FINAL REPORT

Agricultural Research Priority : Vision-2030 and beyond

Sub-sector : Land and Soil Resource Management

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EXECUTIVE SUMMARY

Soil is the greatest resource of Bangladesh. Over the last 2-3 decades, enormous pressure has been exerted on the soil resource to produce more food for its vast population. Intensification of agricultural land use has increased remarkably, along with increasing use of modern crop varieties, which in turn has resulted in deterioration of soil health.

Physiographically, Bangladesh has three categories of lands: floodplains (80%), terraces (8%) and hills (12%). Crop cultivation is intense in floodplain soils. There exist many production problems in the agriculture sub-sectors (crop, livestock, fisheries and forestry).

The major objective of this assignment is to review, identify and suggest researchable problems in relation to land and soil resource management. It covers soil organic matter, soil nutrient status, soil degradation, nutrient use efficiency, soil management in unfavourable ecosystems (coastal lands, hills, char lands), etc.

Suitable approaches and tools have been followed to achieve the objectives. The approaches comprised consultation and review of relevant documents, group discussion, and regional workshop feedback. The documents included National Agriculture Policy (NAP), National Food Policy (NFP), National Land Use Policy (NLUP), and Vision Document – 2020 of BARC for Agricultural Research. Group discussions were made with soil scientists of NARS institutes (BRRI, BARI, BINA & SRDI) and universities (BAU and BSMRAU). Inputs were collected from four regional workshops (Bogra, Chittagong, Barisal and Mymensingh) which were attended by different types of stakeholders. The stakeholders were extension agencies (DAE, DLS and DoF), NARS institutes, universities, NGOs, private sector organizations, and farmers.

The history of soil fertility research in Bangladesh is old. The earliest study on soil fertility was initiated at Dhaka (Monipuri) Farm in 1911. A good progress in soil research has been made after 1970 and a break-through after 1980 through implementation of coordinated national projects, many of them executed by BARC. Those are mostly related to soil fertility and fertilizer management. There has been a considerable progress in the development of BNF (Biological Nitrogen Fixation) technology, particularly *Rhizobium* technology (biofertilizer)

There have been identified many soil health related problems which hinder crop production. The problems are depletion of organic matter and soil fertility, nutrient deficiency, soil salinity, soil acidity, topsoil erosion, degraded rice soils, sandy soils,

drought, drainage impedance, and water logging. These problems have arisen largely due to irrational human interventions.

To solve these problems, efficient research is needed. Not all problems are researchable, so problems need to be prioritized that constraint production, growth and development. Since available resources are limited, careful thought is needed to solve the priority problems.

Depletion of soil organic matter is not true for all soils or all cropping conditions. Practically, in rice-rice (anaerobic-anaerobic) conditions organic matter level has not declined, rather it has slightly increased. Of course, the organic matter in wheat-rice (aerobic-anaerobic) system has clearly declined. Management of soil organic matter has now become a major issue in dealing with the problems of soil fertility and productivity in Bangladesh. Waste management could be a big issue in future research strategies, concerning recycling and environmental protection.

Depletion of soil fertility has arisen principally due to increasing cropping intensity (presently about 190%), increasing use of MVs, soil erosion, sandy soils, and higher decomposition of organic matter due to sub-tropical humid climate. The highest nutrient mining occurs with K, since the farmers are using lesser amount of K fertilizer. An excellent opportunity exists to arrest K mining by retaining 50% crop residues (e.g. rice straw) in the field. Nitrogen is the most deficient element in Bangladesh. More than 60% loss of urea-N occurs in wet land rice culture. There is scope to reduce this N loss from soils. Efficient research is needed on the aspect of reducing the N loss from soils and increase N use efficiency, particularly under wet land rice system. However, the situation of soil N is similar to that of organic matter since more than 85% N comes from decomposition of organic matter. We should not worry about P, since this element balance was found to be slightly negative to slightly positive across the soils and cropping systems. As time advances, new nutrient deficiency arises. Deficiency of micronutrients e.g. Zn, B & Cu has arisen in some soils and crops.

Research is needed to determine all the deficient elements and management is needed on sustainable basis. Fertility management systems that profitable for short-term and sustainable for long-term should be formulated and it needs to be confirmed by on-farm research trials. We need to explore and utilize as much as possible biologically fixed N, both symbiotically and non-symbiotically.

Land and soil resource management research should give special attention to ecologically disadvantaged areas e.g. coasts, hills, char lands where research is not yet strengthened. Soil erosion is a major constraint in hilly areas. Sloppy lands and light textured soils, coupled with jhum cultivation are responsible for soil erosion. So, conservation agriculture techniques e.g. cover crops, contour, strip cropping should be investigated.

Soil fertility research is meager on horticulture crops, especially fruits and vegetables, although nutrient management is important for improvement of mineral nutrition, apart from yield advantage.

The country is receiving natural hazards e.g. drought, flood etc. and experiencing climate change e.g. rise in temperature, change in rainfall pattern. Its impact on natural resources, especially land, soil & water needs to be investigated.

It is not unlikely that tomorrow's agriculture would be significantly influenced by the global climate change that includes increase in CO_2 content, increased emission of gases as CH_4, N_2O etc. which would lead to an increase of temperature of the earth and rise in the sea level. This climate change would have a direct effect on crops, water balance, soil organic matter content, surface energy balance and in deed, the range of soil properties.

There are some policy issues concerning fertilizer management practices. Quality of non-urea fertilizers is often below standard, with more than 80% adulteration for mixed fertilizers (NPKS), above 50% adulteration for privately imported SSP and TSP, and 25-30% adulteration for MoP and DAP (SRDI report, 2007-08). Strong monitoring is needed at storage and distribution points to check adulteration of these fertilizers. Farmers are using lesser amount of TSP and MoP, creating an unbalanced use of fertilizers which produces negative impact on soil fertility and crop yield. Farmers should be motivated to use balanced use of fertilizers, with integrated nutrient management approach. Farmers are using minimum amount of organic fertilizers. Further they are using a significant portion of cowdung as fuel. Policy support is needed to increase the use of organic fertilizers. Further policy support is needed to increase the ability of marginal and small farmers to buy non-urea fertilizers.

There is a rapidly changing demand that soil research should address vital issues in the coming 20 years. We are being called upon to solve problem which we did not face a decade back.

Soil research needs to be integrated with other areas of research (e.g. irrigation, crops) in solving increasing complex problems. Sustainability goals demand that adequate strategies are built in to reduce further degrading of productive soil and all out efforts are made to rehabilitate the already degraded soils.

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1. INTRODUCTION

Soil is the greatest resource of a country. "The wealth of a nation lies in her soils and their intelligent development", says a philosopher, Richard Gordon Moores. There are historical evidences that survival of a civilization depends on soil productivity. Soil can be singled out as one of the most important environmental factors affecting crop yields.

Bangladesh is the largest deltaic floodplain in the world with a total area of 147570 km^2 of which 88892 km^2 is occupied by major rivers and estuaries. The great delta is flat throughout and sketches from near the foothills of the Himalayas Mountain in the north to a southern irregular deltaic coastline that faces the Bay of Bengal. She lies between $20^0 34^{''}$ and $26^0 38^{''}$.

Over the last 2-3 decades, enormous pressure has been exerted on the land resources to produce more food for its vast population. Intensification of agricultural land use has increased remarkably, accompanied with increasing use of modern crop varieties. Unfortunately, this has impacted deterioration of soil health.

Physiographically, Bangladesh has three categories of lands: floodplains (80%), terraces (8%) and hills (12%). Crop cultivation is intense in floodplain soils. During early 60's, the soils of Bangladesh on the basis of origin and properties were broadly classified into seven tracts (Annex. 1). Later, the country was classified into 30 agro-ecological zones (AEZ), based on land form, land types, soil characteristics, and climate (Annex. 2). The country is endowed with a climate favourable for cultivation of a wide variety of crops. The major crops include rice, wheat, jute, cotton, sugarcane, vegetables, oilseeds, pulses, tuber crops, tobacco and tea. However, rice alone covers about 75% of arable land and the cropping pattern is mainly rice based.

Not all are researchable problems, so problems need to be prioritized that constraint production, growth and development. There exist many production problems in the agriculture sub-sectors (crop, livestock, fisheries and forestry). Since available resources are limited, judicious allocation is needed to solve the priority problems.

There are a number of soil health related problems which affect crop production. These problems are depletion of organic matter, depletion of soil fertility, nutrient deficiency, soil salinity, soil acidity, topsoil erosion, degraded rice soils, sandy soils, drainage impedance, and water logging. These problems are mostly due to irrational human interventions.

To address soil related problems it is necessary to identify the constraints related to physical, chemical and biological in nature and integrating them to suggest measures for improvement in effectiveness of input use, crop yield and quality, soil fertility and overall sustainability. Our life and food security depend on improved soil management.

Although generation of technology is our concern, we should consider whether or not, it finds a place with the users and whether or not is the concern of extension workers. It is being increasingly recognized that many research recommendations are not adopted because they are not consistent with the local circumstances.

The 21st Century poses a formidable challenge to the agricultural scientists in general, and soil scientists in particular. There is a rapidly changing demand that soil research should address some vital issues in the coming 20 years. We are being called upon to solve problem which we did not face a decade back.

2. GROUP LEADER'S TOR

The major task of the present Group Leader was to review, identify and suggest researchable problems in relation to land and soil resource management. It covers soil organic matter, soil nutrient status, soil degradation, nutrient use efficiency, soil management in unfavourable ecosystems (coastal lands, hills, char lands), etc.

The detailed and common ToR of every group leader can be seen in Annex 3.

3. METHODOLOGY

Suitable approaches and tools were followed to achieve the objectives of this study. Information and data were collected in three ways: (i) consultation and review of relevant documents, (ii) group discussion, and (iii) regional workshop feedback. They are briefly described below.

Consultation and review of previous documents

Some policy documents were consulted such as National Agriculture Policy (NAP), National Food Policy (NFP), National Land Use Policy (NLUP), and Bangladesh NARS - 2020: A Vision for Agricultural Research. Annual research reports (NARS institutes), workshop proceedings and research publications related to soil and fertility management have been studied. This has helped make a comprehensive literature review of soil related works done in the past in Bangladesh. The review has served as a good basis for formulation of future research need. Annual research progress report and future research programmes of BRRI, BARI and BINA have been reviewed. The proceedings of the National Workshop on Hill farming Practices in Bangladesh: Constraints and Opportunities and on Soil Fertility, Fertilizer Management and Future Research Strategy have been especially helpful.

Group discussion

The team (group leader and member-secretary) had met a number of soil scientists of various institutes and discussed with them various aspects of soil related research about what was done and what to be done. The institutes visited were BRRI (Soil Science Division), BARI (Soil Science Division and OFRD), BINA (Soil Science Division), SRDI, BAU (Soil Science and Agricultural Chemistry Departments), and BSMRAU (Soil Science Department). There was a threadbare and viable discussion over several hours in each institute. The team attended the National Workshop on Soil fertility, Fertilizer Management and Future Research Strategy, held at BARC during 19-20 January 2010 and obtained valuable inputs.

Regional workshop feedback

Pertinent information was also collected from regional workshops where different types of stakeholders were present. The stakeholders were extension agencies (DAE, DLS and DoF), NARS institutes, universities, NGOs, private sector organizations, and farmers. This was quite effective in obtaining field observations and experiences across the country.

This is a new approach for determining priority research in agriculture sub-sectors. So, it’s a ‘bottom up’ process rather than ‘top-down’ process. In the past, research priority was determined in a somewhat different way.

The regional workshops on Agricultural Research Priority Setting were held at Bogra, Chittagong, Barisal and Mymensingh. At all places, a day-long workshop was held, the dates being 29 December in 2009 and 11 January, 27 January and 17 February in 2010, respectively. In these workshops, DAE personnels (AD, DD, UAO, AEO), scientists of NARS institutes, university teachers (BAU, SAU) and some NGOs presented their group presentations regarding practical problems existing in the field, with an indication of future research need in relation to obtaining higher and satisfactory crop production, without affecting soil health. Such information has been compiled and taken into account in the research priority setting.

4. LITERATURE REVIEW

A review has been made on the soil research history and progress in Bangladesh, with an objective of determining future soil research in this country.

History of Soil Research

Research on crop agriculture was initiated in the then Bengal in the beginning of 20th century, with the establishment of the Central Agricultural Research Station (Known as Dhaka Farm) in 1909 at Tejgaon when Dhaka was the capital of East Bengal and Assam (Islam, 1992). The research station had three divisions: Economic Botany (Cereal), Economic Botany (Fibre) and Agricultural Chemistry. Soil fertility research was carried out under the Agricultural Chemistry Division.

The history of soil fertility research in Bangladesh is old. The earliest study on soil fertility was initiated at Dhaka (Monipuri) Farm in 1911 to investigate the effect of bone meal and cowdung on Aus rice (Alim *et al*. 1962). Later on, the fertilizer trials were made with bulky and concentrated manures such as city wastes compost, FYM, mustard oilcake and fish meal applied singly or in combination with bone meal and/or chemical fertilizers such as rack phosphate, ammonium sulphate and muriate of potash at different locations of Comilla, Faridpur, Rajshahi and Barisal. Effects of mustard oilcake and fish meal were found superior to other manures, and among the fertilizers, the effect of ammonium sulphate was found distinct in rice. These studies started during 1943-44 and continued up to 1953-54 (Idris, 1998).

The activities of this institute were continued up to mid 70s after which it was reconstructed as On-Farm Research Division (OFRD) and Analytical Services Division (ASD) under the Bangladesh Agricultural Research Institute (BARI). In 1957, a research scheme entitled, “Rapid Soil Fertility Survey and Popularization of the Use of Fertilizer in East Pakistan” was implemented (Islam, 1992) with 50 experimental centres across the country and later, the work expanded under the East Pakistan Soil Fertility and Soil Testing Institute in 1963 with 200 experimental centres.

