻¹)	S uptake (kg ha ⁻¹)
T ₁ : Control	66.06h	16.49e	69.51c	22.57f
T ₂ : Lime 1	73.27g	19.97d	77.32d	25.04e
T ₃ : Lime 2	77.1f	21.83c	81.74cd	26.77d
T ₄ : OM1	79.04e	20.22d	79.03cd	26.65d
T ₅ : OM2	84.26c	21.73c	82.5bc	28.21c
T ₆ : Lime1 OM1	81.17d	21.31c	79.73cd	28.48c
T ₇ : Lime1 OM2	87.58ad	24.61a	87.81a	32.73ab
T ₈ : Lime2 OM1	86.66b	23.49b	88.66a	31.99b
T ₉ : Lime2 OM2	88.27a	23.96ab	86.62ab	33.24a
SE(±)	0.681	0.320	2.17	0.440
CV(%)	3.04	2.84	3.26	2.89

Same letter in a column represents insignificant difference at $p < 0.05$.

Table 23: Effect of lime and organic matter amendment on total nutrient uptake by mustard in T. Aman rice - Mustard - Boro cropping pattern in acid prone area of Fulbaria

Treatment	N uptake (kg ha ⁻¹)	P uptake (kg ha ⁻¹)	K uptake (kg ha ⁻¹)	S uptake (kg ha ⁻¹)
T ₁ : Control	40.16d	17.26d	44.44e	22.72e
T ₂ : Lime 1	51.84c	22.7c	58.25c	29.35cd
T ₃ : Lime 2	58.75b	25.33b	63.02b	32.4abc
T ₄ : OM1	47.61c	20.6c	53.25d	27.18d
T ₅ : OM2	51.07c	22.25c	56.21cd	28.38d
T ₆ : Lime1 OM1	58.66b	25.42b	62.63b	32.01bc
T ₇ : Lime1 OM2	63.38ab	27.4ab	65.9ab	33.87ab
T ₈ : Lime2 OM1	64.75ab	28.4a	66.66ab	34.34ab
T ₉ : Lime2 OM2	67.36a	29.41a	69.29a	35.66a
SE(±)	2.72	1.00	2.04	1.5
CV(%)	5.96	5.03	4.16	5.98

Same letter in a column represents insignificant difference at $p < 0.05$.

Table 24: Effect of lime and organic matter amendment on total nutrient uptake by boro rice in T. Aman rice - Mustard - Boro cropping pattern in acid prone area of Fulbaria

Treatment	N uptake (kg ha ⁻¹)	P uptake (kg ha ⁻¹)	K uptake (kg ha ⁻¹)	S uptake (kg ha ⁻¹)
T ₁ : Control	54.05d	13.19f	81.89e	19.2f
T ₂ : Lime 1	80.97c	21.84d	117.04bcd	33.9cd
T ₃ : Lime 2	88.86b	24.55c	127.58abc	39.5b
T ₄ : OM1	76.38c	18.58e	102.98d	27.96e
T ₅ : OM2	77.98c	19.96de	111.02cd	30.72de
T ₆ : Lime1 OM1	89.72b	24.62c	120.92abc	36.04bc
T ₇ : Lime1 OM2	92.54b	26.85bc	126.15abc	39.61b
T ₈ : Lime2 OM1	96.97ab	28.99ab	133.34ab	43.35a
T ₉ : Lime2 OM2	101.89a	31.19a	137.27a	45.65a
SE(±)	3.59	1.10	7.55	1.76
CV(%)	5.21	5.79	7.87	6.12

Same letter in a column represents insignificant difference at $p < 0.05$.

