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Strengthening of Soil Research and Research Facilities (SRSRF) Project

Soil Resource Development Institute (SRDI)
Ministry of Agriculture

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Acronyms

AEZ	Agro Ecological Zones
BARC	Bangladesh Agricultural Research Council
B	Boron
Ca	Calcium
CEC	Cation Exchange Capacity
Cl	Chlorine
Cu	Copper
DPS & ICT	Data Processing and Statistical and Information and Communication Technology
DSM	Digital Soil Mapping
EC	Electrical Conductivity
Fe	Iron
Fig.	Figure
FY	Fiscal Year
HYV	High Yielding Varieties
K	Potassium
mha	Million hectare
Mg	Magnesium
Mo	Molybdenum
Mn	Manganese
MT	Metric Ton
N	Nitrogen
NARS	National Agricultural Research System
N_2O	Nitrous Oxide
P	Phosphorus
pH	Soil Reaction
S	Sulphur
SDG	Sustainable Development Goal
SOM	Soil Organic Matter
SRDI	Soil Resource Development Institute
Zn	Zinc

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Preface

Soil is the greatest and most valuable natural resource in Bangladesh. Bangladesh's reputation as a land of fertile soils was perhaps true in the past when pressure on land was low and food grains harvested from a single crop per year were adequate to feed the nation. Because of the country's alluvial nature, many soils possess the physical conditions for easy tillage and allowing plant roots to grow deeply and spread widely. Bangladesh's climatic condition and different alluvial deposition also favors a wide range of crops, with soils under the influence of the tropical monsoon climate.

At present Bangladesh has secured 10th position in food production across the globe. Cropping intensity reaches to 194 percent in 2017-18 compare to 180 percent in 2006. Bangladesh has achieved a remarkable progress in cereal food (rice) production with a transformation from a food deficit into a food sufficient country. In deed this has been achieved mainly through increasing cropping intensity coupled with use of high yield potential varieties. Bangladesh is in the 4th across the globe in rice production. Bangladesh has secured 3rd position around the world in vegetable production. Country produced 15.954 million metric ton vegetables in 2017-18 fiscal year. Bangladesh stands 7th in mango production around the world.

Quality seed including high yielding varieties, stress tolerant verities, expansion of irrigated areas, adequate plant protection measures, soil fertility and fertilizer management, research and extension made it possible to achieve greater height in world agricultural arena. Government provided huge development support in fertilizers especially in nitrogen, phosphorus and potassium fertilizers.

Soil fertility and fertilizer management plays a key role in Bangladesh agriculture. Soil fertility does not mean only the status plant nutrients in the soil but it is the combination of soil physical properties such as soil texture, bulk density, aggregate stability; chemical properties such as pH, EC, CEC, plant nutrients; and biological properties such as soil organic carbon, microbial biomass carbon, microbial biomass nitrogen, soil biodiversity etc.

Lack of sufficient data on soil physical, chemical and biological properties, this trend of soil fertility in Bangladesh 2010 to 2020 study, concentrated with available plant nutrients Status such as phosphorus, potassium, sulphur, zinc, boron, calcium and magnesium; organic matter and soil pH. Total nitrogen is not included in this study as its status is very low to low across the country over the years.

There is an increasing trend in soil health degradation which can be attributed to higher crop removal due to increasing cropping intensity, use of modern varieties of crops (HYVs and hybrids), soil erosion, soil salinity, soil acidity, deforestation, nutrient leaching and minimum manure application. These factors are mostly related to irrational human interventions. Consequently, with advancement of time, new nutrient deficiency arises. Chronologically N, P, K, S, Zn and B deficiencies have appeared. Calcium and magnesium deficiency is reported in Old Himalayan Piedmont Plain and TistaFloodplain soils. There is sporadic information of Cu, Mo and Mn deficiencies in crops. Deficiencies of Fe and Cl are not yet found. It is estimated that the overall N balance of Bangladesh soils is negative, the P balance near zero and the K balance is highly negative.

For proper soil fertility and fertilizer management, it is necessary to understand the present soil fertility specially soil nutrient status of the arable soils of the country, their trends of building or declining over the years and where to pay more stress to recover the situation.

We hope this book will be helpful to the agriculturist, soil scientist, researcher, extension people, policy maker, planner and finally our farmers.

We humbly request our readers to acknowledge us if any thing does not correlate the present knowledge, so that we can improve our next version of the monographs.

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Executive Summary

Bangladesh's reputation as a land of fertile soils was perhaps true in the past when pressure on land was low and food grains harvested from a single crop per year were adequate to feed the nation. Because of the country's alluvial nature, many soils possess the physical conditions for easy tillage and allowing plant roots to grow deeply and spread widely. Bangladesh's climatic condition also favors a wide range of crops, with soils under the influence of the tropical monsoon climate.

Soil fertility does not mean only the status plant nutrients in the soil but it is the combination of soil physical properties such as soil texture, bulk density, aggregate stability; chemical properties such as pH, EC, CEC, plant nutrients; and biological properties such as soil organic carbon, microbial biomass carbon, microbial biomass nitrogen, soil biodiversity etc.

Lack of sufficient data on soil physical, chemical and biological properties, this trends of soil fertility in Bangladesh study, concentrated with available plant nutrients such as phosphorus, potassium, sulphur, zinc, boron, calcium and magnesium; organic matter and soil pH. Total nitrogen is not included in this study as its status is very low to low across the country over the years. Other plant nutrients such as copper, iron, manganese is not included in the study as there is no information of deficiencies of these elements. Chlorine and molybdenum are also not in the study as because the unavailability of the data. Land use changes over the years is included in this study to understand how much crop land is shifted to non-crop uses.

There is a significant change in land use since 2010 to 2020. Crop land or arable land decreases from 65.05% of Bangladesh in 2010 to 58.19% in 2020. Average annual loss of crop land is about 0.685%. Area under homestead, rivers, urban etc., increases from 30.13% to 36.93% over the years.

Area under very strongly acidic to strongly acidic soils increase from 41.23% of total arable land to 45.67% over the years and decreases area under slightly acidic and neutral soils from 28.53% to 25.42% and 15.02% to 11.71% over the years respectively. This indicates soil pH decreases since 2010 to 2020.

There is an increase in organic matter since 2010 to 2020. Area under very low to low content of soil organic matter decreases from 37.94% in 2010 to 34.83% in 2020 and increase of area under medium content from 55.57% to 59.19% over the years indicates the build of organic matter.

Phosphorus status in soil decreases from 2010 to 2020 substantially. Area under very low to low status soil phosphorus in loamy to clayey soils of wetland rice crops increases from 38.60% to 50.27% over the years indicates the decrease of soil phosphorus status.

Potassium status in soil decreases from

2010 to 2020 significantly. Area under very low to low status soil potassium in loamy to clayey soils of wetland rice crops increases from 28.34% to 43.23% over the years indicates the sharp declining of soil potassium over the years.

Sulphur status in soil also decreases from 2010 to 2020 notably. Area under very low to low status soil sulphur in loamy to clayey soils of wetland rice crops increases from 34.45% to 46.41% over the years, which indicates the decrease of soil sulphur over the years.

Zinc status in soil decreases from 2010 to 2020 sharply. Area under very low to low status soil zinc in loamy to clayey soils of upland crops and wetland rice crops increases from 28.71% to 78.84% and medium status decreases from 18.99% to 11.54% over the years indicates the sharp decrease of soil zinc over the years.

Boron status in soil decreases from 2010 to 2020 considerably. Area under very low to low status soil boron in loamy to clayey soils of upland crops and wetland rice crops increases from 25.99% to 30.78 over the years indicates the considerable decrease of soil boron over the years.

Calcium status in soil decreases from 2010 to 2020 sharply. Area under very low to low status soil calcium in loamy to clayey soils of upland crops and wetland rice crops increases from 3.13% (300,000 hectares as estimated by SRDI) of crop land to 24.53% over the years indicates the sharp decrease of soil calcium over the years.

Magnesium status in soil decreases from 2010 to 2020 sharply. Area under very low to low status soil magnesium in loamy to clayey soils of upland crops and wetland rice crops increases from 3.13% (300,000 hectares as estimated by SRDI) of crop land to 12.31% over the years indicates the sharp decrease of soil magnesium over the years.

Soil fertility maps 2010 and 2020 are the principal base materials of this study. Soil fertility mapping is based on the data generated for the preparation of Land and Soil Resources Utilization Guides popularly known as Upazila Nirdeshika for every upazilas of the country. First phase of the preparation of Upazila Nirdeshika started in 1985 and ends in 2002. It means data generation for first phase of the preparation of Upazila Nirdeshika took about 17 years. Based on this database, Soil Fertility Maps 2010 prepared. Thus, Soil Fertility Maps 2010 does not actually represent the status of soil nutrients of 2010. Second phase of the preparation of Upazila Nirdeshika starts in 2006 and continues till today. So far 245 Upazila Nirdeshika has been prepared and published. Based on the database of these updated Upazila Nirdeshika Soil Fertility Maps 2020 were prepared. Similarly Soil Fertility Maps 2020 does not represent actual soil nutrient status of 2020.

Thus, it is recommended to conduct a special program to prepare soil fertility status maps of the country. This program may conduct through soil sampling following grid method of soil survey. At least 25 soil samples may be collected from each upazila covering every physiography, agro-ecological zones, land type and soil series or groups. Sample volume may not exceed 15000. These sample will be analyzed for pH, EC, OM, Nitrogen, Phosphorus, Potassium, Sulfur, Zinc, Boron, Calcium and Magnesium and if possible, Molybdenum. Moreover, routine analysis for Fe, Cu, Mn and exchangeable acidity may be done. Determination Cation Exchange Capacity (CEC) and texture (may be through finger feelings) must be done for every sample. Determination of Bulk density may add precious value. Microbial biomass carbon, microbial biomass nitrogen may also be analyzed. Based on these analytical databases a real time soil fertility mapping may be prepared. Every sample should have geo-reference. SRDI has the capacity to conduct survey to collect soil samples from more or less 15,000 sampling point and made analysis for physical, chemical and biological properties through its laboratories within a year or two. Thus, a baseline maps and database will be prepared and which can be updated in every five-year interval. It will enable SRDI to analyze soil fertility trends over the years.

1. Introduction

Bangladesh's reputation as a land of fertile soils was perhaps true in the past when pressure on land was low and food grains harvested from a single crop per year were adequate to feed the nation. Because of the country's alluvial nature, many soils possess the physical conditions for easy tillage and allowing plant roots to grow deeply and spread widely. Bangladesh's climatic condition also favor a wide range of crops, with soils under the influence of the tropical monsoon climate.

Soil is a dynamic, living resource whose condition is vital to both the production of food and fiber and to global balance and ecosystem function (Doran et al. 1996, cited in Islam, Aminul and Md Nazmul Hasan, 2015). The quality and health of soils determine agriculture sustainability, environmental quality (Pierzynski et al. 1994, cited in Islam, Aminul and Md Nazmul Hasan, 2015) and as a consequence of both – plant, animal and human health (Haberern, 1992, cited in Islam, Aminul and Md Nazmul Hasan, 2015).

Quality of soil, as distinct from health, is largely defined by the ability of soil to perform various intrinsic and extrinsic functions. Quality is represented by a suit of physical, chemical, and biological properties that together: (i) provide a medium for plant growth and biological activity; (ii) regulate and partition water flow and storage in the environment; and (iii) serve as an environmental buffer in the formation and destruction of environmentally hazardous compounds (Larson and Pierce, 1991, 1994, cited in Islam, Aminul and Md Nazmul Hasan, 2015).

Soil has either inherent or dynamic qualities. Inherent soil quality is a soil's natural ability to function. For example, sandy soil drains faster than clayey soil. Deep soil has more room for roots than soils with bedrock near the surface. These characteristics do not change easily.

Dynamic soil quality is how soil changes depending on how it is managed. Management choices affect the amount of soil organic matter, soil structure, soil depth, and water and nutrient holding capacity. One goal of soil health research is to learn how to manage soil in a way that improves soil function. Soils respond differently to management depending on the inherent properties of the soil and the surrounding landscape. These are listed in Table 1.

Healthy soil gives us clean air and water, bountiful crops and forests, productive grazing lands, diverse wildlife, and beautiful landscapes.

Soil health, also referred to as soil quality, is defined as the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans. This definition speaks to the importance of managing soils so they are sustainable for future generations. To do this, we need to remember that soil contains living organisms that when provided the basic necessities of life - food, shelter, and water - perform functions required to produce food and fiber.

Soil is an ecosystem that can be managed to provide nutrients for plant growth absorb and hold rainwater for use during dryer periods, filter and buffer potential pollutants from leaving our fields, serve as a firm foundation for agricultural activities,

Table 1 : Soil quality indicator properties

Physical property	Chemical property	Biological property
Bulk density	pH	Microbial biomass carbon
Rooting depth	Electrical conductivity	Microbial biomass nitrogen
Water infiltration rate	Cation-exchange capacity	Earthworm
Water holding capacity	Organic matter	Enzymes
Aggregate stability	Mineralizable nitrogen	Disease suppressiveness
	Exchangeable potassium	
	Exchangeable calcium	

Source: Division of Agricultural and Natural Resources, University of California, USA, 2000.

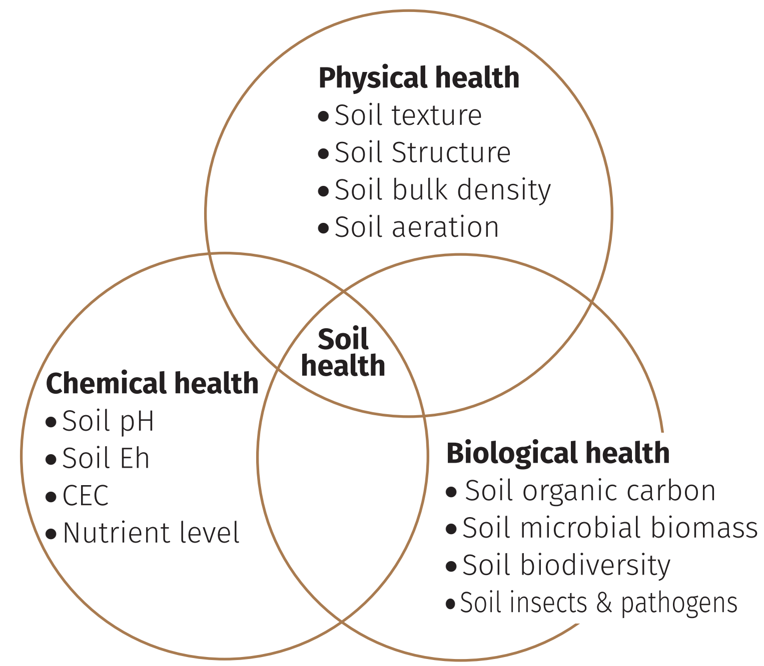

Fig. 1: Components of soil health (Lal, 2011)

and provide habitat for soil microbes to flourish and diversify to keep the ecosystem running smoothly.

Soil is an important component of terrestrial ecosystems that support life on the earth. Globally land and soil have received much importance and to make awareness of people the 5th December is observed as Soil Day by UN declaration. It is well agreed, healthy soils for healthy lives (plants, animals and humans).

Terms 'soil health' and 'soil quality' are practically synonymous with each other. The 'soil health' term is generally used by the farmers, land managers and extension agents, and the 'soil quality' by soil scientists and ecologists (Karlen et al., 2003). However, many indices of assessing soil quality are also used to assess soil health. Soil health encompasses physical, chemical and biological characteristics (Fig. 1).

Although parameters of soil health are similar to those of soil quality, parameters are assessed qualitatively for soil health and quantitatively for soil quality (Table 2). Soil organic matter is a key indicator of soil quality as well as soil health.

There is an increasing trend in soil health degradation which can be attributed to higher crop removal due to increasing cropping intensity, use of modern varieties of crops (HYVs and hybrids), soil erosion, soil salinity, soil acidity, deforestation, nutrient leaching and minimum manure application. These factors are mostly due to irrational human interventions. Consequently, with advancement of time, new nutrient deficiency arises. Chronologically N, P, K, S, Zn and B deficiencies have appeared. Magnesium deficiency is reported in Old

Table 2 : Parameters to measure soil quality and soil health (Lal, 2011)

Soil quality parameters (quantitative)	**Soil health parameters (qualitative)**
Particle size distribution	Texture
Water retention capacity	Drought, waterlogging
Erodibility	Erosion
pH	Reaction (acid, alkaline, neutral)
Cation/anion exchange capacity	Buffering capacity
Electrical conductivity	Salinity
Nutrient status	Fertility
SOC status	Color
Microbial biomass carbon	Biodiversity
Time to restore following disturbance	Resilience

Himalayan Piedmont Plain and Tista Floodplain soils. There is sporadic information of Cu, Mo and Mn deficiencies in crops. Deficiencies of Fe and Cl are not yet found (Jahiruddin, 2015). It is estimated that the overall N balance of Bangladesh soils is negative, the P balance near zero and the K balance is highly negative (Rijmpa and Jahiruddin, 2004).

From 1980 to 2013, crop production has increased by a factor of 2.6. This has been supported by increased cropping intensity (195% at present, 154% in 1980), use of modern varieties (HYV and hybrids) and improved management along with developing irrigation system. This has resulted in deterioration of soil fertility and consequently increased use of nutrients from 160 kg ha-1 in 2003 to 209 kg ha-1 in 2013 (World Development Indicators, 2016). Again, the increased use of nitrogen fertilizers causes an increased emission of N2O from wetland rice field (Aryl et al., 2019).

Soil fertility does not mean only the status plant nutrients in the soil but it is the combination of soil physical properties such as soil texture, bulk density, aggregate stability; chemical properties such as pH, EC, CEC, plant nutrients; and biological properties such as soil organic carbon, microbial biomass carbon, microbial biomass nitrogen, soil biodiversity etc.

The SRDI is generating national data base on soil pH, organic matter, soil salinity and 11 nutrient elements (N, P, K, Ca, Mg, S, Zn, B, Fe, Mn & Cu) across the AEZs of Bangladesh. The scientists of the institute periodically update the data and change the nutrient maps accordingly. The institute has produced Upazila (sub-district) Soil and Land Resources Utilization Guide popularly known as Upazila Nirdeshika based on soil data.

As a first step of graduation from developing to developed country ensuring food security, necessity of sustainable and environment-friendly agricultural system is imperative. To make Bangladesh food sufficient agriculture sector has been given highest priority. The government is trying sincerely for developing agriculture sector in consideration with 7th five-year plan, National Agriculture Policy and SDG. As per vision 2021, sufficiency in food was targeted by 2013. Despite population growth, various steps were taken by present pro people government to make Bangladesh food sufficient before estimated time (Bangladesh Economic Review 2019, Ministry of Finance, Bangladesh).

The expansion of modern agricultural farming practices like use of High Yielding Variety (HYV) together with intensified cultivation is needed to ensure food for all, which leads to an increased demand for fertilizers. Therefore, it is necessary to ensure timely supply of both organic and chemical fertilizers to meet the nutritional demand of these varieties. The use of chemical fertilizer is increasing with the increased demand for food production in the country. The use of urea fertilizer alone is the highest in the agriculture of the country. In FY2017-18, the total quantity of fertilizer used was 50.93 lakh MT, of which the use of

Urea fertilizer is 24.27 lakh MT. Development support in fertilizer was 5200.67 crore taka in FY2017-18 (Bangladesh Economic Review, 2019, Ministry of Finance, Bangladesh).

