Food and Agriculture Organization of the United Nations

VOLUME 6

RECARBONIZING GLOBAL SOILS

A technical manual of recommended management practices

CASE STUDIES

FORESTRY, WETLANDS, URBAN SOILS

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INTERGOVERNMENTAL TECHNICAL PANEL ON SOILS

GLOBAL SOIL PARTNERSHIP

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Contents

13. Long term fertilization in a subtropical floodplain soil in Bangladesh

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1. Related practices

Crop rotations, Chemical fertilization, Cattle manure application, Rice paddy management

2. Description of the case study

A long-term field experiment was established on a young floodplain soil at Bangladesh Agricultural University (BAU) in the Field Lab of the Department of Soil Science, Mymensingh in 1978 with an annual rice (*Oryza spp.*)-rice-pulse crop rotation to evaluate the influence of different fertilizer application on soil fertility and crop productivity. It involves different mineral fertilizer treatments including one with farmyard manure (FYM) and control (control, 100%N, 100%NP, 100%NPK, 100%NPKSzn and 50% N +FYM). Crop rotation and fertilizer rate were adjusted over time based on the current practices and crop demand (Mostofa *et al.*, 2015; Islam *et al.*, 2019a, 2019b). The rate of fertilizer application was updated based on crop requirement in 1982 and 2013 and initial FYM was changed to 50% N+FYM in 1982 and later further changed to 100% NPK + FYM in 2013 (Table 53).

Three crops were cultivated each year during 1978-1982. Rice was grown in two seasons: Transplant Aus (local) (March-June) and T. Aman (July-November), with a leguminous pulse (grass pea sown in the dry winter season: December- February). No fertilizer was applied for grass pea as it is grown as a relay crop with Aman and sown on standing Aman crop before harvest.

With the availability of irrigation facilities and high yielding varieties (HYV), rice was cultivated in two growing seasons from 1983 onwards following a cropping pattern of Boro rice (irrigated winter rice transplanted on mid-January and harvested mid-May)-Fallow-T. Aman (Kader *et al.*, 2017; Begum *et al.*, 2018a). Leguminous pulse was omitted from the yearly cropping pattern to accommodate irrigated Boro rice, as both are cultivated in the same time of the year.

Current application rates of N, P, K, S, and Zn are 180 (120+60), 18 (14+4), 87 (58+29), 14 (8+6) and 1 (1+0) kg/ha/yr, respectively applied as urea, triple super phosphate, potassium chloride, gypsum, and zinc oxide (Mostofa *et al.*, 2015). Cow dung was mixed with rice straw applied once a year 10-15 days prior transplantation of Boro rice at a rate of 5 t/ha fresh material (1-1.5%N, 0.3-0.4%P and 1-1.5%K). The experiment was conducted in a randomized block design with three replications (12m × 6m) (Photo 33).

Table 53. Fertilizer dose and cropping pattern at BAU long-term field experiment and its modification over time

Nutrient element	Dose (kg/ha)						
	1978-1982			1983-2012 (T. Aman)		2013 (Boro)-till date	
	T. Aus	T. Aman	Grass pea	Boro rice	T. Aman	Boro rice	T. Aman
N	60	60	-	90	80	120	60
p	20	20	-	20	20	14	4
K	15	15	-	19	19	58	29
S	-	-	-	30	30	8	6
Zn	-	-	-	5	5	1	-
FYM	15 000	15 000	-	5 000	-	5 000	-

3. Context of the case study

Floodplain is the dominant soil physiography of Bangladesh and represents 80 percent of soil area (9.7 million ha) (Brammer, 1996). The study area has sub-tropical humid climate and is characterized by hot and humid summers and cool winters with an annual mean temperature of 25.8 °C and rainfall of 2 427 mm, 80 percent of which falls between May to September (Begum and Kader, 2018). Floodplain soils are very fertile and intensively cultivated area in Bangladesh and have a cropping intensity of more than 200 percent (Uddin *et al.*, 2019). However, at the beginning of green revolution in Bangladesh during 1970s, farmers did not apply fertilizers or manure to supplement the nutrients taken up by crops, if applied very sporadically and only little N fertilizer. Considering this situation, agricultural scientists were afraid that this intensively cultivated soil would be degraded soon and would be showing different nutrient deficiency symptoms. Thus, a long-term experiment was established in 1978 at Bangladesh Agricultural University (BAU) farm at Mymensingh (24°43' N, 90°25' E), Bangladesh on a loamy, mixed, non-acidic Aeric Haplaquept to demonstrate the effect of balanced fertilization on crop productivity and soil fertility to farmers and policy makers (Mian *et al.*, 1991; Egashira *et al.*, 2005; Kader *et al.*, 2017).

4. Possibility of scaling up

Findings of this experiment have been using for formulation of national fertilizer guide particularly for floodplain soils of Bangladesh. In addition, good fertilizer practices adapted here in this long-term field experiment for maintaining better crop productivity and soil fertility are promoted throughout the region.