Acid soil is a major constraint of crop productivity in 11 AEZs of Bangladesh including Madhupur Tract and Northern & Eastern Piedmont Plains. Strong soil acidity makes macronutrients unavailable for plant. To increase the pH of acid, soil liming is the first step. Liming also improves crop productivity. In addition to lime, organic matter can increase soil pH through buffering action and thereby uphold the crop productivity in acid prone areas of Bangladesh. An initiative was, therefore undertaken to evaluate the effects of lime and organic matter amendment on crop productivity of different cropping patterns in acidic terrace soils. It will also enhance the farmer knowledge for extending the crop production and develop sustainable agriculture. Lime and organic matter were applied in T. aman rice and their residual effects were evaluated in succeeding crops. In case of the first crop, T. aman rice, the effect of lime and organic matter was not so prominent. However, a significant effect of lime or organic matter alone or in combination was observed in the following crops. The beneficial effect of liming on rice productivity was reported by many authors (Mutanal, 1998; Mamaril *et al.*, 1990; Subbiah and Mittra, 1997; Mongia *et al.*, 1998). Fageria and Baligar (2008) have also reported that the application of lime at an appropriate rate brings several chemical and biological changes in the soils, which are beneficial or helpful in improving crop growth and yields on acid soils. Similar findings were also reported by Sukristiyonubowo *et al.* (2013) who found that the combined addition of organic matter (straw compost), lime and mineral fertilizer improved the grain yield of rice. Asrat *et al.* (2014) also found significant variation on grain yield while the combined application of 5 t manure and 2.2 t ha⁻¹ lime increased grain yield by 279%. Whalen *et*

al. (2002) found that the straw yield was highly influenced by the application of lime in acid soil. This result also supported the findings of Sukristiyonubowo *et al.* (2013) and Fageria and Baligar (2008). The results of the present study are also in agreement with findings of Rahman *et al.* (2005) and Halim *et al.* (2014) who reported that application of lime significantly increased crop yields in acid soils of Rangpur and Dinajpur areas of Bangladesh. Therefore it is clear from the results that the addition of lime and organic matter uplifted the crop yields over recommended dose of chemical fertilizers. This was the cherished benefits of lime and organic matter amendment in acidic terrace soils of Madhupur Tract and Northern & Eastern Piedmont Plains.

12. Research highlight/findings:

- i) All crops of three cropping patterns (T. Aman rice - Wheat- Mungbean, T. Aman rice -Maize - Fallow and T. Aman rice -Mustard - Boro) showed reductions in grain and straw yields in acid prone areas of Fulbaria and Nalitabari.
- ii) Plants grown in acid prone areas without lime or organic manure showed reductions in nutrient uptake by crops.
- iii) Application of lime showed increases in grain and straw yields of crops as well as nutrient uptake in three cropping patterns.
- iv) Additionally, organic manure alone or in combination with lime significantly increased yield and nutrient uptake by all crops.
- v) In conclusion, addition of lime and organic manure to acid soils is beneficial for achieving sustainable crop productivity in the areas of Madhupur Tract and Northern & Eastern Piedmont Plains.

B. Implementation Position

1. Procurement:

Description of equipment and capital items	PP Target		Achievement		Remarks
	Phy (#)	Fin (Tk)	Phy (#)	Fin (Tk)	
(a) Office equipment	Desktop computer	59,900.00	Desktop computer	59,900.00	Timely procured
(b) Lab &field equipment	pH meter and GPS unit	1,19,350.00	pH meter and GPS unit	1,19,350.00	Timely procured
(c) Other capital items					

2. Establishment/renovation facilities: Not applicable

Description of facilities	Newly established		Upgraded/refurbished		Remarks
	PP Target	Achievement	PP Target	Achievement	

3. Training/study tour/ seminar/workshop/conference organized: Not applicable

Description	Number of participant			Duration (Days/weeks/ months)	Remarks
	Male	Female	Total		
(a) Training					
(b) Workshop					