The first national soil fertility maps were prepared by Soil Resource Development Institute (SRDI) in 1998. These maps were prepared on the basis of soil nutrient data generated during Reconnaissance Survey (RSS) and semi-detailed soil survey for the preparation of upazila wise "Land and Soil Resources Utilization Guides" popularly known as "Upazila Nirdeshika". Soil fertility maps includes phosphorus, potassium, sulfur, zinc, boron, organic matter and pH status maps. These maps were incorporated in "Fertilizer Recommendation Guide-2005". Second soil fertility maps include phosphorus, potassium, sulfur, Zinc, boron, organic matter and pH status maps were prepared in 2010. These maps were prepared on the basis of soil nutrient database generated for the preparation of Upazila Nirdeshika. These maps also incorporated in "Fertilizer Recommendation Guide-2012" and "Fertilizer Recommendation Guide-2018". Phosphorus status map was made for only for Loamy to Clayey Soils of Wetland Rice Crops considering critical limits for modified Olsen method (neutral to calcareous soils) values for both Bray & Kurtz method (Acid soils) values and modified Olsen method values. Potassium and sulfur status maps were prepared for Loamy to Clayey Soils of Wetland Rice Crops. Zinc and Boron status maps were prepared considering as usual soil fertility class described in "Fertilizer Recommendation Guide- 2005, 2012 and 2018". Soil Reaction (pH) and Soil Organic Matter (SOM) status maps were also prepared, considering classification described in Fertilizer Recommendation Guides. There is an urgent necessity to have new soil fertility maps by National Agricultural Research System (NARS) scientists and also by Bangladesh Agricultural Research Council (BARC). These maps were used in Agro-Ecological Zones (AEZ) wise fertilizer recommendation for major crops and cropping patterns of that particular AEZ. These maps also used for the estimation of fertilizer requirements and distribution of fertilizers. These data and maps were also used in location specific soil fertility management.

Understanding the necessity of updated national soil fertility maps "Strengtheing of Soil Research and Research Facilities (SRSRF)" project under SRDI took initiative to prepare new national level soil fertility maps. Soil Resources Development Institute collected soil samples during semi-detailed soil survey conducted for preparing "Land and Soil Resources Utilization Guides" popularly known as Upazila Nrdeshika for every upazilas of the country. Sample intensity is at least one sample for every 200 hectares of land. Intensity increases with the differences in the physiography, agro-ecological zones, mapping units, land type, soil group etc. Collected soil samples were analyzed for plant nutrients such as nitrogen, phosphorus, potassium, sulphur, zinc, boron, calcium, magnesium, iron, copper, manganese and also for soil pH, organic matter and soil salinity. These chemical data were inserted in Upazila Nirdeshika as hard copy and also digitized in GIS platform. First round of soil survey and Upazila Nirdeshika publication completed during 1985 to 2002. Second round of survey and publication is going on and so far, 245 Upazila Nirdeshika is already published and chemical data is digitized in GIS platform. Present Soil Fertility Maps 2020, are prepared, based on soil chemical data of the Upazila Nirdeshika updated up to 2018. Maps included phosphorus (Loamy to Clayey Soils of Upland Crops), phosphorus (Loamy to Clayey Soils of Wetland Rice Crops), potassium (Loamy to Clayey Soils of Upland Crops), potassium (Loamy to Clayey Soils of Wetland Rice Crops), sulfur (Loamy to Clayey Soils of Upland Crops), sulfur (Loamy to Clayey Soils of Wetland Rice Crops), zinc, boron, calcium, magnesium, pH and organic matter status map. Nitrogen status map is not prepared as because nitrogen status is between very low to low in entire country.

These maps were useful for fertilizer management planning, procurement of fertilizers, distribution and for fertilizer recommendations broadly. Moreover, these maps had a role for selection of research topic and research sites.

Whether the land is plentiful or in short supply, efficient soil fertility management is the key to sustainable agriculture.

Soil fertility research and management is primarily concerned with the essential plant nutrients – their amounts, availability to crop plants, chemical reactions that they undergo in soil, loss mechanisms, processes making them unavailable or less available to crop plants, ways and means of replenishing them in these soils (Prasad and Power, 1997).Maintenance and management of soil fertility is central to the development of sustainable food production systems.

Maintaining and managing soil fertility, it is necessary to understand soil fertility status of the country, trends of soil fertility over the years, soil degradation situation. As because of the nationwide non availability of the physical properties such as bulk density, aggregate stability, biological properties such as microbial biomass carbon, microbial biomass nitrogen this study aims to understand soil nutrient status of arable soils and their trends over the time.

2. Objectives

The objective of the study is analyzing soil fertility trends over the years and to prepare a guideline soil fertility trends study. More specifically-

i) To analyze soil fertility status over the years;

ii) To analyze trends of soil fertility over the years; and

iii) To prepare a guideline for soil fertility trends study.

3. Study Area

The present study was carried out mainly in the area of the cultivable/arable land of Bangladesh (26° 37' 54.86" N and 87° 59' 59.96" E, and 20° 34' 1.85" N and 92° 40' 40.93" E), with a total area of 14,757,000 hectares.

4. Methodology

This study is based on the review of available literatures, maps, books, monographs, research papers including web pages and documents. This study mainly based on the information described in soil fertility maps of 2010 and soil fertility maps prepared in 2020. Weakness of the maps was studied carefully to prepare guide line for soil fertility trends analysis.

The principal base materials of this study are soil fertility maps of 2010 and 2020. Soil fertility maps of 2010 are prepared on the basis of soil nutrient database generated for the preparation of first generation of Upazila Nirdeshika during 1985 to 2002. Soil Resources Development Institute collected soil samples during semi-detailed soil survey conducted for preparing "Land and Soil Resources Utilization Guides" popularly known as Upazila Nrdeshika for every upazilas of the country. Sample intensity is at least one sample for every 200 hectares of land. Intensity increases with the differences in the physiography, agro-ecological zones, mapping units, land type, soil group etc. Collected soil samples were analyzed for plant nutrients such as nitrogen, phosphorus, potassium, sulphur, zinc, boron, calcium, magnesium, iron, copper, manganese and also for soil pH, organic matter and soil salinity. These chemical data were inserted in Upazila Nirdeshika as hard copy and also digitized in GIS platform. These maps also incorporated in "Fertilizer Recommendation Guide-2012" and "Fertilizer Recommendation Guide-2018". Phosphorus status map was made for only for Loamy to Clayey Soils of Wetland Rice Crops considering critical limits and fertility class for modified Olsen method (neutral to calcareous soils) values for both Bray & Kurtz method (Acid soils) values and modified Olsen method values. Potassium and sulfur status maps were prepared for Loamy to Clayey Soils of Wetland Rice Crops. Zinc and Boron status maps were prepared considering as usual soil fertility class described in "Fertilizer Recommendation Guide- 2005, 2012 and 2018". Soil Reaction (pH) and Soil Organic Matter (SOM) status maps were also prepared, considering classification described in Fertilizer Recommendation Guides.

There is an urgent necessity to have new soil fertility maps by National Agricultural Research System (NARS) scientists and also by Bangladesh Agricultural Research Council (BARC). These maps were used in Agro-Ecological Zones (AEZ) wise fertilizer recommendation for major crops and cropping patterns of that particular AEZ. These maps were also used for the estimation of fertilizer requirements and planning for distribution of fertilizers. These data and maps were also used in location specific soil fertility management program and research.

Understanding the necessity of updated national soil fertility maps "Strengtheing of Soil Research and Research Facilities (SRSRF)" project under SRDI took initiative to prepare new national level soil fertility maps. Second round of soil survey and publication started in 2006 and is going on and so far, 245 Upazila Nirdeshikahas already been published and chemical data is digitized in GIS platform.

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Methodology for preparing soil fertility maps: The soil sample points were collected from the Upazila Nirdeshika. The soil samples were subjected to physical and chemical analyses according to SRDI module for Upazila Nirdeshika. The mapping units (MUs) were defined by grouping areas of soils on a 1:50,000 scale, according to the Upazila Nirdeshika. The upazila Soil and Landform map was delineated using visual interpretation of the soil distribution in the area. Soil-landscape relationships were established using visual interpretation of field observations, soil descriptions, and the subsidiary Aerial Photos and topographic maps.

Due to the large amount of data available for use as covariates in modelling, it was necessary to use a data-mining technique to select the most suitable dataset as an optimal set of predictors to run the model, affording the lowest error. Generally, we use smaller neighborhoods or a minimum number of points when the phenomenon has a great amount of variation.

A selection process is used where the covariates were ranked based on their importance, selecting the top twelve with highest importance for soil mapping. The selection procedure was performed by using the IDW, combined with correlation analyses for removal of covariates with higher correlation with others. Inverse distance weighted (IDW) interpolation determines cell values using a linearly weighted combination of a set of sample points. The weight is a function of inverse distance. The surface being interpolated should be that of a locationally dependent variable.

Workflow for developing Digital Soil Mapping (DSM) is shown below-

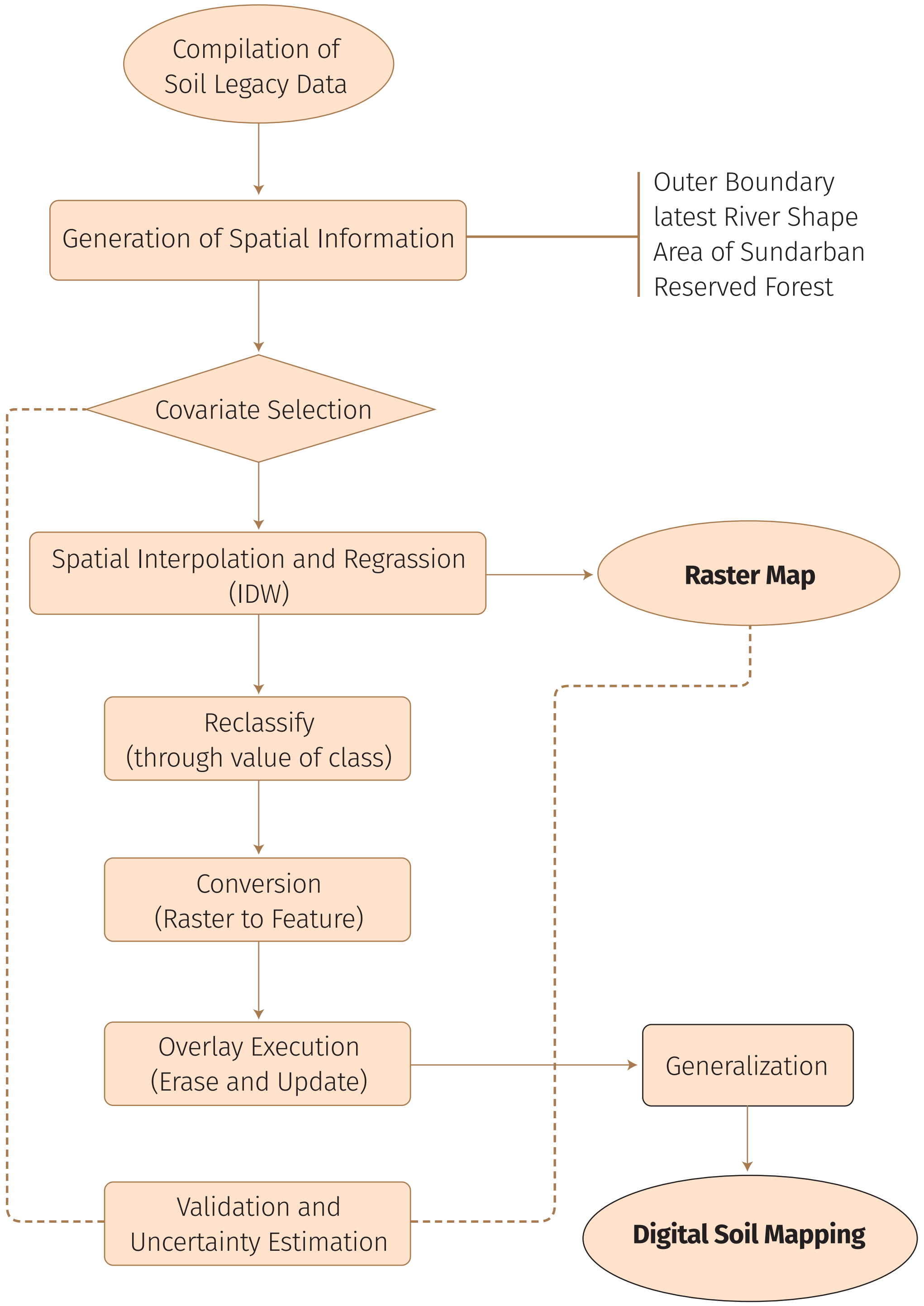

Fig. 2 Workflow for developing Digital Soil Mapping (DSM)

5. Results and Discussion

Whether the land is plentiful or in short supply, efficient soil fertility management is the key to sustainable agriculture. Soil fertility does not mean only the status plant nutrients in the soil but it is the combination of soil physical properties such as soil texture, bulk density, aggregate stability; chemical properties such as pH, EC, CEC, plant nutrients; and biological properties such as soil organic carbon, microbial biomass carbon, microbial biomass nitrogen, soil biodiversity etc.

Soil fertility research and management is primarily concerned with the essential plant nutrients – their amounts, availability to crop plants, chemical reactions that they undergo in soil, loss mechanisms, processes making them unavailable or less available to crop plants, ways and means of replenishing them in these soils (Prasad and Power, 1997).

Maintenance and management of soil fertility is central to the development of sustainable food production systems. Sustainability is dependent to a large degree on recycling, to the extent possible, the inputs into the production system, thereby increasing efficiency of output per unit of resource input. The discipline of soil fertility defines and outlines the mechanisms by which nutrients contained in these inputs are transformed, made available to crops, and cycled through the production system. Thus, the principles that regulate soil fertility are fundamental to the philosophy of sustainability.

Lack of sufficient data on soil physical, chemical and biological properties, this soil fertility trends study, concentrated with available plant nutrients such as phosphorus, potassium, sulphur, zinc, boron, calcium and magnesium; organic matter and soil reaction (pH). Total nitrogen is not included in this study as its status is very low to low across the country over the years. Other plant nutrients such as copper, iron, manganese is not included in the study as there is no information of deficiencies of these elements. Chlorine and molybdenum is also not in the study as because the unavailability of the data. Land use changes over the years is included in this study to understand how much crop land is shifted to non-crop uses. Soil fertility trends over the years are discussed below.

5.1 Land Use Changes

Based on SRDI database of Land and Soil Resources Utilization Guides popularly known as Upazila Nirdeshika prepared during 1985 to 2002 and subsequently published, total land area (total arable land) was estimated 95,98,381 hectares or 65.05 percent of Bangladesh. Sundarban comprises 2.90 percent, Reserve forest comprises 1.93 percent and others including homestead, rivers, urbans comprise 30.13 percent of Bangladesh (Land and Soil

Statistical Appraisal Book of Bangladesh, SRDI, 2010). Another study conducted by Hasan et.al., 2013, showed that in 2010, cropland covers 8,751,937 hectares of land comprises 60.04 percent of Bangladesh, Sundarban comprises 3.03 percent and forest including reserve forest comprise 9.48 percent of Bangladesh. Their study was conducted through digital interpretation of satellite imagery, secondary information and ground truthing in selected location in Bangladesh. They also studied the same for 1976 and 2000. They described that yearly average decrease of crop land during 2000 to 2010 was 0.73 percent. The present study is based on database of second generation of Upazila Nirdeshika published up to 2018. In this study it showed that crop land covers 8,586,864 hectares of land comprises 58.09 percent of the country, which is less than 6.85 percent that that of 2010 and annual average decrease of crop land is 0.685 percent and lesser than the study made by Hasan, et.al., 2013. This difference may be due to the methodology of the study or transfer of crop land to aquaculture became saturated and government policy and enactment. More over may be of shifting of crop land to rural settlement is lesser than that of 2000 to 2010. Land use changes during 2010 to 2020 are shown in fig. 3 and table 3.

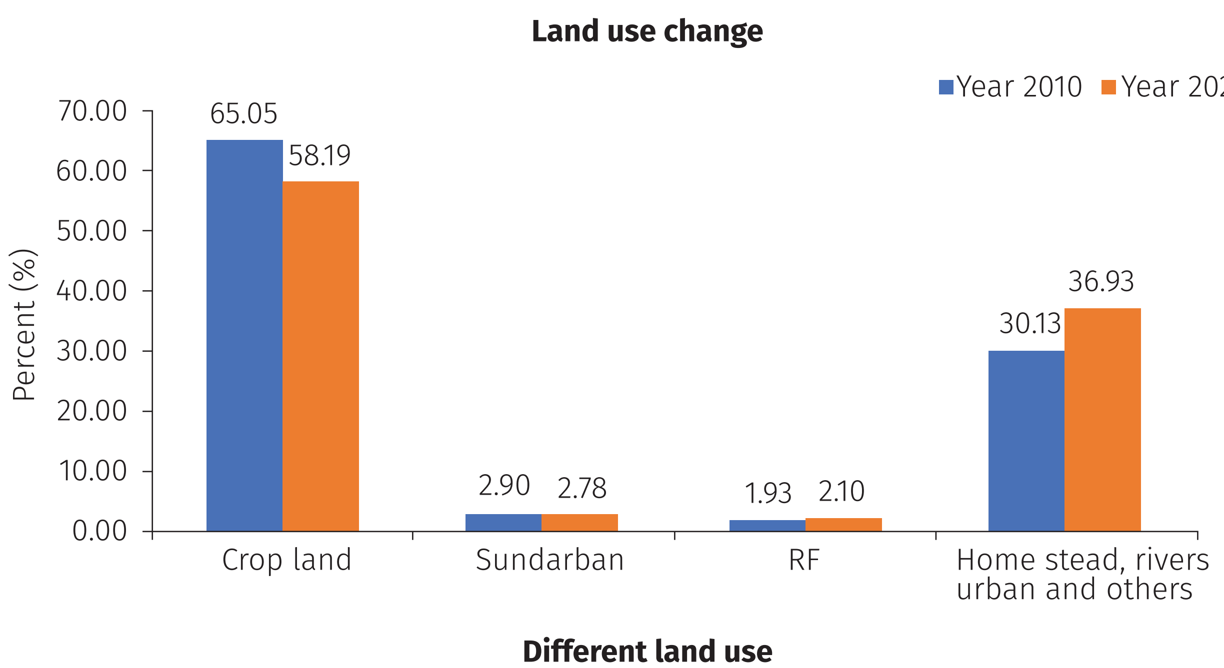

Fig 3. Changing pattern of land use of Bangladesh since 2010 to 2020.

Table 3 : Change in land use (area and percentage) since 2010 to 2020

Land use type	2010		2020	
	Area(ha)	Percent (%)	Area(ha)	Percent (%)
Crop land	9598381	65.04	8586864	58.19
Sundarban	427418	2.90	409999	2.78
Reserve forest	284210	1.93	130345	2.10
Homestead, rivers, urban and others	4446991	30.13	5449792	36.93
Total	14757000	100	14757000	100

5.2 Soil Reaction (pH)

Acid soils are an important issue because of its adverse effect on soil fertility and crop productivity. Geomorphologically acid sulfate soils, peat soils, acid basin clays, terrace soils and hill brown soils are moderately to strongly acidic in reaction. Apart from soil formation, leaching of basic cations (Ca^{2+}, Mg^{2+}, K^{+} and Na^{+}) and continuous use of urea application are the principal causes of soil acidity in this country. Urea acidifies soils through the process of nitrification ($NH_4^+ + 2O_2 = NO_3^- + 2H^+ + H_2O$). Inputs of S as elemental S or as SO_2 from the atmosphere can also produce soil acidity when they are oxidized: (i) $2S + 3O_2 + 2H_2O = 2H_2SO_4$ (ii) $2S_2O + O_2 + 2H_2O = 2H_2SO_4$. When microorganisms decompose soil organic matter they produce CO_2, which dissolves in soil water to form H_2CO_3 in the same way as in rain. However, soil pH is not easily altered because of inherent buffering capacity which depends on clay and organic matter contents.