5. Impact on soil organic carbon stocks

This 42-year long-term experiment has been running on a loamy, mixed, non-acidic Aeric Haplaquept under tropical wet climate in Bangladesh. Soil organic carbon (SOC) has mostly doubled from initial 7.3 g/kg soil to 14.9-17.0 g/kg depending on treatments including control. However, more SOC build up was observed in NPK and NPK + FYM treatments compared to the others. As a result, higher crop yields were also recorded in these two treatments. The highest accumulation rate of SOC was calculated around 0.51 t/ha/yr in NPK treatment (

Table **54**). SOC build up in NPK + FYM treatment was lower than the NPK treatment because only 50 percent N and no P and K fertilizer was applied in this treatment until 2013. It was also observed that the accumulated SOC in NPK treatment was more stable and less prone to de-composition if present crop management has been changed. Balanced fertilization, particularly K might contributed to the formation of stable organic carbon in plant root system that latter added to soil. This high accumulation of SOC even in control treatment might be related with practicing yearly double rice cropping pattern that kept the field wet around nine months of a year. This anaerobic environment favors SOC accumulation by producing large aquatic biomass as well as reducing the decomposition rate. In addition, obtaining a substantial yield (2-3 t/ha) continuously in control treatment indicates that there are other N sources supporting plant growth other than the inputs through fertilization and atmospheric deposition, and mineralization of residues and SOM. This N could be supplied by microbial N fixation, blue green algae (BGA) or other aquatic biomass (*Azolla*, weeds) that grow in the standing water with the main crop and during the fallow period (Begum *et al.*, 2018a).

Table 54. Carbon storage potential of yearly double rice cropped soil under different long-term nutrient management

Treatments	Baseline C stock (tC/ha)	Additional C storage (tC/ha/yr)	More information
Control	13.4 (0.73%)	0.44	Aquatic biomass helps SOC accumulation
N (100% N)		0.43	-
NP (100% N & P)		0.44	-

Treatments	Baseline C stock (tC/ha)	Additional C storage (tC/ha/yr)	More information
NPK (100% N, P & K)		0.51	Under NPK management SOC increased to 1.61%
NPKSZn (100% N, P, K, S & Zn)		0.44	S and Zn fertilizer was applied later since 1982
NPK+FYM (100% N, P & K+ FYM @ 5 t/ha/yr)		0.46	100% P & K and 50% additional N was applied later since 2013

6. Other benefits of the practice

6.1. Benefits for soil properties

Physical properties

Over time the plough pan become thicker due to continuous puddling for cultivation of two wetland rice per year which reduces the percolation loss of irrigation water. In addition, bulk density of the surface soil declined due to accumulation of SOC.

Chemical properties

Soil pH and available phosphorous content remain mostly stable over time. However, a sharp decline of available K (mostly half) was observed in all the treatments. The depletion of available K was remarkable particularly in treatments without K fertilizer application. Soil total N content was also doubled like SOC that varied from 1.60 g N/kg (control) to 1.78 g N/kg (application of NPK) (Kader *et al.*, 2017, Islam *et al.*, 2019a). Cation exchange capacity (CEC) also increased mostly in balanced fertilized treatments (NPK and/or NPK+ FYM) due to accumulation of more SOC.

Biological properties

Better soil respiration and enzyme activities were observed in balanced fertilized treatments (Islam *et al.*, 2019b).

6.2 Minimization of threats to soil functions

Table 55. Soil threats

Soil threats	
Nutrient imbalance and cycles	Available P remained stable over time while there is a significant increase of soil total N in balanced fertilizer treatments. However, available K was declined sharply in all treatments though it was slightly low where K fertilizer was applied.
Soil salinization and alkalinization	No salinity and alkalinity were developed in any treatment.
Soil acidification	Soil pH remains stable in all the treatments.
Soil sealing	No soil sealing was observed.
Soil compaction	Density of surface soil decreases due to SOC accumulation.

6.3 Increases in production (e.g. food/fuel/feed/timber/fiber)

Crop yields increased by 30-40 percent in balanced fertilized treatments over the time compared to other treatments (Mostofa *et al.*, 2015).

6.4 Mitigation of and adaptation to climate change

Due to sequestration of more C in balanced fertilized treatments over time will indirectly reduce GHG (Begum *et al.*, 2018a, 2018b).

6.5 Socio-economic benefits

As the balanced fertilized plots provide 30-40 percent higher yield and maintain soil fertility better, thus it is economically much profitable.

7. Potential drawbacks to the practice

7.1 Tradeoffs with other threats to soil functions

Table 56. Soil threats

Soil threats	
Soil contamination / pollution	There could be some soil contamination. However, it was not studied yet.

7.2 Increases in greenhouse gas emissions

Overall net GHG mitigation 2 t CO_2-eq/ha/yr (equivalent to 0.6 tCeq/ha/yr) achieved when estimated with a 100-year global warming potential for CH_4, N_2O and CO_2 in NPK treatment under double rice cropping system (Begum *et al.*, 2018a; 2018b).

8. Recommendations before implementing the practice

This long-term field experimentation shows that balanced fertilizer application with NPK and/or NPK+ FYM based on soil nutrient status and crop requirement maintains crop productivity and soil fertility as well as increases soil organic carbon under rice-rice cropping pattern in subtropical soils of Bangladesh. Thus, farmers are encouraged to apply balanced fertilizer along with 5 t/ha well decomposed organic fertilizer once a year if available for maintaining their crop productivity and soil fertility.

9. Potential barriers for adoption

Table 57. Potential barriers to adoption

Barrier	YES/NO	
Biophysical	No	No biophysical barriers.
Cultural	No	There are no cultural barriers nowadays though earlier few people thought that quality of product deteriorates due to fertilization.
Social	No	There are no social barriers.
Economic	Yes/No	Sometimes farmers did not apply balanced fertilizer as the price of P and K containing fertilizers are higher than that of N containing fertilizer as government provide high subsidy on N fertilizer.
Institutional	No	Government and other agricultural research organization promote balanced fertilization practices.
Legal (Right to soil)	No	There are no legal barriers for adopting the practice.
Knowledge	Yes	Some farmers are still do not know the importance of balanced fertilization, thus there is still a knowledge gap.

Photos

Photo 33. Experimental layout showing all the unit plots (top) and growing rice crop (bottom)

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