C. Financial and physical progress

Fig in Tk

Items of expenditure/activities	Total approved budget	Fund received	Actual expenditure	Balance/ unspent	Physical progress (%)	Reasons for deviation
A. Contractual staff salary	7,32,630.00	7,32,630.00	7,19,408.00	13,222.00	96	Fund not yet released
B. Field research/lab expenses and supplies	12,08,310.00	9,70,600.00	9,70,600.00	237,710.00	about 75	Fund not yet released
C. Operating expenses	1,36,385.00	1,36,385.00	1,31,185.00	5,200.00	about 97	Fund not yet released
D. Vehicle hire and fuel, oil & maintenance	75,000.00	75,000.00	75,000.00	0.00	100	-
E. Training/workshop/seminar etc.	0.00	0.00	00.00	0.00	-	-
F. Publications and printing	90,000.00	15,000.00	15,000.00	75,000.00	about 20	Fund not yet released
G. Miscellaneous	60,000.00	60,000.00	75311.25.00	-4,317.25	100	-
H. Capital expenses	1,79,250.00	1,79,250.00	1,79,250.00	0.00	100	-

D. Achievement of Sub-project by objectives: (Tangible form)

Specific objectives of the sub-project	Major technical activities performed in respect of the set objectives	Output(i.e. product obtained, visible, measurable)	Outcome(short term effect of the research)
i) To determine lime and organic manure requirement to attain suitable pH for field crop production	Collection of soil samples from acid prone areas of Nalitabari and Fulbaria	Soil samples were collected from acid prone areas of Nalitabari and Fulbaria for determining pH, texture, organic carbon and nutrient status	Lime and organic manure requirement were known for the amendment of acid soils
ii) To evaluate the effect of lime and organic matter amendment on yield and nutrient uptake of major crops of the cropping patterns	Set-up of field experiments at farmer's field of acid prone areas with addition of lime and organic manure. Harvesting crops at maturity. Recording of crop yields. Analysis of plant samples	Addition of lime and organic manures to acid soils significantly increased crop yields and nutrient uptake by crops	Addition of lime and organic manure to acid soils is beneficial for achieving sustainable crop productivity in the areas of Madhupur Tract and Northern & Eastern Piedmont Plains

E. Materials Development/Publication made under the Sub-project:

Publication	Number of publication		Remarks (e.g. paper title, name of journal, conference name, etc.)
	Under preparation	Completed and published	
Technology bulletin/ booklet/leaflet/flyer etc.			
Journal publication	03		
Information development			
Other publications, if any(MS thesis)	03	01	

F. Technology/Knowledge generation/Policy Support (as applied):

i. Generation of technology (Commodity & Non-commodity)

ii. Generation of new knowledge that help in developing more technology in future

Application of lime and organic manure to acid soils is beneficial for achieving sustainable crop production in Madhupur Tract and Northern & Eastern Piedmont Plains

iii. Technology transferred that help increased agricultural productivity and farmers' income

iv. Policy Support

G. Information regarding Desk and Field Monitoring

i) Desk Monitoring [description & output of consultation meeting, monitoring workshops/seminars etc.):

- (a) A desk monitoring was done by PIU-BARC-NATP-2 team on 07 March, 2018. According to the comments of monitoring team, the project was going on accurately and scheduled based.
- (b) Research progress was presented on 01 April, 2018 at BARC auditorium.
- (c) Annual research workshop was presented on 24 September, 2018 at BARC auditorium.

ii) Field Monitoring (time& No. of visit, Team visit and output):

- (a) Internal field monitoring was done by PI, Co-PI, UAO and AEO frequently.

I. Lesson Learned/Challenges (if any)

- i) Acid soils possess toxic concentrations of Al^{3+} , Fe^{3+} and Mn^{2+} , and lower concentrations of P, causing reduction in crop yield. Dry land farming is highly affected due to soil acidity.
- ii) Application of lime or organic manure reduces soil acidity, thereby increasing crop yield.

J. Challenges (if any)

- i) Farmers are not well-known the problems of soil acidity.
- ii) Farmer's training should be performed frequently for the management of acid soils by liming or organic amendments.