A good progress in soil research has been made after 1970 and a break-through after 1980. During 1980s several national soil fertility research projects were undertaken such as Soil Response Correlation Studies (Project), Potassium Project, Micronutrient Project, and Sulphur & Zinc Project. In 1998-2000, BARC executed ARMP under which several soil fertility projects were implemented. During 1997-2005, a national project was completed under the Soil Fertility and Fertilizer Management Programme (SFFP). Presently a project entitled, “Management of Soil Fertility for Sustainable Crop Production in Monga Affected Areas of Kurigram”, as a component of SPSS-II Adaptive Research (AEC, Khamarbari) is going on at BAU, Mymensingh.

The Ministry of Agriculture (MoA, GoB) with the financial assistance of EC is going to implement a project, Food Security Programme 2006: Soil Fertility Component (FS/SFC) Project. The project aims at addressing the challenges of sustainability of food security through improved and adaptive soil management in the agro-ecologically disadvantaged areas (coasts, haors, hills, piedmonts and peats).

Relatively Soil Physics research in this country is far behind. So far, one national project entitled, “Evaluation of Physical Properties of Bangladesh Soils” and one contract project initiated by BARI entitled, “Soil Erosion and Conservation” have been completed.

Organic Matter Depletion and Management

Organic matter depletion

Soil organic matter is a key factor in maintaining long-term soil fertility since it is the reservoir of metabolic energy, which drives soil biological processes involved in nutrient availability. A good soil should have at least 2.5% organic matter, but in Bangladesh most of the soils have less than 1.5%, and some soils even less than 1% organic matter (BARC, 2005). Organic matter content of top soils particularly under high land and medium high land situations has declined over time (Annex. 4). Organic matter is known as 'storehouse of plant nutrients' and ‘life force of a soil'.

As the time advances, organic matter content in soil declines (Fig. 1). Ali (1997a) reported that during the years 1967-1995, the highest depletion of organic matter occurred in soils of Meghna River Floodplain (35%) followed by Madhupur Tract (29%), Brahmaputra Floodplain (21%), Old Himalayan Piedmont Plains (18%) and Gangetic Floodplain (15%).

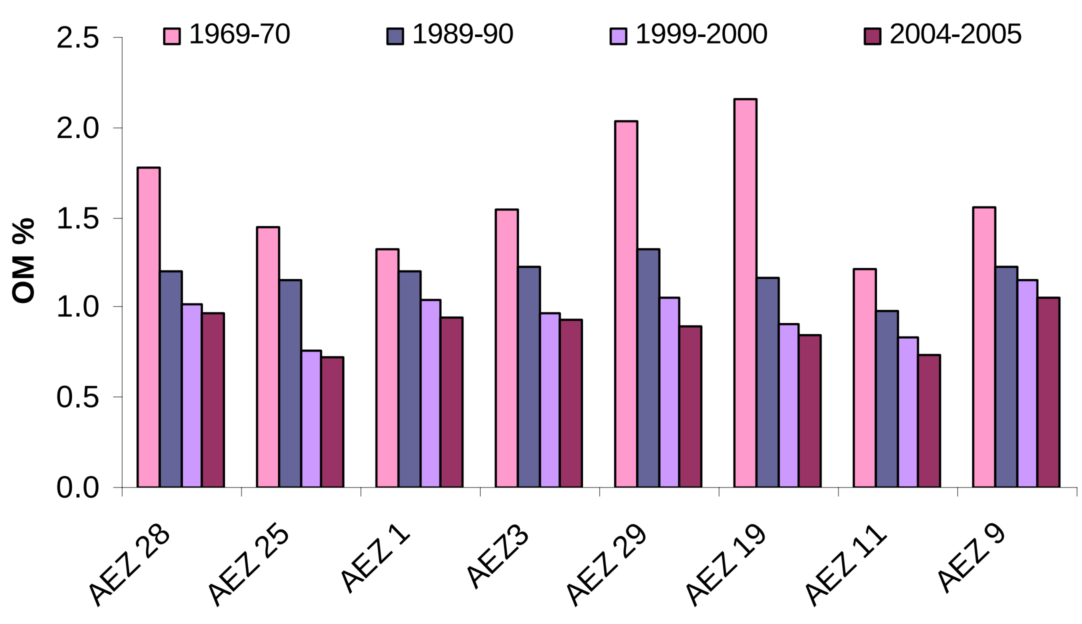


Fig. 1 Depletion of soil organic matter in Bangladesh (BARI, 2008-09)

These results were obtained from an average of several soil samples of an AEZ. However, there is a weakness of the reliability of results since soil sampling was not done based on GPS bearing.

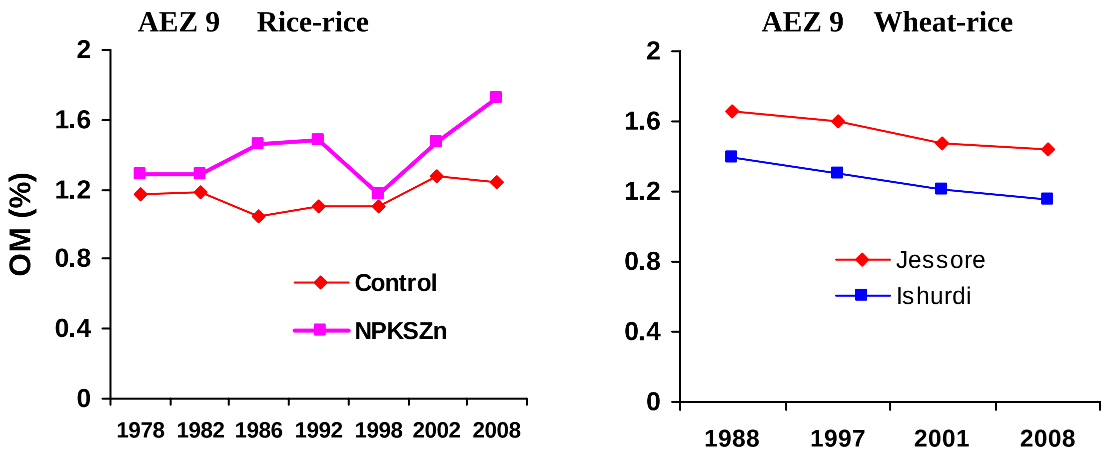


Fig. 2 Changes in soil organic matter over time in the rice-rice and wheat-rice patterns

The long-term fertilizer trials at BRRI and BAU farms indicate that in the rice-rice (anaerobic-anaerobic) cropping system, the soil organic matter has slightly increased (Fig. 2 and Table 1) (BRRI, 2007-08; Mithu, 2008). On the other hand, in the wheat-rice (aerobic-anaerobic) system, experiments conducted at WRC, RARS Jessore & Ishurdi show that the soil organic matter has decreased (Fig. 2) (Bodruzzaman and Sadat, 2008; BARI, 2007-08). The long-term studies at IRRI, Philippines over the period 1983-2008 also demonstrate that in the rice-rice-rice system, the SOM tends to increase (Pampolino et al., 2008). Hence, depletion of soil organic matter can not be generalized across the country.

Table 1. Changes in soil properties as influenced by fertilization in intensive rice cropping under perpetually wetland condition after 36 years (1971-2007)

Treatments	**OM (%)**	**Total N (%)**	**Avail. P (mg/kg)**	**Exch. K (meq/ 100g)**	**Avail. S (mg/kg)**
Control	1.61	0.09	5	0.09	4.6
NPK	1.87	0.11	23	0.17	6.1
NPKS	2.27	0.13	14	0.12	5.4
NPKSZn	2.60	0.15	28	0.12	9.0
NPKSZnCu	2.41	0.14	22	0.14	8.5
Initial soil	2.13	0.12	14	0.13	5.2

Organic matter mineralization

Soil organic matter undergoes mineralization and releases substantial quantities of N, P, S and smaller amount of micronutrients. Application of organic residues returns mineral nutrients to the soil. The conversion of organic N, P and S to available forms occurs through the activity of microorganisms and is influenced by those factors affecting microbial activity (temperature, moisture, pH etc.). The rate and extent of mineralization determine crop availability of nutrients from added organic materials. All the bio-forms use soil as their home or they live on organic matter and decompose it to simple products. These products are responsible for sustaining soil productivity and performing environmental regulatory function.

Organic matter management

Soil organic matter plays an important role on physical, chemical and biological properties of a soil. Application of organic materials once a year is essential to increase or maintain the fertility status of a soil.

Destruction of vegetation to create more cropland and consequent rise in temperatures are the cause of soil carbon loss and this happens since diminishing soil carbon stock provokes fall in soil quality.

Lal (2004) states that the rate of organic carbon sequestration in soil with adoption of recommended technologies depends on soil texture, soil structure, rainfall, temperature, farming system and its management. An increase of 1 ton of soil organic tool of degraded crop land soils may increase crop yield by 20-40 kg $ha^{-1}$for wheat, 10-20 kg $ha^{-1}$for maize and 0.5-1 kg $ha^{-1}$for cowpea. Apart from enhancing food security, carbon sequestration has the potential to offset fossil fuel emissions by 0.4-12 gigatons of carbon per year or 5-15% of the global fossil fuel emissions.

No-till farming is a complex management system that integrates natural processes and implements three key management strategies: minimum soil disturbance, continue crop residue cover and diverse crop rotations and/or cover crops.

Bio-slurry could be a potential source of organic matter in soils. During anaerobic digestion, 25-30% of total solid content of organic manure e.g. cowdung, poultry manure, buffalo dung etc. is converted into combustible gas (CH_4) and the rest 70-75% solids come out as sludge (bio-slurry). A significant portion of cowdung is used as fuel in the rural areas. So, biogas plant produces biogas which helps meet the fuel crisis and its by-product i.e. bio-slurry can help improve the soil organic matter level. Historically, the first biogas plant was constructed in 1972 at BAU, Mymensingh. So far, 24,000 biogas plants have been constructed in Bangladesh, the vast majority at domestic level. The National Domestic Biogas and Manure Programme, with the financial support of Netherlands and Germany, has established 10,000 plants since 2006 (Islam, 2010). The major constraint of bio-slurry use in crop production is the management and utilization of bio-slurry. Research is needed on bio-slurry quality, mineralization and management for crop production. City wastes can also be another potential source of organic matter (Fig. 3).

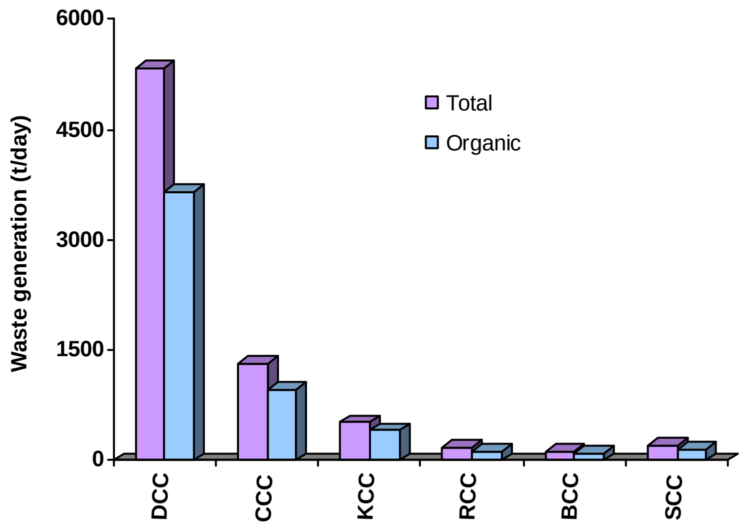


Fig. 3 Waste generation in different cities of Bangladesh (Alamgir and Ahsan, 2007)

Selection of crops and cropping pattern is an important factor for maintaining fertility status of a soil. Mungbean is the most common grain legume grown in the summer to utilize the gap between the winter and rainy season crops. Incorporation of mungbean residues after picking pods has been found as effective as green manuring with other legumes and this has been reflected on the growth and yield of T. aman rice (Sarkar, 2005).

Ali (2003) views that legume not only provides a bonus yield but also benefits the succeeding or companion crop. The highest grain yield was obtained from 100% NPKS fertilizer application which was comparable to that recorded for the treatment 75% NPKS fertilizers + legume residue incorporation.

Mandal *et al.* (2003) found that the organic matter and total soil nitrogen concentrations were found to be higher under green manuring treated plots. Rahman (2003) reported that soil aggregation, structure, permeability, fertility and infiltration rate were improved with the inclusion of legumes in the cropping system.

Agricultural production can not be sustained if the nutrients removed during the cropping phase are not replenished and if appropriate agricultural practices are not implemented to maintain soil organic matter level.

Soil Fertility and Fertilizer Management

Soil fertility depletion

Depletion of soil fertility is mainly due to exploitation of land without proper replenishment of plant nutrients. The problem is enhanced by intensive land use without appropriate soil management. The situation is worse in areas where HYV crops are being grown using low to unbalanced doses of mineral fertilizers, with little or no organic recycling. Because of increasing cropping intensity (presently 198%) and cultivation of modern varieties of crops, the net removal of plant nutrients is far from the nutrient supply through fertilizers and manures.

Like SOM, soil nutrient status is declining with time (Annex. 5). Again, land use with higher cropping intensity shows higher nutrient mining (Annex. 6), and the addition of OM may help reduce nutrient mining.

Nitrogen status in this country's soils resembles the results of SOM. In the rice-rice system, the level of soil N has little increased and in the wheat-rice system, the N level has rather slightly decreased (Fig. 4). Practically, P availability in soils remains mostly unchanged over the years, particularly in the P fertilized plots. Unlike N and P level, K mining is clearly visible in soils for all cropping systems (Fig. 5).

Ali *et al.* (1997) reported that the total carbon content on an average decreased by 11%, the total N by 12%, pH decreased by 4% and the exchangeable acidity increased by 30%. The exchangeable K content in soil decreased by 31% and available P showed a 9% decrease over 27 years (1967-1995).