Soil acidity affects crop growth in two ways: directly by acidity effect and indirectly by affecting nutrient availability. Acid soils possess toxic concentration of Al^{3+}, Fe^{3+} and Mn^{2+}, deficient concentrations of P and Mo, and low availability of bases (Ca^{2+}, Mg^{2+}) which together cause reduction of crop yield. Legumes are highly affected due to soil acidity. Acidity limits both survival and persistence of nodule forming bacteria in soil, and the process of nodulation itself. Soil acidifation may intensify and affect crop production if effective management strategies for amelioration are not implemented (BARC, 2018). Zahid et.al. 2020, reported that soil productivity reduces 50-75% if soil pH is <4.5, 25-50% if soil pH is 4.5-5.5. They also reported that soil productivity may also reduced to 10-25% if soil pH is 5.1-5.5.

SRDI estimated that about 2.50 mha land across the country was very strongly acidic (pH < 4.5) and about 3.70 mha was under strongly acidic (pH 4.5-5.5) in 2010. In the present study (2020) it roses to 2.77 mha of lands are under very strongly acidic and 3.64 mha of land are under strongly acidic. Very strongly to strongly acidic soils which reduces soil productivity upto 75%, if not ameliorated, comprises 41.23 % of arable land in 2010, which roses to 45.67 % in 2020, i.e., almost half of the arable lands. SRDI estimated that soil of 0.30 mha lands was deficient in both Ca^{2+} and Mg^{2+} in 2010 (Islam Aminul and Md. Nazmul Hasan, 2015, though they did not prepare map on soil Ca and Mg. In thepresent study (2020) it was observed that arable lands under very low to low status in Ca^{2+} and Mg^{2+} are about 2.10 and 1.05 mha which is 24.53% and 12.31% of the total arable land respectably,of Bangladesh. Deterioration of both Ca and Mg from top soil, continuous use of urea fertilizer and also use of S as fertilizer are the main cause of lowering of soil pH in the country. Calcium and Magnesium status (fig. 31 and fig. 33) of the arable soils of Bangladedh made a good correlation with soil reaction (pH) of Bangladesh (fig. 5). Immediate actions to be taken to ameliorate soil pH otherwise it will affect soil productivity and ultimately crop yield. Soil reaction map (pH) 2010, 2020 are presented in Fig. 4 and Fig. 5 and Fig. 6 shows the graphical presentation of changing pattern of soil pH during 2010 to 2020 and data presented inTable 4 indicates the changing pattern of soil pH of arable land in Bangladesh since 2010 to 2020. In general it can be concluded that lowering of soil pH is occuring day by day.

As soil pH indicates the soil environment as well as soil quality which regulate the availability of plant nutrients and crop yield and also crop quality. Crop quality is directly related to human health. Many unwanted toxic elements, heavy metal and metalloids like cadmium, lead, chromium, nickel, arsenic may become available in a very strongly to strongly acidic soil and plant can uptake those elements in absence of desirable base materials like calcium (Ca) and magnesium (Mg) which might affect human health (Hasan et al., 2016). In acidic soils, availability of certain nutrients like aluminum, iron and manganese are increased due to higher dissolution and at times become toxic. In strongly acidic conditions, phosphorus reacts with active iron and aluminum, forming insoluble phosphates. More than 80 percent of applied phosphate is converted into unavailable forms in acid soils within very short periods (Yuan et al., 1960; Mandal and Khan, 1972). Under such conditions, calcium and magnesium supply is reduced and plant growth suffers. In addition to these, other essential nutrients such as nitrogen and sulfur are also in deficient concentration (Ranjit, 2000).

Acid soils often contain soluble forms of aluminum and manganese. As soil acidity increases (pH decreases), soluble aluminum and manganese increase to toxic levels.

Aluminum toxicity restricts root growth and phosphorous uptake. Manganese toxicity causes black necrotic spots or streaks on leaves of cereals and chlorosis on leaf margins and cupping of leaves of canola and legumes. Aluminum and manganese toxicity often reduce the yield of crops grown on acid soils. Soil acidity also has a direct effect on the survival and growth of rhizobium bacteria which fix nitrogen in association with legumes. The application of lime reduces soil acidity (pH increases) which reduces soluble aluminum and manganese to nontoxic levels and creates a suitable environment for rhizobium bacteria. Reduced soil acidity following liming also increases the availability of several other plant nutrients, notably phosphorus. Only about 20 per cent of fertilizer phosphorus is taken up by a crop in the year of application. The remainder is fixed in the soil in various degrees of availability to succeeding crops. On acid soils (pH < 6.0) the fixed phosphorus is retained in less available forms than on slightly acid and neutral soils (pH 6.1 to 7.5).

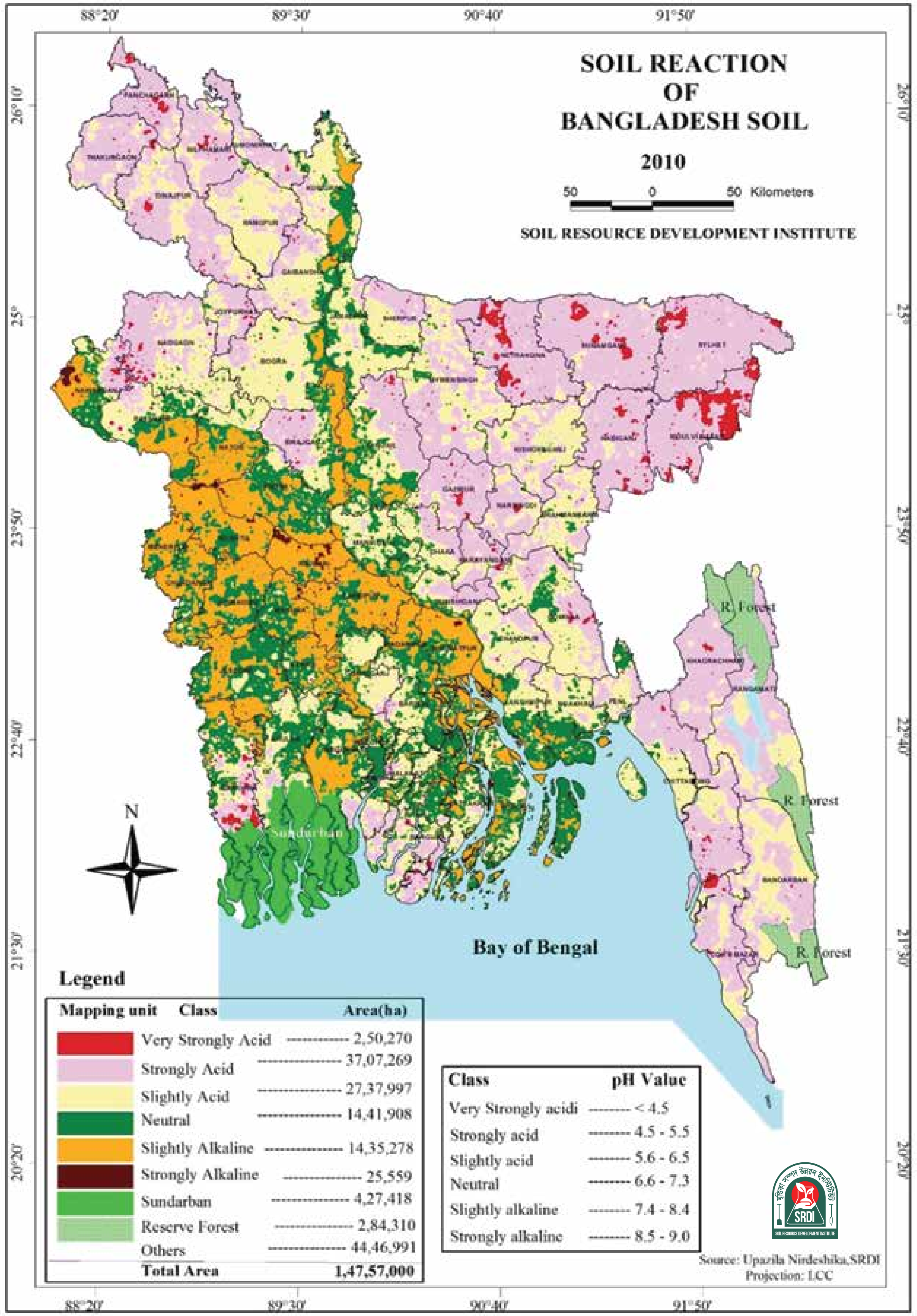

Fig 4. Soil Reaction (pH) Status Map, Year 2010.

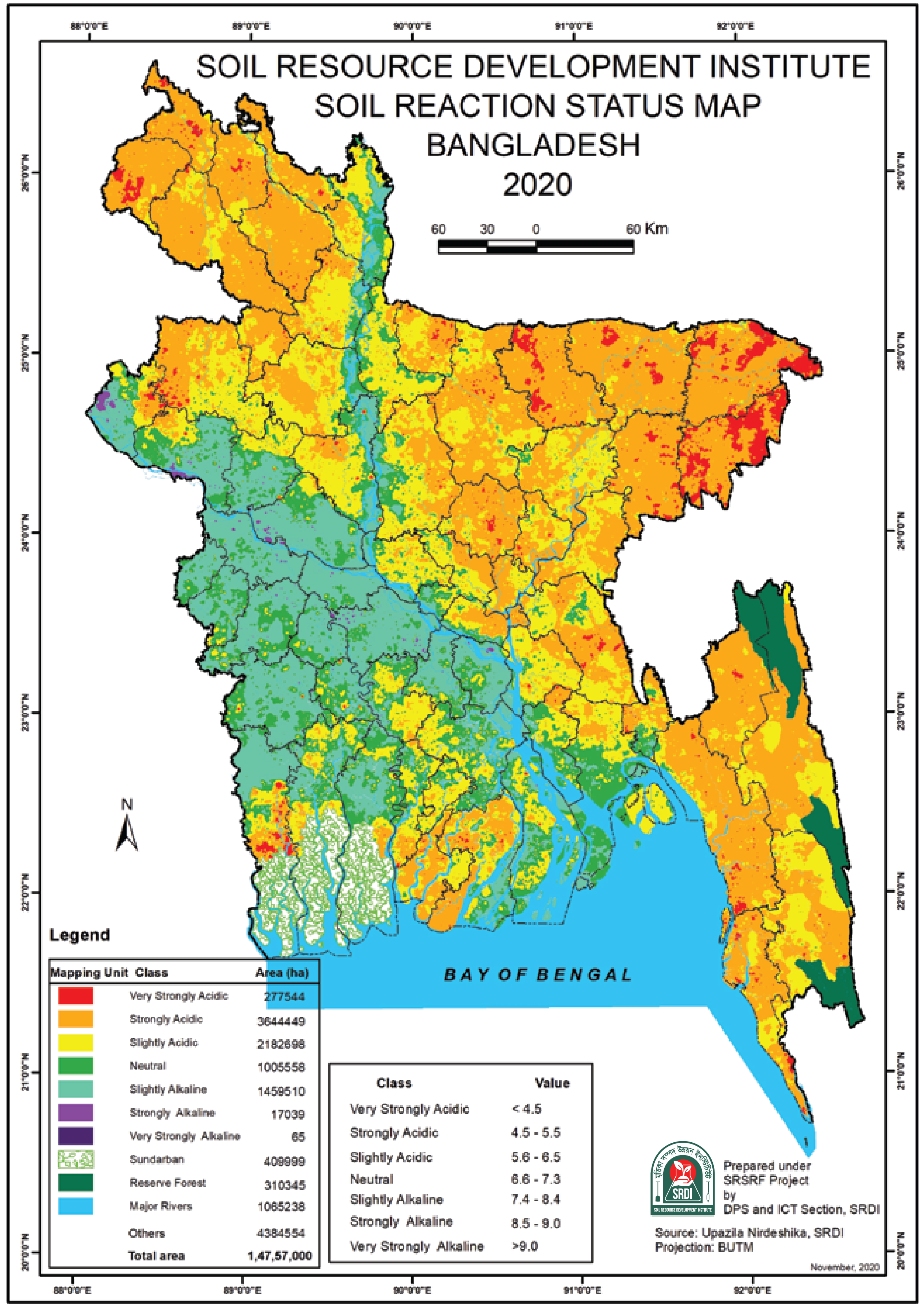

Fig 5. Soil Reaction (pH) Status Map, Year 2020.

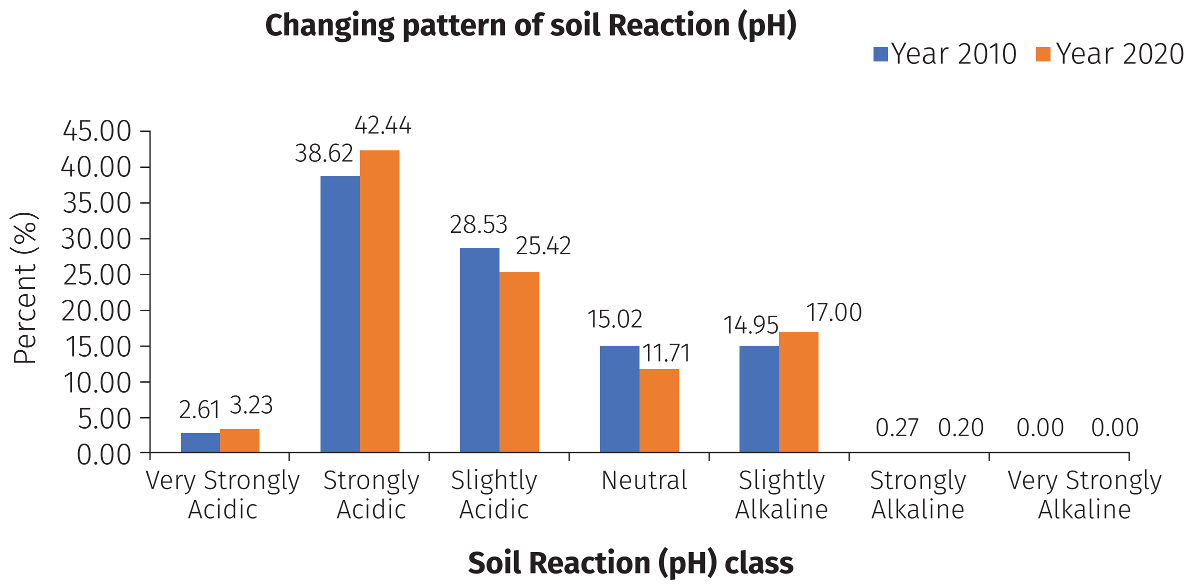

Fig 6 Changing pattern of soil reaction (pH) status (% of arable lands) in loamy to clayey soils since 2010 to 2020.

Table 4 : Changing pattern of soil reaction (pH) status (area and percentage of arable lands) in loamy to clayey soils since 2010 to 2020

Soil pH class	Year 2010		Year 2020	
	Area (ha)	Percent (%)	Area (ha)	Percent (%)
Very Strongly to Strongly Acidic	3957539	41.23	3921993	45.67
Slightly Acidic	2737997	28.53	2182698	25.42
Neutral	1441908	15.02	1005558	11.71
Slightly Alkaline	1435378	14.95	1459510	17.0
Strongly Alkaline	25559	0.27	17039	0.20
Very Strongly Alkaline	0	0	65	0
Total	9598381	100.00	8586863	100.00

5.3 Organic Matter

Soil organic matter is a key factor in maintaining long-term soil fertility since it is the reservoir of metabolic energy, which drives biological processes in nutrient availability. Soil organic matter undergoes mineralization and release substantial quantities of N, P, S and very important source 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. Applied fertilizers needs to transform into available through the activity of microorganism. Organic matter also acts as buffer against rapid change in soil pH. Organic matter itself is composed of living biomass like microorganisms, dead tissue or partly decomposed materials and stable, fully decomposed humus. Soil organic matter contributes to soil productivity in many ways. It influences physical, chemical and biological properties of soil. It serves as reservoir of nutrients for crops, enhance aggregate stability, increases nutrient exchange (CEC, mainly Ca, Mg and K), improves water holding capacity, water infiltration, soil aeration, reduces compaction, helps to reduce water runoff and provides food for the living organism. Organic matter not only supplies plant nutrient but also acts as the store house or reservoir of plant nutrients. It resists the losses of plant nutrient through leaching by its higher capacity of CEC. It is impossible to maintain soil fertility trough chemical fertilizer without sufficient quantity of organic matter. Organic matter increases the use efficiency of the chemical fertilizer. Depletion of soil organic matter is a major constraint to higher crop production in Bangladesh. Soil organic matter is continuously undergoing changes and needs to be replenished regularly to maintain soil productivity. The major sources of soil organic matter include animal manure, farmyard wastes, domestic wastes, industrial wastes, sewage sludge, green manure etc. A large variety of organic waste are available in the country that can be used as potential source of manure to improve soil. These are domestic wastes (non-edible vegetables, food and fruit parts, after-meal wastes etc.), farmyard wastes (cattle dung and urine, feed/fodder refuse, harvested crop residues, poultry manure etc.), agro-industrial wastes (sugarcane trash, oil cakes, bagasse, molasses, bone meal, blood meal, rice husk, brans, saw dust etc.), farm wastes (crop residues, weeds, dead animals, water hyacinth etc.) and city wastes (solid wastes and sewage sludge). Farmyard manure, poultry manure, bio-slurry, compost and vermi-compost may be used in cropping system.

SRDI estimated that about 0.76 mha of arable land across the country was under very low organic matter content and 2.88 mha was under low organic matter content in 2010, which is 7.94 and 30.00 % of total arable lands. About 55.57 %, 5.28% and 1.21% of arable lands were under medium, high and very high level of organic matter contents. Organic matter status map 2020 indicated that about 4.75% and 30.08% of arable lands are under very low and low content of organic matter respectively. About 59.19%, 4.58% and 1.40% of arable land is under medium, high and very high content of organic matter respectively. In 2010 very low to low content of organic matter comprises 37.94% of arable land, which reduces to 34.83% in 2020. Medium organic matter content of organic matter comprises 55.57% of arable land in 2010, which increases to 59.19%. Reduction of the area under very low to low content of organic matter and increase of area under medium content of organic matter indicates increase of organic matter in soils of Bangladesh over the time. This may be because of rice-rice cropping system, increasing cropping intensity and awareness of the farmers on incorporation of organic manures to their farm specially in vegetable farming. Area under high and very high content of organic matter was 5.28% and 1.21% respectively, in 2010 and 2020 it becomes to 4.58% and 1.40% respectively in 2020. Fig. 7 and Fig. 8 shows the organic matter status of soils in 2010 and 2020 respectively and Fig. 9 shows the change of organic matter during 2010 to 2020. Information in Table 5 shows the changing patterns soil organic matter status (area and percentage of arable lands) of Bangladesh since 2010 to 2020.