Signature of the Principal Investigator
Date
Seal

Counter signature of the Head of the
organization/authorized representative
Date
Seal

13. References:

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Appendices

Appendix I: Effect of lime and organic matter amendment on nutrient contents in T. aman rice of T. Aman rice - Wheat - Mungbean cropping pattern in acid prone area of Nalitabari

Treatment	N content (%)		P content (%)		K content (%)		S content (%)	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T ₁ : Control	1.01	0.31	0.209	0.12	0.26	1.12	0.27	0.18
T ₂ : Lime 1	1.10	0.34	0.241	0.15	0.31	1.19	0.29	0.20
T ₃ : Lime 2	1.14	0.34	0.246	0.17	0.34	1.19	0.30	0.21
T ₄ : OM1	1.12	0.37	0.240	0.14	0.31	1.16	0.28	0.22
T ₅ : OM2	1.18	0.38	0.241	0.16	0.34	1.17	0.29	0.23
T ₆ : Lime1 OM1	1.22	0.38	0.249	0.17	0.35	1.21	0.33	0.23
T ₇ : Lime1 OM2	1.22	0.39	0.251	0.20	0.35	1.25	0.35	0.25
T ₈ : Lime2 OM1	1.23	0.39	0.254	0.18	0.36	1.24	0.33	0.26
T ₉ : Lime2 OM2	1.29	0.39	0.254	0.20	0.36	1.27	0.36	0.27

Appendix II: Effect of lime and organic matter amendment on nutrient contents in wheat of T. Aman rice - Wheat - Mungbean cropping pattern in acid prone area of Nalitabari

Treatment	N content (%)		P content (%)		K content (%)		S content (%)	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T ₁ : Control	1.70	0.330	0.215	0.065	0.401	1.42	0.202	0.146
T ₂ : Lime 1	1.75	0.380	0.272	0.073	0.441	1.45	0.223	0.176
T ₃ : Lime 2	1.81	0.390	0.292	0.075	0.442	1.46	0.244	0.192
T ₄ : OM1	1.78	0.390	0.262	0.071	0.418	1.46	0.208	0.154
T ₅ : OM2	1.83	0.40	0.290	0.071	0.480	1.49	0.223	0.185
T ₆ : Lime1 OM1	1.85	0.430	0.312	0.072	0.491	1.53	0.243	0.168
T ₇ : Lime1 OM2	1.88	0.436	0.333	0.075	0.514	1.54	0.245	0.167
T ₈ : Lime2 OM1	1.89	0.433	0.338	0.078	0.525	1.53	0.255	0.201
T ₉ : Lime2 OM2	1.89	0.436	0.357	0.082	0.547	1.54	0.283	0.208

Appendix III: Effect of lime and organic matter amendment on nutrient contents in Mungbean grain of T. Aman rice - Wheat - Mungbean cropping pattern in acid prone area of Nalitabari

Treatment	N content (%)	P content (%)	K content (%)	S content (%)
T ₁ : Control	3.63	0.40	1.42	0.40
T ₂ : Lime 1	3.74	0.53	1.48	0.47
T ₃ : Lime 2	3.79	0.58	1.48	0.52
T ₄ : OM1	3.68	0.46	1.49	0.43
T ₅ : OM2	3.72	0.48	1.52	0.47
T ₆ : Lime1 OM1	3.80	0.56	1.53	0.52
T ₇ : Lime1 OM2	3.84	0.59	1.54	0.53
T ₈ : Lime2 OM1	3.91	0.60	1.56	0.54
T ₉ : Lime2 OM2	3.92	0.61	1.59	0.56

Appendix IV: Effect of lime and organic matter amendment on nutrient contents in T. aman rice of T. Aman rice - Wheat - Mungbean cropping pattern in acid prone area of Fulbaria