The annual removal of nutrients from soil is higher compared to their addition. From an extensive review, Rijmpa and Jahiruddin (2004) reported that the overall N balances of Bangladesh soil were negative (-10 to –100 kg N ha^{-1} yr^{-1} depending on the nutrient management and cropping systems), the P balances were near zero and the K balances were highly negative (-100 to –225 kg ha^{-1} yr^{-1}).

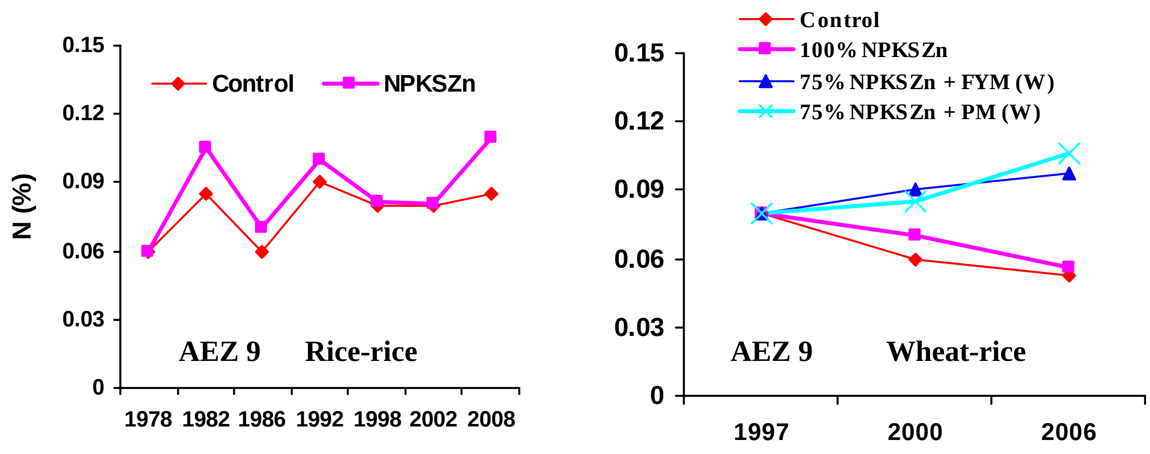


Fig. 4 Changes in soil N level over time in the rice-rice and wheat-rice cropping systems

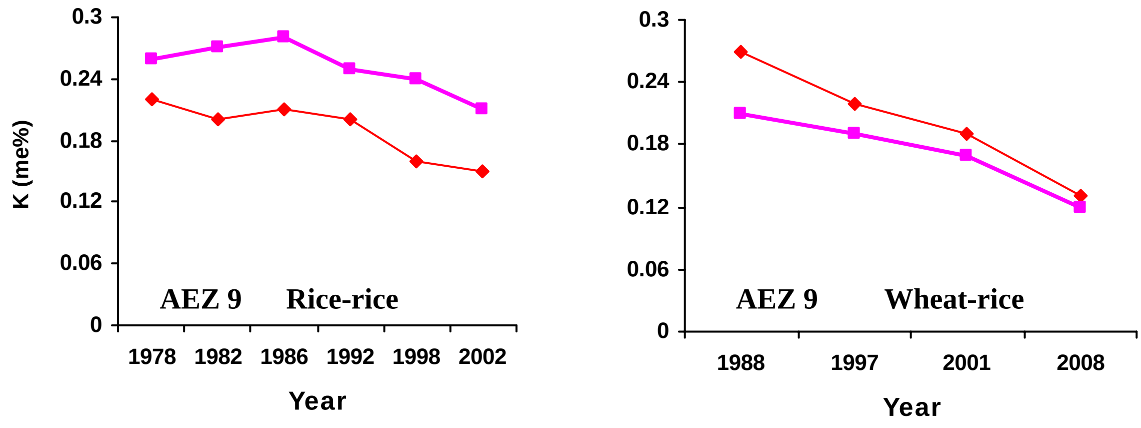


Fig. 5 Changes in soil K level over time in the rice-rice and wheat-rice cropping systems

Maize cultivation has greatly increased in the recent years because of its higher yield potential and its high market demand as poultry feed. However, nutrient uptake by maize is much higher compared to rice and wheat, and consequently, high nutrient depletion occurs in maize land. A recent estimate shows that rice (HYV) uptakes 108 kg N, 18 kg P, 102 kg K and 11 kg S ha^{-1}from soils while maize cropping removes about 160 kg N, 29 kg P, 134 kg K and 34 kg S ha^{-1} (Islam et al., 2010).

Nutrient deficiency

As the time advances, new nutrient deficiency arises (Table 2). Six mineral elements such as N, P, K, S, Zn and B are commonly deficient in Bangladesh soils (Annex. 7-11). Of them, nitrogen is the most limiting nutrient in Bangladesh agriculture. Until 1980, deficiencies of three nutrients viz. N, P and K were identified in Bangladesh soils. In early 1980s, S and Zn deficiencies in rice were observed. In early 1990's, the B deficiency of some crops was reported. There is sporadic information of Cu, Mo and Mn deficiencies in crops (Khanam et al., 2000; Ferdoush et al., 2003). Deficiencies of Fe and Cl are not yet reported in this country. Magnesium is reported to be deficient in Old Himalayan Piedmont Plain and Tista Floodplain soils (OFRD report, 1998)

							?
						Mg	**Mg**
					B	**B**	**B**
				Zn	**Zn**	**Zn**	**Zn**
			S	**S**	**S**	**S**	**S**
		K	**K**	**K**	**K**	**K**	**K**
	P	**P**	**P**	**P**	**P**	**P**	**P**
N	**N**	**N**	**N**	**N**	**N**	**N**	**N**
1951	**1957**	**1960**	**1980**	**1982**	**1995**	**2000**	**2010**

Table 2. Emergence of new nutrient deficiency with time

Zinc deficiency is particularly evident in calcareous and wetland rice soils (Islam et al., 1997; Alam et al., 2000). The highly Zn deficient areas are Rajshahi, Pabna, Kushtia, Jessore, Faridpur, and Barisal (SRDI, 2008). Zinc deficiency in crops reduces not only the grain yield, and also hampers nutritional quality (Hossain et al., 2007). Zinc deficiency is ranked as the 5th leading risk factor for human diseases in the developing countries (WHO, 2002).

Boron deficiency is common in rabi crops such as mustard, wheat and chickpea (Haque et al., 2000; Khanam et al., 2000; Hossain, 2006). This element influences more reproductive development rather than vegetative. Brassica crops are more sensitive to boron deficiency. Again, crop species and varieties may differ in their sensitivity to boron deficiency (Ahmed et al., 2007). The most B deficient areas are Dinajpur, Rangpur, Bogra, Sirajgonj, Comilla and Sylhet (SRDI, 1998).

Fertilizer management

Soil is not an inexhaustible store of plant nutrients, even though it is called the bank of nutrients. The farmers of Bangladesh use only about 172 kg nutrients ha^{-1} annually (132 kg N, 17 kg P_2O_5, 17 kg K_2O, 4 kg S, 2 kg Zn + B), as against the crop removal of about 250 kg ha^{-1} (Islam, 2002). Agricultural production can not be sustained if the nutrients removed during the cropping phase are not replenished. Fertilizer recommendations should consider short-term as well as long-term crop response to applied fertilizer. Changes in soil nutrient pools need to be accounted for evaluating nutrient management strategies by estimating the system level nutrient use efficiency.

Fertilizer is the key input for successful crop production. Fertilization always gives benefits over no fertilization (Fig. 6).

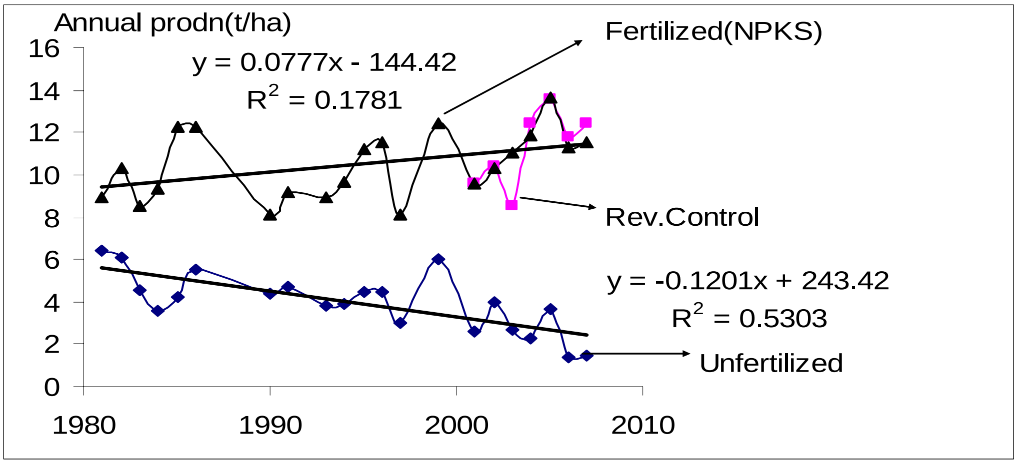


Fig. 6 Changes in annual production of rice with and without fertilization over 27 years (BRRI, 2007-08)

Integrated Plant Nutrition System (IPNS) for crop production

The basic concept of Integrated Plant Nutrition System (IPNS) is the management of all available plant nutrient sources, organic and inorganic, to provide optimum and sustainable crop production conditions within the prevailing farming system. Therefore, in IPNS an appropriate combination of mineral fertilizers, organic manures, crop residues, compost, N-fixing crops and bio fertilizer is used according to the local ecological conditions, land use systems and the individual farmer's social and economic conditions.

The main aim of integrated plant nutrition system is to increase and sustain soil fertility to provide a sound basis for flexible food production systems that, within the constraints of soil and climate, can grow a wide range of crops to meet changing needs (FAO, 2001). Therefore, it is necessary to use inorganic and organic fertilizers in an integrated way so as to obtain economically profitable crop yield, without incurring loss to soil fertility (Haque *et al*., 2001). IPNS can produce comparable or higher crop yiel0d compared to sole fertilizer use (Fig. 7) (BARC, 2005).

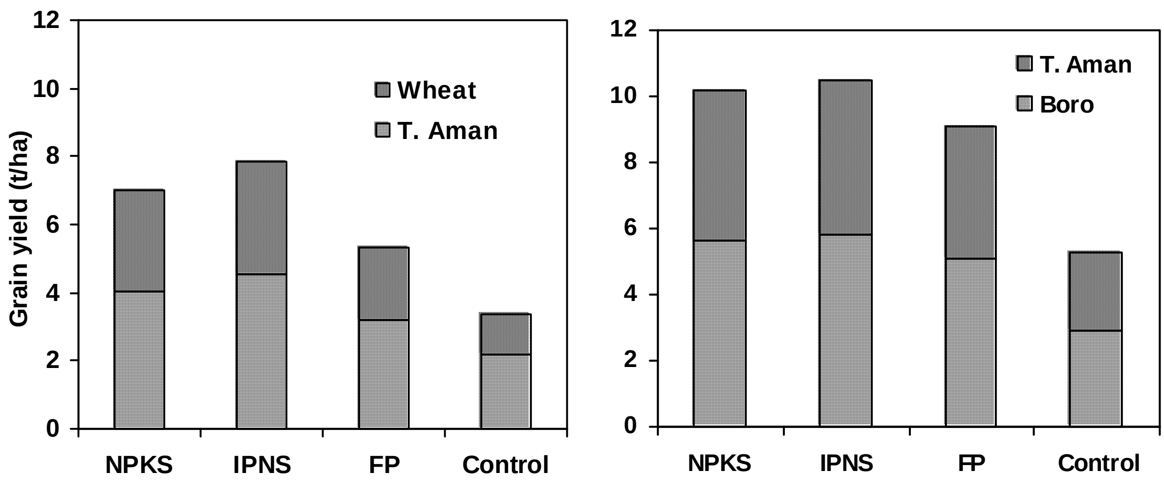


Fig. 7 Grain yields of crops in the wheat-rice and rice-rice systems under different nutrient management practices

From the long-term fertilizer trial, Bodruzzaman and Sadat (2008-09) reported that integrated nutrient management with chemical fertilizers and FYM or PM had positive effect on soil properties and crop yield in the wheat-rice pattern (Fig. 8) (Bodruzzaman and Sadat, 2008).

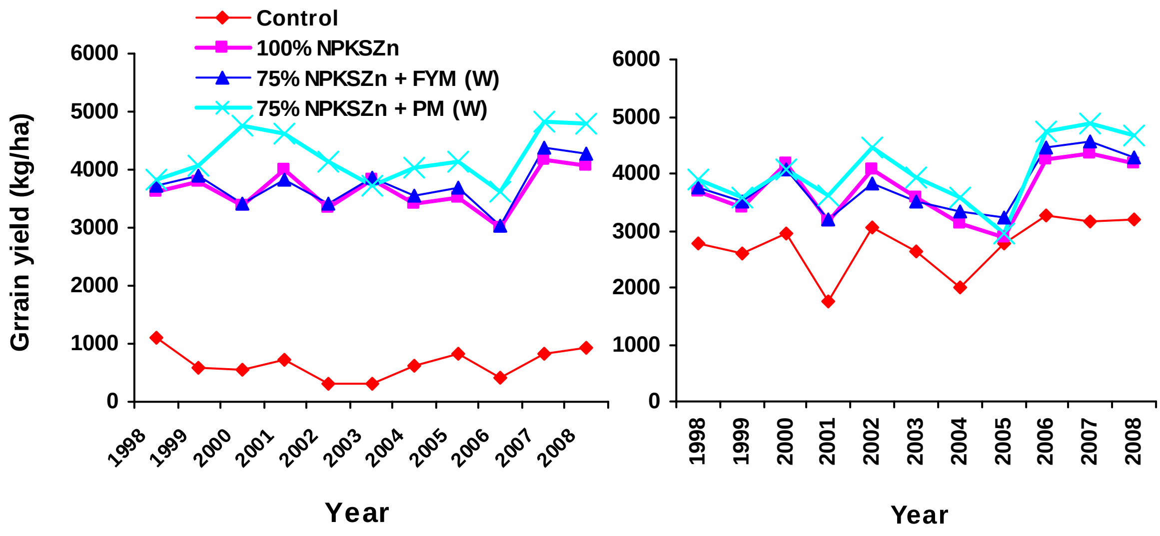


Fig. 8 Grain yield of crops in the wheat-rice system under different nutrient management practices

Saleque *et al.* (2004) stated that application of balanced doses of chemical fertilizers and integrated use of cowdung, ash and chemical fertilizers gave positive yield trend of rice. Zaman (2002) observed that in rice-rice cropping pattern, 70% NPKS fertilizers + mungbean residues produced identical grain yields with 100% NPKS fertilizers. Rahman (2001) reported that the treatments containing 75% PKS fertilizers + GM gave the highest or an identical grain yield of T. aman rice compared to the rate of 100% NPKS fertilizers. Biologically N-fixing systems offer an economically attractive and ecologically sound means of reducing external inputs of industrial N fertilizers and improving internal resources.