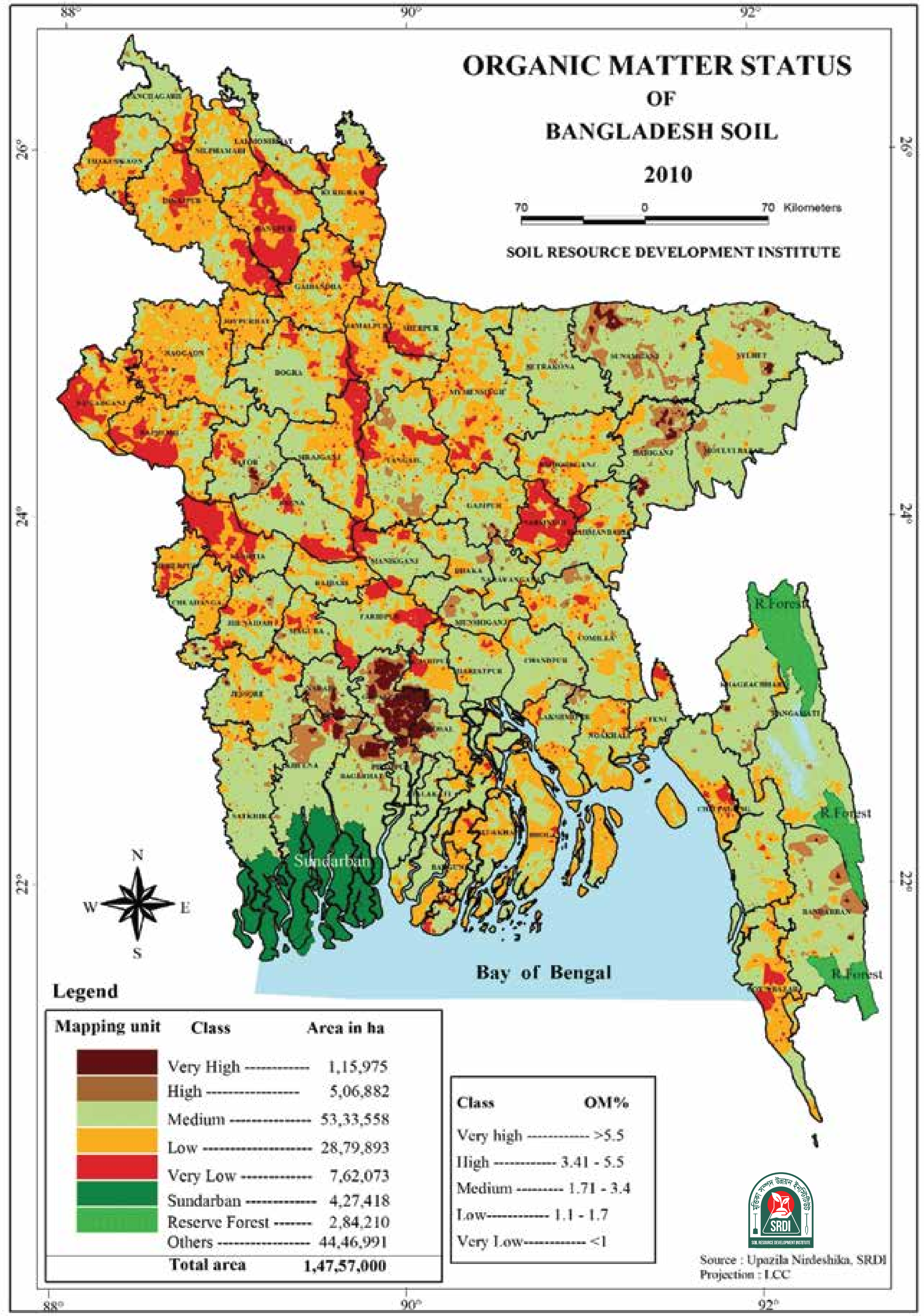

Fig 7. Soil Organic Matter Status Map, Year 2010.

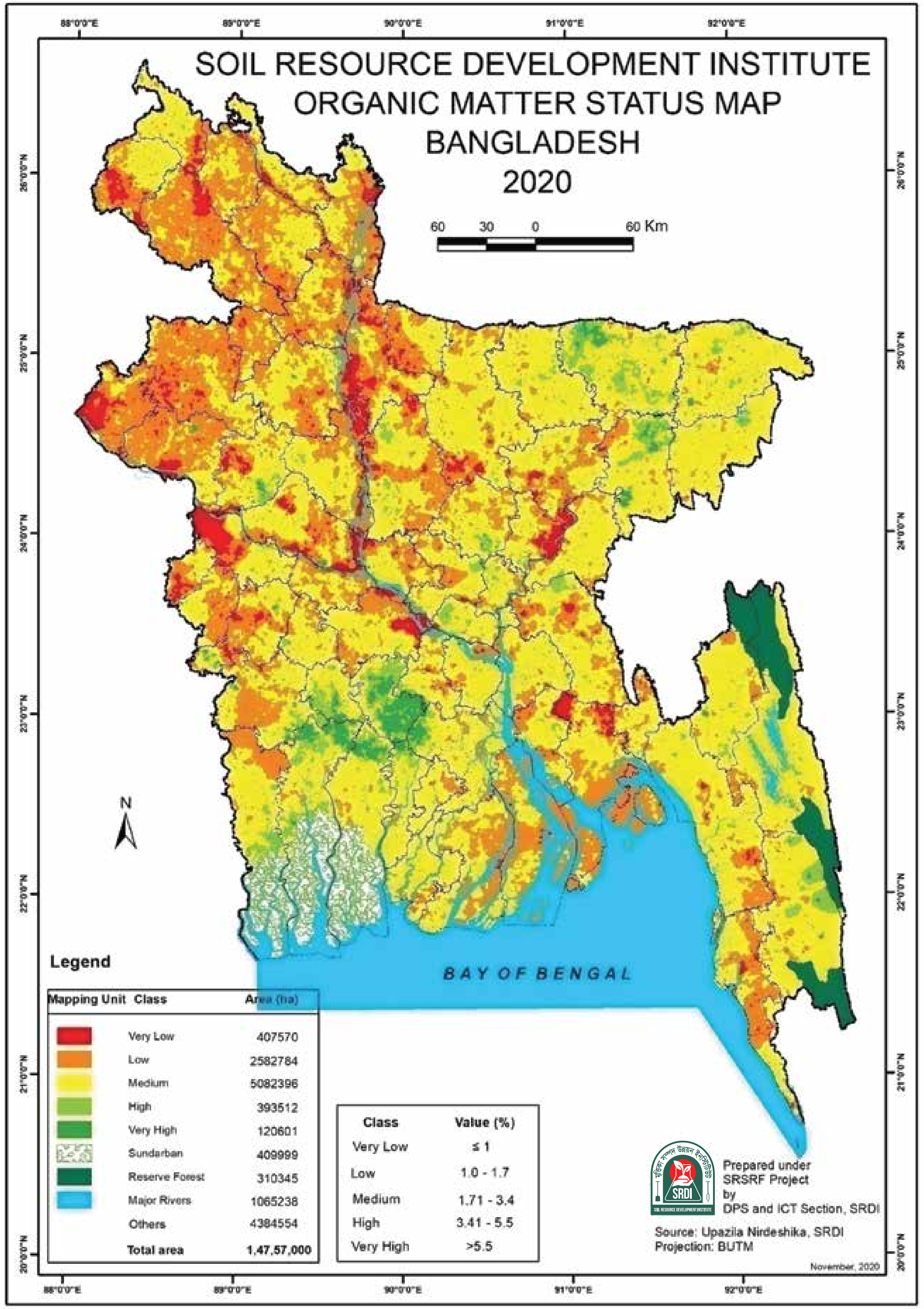

Fig 8. Soil Organic Matter Status Map, Year 2020.

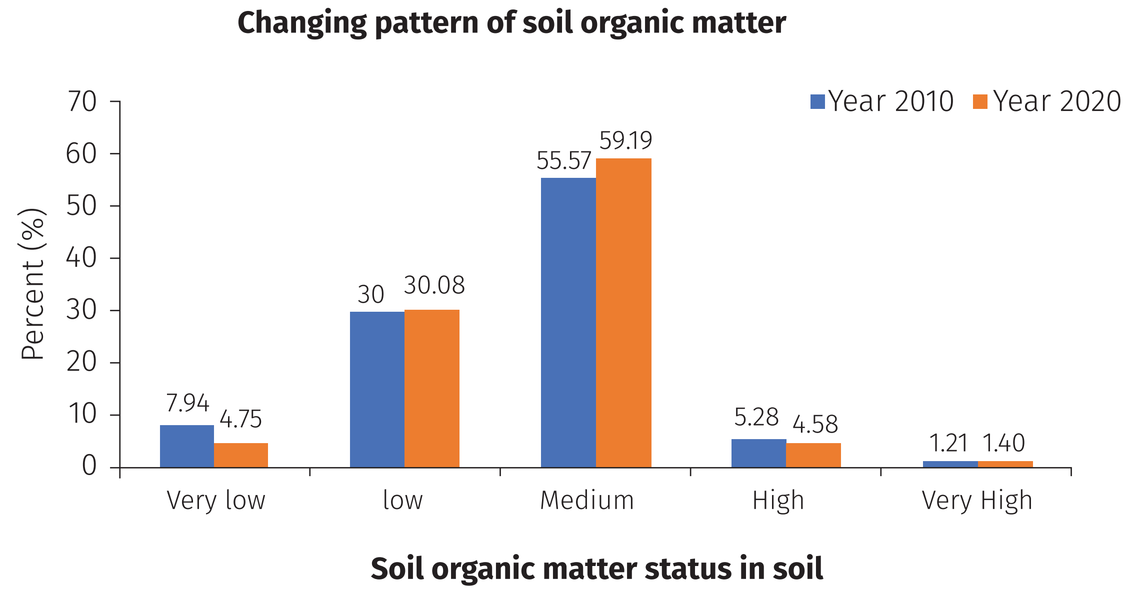

Fig 9. Changing pattern of soil organic matter (% of arable lands) in loamy to clayey soils since 2010 to 2020.

Table 5 : Changing pattern of soil organic matter status (area and percentage of arable lands) in loamy to clayey soils since 2010 to 2020

Fertility class	**Year 2010**		**Year 2020**	
	Area (ha)	**Percent (%)**	**Area (ha)**	**Percent (%)**
Very Low to Low	3641966	37.94	2990354	34.83
Medium	5333558	55.57	5082396	59.19
High	506882	5.28	393512	4.58
Very High	115975	1.21	120601	1.4
Total	9598381	100.00	8586863	100.00

5.4 Phosphorus

Phosphorus is the second most important plant nutrient after Nitrogen. It is an essential macronutrient that plays important role in all crop biochemical processes such as photosynthesis, respiration, energy storage, transfer, cell division, cell enlargement and nitrogen fixation. It is also important in seed germination, seedling establishment, root, shoot, flower and seed development. Despite its importance in crop nutrition, availability of the nutrient in soils for plant uptake is limited by several soil factors. The factors include: soil pH levels, clay mineralogy, organic matter, free iron and aluminum, calcium carbonate, soil temperatures and availability of other nutrients among other factors. Availability of phosphorus for plant uptake can be managed by adoption of practices such as liming acidic soils, application of organic amendments in both alkaline and acidic soils, tillage practices and regulation of time and method of P fertilizer application.

Phosphorus is a key nutrient for higher and sustained agricultural productivity and which limits plant growth in many soils. Phosphorus forms an important component of organic compound adenosine triphosphate (ATP), which is the energy currency that drives all biochemical process in plants. It is also an integral component of nucleic acids, coenzymes, nucleotides, phosphoproteins, phospholipids and sugar phosphates as well as intermediates of signal transduction events. It is also involved in an array of processes in plants such as photosynthesis, respiration, nitrogen fixation, flowering, fruiting, and maturation. Plant dry matter may contain up to 0.5% phosphorus.

Phosphorus status map was prepared in 1998 and 2010 but these maps were prepared for Loamy to Clayey soils for rice crops and fertility class and critical limit were considered for Olsen phosphorus. In 1998, RSS and Upazila Nirdeshika database were used for mapping. In 2010 phosphorus map was prepared based on Upazila Nirdeshika database. No map was prepared for Loamy to Clayey Soils of upland crops.

In 2020 phosphorus status map for both Loamy to Clayey Soils of upland crops and wetland rice crops are prepared and both Olsen and Bray & Kurtz phosphorus was considered for critical limit and fertility class. Area under different fertility class is mentioned in all the maps. In this study soil fertility maps of 2010 and 2020 is considered.

Soil phosphorus map, year 2020 for Loamy to Clayey Soils of Upland Crops showed that very low to low content of soil phosphorus across the country is 4,822,353 hectares and is about 56.16% of total arable land and medium content of soil phosphorus is about 20.75% of arable land (1,781,569 hectares). As there is no map or data of 2010, for loamy to clayey soil of upland crops, so trend analysis could not be done. Fig. 10 shows the phosphorus status map for loamy to clayey soils of upland crops in 2020 and fig. 11 shows soil phosphorus status (% of arable lands) for upland crops in 2020 and table 6 shows the distribution (area and percentage) of arable lands under different fertility class of upland crops.

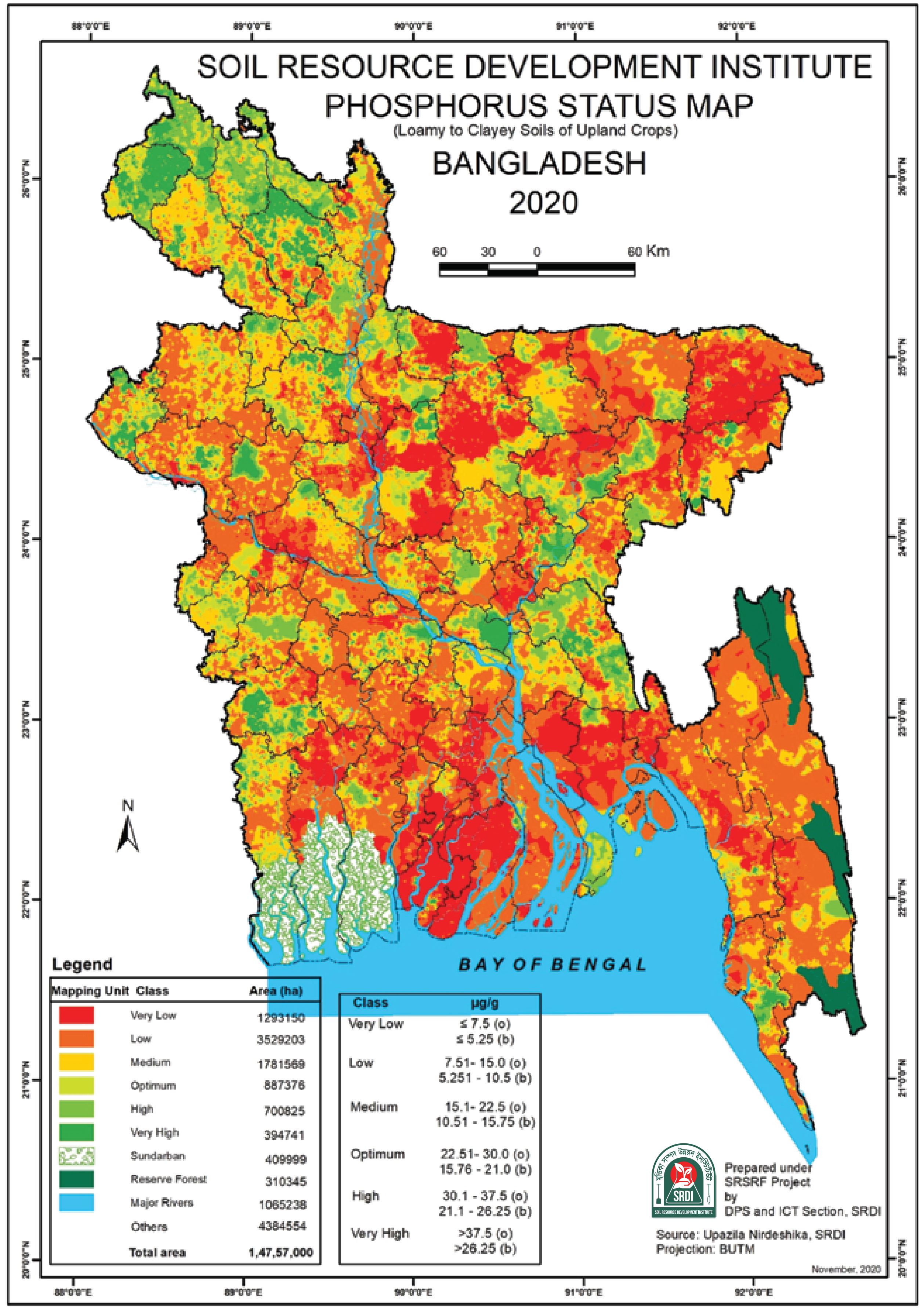

Fig 10. Phosphorus Status Map for Loamy to Clayey Soils of Upland Crops, Year 2020.

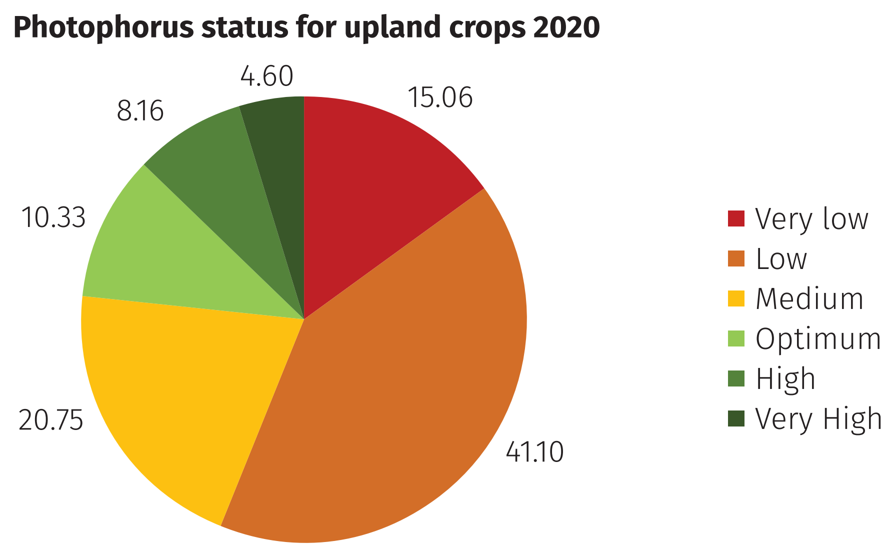

Fig. 11 Soil phosphorus status (% of arable lands) under different fertility class for loamy to clayey soils of upland crops in 2020.

Table 6 : Phosphorus status (area and percentage of arable lands) under different fertility class for loamy to clayey soils of upland crops in 2020

Fertility Class	Area (Ha)	Percentage of arable land
Very Low to Low	4822353	56.16
Medium	1781569	20.75
Optimum	887376	10.33
High to Very High	109566	12.76
Total	8586864	100.00

Very low to low content of phosphorus in loamy to clayey soils of wetland rice crops in 2010 was 38.60% and it increases to 50.27% in 2020 and medium content of phosphorus was 21.14% in 2010 and it reached to 21.43% in 2020. There are slight increase of the area (%) of optimum content and a sharp decrease of area (%) of high to very high content of phosphorus in 2020 than that of 2010. Over all impresssion is that phosphorus content in loamy to clayey soils of wetland rice crops declined largely over the years. It may be because of increasing cropping intensity and decrease of soil pH which restricts phosphorus availability in soils. In 2019-20 TSP and DAP used in agriculture was 691,000 and 962,000 mt, which means average use of phosphatic fertilizer was 192.50 kg per hectare. Fig. 12 and fig. 13 shows the phosphorus status map for loamy to clayey soils of wetland rice crops in 2010 and 2020 respectively and fig. 14 represents changing pattern of soil phosphorus status (% of arable lands) in loamy to clayey soils of wetland rice crops, Bangladesh since 2010 to 2020. Table 7 shows changing pattern of soil phosphorus content of arable land (area and percentage) of Bangladesh.