Treatment	N content (%)		P content (%)		K content (%)		S content (%)	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T ₁ : Control	1.03	0.292	0.212	0.117	0.28	1.10	0.263	0.187
T ₂ : Lime 1	1.11	0.332	0.244	0.148	0.319	1.18	0.282	0.208
T ₃ : Lime 2	1.15	0.331	0.251	0.165	0.343	1.19	0.298	0.212
T ₄ : OM1	1.14	0.352	0.236	0.144	0.331	1.14	0.276	0.224
T ₅ : OM2	1.18	0.379	0.238	0.163	0.361	1.15	0.292	0.228
T ₆ : Lime1 OM1	1.22	0.381	0.243	0.176	0.361	1.20	0.327	0.233
T ₇ : Lime1 OM2	1.23	0.379	0.256	0.195	0.377	1.22	0.353	0.247
T ₈ : Lime2 OM1	1.23	0.389	0.252	0.182	0.372	1.23	0.340	0.269
T ₉ : Lime2 OM2	1.27	0.411	0.255	0.199	0.380	1.25	0.358	0.272

**Appendix V: Effect of lime and organic matter amendment on nutrient contents in wheat T. Aman rice -
Wheat - Mungbean cropping pattern in acid prone area of Fulbaria**

Treatment	N content (%)		P content (%)		K content (%)		S content (%)	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T ₁ : Control	1.68	0.341	0.22	0.060	0.40	1.42	0.21	0.14
T ₂ : Lime 1	1.74	0.387	0.27	0.070	0.44	1.45	0.23	0.17
T ₃ : Lime 2	1.80	0.400	0.29	0.075	0.44	1.46	0.26	0.18
T ₄ : OM1	1.78	0.393	0.28	0.065	0.43	1.45	0.20	0.16
T ₅ : OM2	1.82	0.407	0.29	0.068	0.47	1.50	0.23	0.18
T ₆ : Lime1 OM1	1.86	0.423	0.31	0.077	0.49	1.53	0.24	0.17
T ₇ : Lime1 OM2	1.88	0.435	0.34	0.076	0.50	1.55	0.24	0.17
T ₈ : Lime2 OM1	1.91	0.419	0.34	0.079	0.51	1.54	0.27	0.19
T ₉ : Lime2 OM2	1.91	0.445	0.36	0.081	0.52	1.56	0.28	0.21

**Appendix VI: Effect of lime and organic matter amendment on nutrient contents in mungbean grain of T.
Aman rice - Wheat - Mungbean cropping pattern in acid prone area of Fulbaria**

Treatment	N content (%)	P content (%)	K content (%)	S content (%)
T ₁ : Control	3.62	0.402	1.40	0.410
T ₂ : Lime 1	3.75	0.533	1.49	0.472
T ₃ : Lime 2	3.78	0.582	1.49	0.518
T ₄ : OM1	3.67	0.465	1.48	0.431
T ₅ : OM2	3.71	0.478	1.51	0.469
T ₆ : Lime1 OM1	3.81	0.562	1.54	0.521
T ₇ : Lime1 OM2	3.83	0.593	1.54	0.530
T ₈ : Lime2 OM1	3.92	0.602	1.57	0.541
T ₉ : Lime2 OM2	3.92	0.612	1.60	0.559

Appendix VII: Effect of lime and organic matter amendment on nutrient contents in T. aman rice of T. Aman rice -Maize - Fallow cropping pattern in acid prone area of Nalitabari

Treatment	N content (%)		P content (%)		K content (%)		S content (%)	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T ₁ : Control	1.04	0.283	0.224	0.106	0.269	1.11	0.258	0.192
T ₂ : Lime 1	1.11	0.331	0.248	0.143	0.328	1.17	0.280	0.210
T ₃ : Lime 2	1.13	0.350	0.252	0.164	0.345	1.19	0.293	0.217
T ₄ : OM1	1.13	0.360	0.228	0.152	0.310	1.16	0.281	0.219
T ₅ : OM2	1.19	0.369	0.240	0.161	0.340	1.17	0.288	0.232
T ₆ : Lime1 OM1	1.20	0.398	0.248	0.171	0.362	1.20	0.326	0.234
T ₇ : Lime1 OM2	1.22	0.392	0.258	0.194	0.372	1.23	0.348	0.253
T ₈ : Lime2 OM1	1.22	0.401	0.252	0.183	0.371	1.23	0.340	0.251
T ₉ : Lime2 OM2	1.26	0.417	0.264	0.190	0.380	1.25	0.362	0.268