Fertilizer Recommendation Guide

During early 1960s, on the basis of origin and properties, the soils of Bangladesh were broadly classified into seven tracts. According to these soil test values, fertilizer recommendations for different crops were formulated and published for the first time in the name of *Fertilizer Use in East Pakistan* in January 1961. The Department of Soil Survey carried out reconnaissance surveys during 1961-70 and classified the soils into 18 General Soil Types and 20 Soil Units. The second Fertilizer Recommendation Guide entitled, *Soil Fertility Investigation in East Pakistan*, was published in 1967, and updated recommendations were published in 1969 in the name of *Studies on Fertilizer and Soils of East Pakistan*.

The FAO/UNDP Fertilizer Demonstration and Distribution Project during 1975-80 conducted a series of on-farm trials and demonstrations across the country on local/improved local varieties of crops. The Bangladesh Agricultural Research Council

(BARC) had published the First Fertilizer Recommendation Guide (FRG) in 1979 entitled, *Fertilizer Guide for Major Crops of Bangladesh*. Eventually with the progress of soil fertility research, the Second Fertilizer Recommendation Guide was published in 1985, with the title of *Fertilizer Guide for Major Crops of Bangladesh*. The third Fertilizer Recommendation Guide came out in 1989 with the name of *Fertilizer Recommendation Guide-1989*. The 4th Fertilizer Recommendation Guide appeared as *Fertilizer Recommendation Guide-1997* and the 5th or the last Guide as *Fertilizer Recommendation Guide - 2005*.

Management of Soils in Unfavourable Ecosystems

The soils in the unfavourable ecosystems are known as problem soils since these are unproductive or less productive soils. The soils occur in agro-ecologically disadvantaged areas such as coasts, chars, hills, piedmonts, haors and peats.

Coastal lands

The major costal districts are Satkhira, Khulna, Pirojpur, Barguna, Patuakhali, Noakhali and Cox's Bazar. This area is relatively flat and suffers from saline soil-water to different degrees. Other environmental challenges include tidal surge, cyclone, acid sulphate soils (Sunderbans and Chakaria), waterlogging in polder areas, river erosion and unstable atolls.

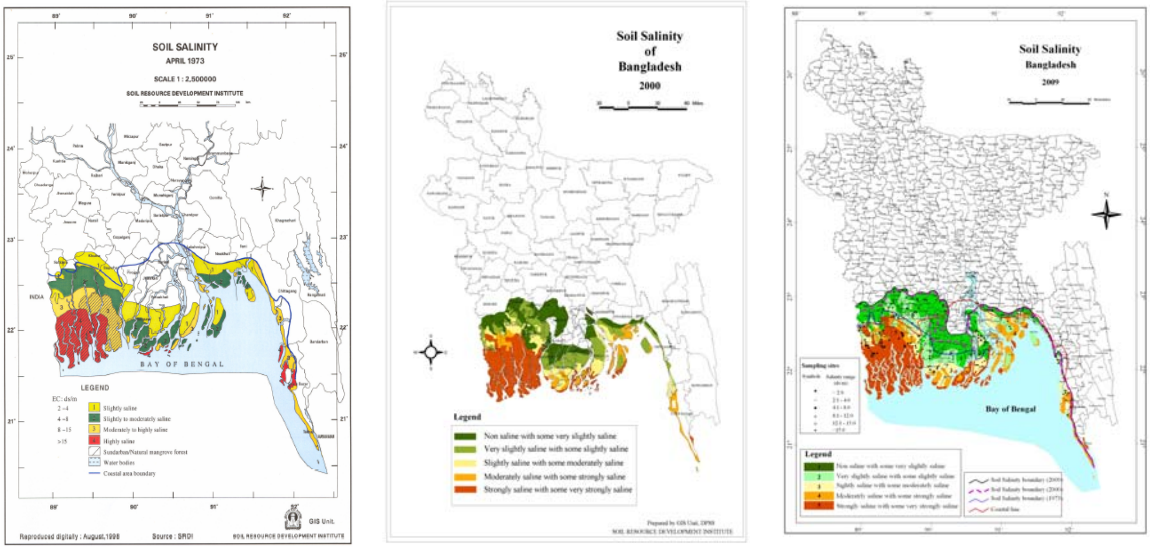
The coastal and offshore areas include tidal, estuarine and meander floodplains. The tidal floodplain occurs mainly in the south of the Ganges floodplain (49%) and also on large parts of Chittagong coastal plains (6%). Estuarine floodplain occupies about 18% of the coastal area located in greater Noakhali, Barisal, Patuakhali and a smaller area of Chittagong districts (Ahsan and Sattar, 2010).

More than 30% of the cultivable land is in the coastal areas. Soil salinity is in increasing trends with time (Table 3, Fig. 9). The soil salinity maps (1973 and 2009) indicate that soils of Jessore, Magura, Narail, Faridpur, Gopalgonj, Barisal, Jhalakhati and Patuakhili have been newly salinized during 36 years and the salinity area has increased to 3.76 mha in 2007 from 2.96 mha in 2000 (Ahsan and Sattar, 2010).

The agricultural production constraints include soil and water (irrigation) salinity, high flooding depth in monsoon season, late draining, heavy soil consistency, poor nutrient status and cyclonic storm surges. Salinity increases in dry months. It shows the highest amount in Marh-May (Fig. 10).

Table 3. Increase of soil salinity in coastal areas during 1973 to 2009

1973	2000	2009	Salt affected area increased during last 9 years (000’ha) (2000-2009)	Salt affected area increased during last 36 years (000’ha) (1973-2009)
Salt affected area (000’ha)				
833.45	1020.75	1056.19	35.44 (3.5%)	222.74 (26.7%)



1973 **833450 ha**

2000 **1020750 ha**

2009 **1056190 ha**

Fig. 9 Increase of soil salinity during 1973 to 2009

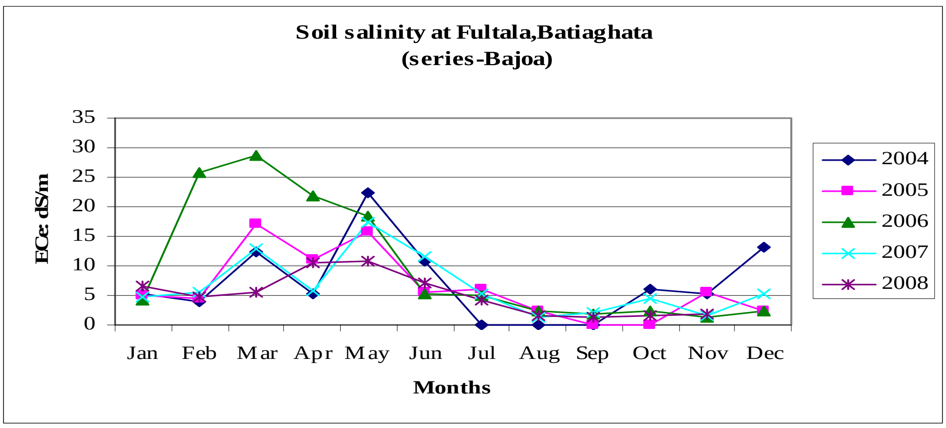


Fig. 10 Variation in soil salinity over the months of a year

Char lands

This area occurs along the major river systems which have a complex topography. Land instability is a great problem. Other problems include corase textured soils, low water holding capacity, low nutrient capacity, river bank erosion and flooding. Crops are often lost through active changes in river alignment and complete alteration of landscape at a local level.

Char land may emerge either as islands within the river channel or as char attached to the riverbanks (Fig. 11). The active floodplain and char land soils occur in the 11 districts (Table 4): Kurigram, Lalmonirhat, Sirajgonj, Pabna, Jamalpur, Manikgonj, Faridpur, Shariatpur, Madaripur, Chandpur and Bhola (Sattar and Islam, 2010; Khan, 2010).

Burial of standing crops and good agricultural lands pose serious constraints to crop production by fresh sediment of sandy deposits. Course textured soils, low water holding capacity and low soil fertility are the major constraints for achieving satisfactory yield.

In Bangladesh, soils are mostly floodplains (80%). Floodplain soils are formed due to action of four major rivers-the Padma (Genges), Meghna, Brahmaputra and Jumuna, and their tributaries & distributions. Flood and inundation are regular seasonal phenomena. EGIS (2001) estimates that 0.72 Mha is char lands. However, char are highly changeable, it may decrease or increase depending on the situation (erosion and accretion).

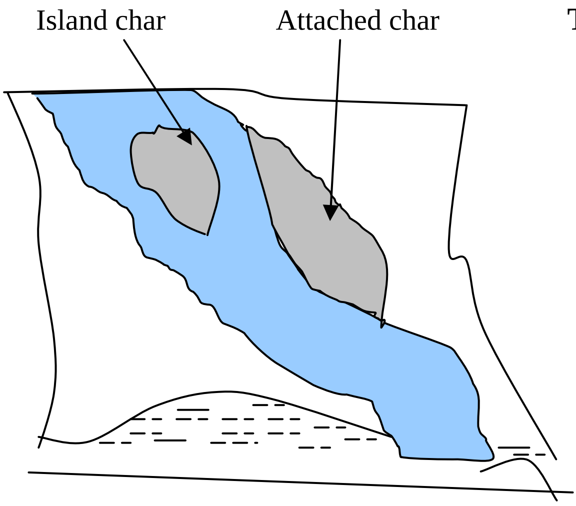


Fig 11. Type of char lands

Table 4. Distribution of char lands in Bangladesh

Region	**Area (000 ha)**	**% of total charlands**
Dhaka	74.6	9.1
Jamalpur-Tangail	116.0	14.2
Comilla-Noakhali	129.9	15.9
Pabna-Rajshahi	125.8	15.4
Bogra-Pabna-Rangpur	321.5	39.3
Faridpur-Kushtia	17.3	2.1
Faridpur	29.8	3.6
Mymensingh-Kishorganj	1.8	0.2
Patuakhali	2.0	0.2
Total	**818.7**	**100**

Hills

Hills (171 sq. km) are concentrated in the Chittagong Hill Tracts, Chittagong, Cox's Bazar, Habigonj and Moulavibazar, and it also occurs in Sherpur, Mymensinhg, Sunamgonj, Sylhet, Brahmanbaria, Comilla and Feni districts.

Chittagonj Hill Tracts (CHT) region, located in the south-east of Bangladesh, covers about 76% of the total hilly areas of the country (Chowdhury and Mallik, 2010). It consists of three districts: Khagrachari, Rangamati and Bandarban. The major constraints are soil erosion (by heavy downpours in July-August), inadequate irrigation facility, soil acidity, limited volume of soil for root anchorage, nutrient leaching and low soil organic matter content. Soil erosion causes due to sloppy land and jhum cultivation. Because of unrest for decades, appropriate research and generation technologies have not been duly advanced. Poor communication, poor marketing facilities, Bengali-Tribal people conflict, land ownership/tenure issues are the further constraints to the food security of the hilly people.

Continuous depletion of soil fertility is the major constraint to crop production. Jhum cultivation (shifting cultivation) and deforestation are the predominant form of land degradation. The major practice of jhum cultivation is to utilize a piece of land for 1-4 years and leaving the land for 10-20 years for fertility restoration naturally. Jhum cultivation is a traditional farming system, difficult to discard it. Rapid loss of soil fertility and toxicity of Al^{3+}, Fe^{3+} and Mn^{4+} are the two major problems for achieving satisfactory yield of jhum crops. A settled farmer should be able to restore soil fertility over short period, may be 6 to 12 months. This is the research challenge.

Jhum cultivation causes gully erosion and losses of soil ranging from 10-120 t $ha^{-1}yr^{-1}$ (Farid et al, 1992). Soil fertility is in declining trend due to loss of nutrients and organic matter.

Currently, hill agricultural research is being carried out by the three agricultural research stations of BARI (located at Khagrachari, Ramgarh and Raikhali), the CHT Development Board and Soil Conservation & Watershed Management Centre (SCWMC). The BARI scientist are carrying out research with regards to varietal screening, planting date, plant spacing, planting methods, crop response to fertilizer application, tillage, mulching, irrigation, etc. (Chowdhury and Mallik, 2010).

Land capability classes of the surveyed area excluding the reserve forest area and the area under different land classes in the Chittagong Hill Tracts assessed is shown in Table 5.

Table 5. Land Capability Classes of the CHT (after Forestal, 1966; Brammer, 1986)

Land Capability Class	% Slope	Area (ha)	%
Class I (Few limitations)	0-5	30,969	3.1
Class II (Moderate limitations)	5-20	27,488	2.7
Class III (Severe limitations)	20-40	148,482	14.7
Class IV(Very severe limitations)	> 40	735,882	72.9
Mixed III and IV	-	12,970	1.3
Settlement and water	-	53,535	5.3
	Total	**1,009,326**	**100.0**

Piedmonts

Piedmont areas, the north-west part of Bangladesh, occur in two of the thirty agro-ecological zones: Old Himalayan Piedmont Plains (AEZ 1), and Northern and Eastern Piedmont Plains (AEZ 22) (FAO/UNDP, 1988). The Old Himalayan Piedmont Plains cover most of Thakurgaon and Panchagor districts, and north-western part of Dinajpur district, with a total area of 3982 km^2.