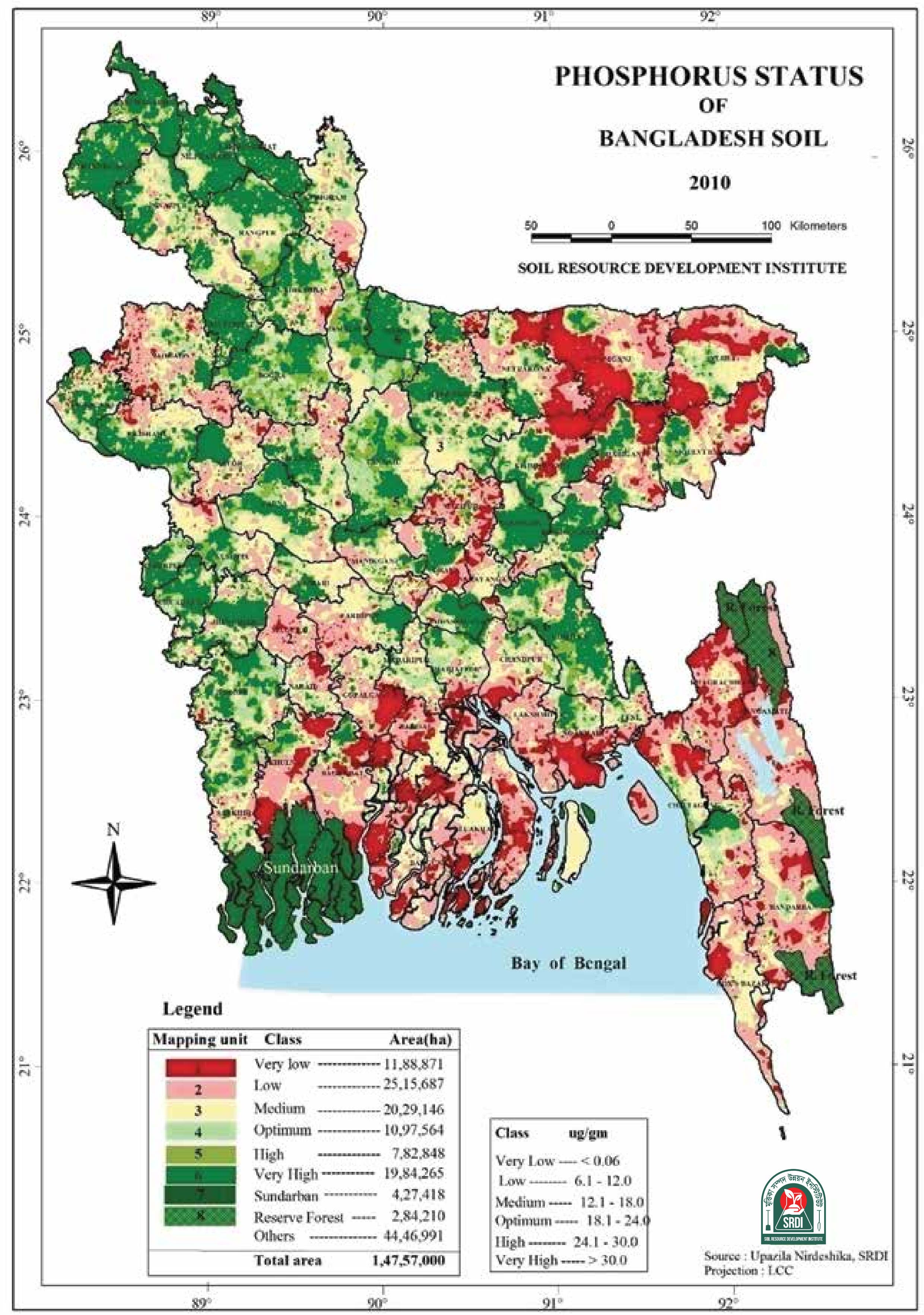

Fig. 12 Phosphorus Status Map for Loamy to Clayey Soils of Wetland Rice Crops, Year 2010.

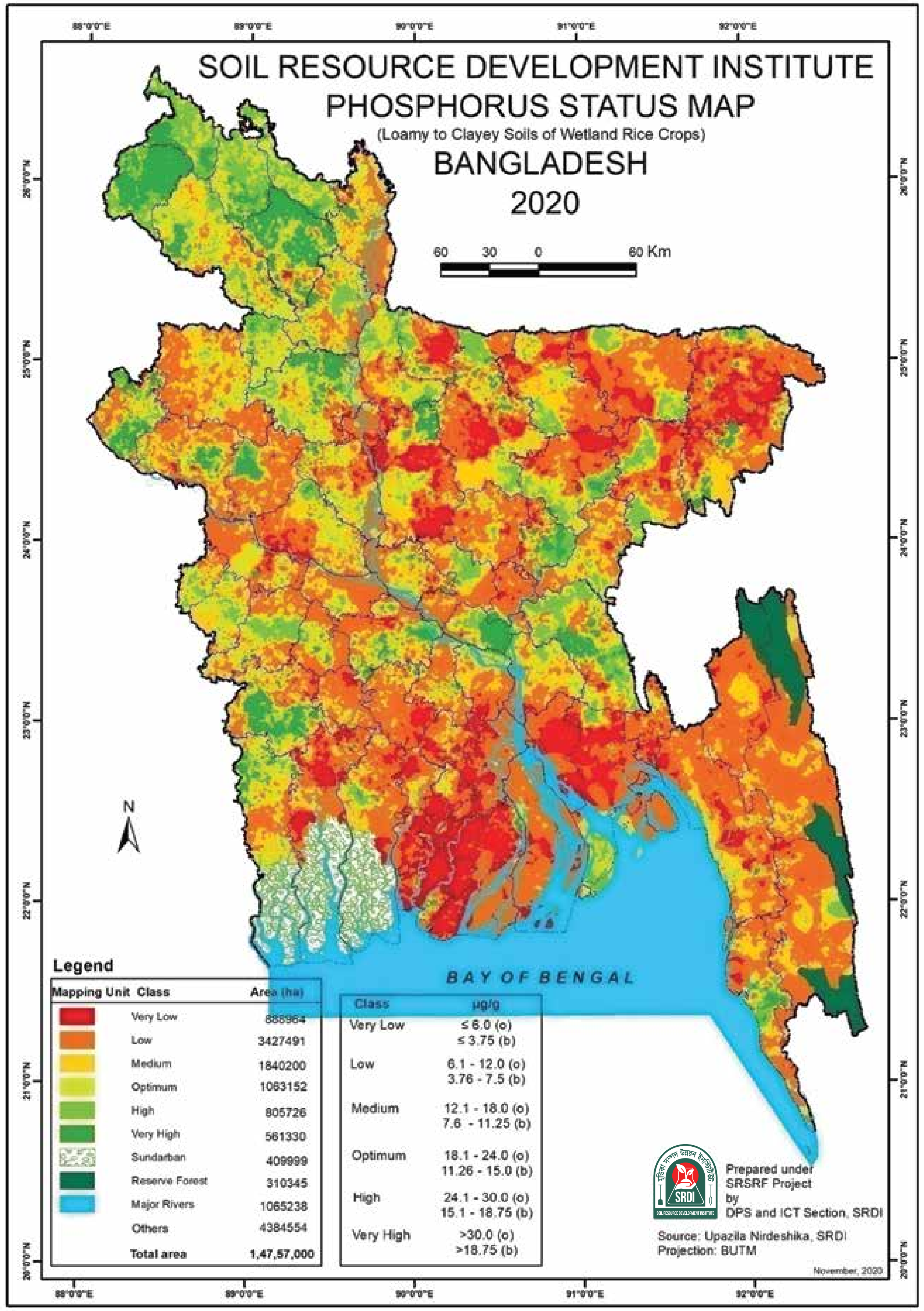

Fig. 13 Phosphorus Status Map for Loamy to Clayey Soils of Wetland Rice Crops, Year 2020.

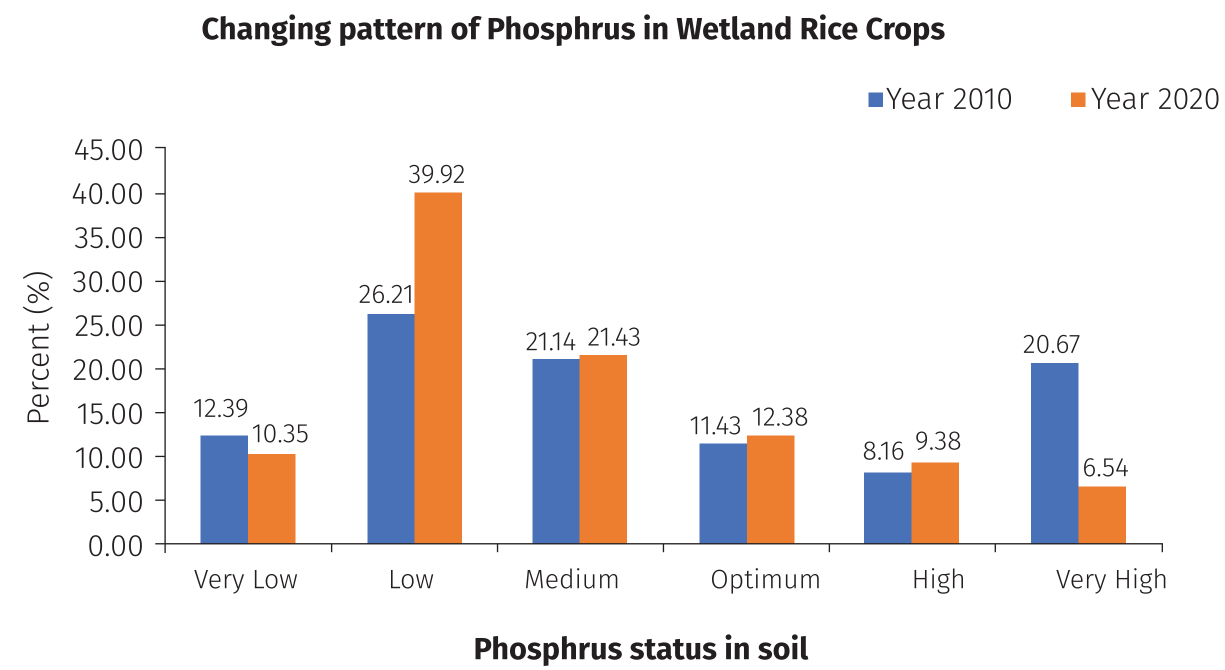

Fig. 14 Changing pattern of soil phosphorus status (% of arable lands) in loamy to clayey soils of wetland rice crops since 2010 to 2020.

Table 7 : Changing pattern of soil phosphorus status (area and percentage of arable lands) in loamy to clayey soils of wetland rice crops since 2010 to 2020

Fertility class	**Year 2010**		**Year 2020**	
	Area (ha)	**Percent (%)**	**Area (ha)**	**Percent (%)**
Very Low to Low	3704558	38.60	4316455	50.27
Medium	2029146	21.14	1840200	21.43
Optimum	1097564	11.43	1063152	12.38
High to Very High	2767113	28.83	1367056	15.92
Total arable land	9598381	99.99	8586863	100.00

5.5 Potassium

Potassium is associated with the movement of water, nutrients and carbohydrates in plant tissue. It is involved with enzyme activation within the plant, which affects protein, starch and adenosine triphosphate (ATP) production. The production of ATP can regulate the rate of photosynthesis.

Involved in activation of enzymes related to starch synthesis, translocation of carbohydrates; regulation of stomatal openings; produces stiff straw in cereals; imparts disease resistance to plants, involved in maintaining turgor pressure of plant cells.

Potassium also helps regulate the opening and closing of the stomata, which regulates the exchange of water vapor, oxygen and carbon dioxide. If K is deficient or not supplied in adequate amounts, it stunts plant growth and reduces yield.

Other roles of K include, increases root growth and improves drought resistance, maintains turgor; reduces water loss and wilting, aids in photosynthesis and food formation, reduces respiration, preventing energy losses, enhances translocation of sugars and starch, produces grain rich in starch, increases plants' protein content, builds cellulose and reduces lodging, and helps retard crop diseases.

Potassium status map was prepared in 1998 and 2010 but these maps were prepared for Loamy to Clayey soils for rice crops. In 1998 RSS and Upazila Nirdeshika database were used for mapping. In 2010 potassium status map was prepared based on Upazila Nirdeshika database. No map was prepared for Loamy to Clayey Soils of upland crops.

In 2020 potassium status map for both Loamy to Clayey Soils of upland crops and wetland rice crops are prepared. Area under different fertility class is mentioned in all the maps. In this study soil fertility maps of 2010 and 2020 is considered.

Soil potassium map, year 2020 for Loamy to Clayey Soils of Upland Crops showed that very low to low content of soil potassium, across the country is 5,139,339 hectares and which is 59.85% of total arable land and medium content is about 23.51% of arable land (2,018,590 hectares). As there is no map or data of 2010, so trend analysis could not be done. Fig 15 shows the potassium status map for loamy to clayey soils of upland crops in 2020 and fig. 16 shows soil potassium status (% of arable lands) for upland crops in 2020 and table 8 shows the area and percentage of arable land under different fertility class of upland crops in 2020.

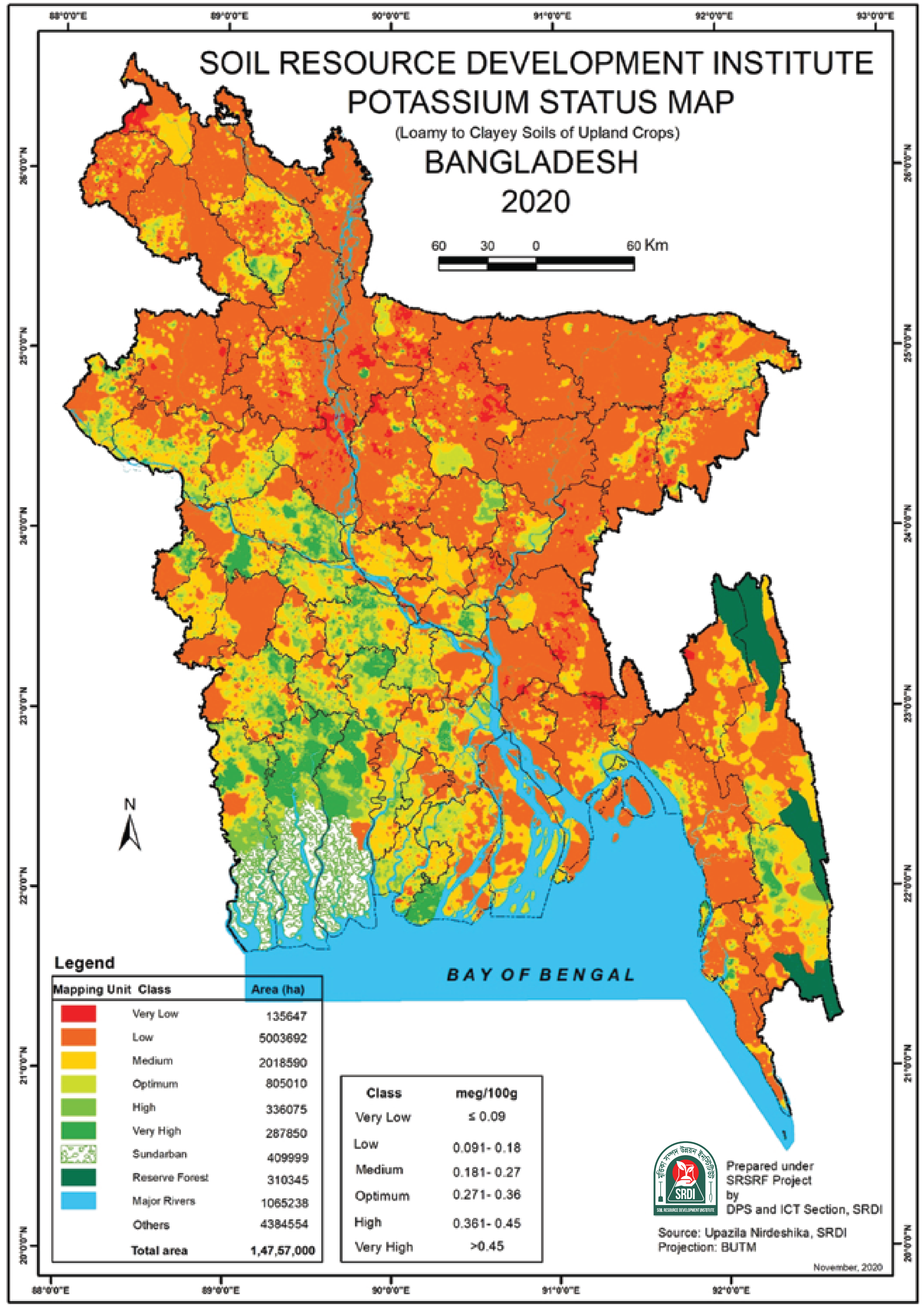

Fig. 15 Potassium Status Map for Loamy to Clayey Soils of Upland Crops, Year 2020.

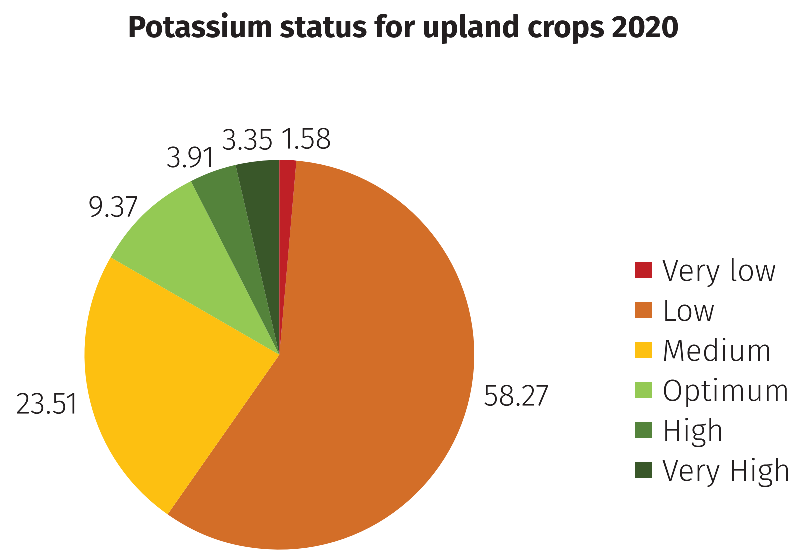

Fig. 16 Soil potassium status (% of arable lands) under different fertility class for loamy to clayey soils of upland crops in 2020.

Table 8 : Potassium status (area and percentage of arable lands) under different fertility class for loamy to clayey soils of upland crops in 2020

Fertility Class	Area (Ha)	Percentage of arable land
Very Low to Low	5139339	59.85
Medium	2018590	23.51
Optimum	805010	9.37
High to Very High	623925	7.27
Total	8586864	100.00

Very low to low content of potassium in loamy to clayey soils of wetland rice crops in 2010 was 28.34% and it increases to 43.23% in 2020 and medium content of potassium was 22.11% in 2010 and 30.87% in 2020. Area under optimum and high to very high content of soil potassium decreases from 20.27% (1,945,245 hectares) to 13.36% (1,147,473 hectares) and 29.29% to 12.54% respectively during 2010 to 2020. Zahid et.al. 2020, reported that soil productivity reduces 50-75% if soil potassium conten is ≤ 0.075 meq/100g of soil and 25-50% if soil potassium is 0.076-0.15 meq/100 g of soil. They also reported that soil productivity may also reduced to 10-25% if soil potassium is in the range of 0.151-0.195 meq/100 g of soil. Over all impresssion is that potassium content in loamy to clayey soils of wetland rice crops declined significantly over the years. It may be because of increasing cropping intensity and inadequate replelishment of potassium through fertilization. In 2019-20 MoP used in agriculture was 716,000 mt, which means average use of potassium fertilizer to soil was 83.38 kg per hectare. Fig 17 and fig. 18 shows the potassium status map for loamy to clayey soils of wetland crops in 2010 and 2020 respectively and fig.19 represents changing pattern of soil potassium status (% of arable lands) of wetland rice crops, Bangladesh since 2010 to 2020. Table 9 shows Changing pattern of soil potassium status (area and percentage of arable lands) in loamy to clayey soils of wetland rice crops since 2010 to 2020.