Appendix VIII: Effect of lime and organic matter amendment on nutrient contents in maize of T. Aman rice - Maize - Fallow cropping pattern in acid prone area of Nalitabari

Treatment	N content (%)		P content (%)		K content (%)		S content (%)	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T ₁ : Control	1.35	0.35	0.169	0.13	0.28	1.11	0.282	0.142
T ₂ : Lime 1	1.43	0.38	0.203	0.15	0.33	1.20	0.289	0.156
T ₃ : Lime 2	1.46	0.40	0.211	0.17	0.33	1.24	0.299	0.159
T ₄ : OM1	1.43	0.37	0.203	0.14	0.33	1.20	0.286	0.154
T ₅ : OM2	1.47	0.39	0.213	0.16	0.35	1.22	0.287	0.158
T ₆ : Lime1 OM1	1.57	0.42	0.214	0.18	0.37	1.24	0.299	0.168
T ₇ : Lime1 OM2	1.63	0.45	0.221	0.20	0.38	1.26	0.300	0.169
T ₈ : Lime2 OM1	1.63	0.45	0.226	0.19	0.38	1.27	0.318	0.172
T ₉ : Lime2 OM2	1.65	0.47	0.228	0.21	0.40	1.30	0.32	0.175

Appendix IX: Effect of lime and organic matter amendment on nutrient contents in T. aman rice of T. Aman rice -Maize - Fallow cropping pattern in acid prone area of Fulbaria

Treatment	N content (%)		P content (%)		K content (%)		S content (%)	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T ₁ : Control	1.05	0.270	0.208	0.121	0.259	1.12	0.242	0.207
T ₂ : Lime 1	1.11	0.329	0.237	0.154	0.307	1.19	0.277	0.212
T ₃ : Lime 2	1.14	0.340	0.250	0.166	0.322	1.21	0.294	0.216
T ₄ : OM1	1.12	0.370	0.233	0.147	0.322	1.15	0.273	0.227
T ₅ : OM2	1.17	0.390	0.242	0.159	0.341	1.17	0.287	0.233
T ₆ : Lime1 OM1	1.20	0.398	0.248	0.171	0.36	1.20	0.319	0.240
T ₇ : Lime1 OM2	1.22	0.388	0.260	0.189	0.366	1.23	0.336	0.266
T ₈ : Lime2 OM1	1.23	0.390	0.250	0.184	0.37	1.23	0.332	0.258
T ₉ : Lime2 OM2	1.26	0.418	0.260	0.194	0.402	1.23	0.353	0.277

Appendix X: Effect of lime and organic matter amendment on nutrient contents in maize of T. Aman rice - Maize - Fallow cropping pattern in acid prone area of Fulbaria

Treatment	N content (%)		P content (%)		K content (%)		S content (%)	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T ₁ : Control	1.362	0.343	0.172	0.128	0.293	1.10	0.270	0.150
T ₂ : Lime 1	1.443	0.372	0.213	0.143	0.344	1.19	0.283	0.160
T ₃ : Lime 2	1.466	0.398	0.218	0.165	0.346	1.23	0.288	0.167
T ₄ : OM1	1.410	0.375	0.200	0.142	0.314	1.21	0.278	0.159
T ₅ : OM2	1.451	0.403	0.208	0.164	0.346	1.22	0.280	0.163
T ₆ : Lime1 OM1	1.557	0.432	0.210	0.183	0.355	1.25	0.295	0.171
T ₇ : Lime1 OM2	1.618	0.462	0.220	0.201	0.380	1.26	0.298	0.171
T ₈ : Lime2 OM1	1.620	0.461	0.224	0.192	0.366	1.28	0.312	0.176
T ₉ : Lime2 OM2	1.646	0.473	0.248	0.196	0.385	1.31	0.316	0.178