Constraints of crop production related to soil management include sandy soils, high permeability, nutrient leaching, low organic matter content (except in black terai soils of Tetulia and Boda), low pH, iron and aluminium toxicity, macro- & micro-nutrient deficiencies, stone lifting in Tetulia upazila (causes degradation of soil). Flash flood (due to degradation of soils and vegetation on the Himalayas) in depression in the north (Panchagor and Thakurgaon districts)

Peats

Peats occupy about 0.13 Mha, occurring in the Gopalganj-Khulna beels (AEZ 14). Because of inherent problem and difficulties in overcoming the constraints, little work has been done in these areas. Organic materials occupy more than half of the upper 80 cm of the profile (Khan, 2010). Soft peat and muck occupy permanently wet basin centres. The area remains wet in the dry season. The soils have low bearing capacity, when wet. The soil contains higher amount of organic matter. The soils are highly permeable, deeply flooded during rainy season, strongly acidic and have low P, Zn and Cu contents (BARC, 2005). Peat soil when dries, it shrinks and cracks making the soils very hard. When there is mineral top soil above the peat, rice cultivation in practiced.

Haors

Haors occupy Surma-Kushiyara floodplain and Sylhet basin areas and it is classified as Acid Basin Clays. It extends in Sylhet, Moulovi Bazar, Sunamgonj, Habigonj, Netrakona, Kishoregonj and Bhahmanbaria districts (AEZ 21). The major problems related to crop production are: strongly acids soils, heavy soil texture, nutrient deficiency and difficult communication. It's predominantly a single cropped (Boro rice) area. It suffers from wave erosion and eutrophication. Farmers usually use lesser amount of fertilizers for crop production (Khan, 2010).

Effects of Climate Change on Soils and Crops

Mandal (2008) has summarized the negatives impacts of climate change on Bangladesh agriculture, as reported in various documents as follows: (i) increasing temperature will lead to increased evapotranspiration and droughts, causing water scarcity for irrigation and domestic uses in north- west Bangladesh (Annex 12); (ii) extended flooding of arable land narrowing scope for crop production, especially in the vast low land areas (Annex 13); (iii) increased inundation and salinity intrusion, limiting crop cultivation with the existing varieties, especially in the coastal regions; (iv) increased intensity of flush floods in Meghna basin and north eastern haor region, damaging standing Boro rice crop; (v) increasing loss of land to river erosion, reducing land-based livelihood opportunities, and increased drainage congestion and water logging due to sedimentation of rivers, limiting production options for the char dwellers.

Loss in terms of land degradation and arsenic contamination of soil and water is becoming a major concern (Annex 14) (Heikens, 2006; Ahmed, 2007).

In quantitative terms, IPCC estimates that, by 2050, changing rainfall patterns with increasing temperatures, flooding, droughts and salinity (in coastal belt) could cause decline in rice production in Bangladesh by 8 percent and wheat by 32 percent, against 1990 as the base year (MoFE, 2008). The recent estimates using different models with changed assumptions predicts for 2050 reduction in production by 1.5- 25.8 percent for Aus rice, and 0.4- 5.3 percent for Aman due to the effect of high temperature. For Boro rice, production could be increased by 1.2 – 9.5 percent, assuming the temperature would not exceed the 35^0 C threshold limit for rice production (Hussain, 2008).

As reported by Khan and Awal (2009), the mean maximum temperature in pre-monsoon (March-May) appears to be static while in south-west monsoon (June-Oct.) and post-monsoon (Oct. – Nov.) temperature is in increasing trend since 1961. As per WARPO (2006), by the middle to the end of the current century (21^{st}), winter temperature is predicted to rise by 1.5 – 2.5^0C. Such elevation of temperature is likely to pose a great threat to the winter or rabi crops. The country's average annual rainfall is also in increasing trend, but erratic.

Climatologically, the coastal belt is most vulnerable and mangrove forests in Bagerhat are most vulnerable. WARPO (2006) estimates that 14, 32 and 88 cm sea-level rise will occur in 2030, 2050 and 2100, respectively which may inundate about 8, 10 and 16% of total land of Bangladesh. As per World Bank report (2001), sea level is rising by about 3 mm/year. Cyclones, floods and tidal surges are common disasters in the coastal regions.

The critical challenge is to mange coastal resources and to adapt the production system with the climate change scenario. The major effects due to climate change are the increased soil and water salinity, inland salinity intrusion, water-logging, loss of crops, loss of mangrove and fisheries diversity, and disease in crops, fishes and animals.

5. CONSTRAINTS AND OPPORTUNITIES

Constraints and opportunities have been identified through review of literature and also through discussion with soil scientists of NARS institutes (BRRI, BARI, BINA & SRDI) and of universities (BAU, BSMRAU).

SOM management

Depletion of soil organic matter is a major constraint to higher crop production in Bangladesh. The organic matter level in soil is in declining trend in most soils. This is especially true for high and medium high land soils.

Depletion of organic matter has arisen due to increasing cropping intensity, higher rate of OM decomposition under the prevailing hot and humid climate situation, use of lesser quantities of organic manure and little or no use of green manure practices.

Strategies to increase soil organic pool include no-till farming, cover crops, manuring, water conservation, agro-forestry practices and growing energy crops on spare lands.

City wastes are a potential source of organic matter. Research is needed to develop technologies for composting for sustainable crop production without deterioration of soil health. Bio-slurry (by-product of biogas) is another good source of organic matter.

It is said, "the grain is for the man and the straw is for the soil". So we must feed the soil as well as feed ourselves. Rice straw when incorporated into soil provides considerable amount of potassium, in addition to carbon. A major constraint of using crop residues is that many farmers use these materials for cooking, building houses and for cattle feed.

Productivity and sustainability of farming systems can be achieved through quantifying the individual and interactive effects of conservation tillage practices, residue management, crop rotations, and nutrient and water inputs to increase soil organic matter, resource use efficiency, agricultural productivity and environmental quality.

Soil fertility and fertilizer management

Three fundamental issues are important in soil fertility and fertilizer management research (Bhuiyan, 1998): (i) nutrient requirement of crops to be grown, (ii) nutrient supplying capacity of soil, (iii) fertilizer management and/or soil amendment (e.g. liming). Future soil research should be directed towards maximizing sustainable crop yield without affecting soil health.

Depletion of soil organic matter, unbalanced use of fertilizers, minimum use of manure, increasing cropping intensity, high pH (e.g. .calcareous soils), nutrient leaching and light textured soils have favoured the emergence of nutrient deficiency in Bangladesh soils.

Continuous field trials with various cropping patterns are essential in major cropping patterns for evaluating long-term fertilization effects on soil and crops; and also to updating fertilizer guide.

Improving nutrient use efficiency could be a major agenda of soil fertility research. The major objective of soil-crop research could be to increase crop productivity without incurring land degradation and unacceptable losses to the environment. This gives rise to proposal for using fertilizer management practices in more balanced, efficient and ecologically sound manner.

Chemical fertilizers may affect the physical, chemical and biological integrity of the soil. A combination of plant nutrient additions from different sources is more effective to guarantee a sustainable soil fertility maintenance and nutrient supply than using inorganic fertilizer only. That is, IPNS approach is important for sustenance of soil fertility and crop productivity. On a national scale appreciable quantities of organic wastes are available, which should be taken into account in future organic matter / nutrient management strategies.

There is an increasing need for interaction between soil fertility research and soil survey and classification in soil-based agro-technology validation and transfer. Unless recommendations are developed and implemented in regions having similar soils, the efficiency of nutrient utilization would be low.

Soil management in unfavourable ecosystems

There are many types of production constraints that exist in unfavourable ecosystems such as coasts, hills, piedmonts, haors and peats. Little attention has been paid to improved soil and crop management research in these areas. These are all vulnerable areas. Although some uncertainty exists, still tremendous scope exists to give due attention to soil and crop management. Saline soil deserves special attention. Unfortunately, extent and magnitude of salinity are in increasing trend. Soil erosion (sloppy hilly areas), OM management, nutrient management, and balanced fertilization research should receive attention.

Soil erosion is another constraint to crop production. It is caused by wind and water; however water erosion is dominant in Bangladesh. Soil erosion occurs in sloppy lands (hilly areas) and in light textured (sandy) soils. During monsoon top fertile soils are removed leaving the soils behind unfertile. Easy removal of the finer fractions (silt and clay) of soil through run-off water leaving behind the coarser fraction (sand) causes the change in soil texture.

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 and hill soils are moderately to strongly acidic in reaction. Strongly acid soils (pH

4.5-5.5) occur in AEZs 1, 6, 13, 14, 15, 21, 22, 23, 25, 27, 28 & 29. It is estimated that 0.108, 3.383 and 1.114 Mha lands across the country have soils very strongly acidic (pH <4.5), strongly acidic (pH 4.5-5.5), and moderately acidic (pH 5.6-6.5), respectively. Acid soils may constraint crop production in more than 30% of lands in this country.

Soil microbiological studies

Soil is a habitat of microorganisms. Microorganisms can play a good role in soil fertility and its management. Biological nitrogen fixation (BNF) is a remarkable example for it. Bacteria such as *Rhizobium*, *Azotobacter*, *Clostridium*, *Azospirillum* etc. can fix atmospheric N_2 to soil for plant uptake. Mycorrhizae (fungal-plant root association) benefit the plants through influencing nutrient availability (e.g. P, Zn). There are some bacteria which are capable of solubilizing fixed P. Considerable progress has been made with legume-*Rhozobium* symbiosis and *Azolla-Anabaena* symbiosis. Bacteria are involved in decomposition of organic matter and composting, both aerobically and anaerobically. Future research needs to be strengthened in microbiological studies to harness benefits from their use e.g. BNF, P solubilization, mycorrhizae, composting.

Soil microorganisms can also play an important role in nutrient cycling and interaction. We need to give due attention to residue and waste disposal management as they influence nutrient cycling.

Climate change and environmental hazard effects on soil

It is not unlikely that tomorrow's agriculture would be significantly influenced by the global climate change that includes increase in CO_2 content, increased emission of gases as CH_4, N_2O etc. which would lead to an increase of temperature of the earth and rise in the sea level. This climate change would have a direct effect on crops, water balance, soil organic matter content, salinity intrusion, surface energy balance and in deed, the range of soil properties. Decomposition of organic matter depends on temperature. Higher is the temperature, higher is the organic matter decomposition. According to Vant Hoff's rule, the rate of organic matter decomposition increases 2-3 times with every 10^0C increase in annual temperature.

Some parts of the country are receiving natural hazards as a regular phenomenon like drought in Barind areas and seasonal floods in low lying areas. The country is also experiencing climate change e.g. rise in temperature, change in rainfall pattern. Its impact on natural resources, especially soil & water, needs to be investigated.

6. FUTURE RESEARCH ISSUES

From the foregoing discussion, the following researchable issues can be listed, though all are not of equal importance or priority.

ORGANIC MATTER MANAGEMENT

Conservation agriculture

- Minimum/no-tillage systems
- Mulching
- Cover crops
- Crop residue management

Organic amendment

- FYM, PM, bio-slurry
- Compost (city wastes, industrial wastes, bio-slurry, vermi-compost)

OM mineralization

- Mineralization in dryland & wetland cropping systems (aerobic & anaerobic systems)
- Mineralization in rabi and kharif seasons (winter & summer temperatures)

Carbon sequestration potential under different land use systems (forests, field crops)

Quality assessment of various sources of OM

SOIL FERTILITY AND FERTILIZER MANAGEMENT

- Fertilizer need assessment for crops & cropping patterns (including fodder, multiple cropping, hill cropping) and updating of Fertilizer Guide in every 5 years
- Nitrogen use efficiency (dryland & wetland, USG use potential)
- Integrated nutrient management for crops and cropping patterns
- Introducing quick growing legumes (e.g. mungbean, blackgram) in the cropping patterns
- Micronutrient deficiency and its effect on crop yield and quality
- Effects of agronomically beneficial elements (Si, Co, Ni & Se)
- Development of soil fertility management model
- Effects of As and other heavy metals' contaminated irrigation water on soil and crop yield & quality
- Changes in soil fertility changes induced by different cropping systems and soil management practices
- Effects of brickfield on soils and vegetation in the surrounding areas

SOIL MANAGEMENT IN ECOLOGICALLY UNFAVOURABLE AREAS

Coastal lands

- Changes in the soil and groundwater salinity under brackish aquaculture
- Monitoring the changes in soil salinity over the years
- Soil and water management
- Nutrient management for salt tolerant crop varieties

Hills

- Estimation of soil erosion rate
- Soil erosion control (contour, terracing), strip cropping)
- Soil acidity amelioration (liming, growing acid loving crops)
- Organic matter build-up through different forest litters and nutrient management
- Water[shed management

Char lands

- Soil moisture conservation
- Sedimentation and nutrient assessment
- OM and nutrient management
- Selection of crops

Peats

- Balanced fertilization
- Micronutrient deficiency

Piedmonts

- OM and nutrient management
- Balanced fertilization
- Lime requirement
- Mg and B deficiency of rabi crops

MICROBIOLOGICAL STUDIES

- Improvement of microbial inoculants for N and P in major crops
- Improvement of microbial strains (*Rhizobium*, cyanobacteria) for stress environment like salinity, heavy metal toxicity and pesticide degradation following molecular approaches
- Characterization of potential and beneficial microbial strains with regards to organic acids, enzymes, antibiotics etc.
- Development of high temperature tolerant Azolla
- Mycorrhiza effect in vegetable, fruit and forest crops
- Identification and use of bio-activators for rapid composting of solid wastes (city wastes, industrial wastes)

PHYSICAL ASPECTS

- Evaluation of different tillage practices for organic matter restoration and soil moisture conservation under wetland and upland crop culture
- Quantification of the annual loss of soil due to erosion in hilly areas under different cropping and cultivation systems.
- Identification if efficient methods (s) for control of soil erosion (e.g. tillage, cover crops and other practices)

ENVIRONMENTAL HAZARDS AND CLIMATE CHANGE

Environmental hazards

- Drought (northern region, hilly areas)
- Floods
- Cyclone (coastal areas)

Climate change effect

- Impact of climate change on soil & crop (temp., rainfall, CO_2 conc.) – Analysis of secondary data
- Effect of climate change on soil & crop (temp., rainfall, CO_2 conc.) – Experimental approach under controlled conditions

BASIC RESEARCH

- Long-term fertilizer/manure expts. (e.g. rice-rice, maize-rice cropping systems)
- Land and soil resource inventory
- Soil fertility evaluation & GIS mapping (every 5 years)
- Determination of critical limit for different nutrients
- Leaching and gaseous loss of N in wetland conditions
- Retention and release characteristics of nutrients in soils
- Mineralogical studies of soils (data base, USDA soil family level classification)
- Mathematical modeling with soil chemical processes (e.g. P, K & Zn)
- CH_4 and N_2O emission from wet land rice soil
- Rhizosphere effect on nutrient availability
- Root growth study and its relationship with nutrient deficiency & heavy metal toxicity

7. REGIONAL WORKSHOP FEEDBACK

Four regional workshops were arranged at Bogra, Chittagong, Barisal and Mymensingh with the objective of knowing the field problems existing with different sub-sectors of agriculture (crop, soil, livestock, fisheries & forestry) and prioritizing the problems for future research. Feedbacks were obtained from these workshops where stakeholders from extension agencies (DAE, DLS & DoF), NARS institutes, universities, NGOs, private sector organizations, and farmers participated and narrated the field problems.