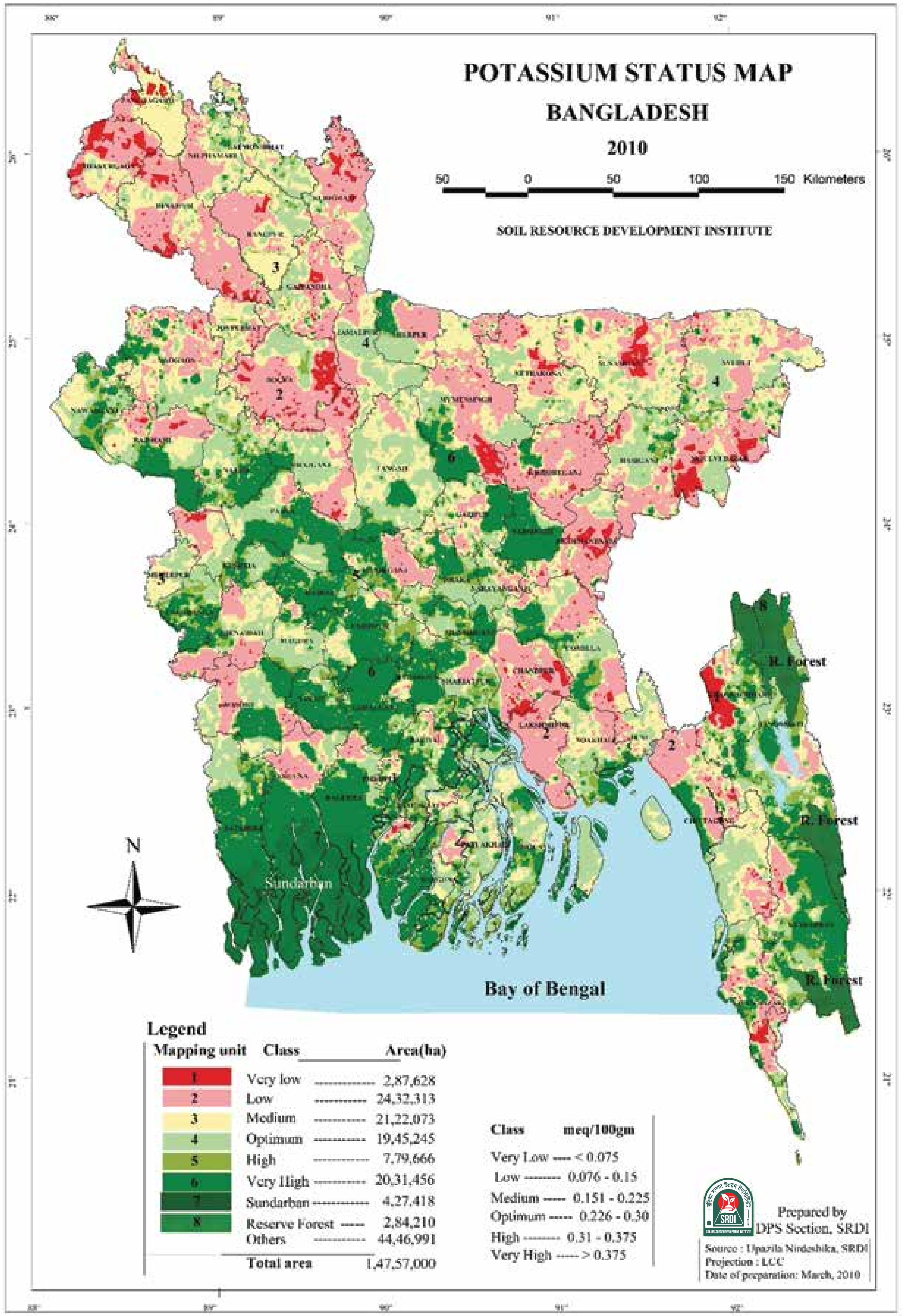

Fig. 17 Potassium Status Map for Loamy to Clayey Soils of Wetland Rice Crops, Year 2010.

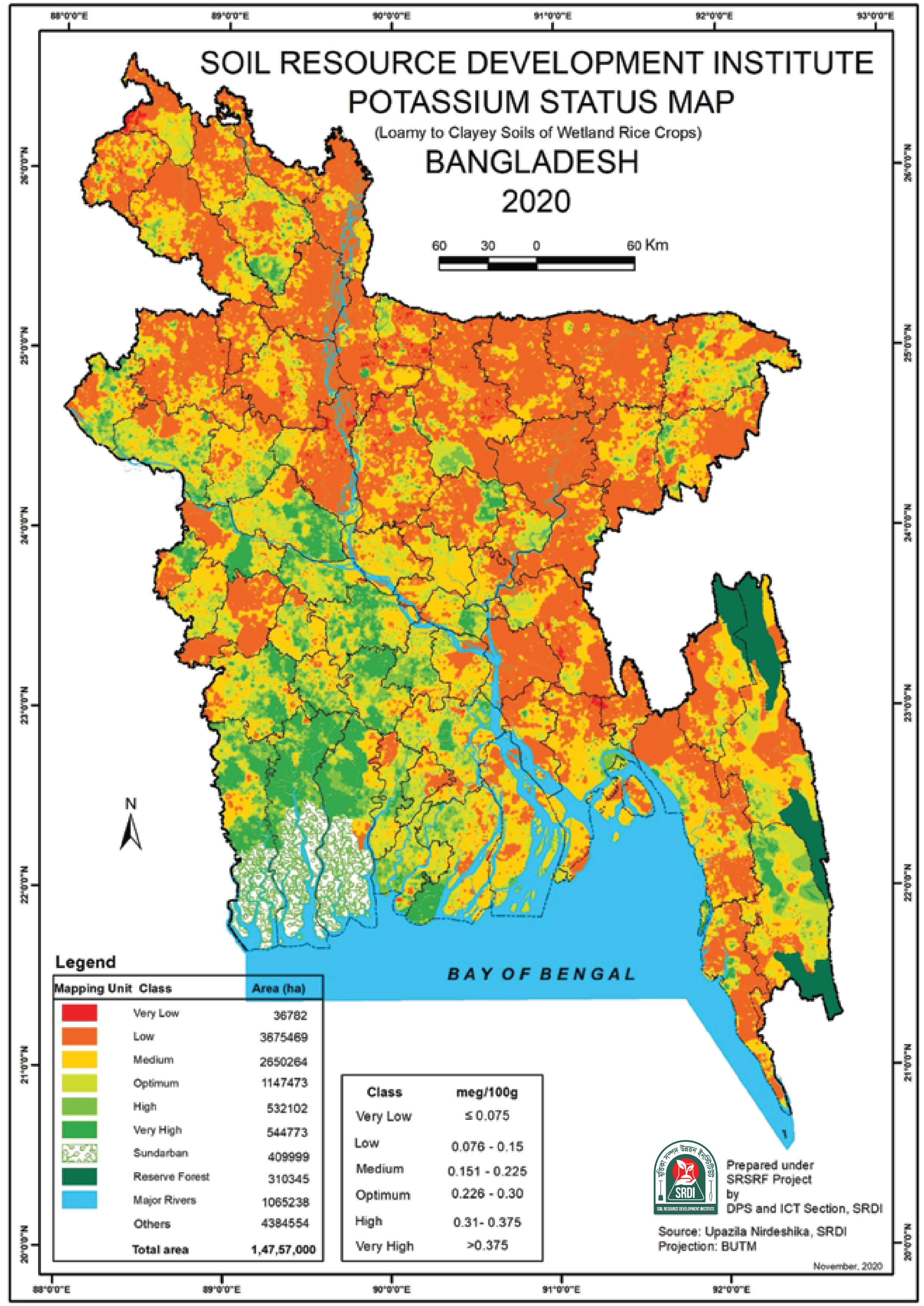

Fig. 18 Potassium Status Map for Loamy to Clayey Soils of Wetland Rice Crops, Year 2020.

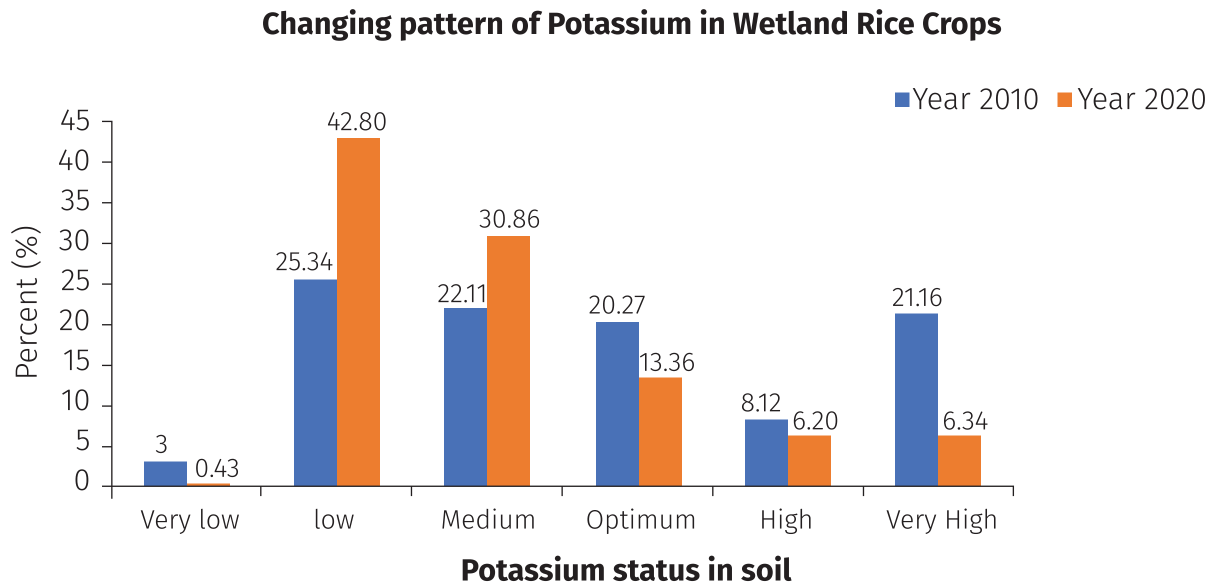

Fig. 19 Changing pattern of soil potassium status (% of arable lands) in loamy to clayey soils of wetland rice crops since 2010 to 2020.

Table 9 : Changing pattern of soil potassium status (area and percentage of arable lands) in loamy to clayey soils of wetland rice crops since 2010 to 2020

Fertility class	Year 2010		Year 2020	
	Area (ha)	Percent (%)	Area (ha)	Percent (%)
Very Low to Low	2719941	28.34	3712252	43.23
Medium	2122073	22.11	2650264	30.87
Optimum	1945245	20.27	1147473	13.36
High-Very High	2811122	29.29	1076875	12.54
Total arable land	9598381	100.00	8586864	100.00

5.6 Sulphur

Sulphur is one of the 17 essential plant nutrients. It is essential for the growth and development of all crops, without exception. Like any essential nutrient, sulphur (S) also has some key functions in plants these are- formation of chlorophyll that permits photosynthesis through which plants produce starch, sugars, oils, fats, vitamins and other compounds; protein production, Sulphur is a constituent of three S-containing amino acids (cysteine, cystine and methionine), which are the building blocks of protein, about 90% of plant S is present in these amino acids; synthesis of oils, this is why adequate sulphur is so crucial for oilseeds; activation of enzymes, which aid in biochemical reactions in the plant; increases crop yields and improves produce quality, both of which determine the market price a farmer would get for his produce; with reference to crop quality, S improves protein and oil percentage in seeds, cereal quality for milling and baking; and it is associated with special metabolisms in plant and the structural characteristics of protoplasm.

Sulphur status map was prepared in 1998 and 2010 but these maps were prepared for Loamy to Clayey soils for wetland rice crops. In 1998 RSS and Upazila Nirdeshika database were used for mapping. In 2010 sulphur status map was prepared based on Upazila Nirdeshika database. No map was prepared for Loamy to Clayey Soils of upland crops.

In 2020 sulphur status map for both Loamy to Clayey Soils of upland crops and wetland rice crops are prepared. Area under different fertility class is mentioned in all the maps. In this study soil fertility map of 2010 and 2020 is taken under consideration.

Soil sulphur map, year 2020 for Loamy to Clayey Soils of Upland Crops showed that very low to low content of soil sulphur, across the country is 3,061,223 hectares and which is 35.66% of total arable land and medium content is about 22.44% of arable lands (1,927,100 hectares). As there is no map or data of 2010, so trend analysis could not be done. Fig. 20 shows the soil sulphur status map for loamy to clayey soils of upland crops and fig. 21 shows soil sulphur status (% of arable lands) under different fertility class for upland crops in 2020 and table 10 shows the sulphur status (area and percentage of arable lands) under different fertility class of upland crops.

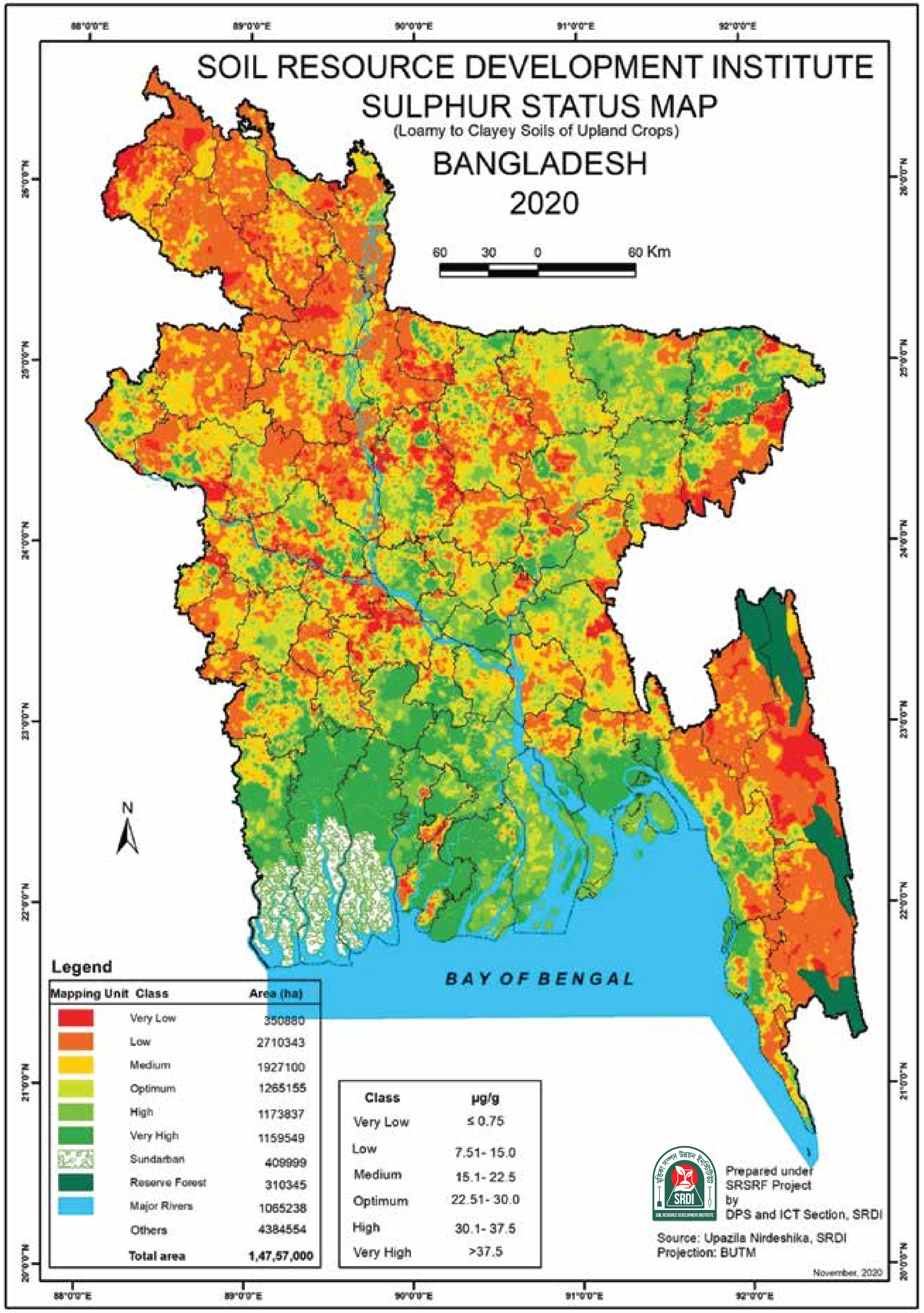

Fig. 20 Sulphur Status Map for Loamy to Clayey Soils of Upland Crops, Year 2020.

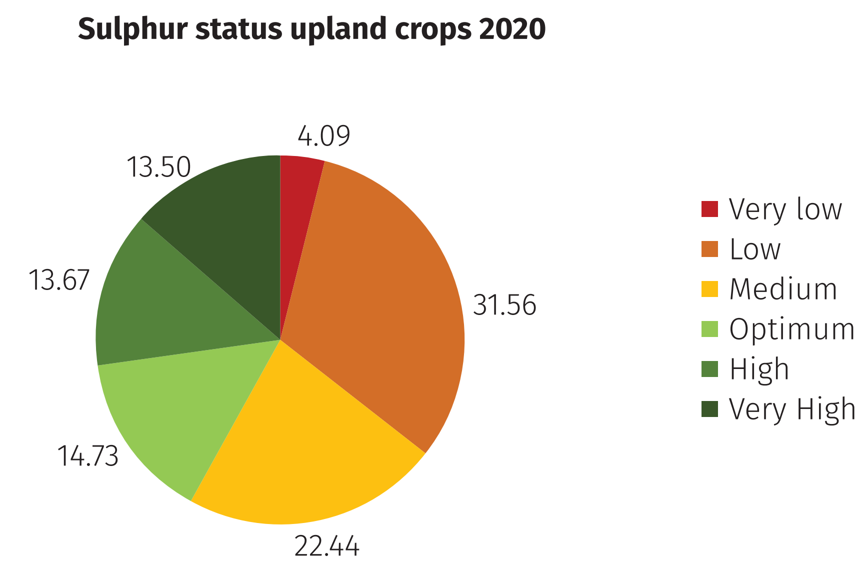

Fig. 21 Soil Sulphur status (% of arable lands) under different fertility class for loamy to clayey soils of upland crops in 2020.

Table 10 : Sulphur status (area and percentage of arable lands) under different fertility class for loamy to clayey soils of upland crops in 2020

Fertility Class	**Area (Ha)**	**Percentage of arable land**
Very Low to Low	3061223	35.66
Medium	1927100	22.44
Optimum	1265155	14.73
High to Very High	2333386	27.17
Total	8586864	100.00

Very low to low content of sulphur in loamy to clayey soils of wetland rice crops in 2010 was 34.45% and it increases to 46.41% in 2020 and medium content of sulphur was 18.65% in 2010 and it reaches to 20.96% in 2020. Area under optimum content of soil sulphur increases from 11.39% (1,093,299 hectares) to 15.21% (1,305,808 hectares) and high to very high content of soil sulphur decreases from 35.51% to 17.43% during 2010 to 2020. Zahid et.al. 2020, reported that soil productivity reduces 50-75% if soil sulphur content is ≤ 9.0 ppm and 25-50% if soil sulphur is between 9.1-18.0 ppm. They also reported that soil productivity may also reduced to 10-25% if soil sulphur is in the range of 18.1-23.5 ppm. Over all impresssion is that soil sulphur content in loamy to clayey soils of wetland rice crops accross the country declined significantly over the years. It may be because of increasing cropping intensity and inadequate replelishment of sulphur through fertilization. In 2019-20 gypsum and sulphur containing zinc fertilizer used in agriculture was 360,000 mt and 115,000 mt respectively, which means average use of sulphur fertilizer added to soil was 55.32 kg per hectare. Fig. 22 and Fig. 23 shows the sulphur status map for loamy to clayey soils of wetland rice crops in 2010 and 2020 respectively and fig. 24 represents Changing pattern of soil sulphur status (% of arable lands) of wetland rice crops in Bangladesh since 2010 to 2020. Table 11 shows Changing pattern of soil sulphur status (area and percentage of arable lands) in loamy to clayey soils of wetland rice crops since 2010 to 2020.