Appendix XI: Effect of lime and organic matter amendment on nutrient contents in T. aman rice of T. Aman rice -Mustard - Boro cropping pattern in acid prone area of Nalitabari

Treatment	N content (%)		P content (%)		K content (%)		S content (%)	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T ₁ : Control	1.04	0.283	0.205	0.124	0.259	1.12	0.245	0.204
T ₂ : Lime 1	1.09	0.350	0.240	0.151	0.329	1.17	0.278	0.212
T ₃ : Lime 2	1.14	0.340	0.245	0.171	0.344	1.19	0.290	0.220
T ₄ : OM1	1.13	0.360	0.232	0.147	0.321	1.15	0.280	0.220
T ₅ : OM2	1.17	0.391	0.242	0.159	0.361	1.15	0.290	0.230
T ₆ : Lime1 OM1	1.20	0.399	0.248	0.171	0.350	1.21	0.322	0.238
T ₇ : Lime1 OM2	1.21	0.402	0.256	0.196	0.381	1.22	0.350	0.250
T ₈ : Lime2 OM1	1.23	0.389	0.255	0.179	0.369	1.23	0.342	0.248
T ₉ : Lime2 OM2	1.27	0.409	0.258	0.196	0.379	1.25	0.364	0.266

Appendix XII: Effect of lime and organic matter amendment on nutrient contents in mustard of T. Aman rice - Mustard - Boro cropping pattern in acid prone area of Nalitabari

Treatment	N content (%)		P content (%)		K content (%)		S content (%)	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T ₁ : Control	2.33	0.45	0.715	0.31	0.828	1.21	1.32	0.254
T ₂ : Lime 1	2.41	0.48	0.720	0.35	0.833	1.32	1.38	0.266
T ₃ : Lime 2	2.47	0.51	0.721	0.37	0.833	1.34	1.39	0.269
T ₄ : OM1	2.40	0.47	0.720	0.34	0.833	1.32	1.38	0.264
T ₅ : OM2	2.44	0.50	0.721	0.36	0.835	1.32	1.38	0.268
T ₆ : Lime1 OM1	2.54	0.52	0.731	0.38	0.837	1.34	1.40	0.278
T ₇ : Lime1 OM2	2.61	0.55	0.742	0.40	0.838	1.36	1.43	0.279
T ₈ : Lime2 OM1	2.63	0.56	0.742	0.42	0.838	1.37	1.43	0.282
T ₉ : Lime2 OM2	2.66	0.58	0.772	0.42	0.840	1.41	1.46	0.285

Appendix XIII: Effect of lime and organic matter amendment on nutrient contents in boro rice of T. Aman rice - Mustard - Boro cropping pattern in acid prone area of Nalitabari

Treatment	N content (%)		P content (%)		K content (%)		S content (%)	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T ₁ : Control	1.01	0.30	0.19	0.12	0.35	1.43	0.27	0.18
T ₂ : Lime 1	1.16	0.33	0.24	0.15	0.43	1.52	0.34	0.26
T ₃ : Lime 2	1.21	0.35	0.26	0.16	0.46	1.59	0.38	0.29
T ₄ : OM1	1.20	0.35	0.24	0.13	0.43	1.5	0.31	0.24
T ₅ : OM2	1.21	0.35	0.25	0.14	0.44	1.58	0.32	0.27
T ₆ : Lime1 OM1	1.24	0.37	0.25	0.18	0.45	1.56	0.37	0.26
T ₇ : Lime1 OM2	1.24	0.39	0.25	0.21	0.48	1.60	0.38	0.30
T ₈ : Lime2 OM1	1.25	0.42	0.29	0.20	0.49	1.67	0.41	0.32
T ₉ : Lime2 OM2	1.32	0.42	0.30	0.22	0.51	1.68	0.43	0.33

Appendix XIV: Effect of lime and organic matter amendment on nutrient contents in T. aman rice of T. Aman rice -Mustard - Boro cropping pattern in acid prone area of Fulbaria