I. Soil health problems in Rajshahi Division

Sl. No.	Problem Specification	Location where the problem exists	Magnitude of the problem (example, area affected, ha)	Extent of severity (1-10 scale, 10 being highest)	Ranking (H, M or L)
1	Depletion of organic matter & soil fertility	Rajshahi Division	Rajshahi Division	8	H
2	Drawdown of groundwater table	Dinajpur	Dinajpur	7	M
3	Micronutrient deficiency in wheat, potato, brinjal, cole crops	Do	Do	7	M
4	Fe & As problem in irrigation water	Gaibandha	Gaibandha	9	H
5	Rapid (digital) soil testing kit	Do	Do	7	M
6	River erosion and siltation of cropped land	Pabna & Sirajganj	Pabna & Sirajganj	8	H
7	Inclusion of legumes in the cropping system	Do	Do	7	M
8	Drawdown of groundwater table	Rajshahi & C.Nawabganj	Rajshahi & C.Nawabganj	8	H
9	Development of no-tillage technology	Do	Do	7	M

Scale: 1-10; L = 1-3 M = 4-6 H = 7-10
Ranking: L = Low M = Medium H = High

II. Soil health problems in Chittagong and Sylhet Divisions

Sl No.	Problem Specification	Location where the problem exists	Magnitude of the problem (example, area affected, ha)	Extent of severity (1-10 scale, 10 being highest)	Ranking H, M or L
Hill Agriculture					
1	Soil erosion	Ctg. Hill Tracts	Ctg. Hill Tracts	9	H
2	Depletion of soil organic matter	Do	Do	8	H
3	Soil acidity	Do	Do	8	H
Coastal Agriculture					
1.	Changes in cropping pattern	Noakhali & Feni (saline areas)	Noakhali & Feni (saline areas)	8	H
2.	Development of salinity testing Kit.	Do	Do	6	M
Plain Land Agriculture					
1.	Deterioration of soil soil fertility	Chittagong & Sylhet	Chittagong & Sylhet	9	H
2.	Quick composting	Do	Do	6	M
3.	Use of USG	Do	Do	6	M

Scale: 1-10; L = 1-3 M = 4-6 H = 7-10
Ranking: L = Low M = Medium H = High

III. Soil health problems in Khulna and Barisal Divisions

Sl No.	Problem Specification	Location where the problem exists	Magnitude of the problem (example, area affected, ha)	Extent of severity (1-10 scale, 10 being highest)	Ranking H, M or L
Plain Land Agriculture and Coastal Agriculture (non-saline phase)					
1	Depletion of soil organic matter	Do	Do	9	H
2	Lowering of groundwater table	Do	Do	8	H
Coastal Agriculture (saline phase)					
1.	Soil and water salinity in dry season (Nov. – April)	Do	Do	8	H
2.	Degraded soil: heavy soil consistency, silty clay texture, crackdown of top soil	Do	Do	6	M

Scale: 1-10; L = 1-3 M = 4-6 H = 7-10
Ranking: L = Low M = Medium H = High

IV. Soil health problems in Dhaka Division

Sl No.	Problem Specification	Location where the problem exists	Magnitude of the problem (example, area affected, ha)	Extent of severity (1-10 scale, 10 being highest)	Ranking H, M or L
Plain Land Agriculture					
1	Depletion of soil fertility & organic matter	Do	Do	9	H
2	Heavy metal pollution of soil & water from industrial wastes	Gazipur, Dhaka	Gazipur, Dhaka	8	H
3	Composting of city & industrial wastes	Do	Do	8	H
4	Lack of use of improved biofertilizer & biopesticides	Do	Do	5	M
Forest, Hill and Terrace Land Agriculture					
1.	Soil erosion	Do	Do	8	H
2	Deterioration of soil fertility	Do	Do	9	H
3	Lack of land zoning	Do	Do	6	M
Haor and Depressed Land Agriculture					
2	Low to medium soil fertility	Kishoreganj & Netrokona	Kishoreganj & Netrokona	6	M
3	Balanced fertilization	Do	Do	6	M

Scale: 1-10; L = 1-3 M = 4-6 H = 7-10
Ranking: L = Low M = Medium H = High

8. SITUATION ANALYSIS

Depletion of soil fertility or nutrient mining arises when the amount of crop removal exceeds the amount of nutrient addition. For sustainability situation, nutrient output must be equal to nutrient input. In practice, the farmers are applying nutrients to soil much less than the crop removal. As a result, soil reserve of nutrients is getting exhausted. Increasing crop intensity and increasing cultivation of modern varieties with high yield potential are the two major causes of soil fertility depletion. Further some high biomass producing crops such as maize, potato, sugarcane uptake very high amount of nutrients from soil.

The highest nutrient mining takes place with K, since the farmers are using a minimum amount of K fertilizer. An excellent opportunity exists to arrest K mining by retaining 50% crop residues (e.g. rice straw) in the field. Nitrogen is the most deficient element globally and Bangladesh is not an exception. More than 60% urea-N occurs in wet land rice culture. Efforts are underway in the world to reduce this N loss from soils. Further research is needed on the aspect of reducing the N loss from soils and increase N use efficiency, particularly under wet land rice system. The principal source of N in soil is organic matter. Organic matter is also recognized as a major source of another two elements i.e. P and S.

Organic matter content in Bangladesh soils is in decreasing trend. Addition of organic matter is generally low and further rate of OM decomposition is very high, due to sub-tropical humid climate. Thus, steady supply of organic matter is essential to maintain soil fertility. We should not worry about P, since P balance is slightly negative to slightly positive across the soils and cropping systems.

As time advances, new nutrient deficiency arises. Micronutrient deficiency e.g. Zn, B & Cu deficiency has arisen in many crops. Farmers seldom use micronutrient fertilizer. As the incorporation of OM is low and on the other hand, the cropping intensity is getting increased every year, so obviously new nutrient deficiency would arise.

Fertility management systems that profitable for short-term and sustainable for long-term should be formulated and it needs to be confirmed by on-farm research trials. We need to explore and utilize as much as possible biologically fixed N, both symbiotically and non-symbiotically.

Soil fertility management research should give special attention to ecologically disadvantaged areas e.g. coasts, hills, char lands where research is not yet strengthened. Soil erosion is a major constraint in hilly areas. Sloppy lands and light textured soils, coupled with jhum cultivation are responsible for soil erosion. So, conservation agriculture techniques e.g. cover crops, contour, strip cropping should be investigated.

Soil fertility research is meager on horticulture crops, especially fruits and vegetables, although nutrient management is important for improvement of mineral nutrition, apart from yield advantage.

Waste management could be a big issue in future research strategies, concerning recycling and environmental protection. The country is receiving natural hazards e.g. drought, flood etc. and experiencing climate change e.g. rise in temperature and change in rainfall pattern. Its impact on natural resources, especially soil & water needs to be investigated.

The NARS institutes viz. BARI, BRRI, BINA, BJRI, BSRI & SRDI and universities viz. BAU, DU & BSMRAU are carrying out soil research in Bangladesh. The NARS institutes are performing mostly applied research and the universities and SRDI are doing mostly basic research.

There are four principal issues which need to be addressed in future. These are as follows:

- Soil organic matter management in intensive cropping areas for improving soil health
- Soil fertility and fertilizer management for increasing nutrient use efficiency and reducing nutrient mining
- Integrated nutrient management (inorganic, organic and bio-fertilizer) for sustenance of soil fertility
- Land management in coastal, char, hilly, piedmont and heavy metal contaminated areas

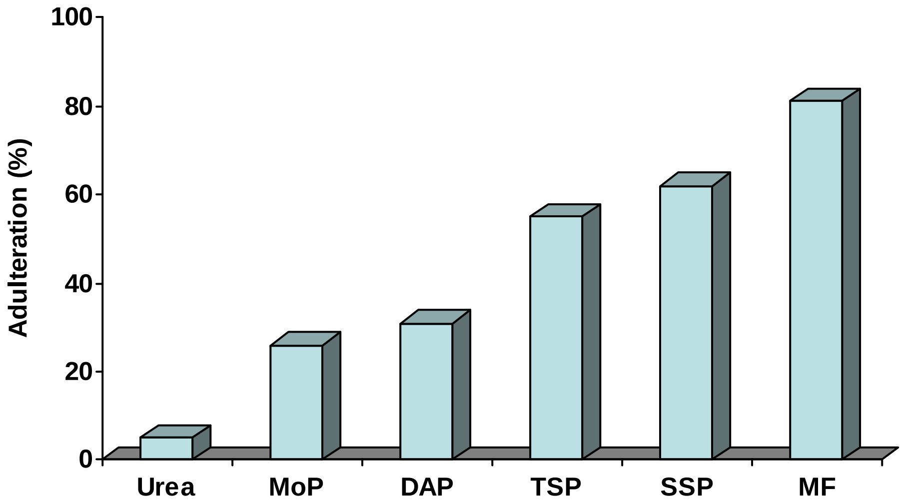
9. POLICY ISSUES

Quality of non-urea fertilizers is often below standard, with more than 80% adulteration for mixed fertilizers (NPKS), above 50% adulteration for privately imported SSP and TSP, and 25-30% adulteration for MoP and DAP (Fig. 12) (SRDI report, 2007-08). Quality of locally produced fertilizers is quite good. Strong monitoring is needed at storage and distribution points to check adulteration of these fertilizers.

Farmers are using fertilizers less than the requirement, particularly for TSP and remarkable difference for MoP, even in 2009 when price of non-urea fertilizer has been much reduced (Jahiruddin et al., 2009). This has created unbalanced use of fertilizers which produces negative impact on soil fertility and crop yield. Training, field demonstration and motivational work need to be strengthened so that the farmers can follow the principle of balanced fertilization.

Farmers are using minimum amount of organic fertilizers. Motivational approach as well as policy support are needed to increase the use of organic fertilizers.

Marginal farmers use lesser amount of fertilizers than the small farmers, and the small farmers use lesser amounts than the medium farmers. Farmers' other characteristics such as age, education, family size, farming experience, training experience, communication exposure and use of organic fertilizer did not show significant relationship with their chemical fertilizer use (Jahiruddin et al., 2009). Policy support is needed to increase the ability of marginal and small farmers to buy fertilizers.



	Urea	MoP	DAP	TSP	SSP	MF
No. of samples analyzed	216	668	183	628	64	199
No. of samples adulterated	10	175	57	323	40	161
Samples adulterated (%)	5	26	31	55	62	81

Fig. 12 Adulteration of different kinds of fertilizers

10. PRIORITY MATRIX

Not all problems are researchable and some of them are policy matters. Again, all researchable problems are not equally important and also tenure of a research is not same. These have been duly considered in priority ranking and determining research tenure.

Type of Problem	Magnitude (% of the total area coverage)	Severity of the problem (1-3)	Expected beneficiary (%)	Priority ranking (H, M or L)
OM management				
• Conservation agriculture (min. / no tillage, mulching, cover crops, etc.)	40	2	40	M
• Organic amendment (FYM, PM, bioslurry, etc)	75	3	75	H
• Composting (city wastes, industrial wastes, vermi-compost, etc.)	10	1	10	M
• OM mineralization (dryland & wetland, rabi & kharif seasons)	80	3	80	M
• Quality assessment of different sources of om	75	2	75	M
Soil fertility management				
• Fertilizer need assessment for crops & cropping patterns (updating FG)	100	3	100	H
• Nutrient use efficiency	80	2	80	M
• Integrated nutrient management	100	3	100	H
• Micronutrient deficiency	80	3	80	H
• Heavy metal contamination of water & soil, effect on crops (eg. As, Cd)	20	1	20	M
• Effects of brickfields on soils & vegetation	10	3	10	L
• Soil fertility model	80	2	80	M
Soil management in ecologically unfavourable areas				
• Coastal areas (soil fertility management)	20	3	20	H
• Hilly areas (soil loss, erosion control, water-shed management)	10	3	10	H
• Char lands (soil moisture conservation, soil fertility management)	10	2	10	H
Soil microbiological studies				
• Microbial inoculants for N & P	60	2	60	H
• Development of microbial strains (*Rhizobium,* cyanobacteria) for stress environment	50	2	50	M
• Mycorrhiza	30	2	30	M
• Bio-activators for composting	60	2	60	H

Priority ranking: H = High M = M L = Low

Type of Problem	Magnitude (% of the total area coverage)	Severity of the problem (1-3)	Expected beneficiary (%)	Priority ranking (H, M or L)
Climate change and environmental hazards				
• Climate change effect on land & water (temp., rainfall, CO_2 conc.)	100	3	100	H
• Environmental hazard effect on land & water (drought, flood, cyclone)	60	2	60	M
Basic research				
• GIS map updating (nutrients & OM)	50	2	50	M
• Long-term fertilizer trials	40	2	40	H
• Mineralogical studies (data base)	20	1	20	M
• Retention & release characteristics of nutrients	40	2	40	M
• C.L. determination	40	2	40	M
• Leaching & gaseous N loss	50	2	50	M
• CH_4 & N_2O emission from rice field	80	2	80	M

Priority ranking: H = High M = M L = Low

Soil physical aspects have been included in issues dealing with OM management and soil management in hilly areas.