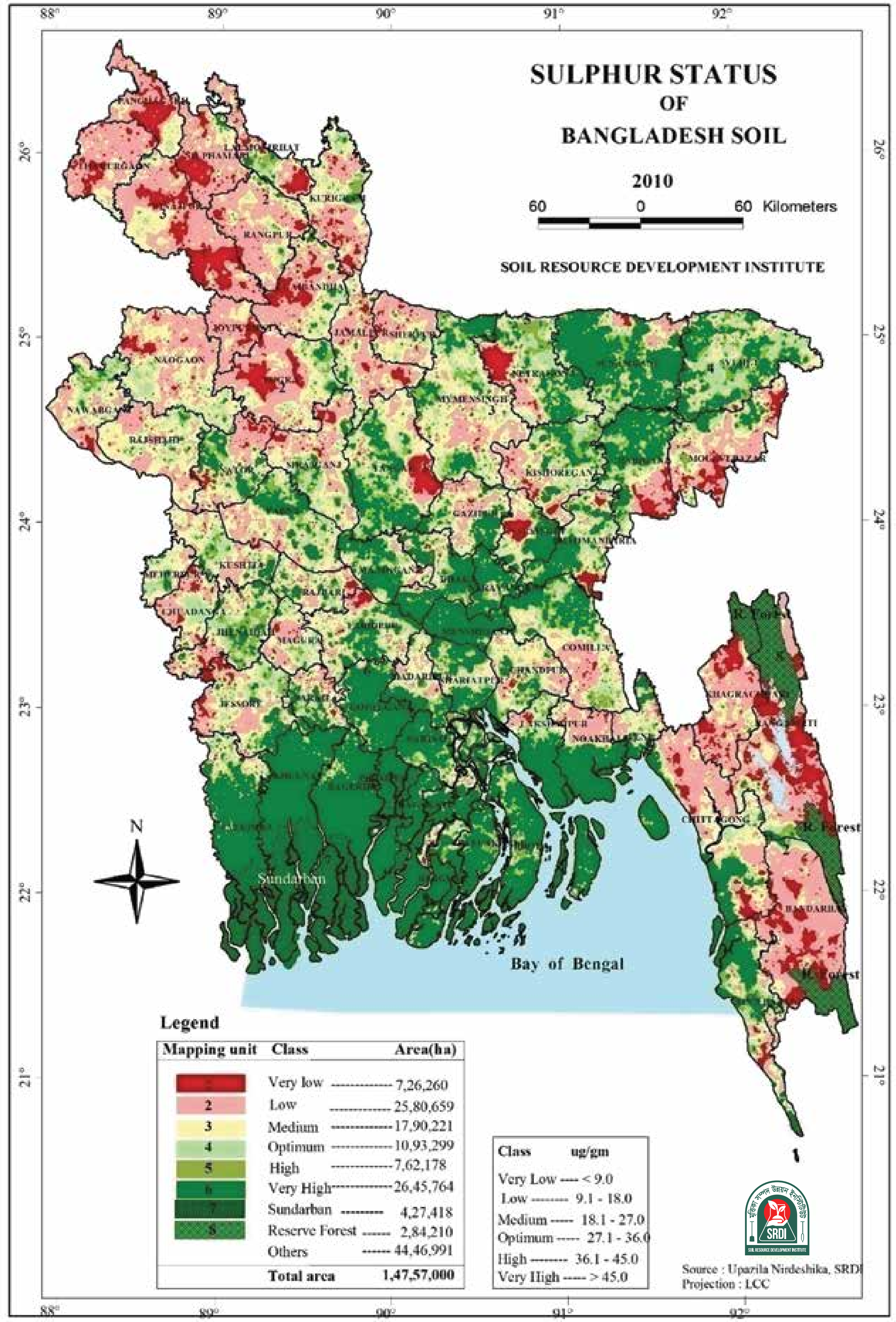

Fig. 22 Sulphur Status Map for Loamy to Clayey Soils of Wetland Rice Crops, Year 2010.

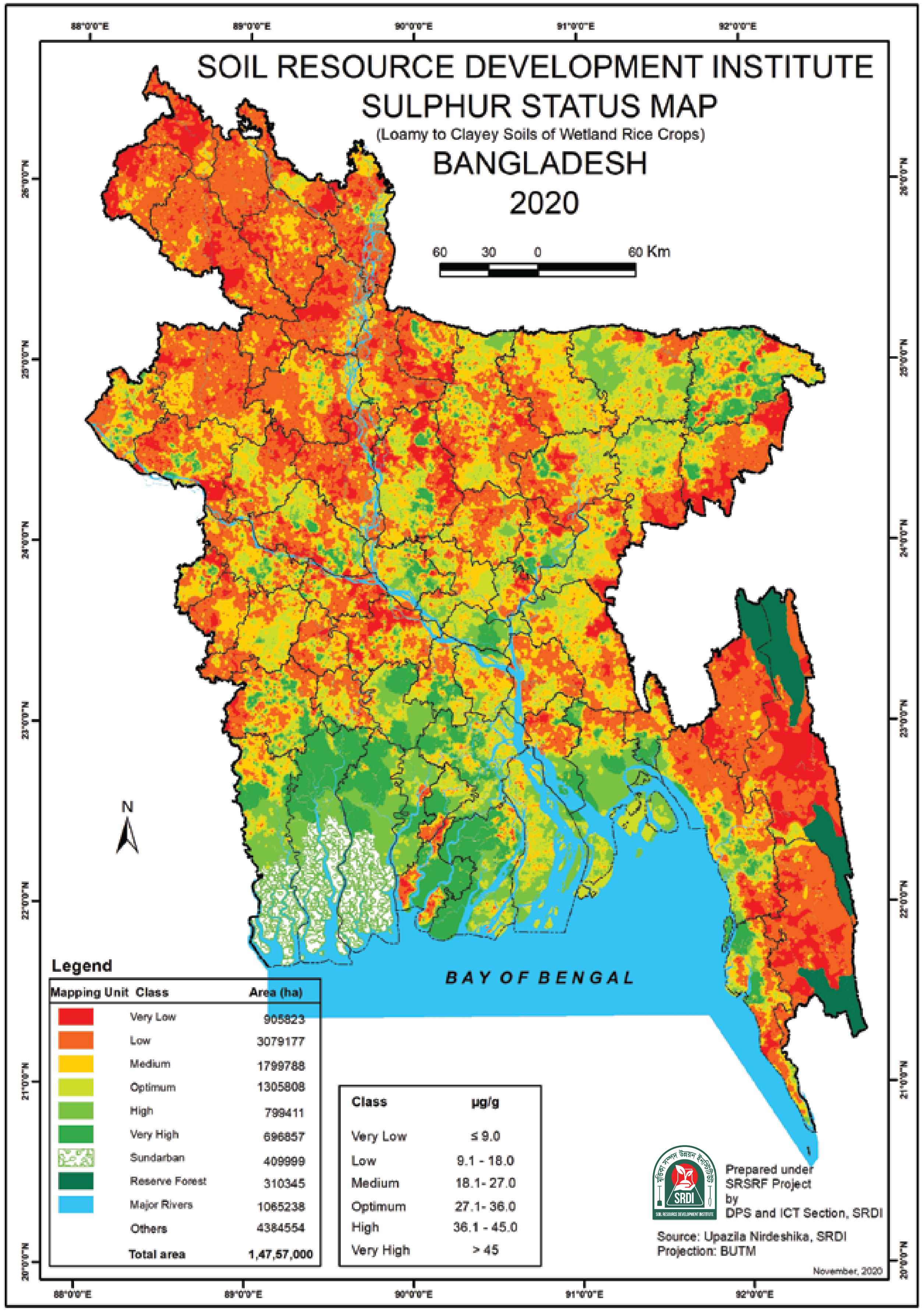

Fig. 23 Sulphur Status Map for Loamy to Clayey Soils of Wetland Rice Crops, Year 2020.

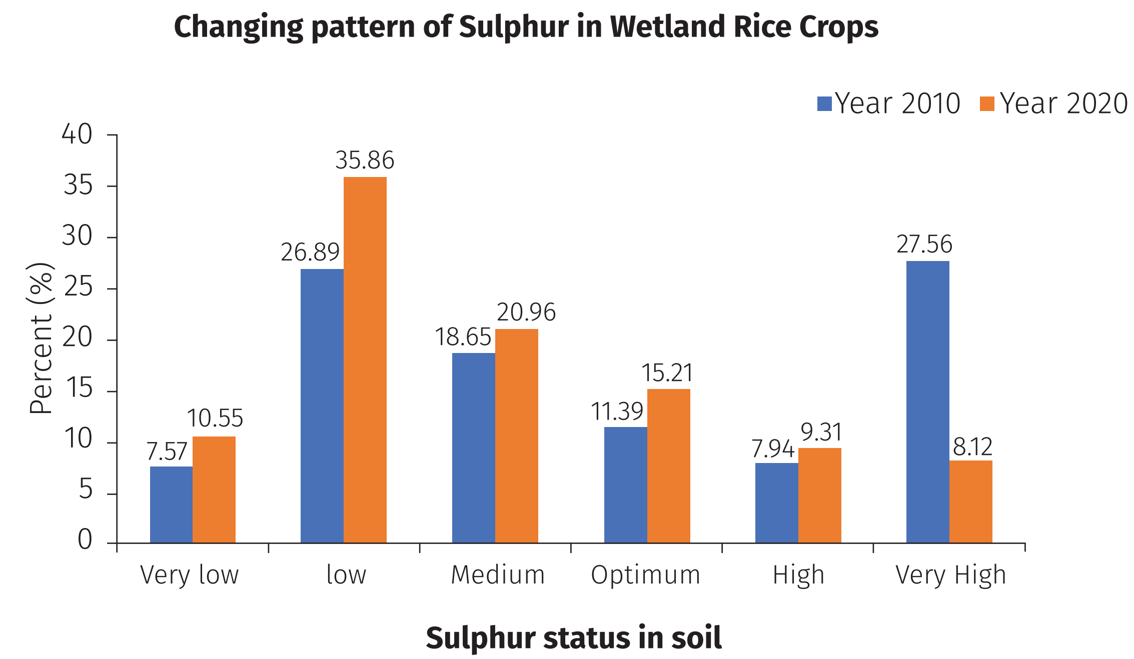

Fig. 24 Changing pattern of soil sulphur status (% of arable lands) in loamy to clayey soils of wetland rice crops since 2010 to 2020.

Table 11 : Changing pattern of soil sulphur status (area and percentage of arable lands) in loamy to clayey soils of wetland rice crops since 2010 to 2020

Fertility class	**Year 2010**		**Year 2020**	
	Area (ha)	**Percent (%)**	**Area (ha)**	**Percent (%)**
Very Low to Low	3306919	34.45	3985000	46.41
Medium	1790221	18.65	1799788	20.96
Optimum	1093299	11.39	1305808	15.21
High to Very High	3407942	35.51	1496268	17.43
Total arable land	9598381	100.00	8586864	100.00

5.7 Zinc

Zinc is plant micronutrient which is involved in many physiological functions, its inadequate supply will reduce crop yields. Zinc deficiency is the most wide spread micronutrient deficiency problem, almost all crops and calcareous, sandy soils, peat soils, and soils with high phosphorus and silicon are expected to be deficient. Zinc deficiencies can affect plant by stunting its growth, decreasing number of tillers, chlorosis and smaller leaves, increasing crop maturity period, spikelet sterility and inferior quality of harvested products.

Zn is required in synthesis of tryptophan, the precursor auxin. Lack of Zn reduces the level of auxins in plants. Zn is necessary for activity of RNA polymerase enzyme and it protects ribosomal RNA from ribonuclease enzyme. Zn is constituent of many enzymes like carbonic anhydrase, aldolase, ribonuclease etc.

Zinc seems to affect the capacity for water uptake and transport in plants and also reduce the adverse effects of short periods of heat and salt stress. The role of Zn in maintaining the integrity of cellular membrane involving structural orientation of macromolecules and maintenance of ion transport system.

Zinc status map was first prepared in 1998 and the second in 2010. In 1998 RSS and Upazila Nirdeshika database were used for mapping. In 2010 zinc status map was prepared based on Upazila Nirdeshika database.

Critical limit and fertility class values are same for both Loamy to Clayey Soils of upland crops and wetland rice crops (BARC, 2018). In 2020 zinc status map is also prepared considering above. Area under different fertility class is mentioned in all the maps. In this study soil fertility map of 2010 and 2020 is taken under consideration.

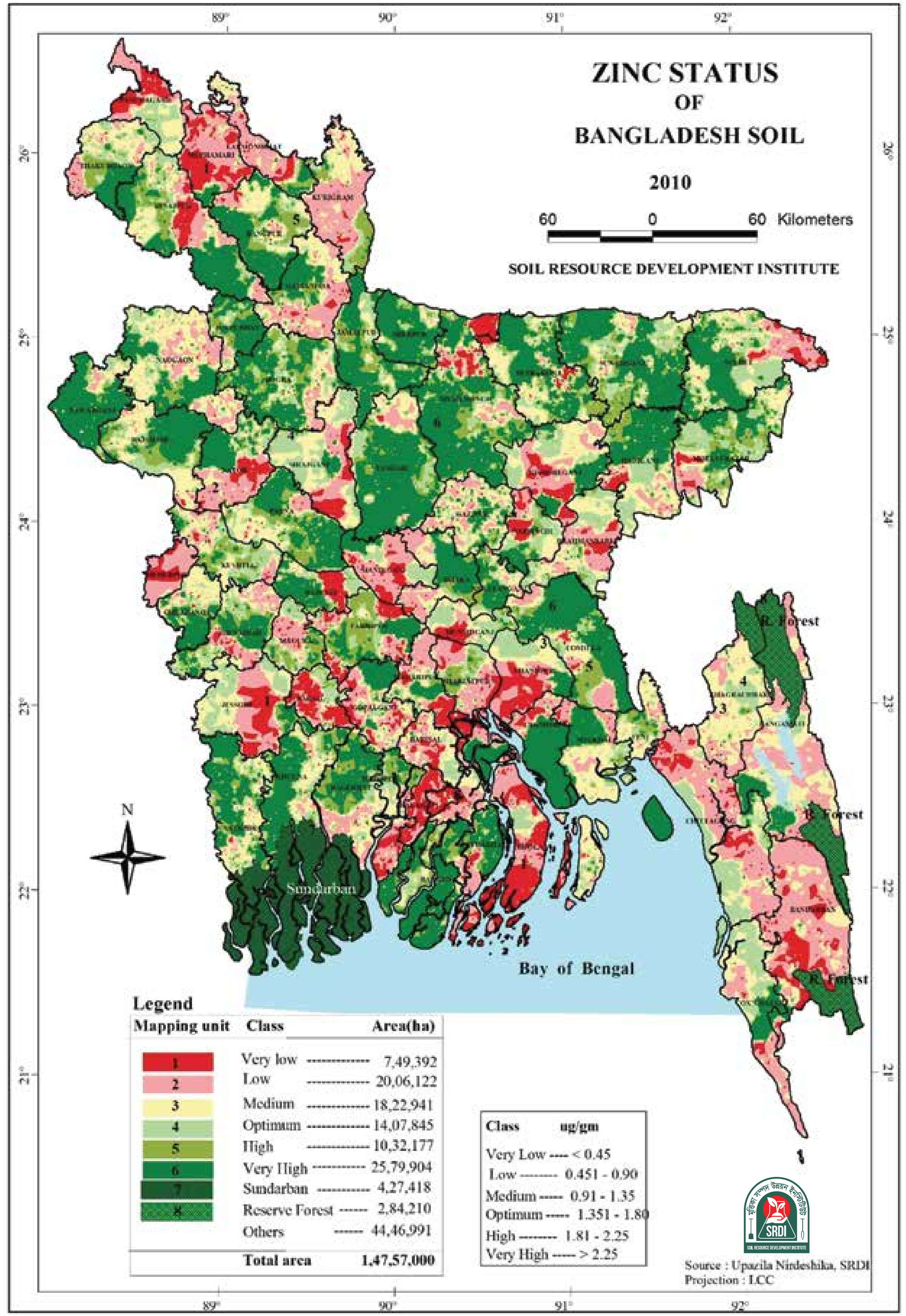

Fig. 25 Zinc Status Map for Loamy to Clayey Soils, Year 2010.

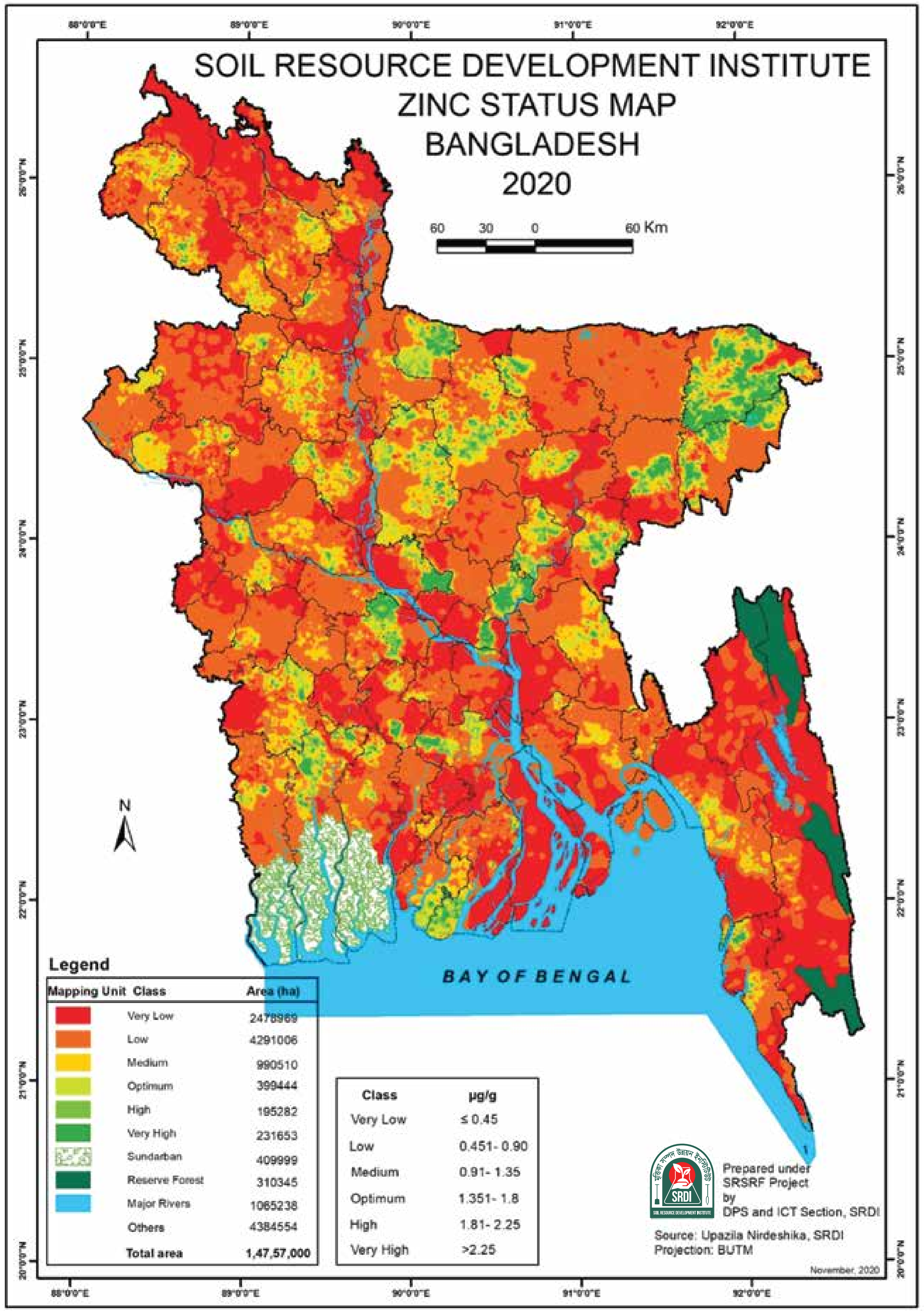

Fig. 26 Zinc Status Map for Loamy to Clayey Soils, Year 2020.