Treatment	N content (%)		P content (%)		K content (%)		S content (%)	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T ₁ : Control	1.03	0.290	0.202	0.127	0.247	1.13	0.260	0.190
T ₂ : Lime 1	1.10	0.339	0.248	0.143	0.328	1.17	0.285	0.205
T ₃ : Lime 2	1.13	0.35	0.258	0.158	0.344	1.19	0.292	0.218
T ₄ : OM1	1.14	0.351	0.230	0.150	0.321	1.15	0.281	0.220
T ₅ : OM2	1.17	0.391	0.242	0.159	0.360	1.15	0.288	0.232
T ₆ : Lime1 OM1	1.21	0.389	0.248	0.171	0.349	1.21	0.322	0.238
T ₇ : Lime1 OM2	1.23	0.380	0.260	0.191	0.380	1.22	0.348	0.252
T ₈ : Lime2 OM1	1.23	0.391	0.255	0.179	0.371	1.23	0.330	0.260
T ₉ : Lime2 OM2	1.26	0.419	0.263	0.191	0.390	1.24	0.355	0.275

Appendix XV: Effect of lime and organic matter amendment on nutrient contents in mustard of T. Aman rice - Mustard - Boro cropping pattern in acid prone area of Fulbaria

Treatment	N content (%)		P content (%)		K content (%)		S content (%)	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T ₁ : Control	2.35	0.442	0.708	0.313	0.807	1.22	1.34	0.246
T ₂ : Lime 1	2.45	0.466	0.724	0.349	0.810	1.33	1.38	0.267
T ₃ : Lime 2	2.55	0.471	0.730	0.365	0.830	1.34	1.40	0.263
T ₄ : OM1	2.44	0.454	0.717	0.342	0.807	1.33	1.38	0.265
T ₅ : OM2	2.47	0.49	0.728	0.358	0.814	1.33	1.38	0.269
T ₆ : Lime1 OM1	2.56	0.513	0.736	0.379	0.842	1.34	1.42	0.271
T ₇ : Lime1 OM2	2.62	0.544	0.748	0.397	0.858	1.35	1.43	0.278
T ₈ : Lime2 OM1	2.62	0.565	0.760	0.413	0.840	1.37	1.44	0.278
T ₉ : Lime2 OM2	2.65	0.584	0.771	0.422	0.867	1.40	1.45	0.289

Appendix XVI: Effect of lime and organic matter amendment on nutrient contents in boro rice of T. Aman rice -Mustard - Boro cropping pattern in acid prone area of Fulbaria

Treatment	N content (%)		P content (%)		K content (%)		S content (%)	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T ₁ : Control	1.03	0.281	0.205	0.104	0.385	1.47	0.291	0.158
T ₂ : Lime 1	1.15	0.340	0.227	0.130	0.380	1.47	0.328	0.225
T ₃ : Lime 2	1.20	0.360	0.241	0.146	0.410	1.53	0.358	0.262
T ₄ : OM1	1.22	0.332	0.224	0.120	0.383	1.45	0.304	0.211
T ₅ : OM2	1.22	0.341	0.233	0.124	0.406	1.51	0.318	0.228
T ₆ : Lime1 OM1	1.26	0.352	0.248	0.158	0.411	1.51	0.351	0.242
T ₇ : Lime1 OM2	1.27	0.362	0.251	0.175	0.418	1.52	0.365	0.263
T ₈ : Lime2 OM1	1.27	0.403	0.269	0.190	0.451	1.60	0.383	0.302
T ₉ : Lime2 OM2	1.30	0.438	0.280	0.203	0.450	1.60	0.401	0.306



Fig 1. Data recording and analysis of soil samples



Fig 2. Crop establishment, harvesting and data recording of T. aman rice at farmer's field



Fig 3. Wheat and maize crops at different growth stages in the experimental plots and crop harvesting



Fig 4. Flowering and maturity stages of Mustard and PI, Co-PI & AEO visited plots



Fig 5. Boro rice transplanting and establishment in the experimental plots of farmer's field