11. MAJOR OUTPUTS

- Land and soil resource related problems that are affecting crop production would be identified.
- Constraints and opportunities of crop production in relation to soil management would be known.
- Priority soil research would be formulated.
- Policy suggestions would be available.
- Efficient management practices for sustenance of soil fertility and crop productivity in both favourable and unfavourable ecosystems would be known.
- Impact of climate change on natural resources would be determined.
- Crop production would be increased and small farmers' livelihood would be improved.

12. CONCLUSION AND RECOMMENDATION

A major challenge of agriculture production is the deterioration of natural resources e.g. land & water due to overexploitation of agricultural land and greatest emphasis on mono-cropping (rice). This would impact food and nutrition insecurity of increasing population.

There are many problems related to soil health issue which hinder crop production. The major problems are depletion of soil organic matter and soil fertility, increasing soil salinity and soil acidity, topsoil erosion, and degraded rice soils. To solve these problems, efficient and judicious research planning is needed. Not all problems are researchable, so problems need to be prioritized that constraint production, growth and development.

Research should be demand driven and location specific. Extension agencies and development partners suggest technology development that require modern tools, basic and strategic research and address issues like climate change effect, restoration of soil health and soil management in less or unfavourable ecosystems.

Soil research needs to be integrated with other areas of research (e.g. irrigation, crops) in solving increasing complex problems. Sustainability goals demand that adequate strategies are built in to reduce further degrading of productive soil and all out efforts are made to rehabilitate the already degraded soils.

In the future soil scientists will need to adopt more comprehensive approaches in formulation and execution of researches. Our piece meal approach tends to view the problems from a short-term perspective neglecting the long-term aspects. This has resulted encountering big problems in managing and protecting our resources and the environment. Increasing development of computer facilities would help develop modeling approaches.

Our basic task of wisely using our soil resources requires that we should have a periodic and regular inventory of our soils- their characteristics, fertility status, distribution and use potential. Such information needs to be readily available through tents, maps and other data basis and so assist the users in making use of this information fruitfully. The Soil Resource Development Institute (SRDI) should have a significant role on it.

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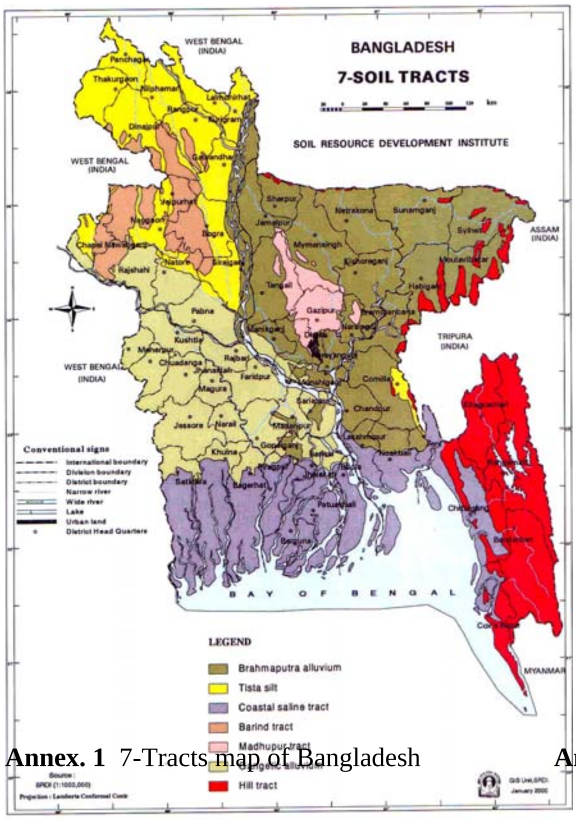
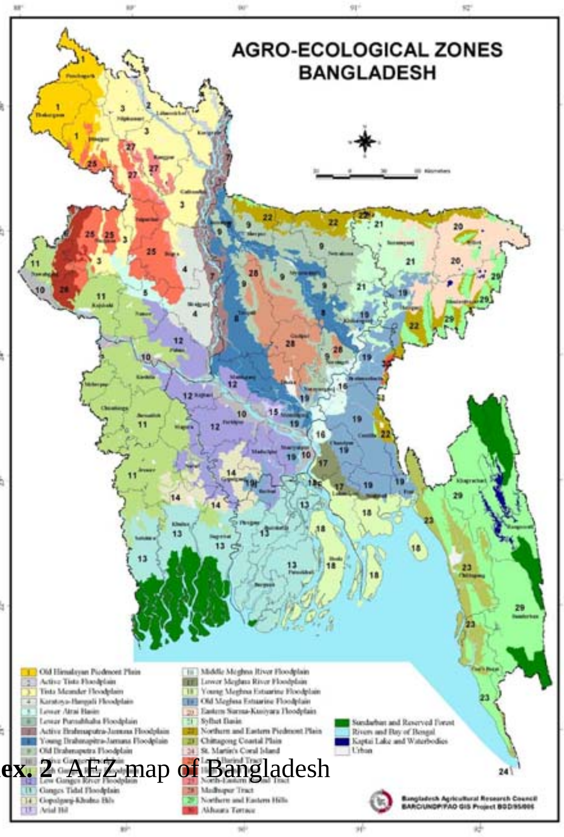


Annex. 1 7-Tracts map of Bangladesh



Annex. 2 AEZ map of Bangladesh

Annex 3. Terms of Reference (ToR) of the Group Leaders

1). Consultation and review of the documents related to agriculture and rural development. These are, but not limited to the followings. To accomplish the task the team may need to visit the concerned institutes.

- Planning Commission Reports on five year plan, annual budgetary documents etc.

- National Agriculture Policy
- Poverty Reduction Strategy of the GoB
- World Bank document on revitalizing agriculture and related others
- Agricultural sector review /Actionable policy briefs of the FAO
- Reports of the DFID, DANIDA and others on the performance of the agriculture sector in Bangladesh
- National Food policy
- National land use policy
- National livestock Policy
- National Fisheries Policy
- National Forestry Policy
- Vision document –2020 of BARC and Strategic plan of 1996
- Land, Soil and management of natural resources
- Reports on Food Security, quality and Safety
- Reports on MDG
- Master Plan & Annual Reports of ARIs
- Websites of various agencies

(***Source:*** BARC Library, P & E Division, BARC, Concerned Institutes, Websites of the concerned Ministry/Organization)

1) Through collection and collation of the information as stated in Sl.-1, work out the countries situation/issues by the sub-sector/area (12 nos.) of agriculture. These are:

    - Rice
    - Cereals other than Rice, Sugarcane and Jute
    - Horticultural crops(Potato, Fruits, Vegetables, Spices including Flowers
    - Pulses and Oilseeds
    - Soil and fertility management
    - Forestry
    - Livestock
    - Fisheries
    - Agricultural mechanization and water management
    - ICT in agriculture
    - Agricultural economics, marketing and supply chain development
    - Technology development, agro-processing post-harvest technology, food quality and human nutrition

2) Sub-sectoral studies are expected to be *in-depth and detailed in nature.* This *to cover all component's current trend in production, demand-supply and gap, opportunities, problems and constraints, required technological interventions and their analysis in the country's context. By the process determine the priority need of the concerned sector/area by the year 2040 and beyond.*

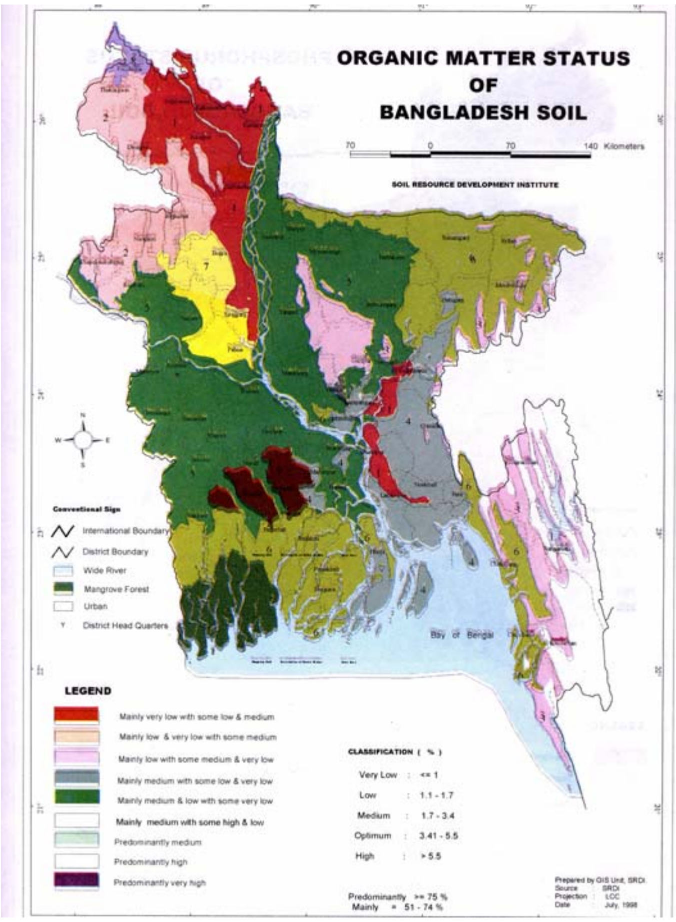
3) Population dynamics, reduction in land resource base and degradation, issues pertaining to climate change & sea level rise (SLR), economics of commodity and non-commodity

related activities, income growth rate etc. all these to be taken into account in formulating the research priority.

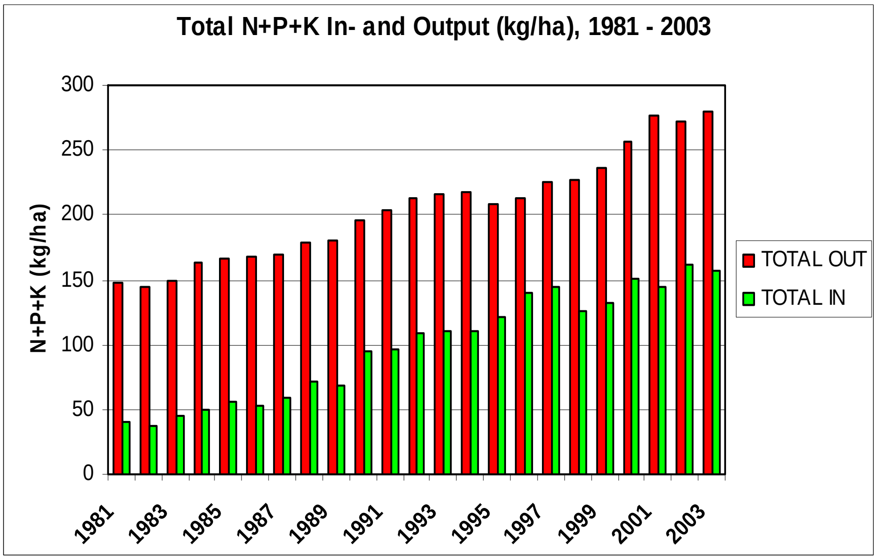
4) Undertake other related tasks as may be deemed necessary or evolved while performing this assignment

5) Draft report of the teams to be presented in the workshops to be organized by the Planning & Evaluation Division of BARC at suitable dates.

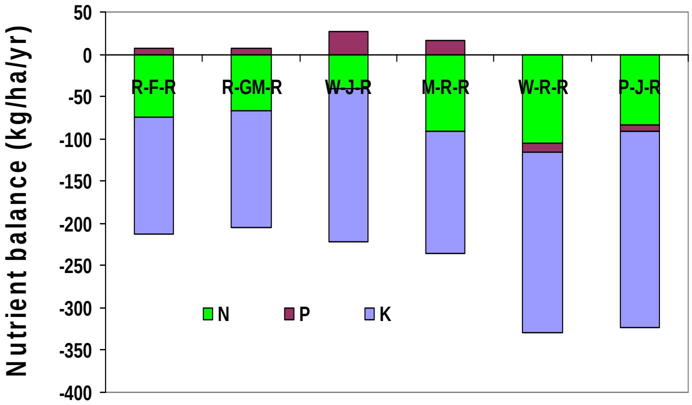
6) Draft final report incorporating the comments/opinion obtained from the workshops, different agencies/individuals to be *submitted within 2 (Two) months from the date of assignment* to the MD (P & E), Bangladesh Agriculture Research Council, Dhaka.

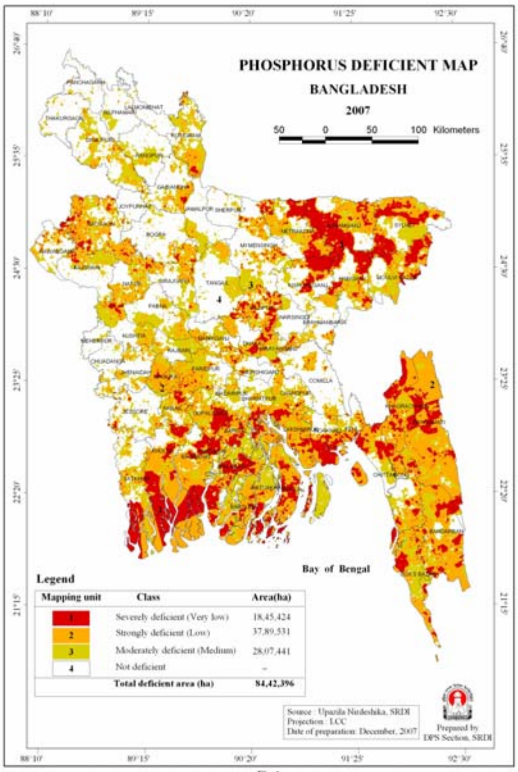


Annex. 4 OM status of Bangladesh soils



Annex. 5 Total N+P+K input and output in Bangladesh (Rijpma and Jahiruddin, 2004)





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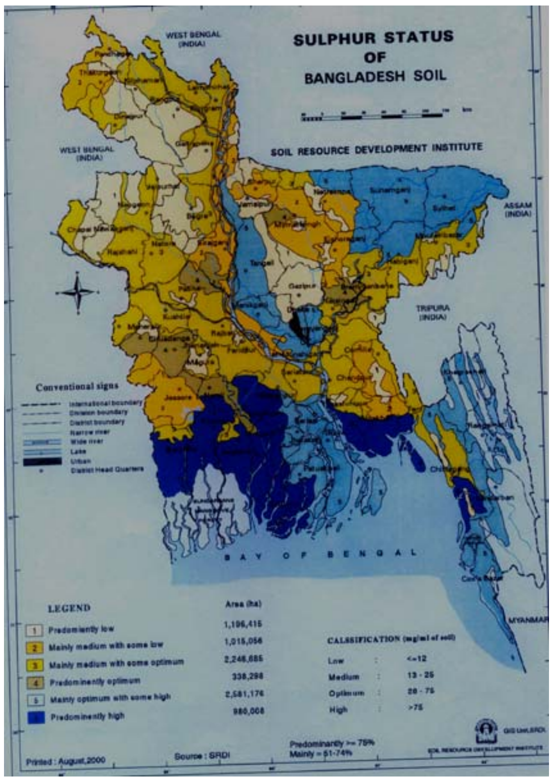
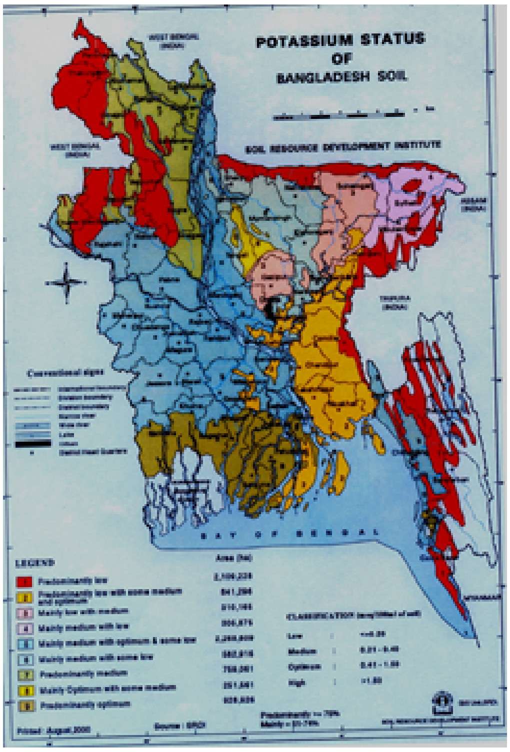
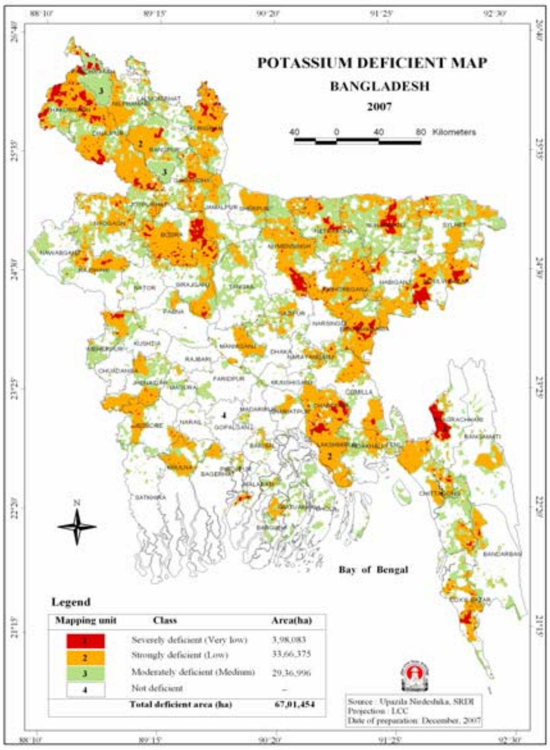


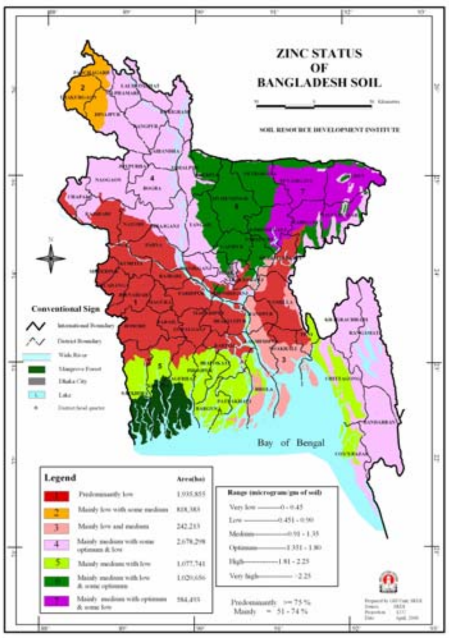
Annex. 7 P status of Bangladesh soils

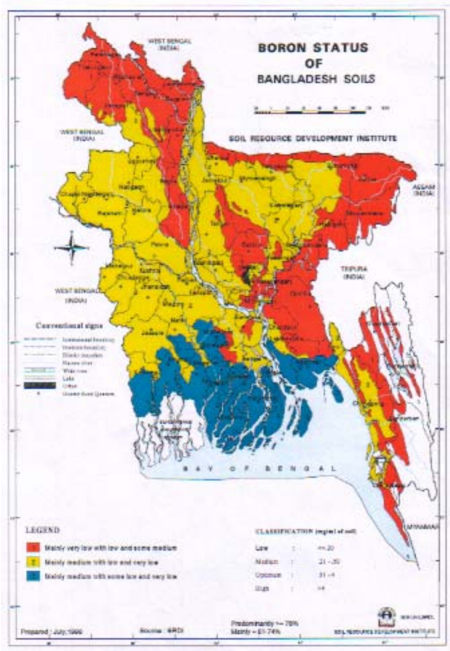
Annex. 8 S status of Bangladesh soils





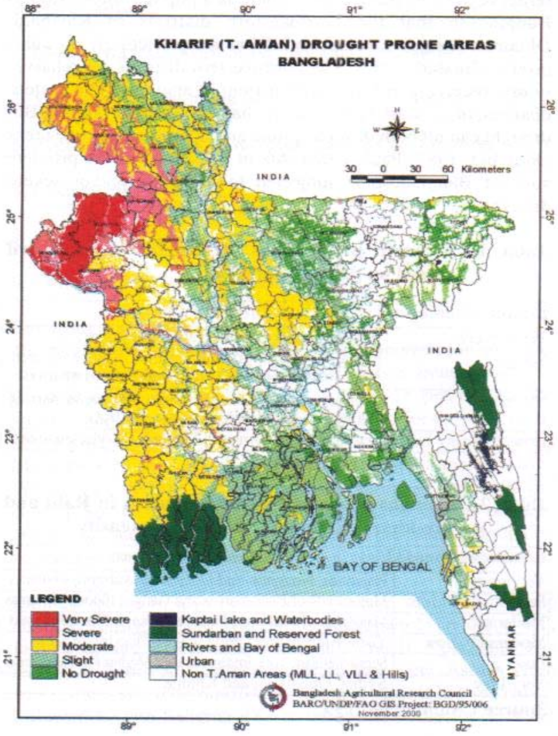
Annex. 9 K status of Bangladesh soils

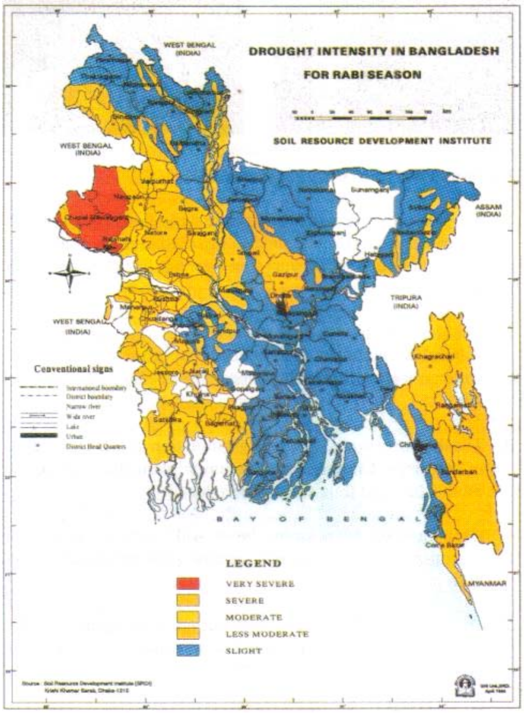




Annex. 10 Zn status of Bangladesh soils

Annex. 11 B status of Bangladesh soils

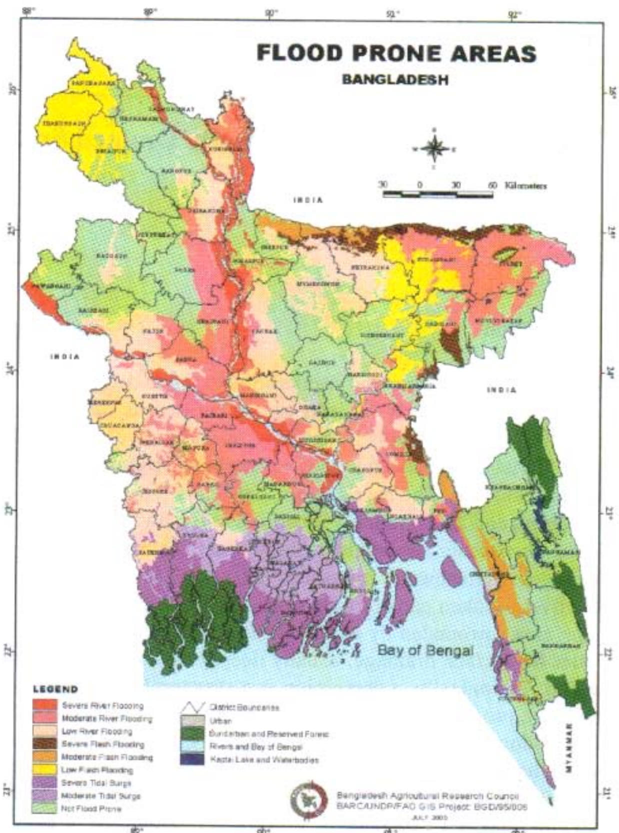




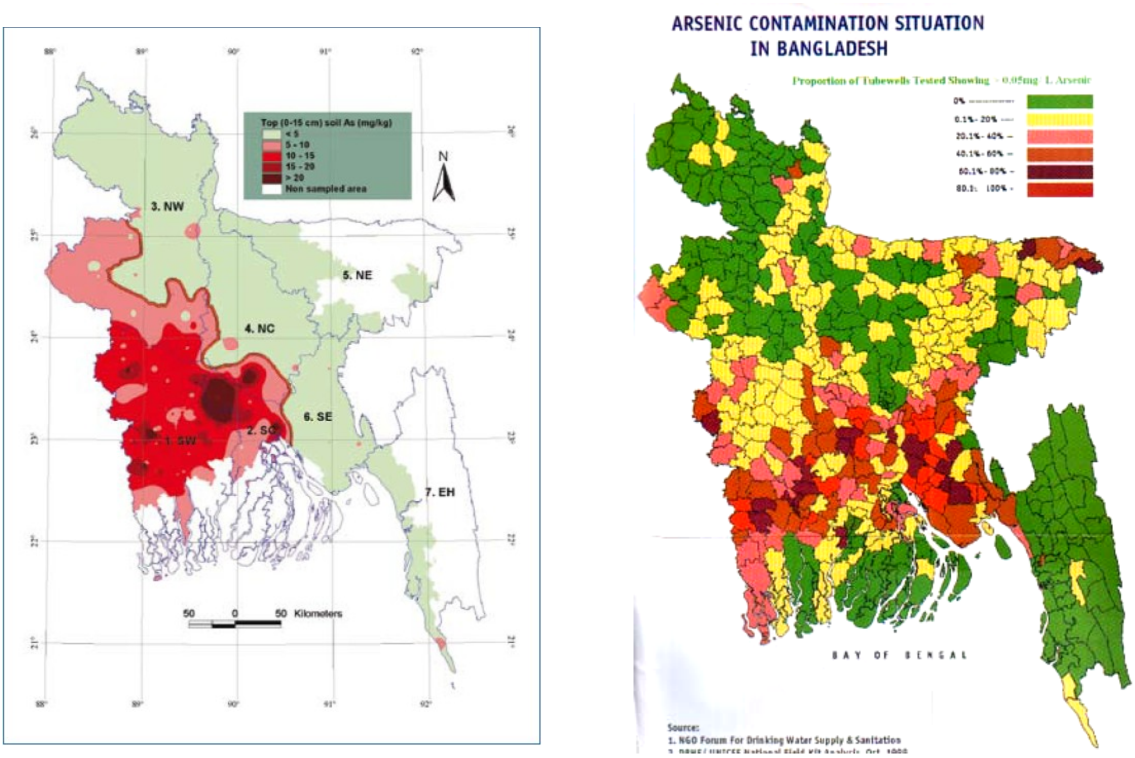
KHARIF

RABI

Annex. 12 Drought prone areas of Kharif and rabi seasons



Annex. 13 Flood prone areas of Bangladesh



Annex 14 Arsenic contamination in groundwater and soils of Bangladesh