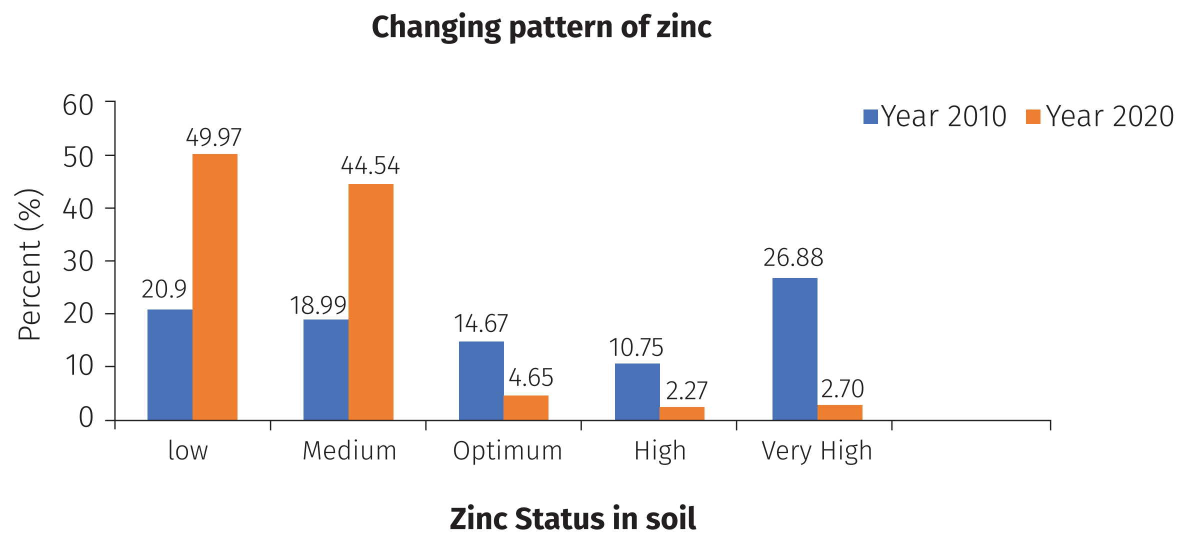

Fig. 27 Changing pattern of soil zinc status (% of arable lands)in loamy to clayey soils since 2010 to 2020.

Table 12 : Changing pattern of soil zinc status (area and percentage of arable lands) in loamy to clayey soils since 2010 to 2020

Fertility class	Year 2010		Year 2020	
	Area (ha)	Percent (%)	Area (ha)	Percent (%)
Very Low to Low	2755514	28.71	6769975	78.84
Medium	1822941	18.99	990510	11.54
Optimum	1407845	14.67	399444	4.65
High to Very High	3612081	37.63	426935	4.97
Total arable land	9598381	100.00	8586864	100.00

Very low to low content of zinc in loamy to clayey soils in 2010 was 28.71% and it increases to 78.84% in 2020 and medium content of zinc was 18.99% in 2010 and it decreases to 11.54% in 2020. Area under optimum content of soil zinc decreases from 14.67% (1,407,845 hectares) to 4.65% (399,444 hectares) and high to very high content of soil zinc decreases from 37.63% to 4.97% during 2010 to 2020. Zahid et.al.2020, reported that soil productivity reduces 50-75% if soil zinc content is ≤ 0.45 ppm and 25-50% if soil zinc is between 0.451-0.90 ppm. They also reported that soil productivity may also reduced to 10-25% if soil zinc is in the range of 0.91-1.20 ppm. Over all impresssion is that soil zinc content in loamy to clayey soils both of upland crops and wetland rice crops accross the country declined significantly over the years. It may be because of increasing cropping intensity and inadequate replelishment of zinc through fertilization. In 2019-20 zinc containing zinc fertilizer used in agriculture was 115,000 mt, which means average use of zinc fertilizer added to soil was 13.39 kg per hectare. Moreover zinc fertilizer is one of the most adulterated fertilizer in the market. Fig.25 and fig 26 shows the zinc status map for loamy to clayey soils of both upland crops and wetland rice crops in 2010 and 2020 respectively and fig 27 represents Changing pattern of soil zinc status(% of arable lands) in loamy to clayey soils of Bangladesh since 2010 to 2020. Table 12 shows changing pattern of soil zinc status (area and percentage of arable lands) in loamy to clayey soils of Bangladesh.

5.8 Boron

Boron plays a key role in a diverse range of plant functions including cell wall formation and stability, maintenance of structural and functional integrity of biological membranes, movement of sugar or energy into growing parts of plants, and pollination and seed set. Adequate B is also required for effective nitrogen fixation and nodulation in legume crops.

Boron deficiency commonly results in poor pollen vitality ultimately produced empty pollen grains and a reduced number of flowers per plant. Low B supply can also stunt root growth.

Boron status map was first prepared in 1998 and the second in 2010. In 1998 RSS and Upazila Nirdeshika database were used for mapping. In 2010 boron status map was prepared based on Upazila Nirdeshika database.

Critical limit and fertility class values are same for both Loamy to Clayey Soils of upland crops and wetland rice crops (BARC, 2018). In 2020 boron status map is prepared considering above. Area under different fertility class is mentioned in all the maps. In this study soil fertility map of 2010 and 2020 is taken under consideration.

Very low to low content of boron in loamy to clayey soils in 2010 was 25.99% and it increases to 30.78% in 2020 and medium content of boron was 20.90% in 2010 and it increases to 27.37% in 2020. Area under optimum content of soil boron decreases from 16.07 % (1,542,449 hectares) to 15.90% (1,365,198 hectares) and high to very high content of soil boron decreases from 37.04% to 25.95% during 2010 to 2020. Zahid et.al.2020, reported that soil productivity reduces 50-75% if soil boron content is ≤ 0.15 ppm and 25-50% if soil boron is between 0.151-0.30 ppm. They also reported that soil productivity may also reduced to 10-25% if soil boron is in the range of 0.31-0.40 ppm.

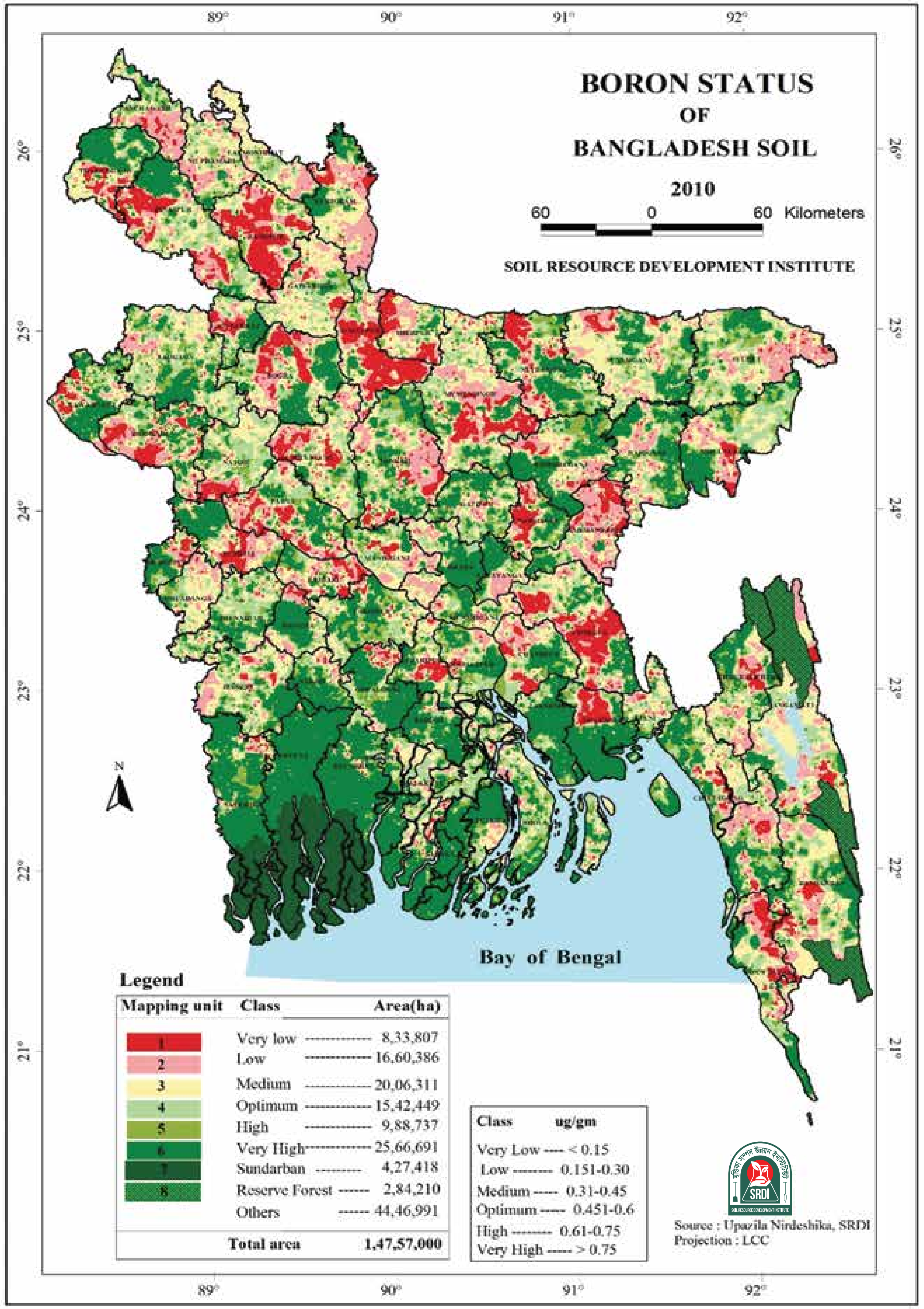

Fig. 28 Boron Status Mapfor Loamy to Clayey Soils, Year 2010.

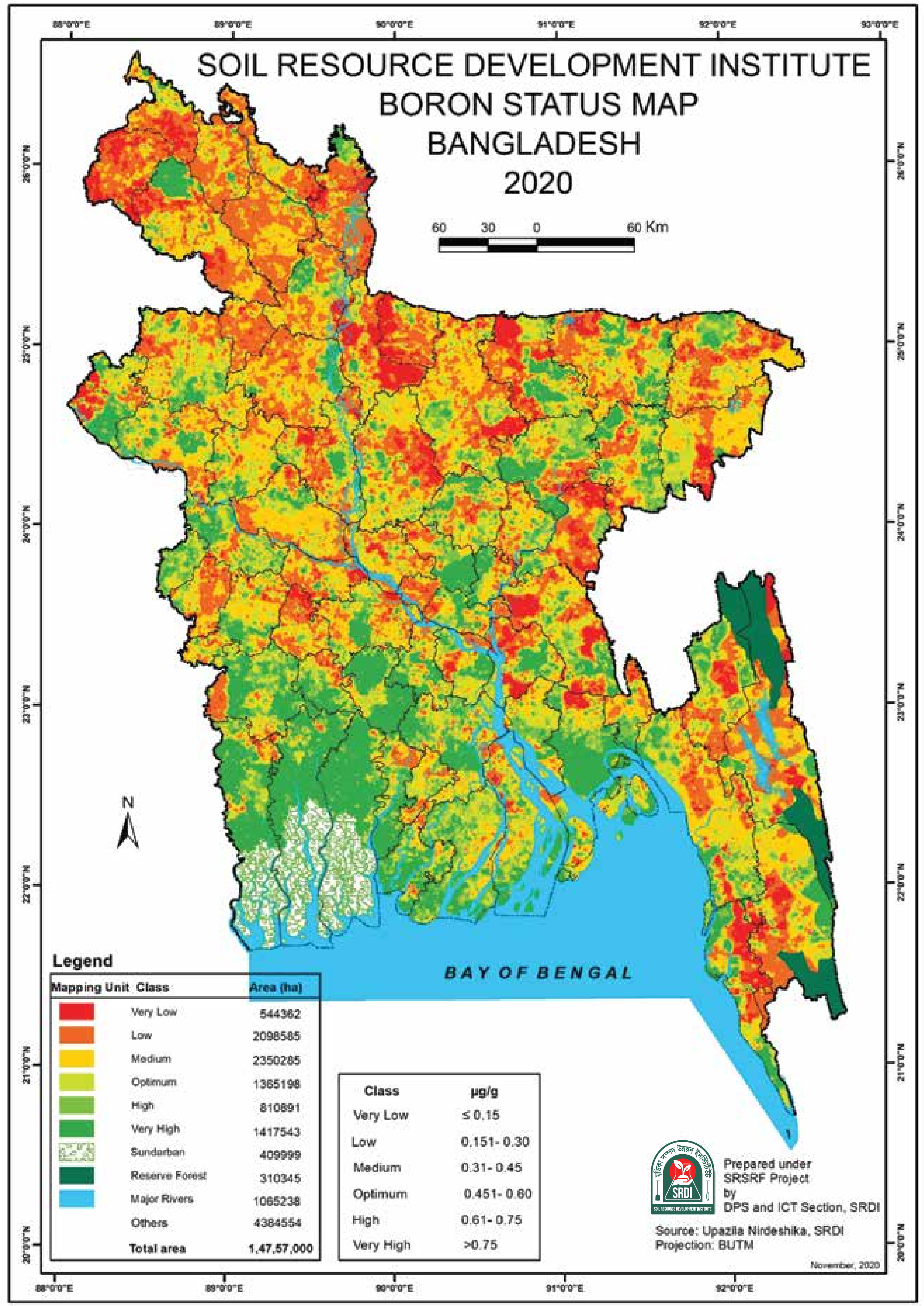

Fig. 29 Boron Status Mapfor Loamy to Clayey Soils, Year 2020.

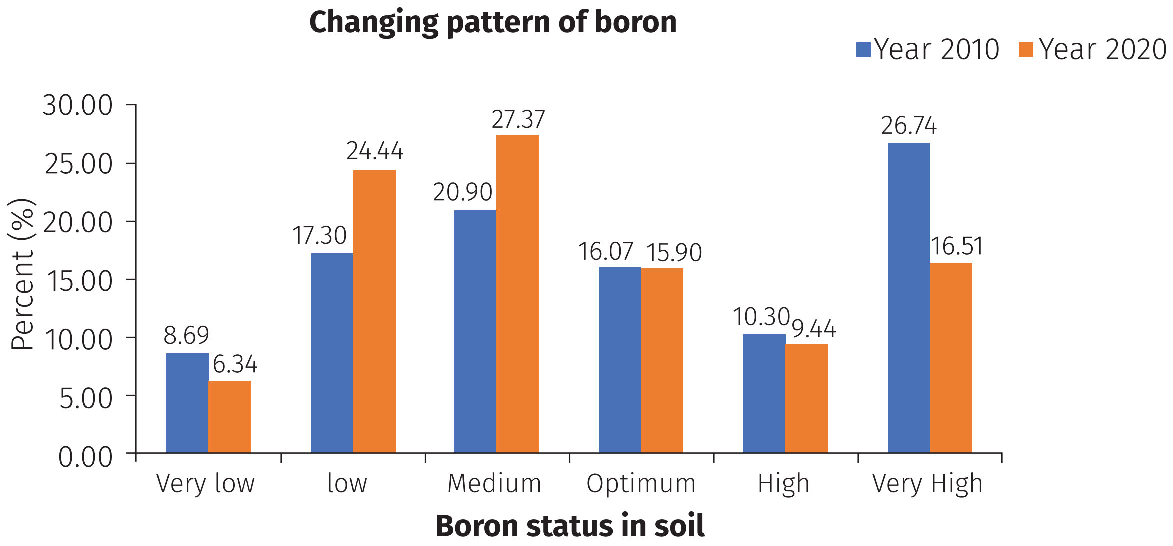

Fig. 30 Changing pattern of soil boron status (% of arable lands) in loamy to clayey soils since 2010 to 2020.

Table 13 : Changing pattern of soil boron status (area and percentage of arable lands) in loamy to clayey soils since 2010 to 2020

Fertility class	**Year 2010**		**Year 2020**	
	Area (ha)	**Percent (%)**	**Area (ha)**	**Percent (%)**
Very Low to Low	2494193	25.99	2642947	30.78
Medium	2006311	20.9	2350285	27.37
Optimum	1542449	16.07	1365198	15.9
High toVery High	3555428	37.04	2228434	25.95
Total	9598381	100.00	8586864	100.00

Over all impresssion is that soil boron content in loamy to clayey soils both of upland crops and wetland rice crops accross the country declined substantially over the years. It may be because of increasing cropping intensity and inadequate replelishment of boron through fertilization. Fig. 28 and fig. 29 shows the boron status map for loamy to clayey soils of both upland crops and wetland rice crops in 2010 and 2020 respectively and fig. 30 represents changing pattern of soil boron status (% of arable lands) in loamy to clayey soils of Bangladesh since 2010 to 2020. Table 13 shows changing pattern of soil boron status (area and percentage of arable lands) in loamy to clayey soils of Bangladesh.

5.9 Calcium

Essential to cell integrity and membrane structure and permeability; role in cell elongation and division; helps in translocation of carbohydrates and protein synthesis, detoxify heavy metals in plant. Calcium is essential for root health, growth of new roots and root hairs, and the development of leaves.

Calcium status map never prepared by SRDI or other institution before. There is an estimation made by SRDI that calcium deficient (very low to low) soils of Bangladeshis around 300,000 hectares (Islam Aminul and Md. Nazmul Hasan 2015) and mostly in extreme north-western part of Bangladesh. Estimation was done by SRDI and based on Upazila Nirdeshika database. The first Calcium status in soil map is prepared in 2020 by SRDI and based on 2nd generation Upazila Nirdeshika database up to 2018.

Critical limit and fertility class values are same for both Loamy to Clayey Soils of upland crops and wetland rice crops (BARC, 2018). In 2020 calcium status map is prepared considering above. Area under different fertility class is mentioned in the map.

Very low to low content of calcium in loamy to clayey soils in 2020 is about 2,106,053 hectares or 24.53% of the arable land in Bangladesh which is more than 7 fold of 2010's estimation of 300,000 hectares (Islam Aminul and Md. Nazmul Hasan 2015). Medium content of calcim is about 1,311,470 hectares or 15.27% of the arable lands. Optimum and high to very high content of calcium is 11.81% and 48.39% of the arable lands respectively. According to Zahid et.al. 2020, soil productivity reduces 50-75% if soil calcium content is ≤ 1.125 meq/100g of soil and 25-50% if soil calcium is between 1.126-3.0 meq/100g of soil. According to them it may be predicted soil productivity may also reduced to 10-25% if soil calcium is in the range of 3.1-4.5meq/100g of soils.

Over all impresssion is that soil calcium content in loamy to clayey soils both of upland crops and wetland rice crops accross the country declined alarmingly over the years. Though the earlier estimation is made in Old Himalayan Piedmontplain (AEZ-1), Active Tista Floodplain (AEZ-2) and Tista Meander Floodplain (AEZ-3) floodplan. It may be because of increasing cropping intensity and inadequate replelishment of calcium through fertilization. Hasan et.al. 2015, reported that there is a considerable leaching of base materials such as Ca, Mg and K from top soils and subsequent accumulation in sub soils of Birganj upazila of Dinajpur and Hatibanda upazila of Lalmonirhat district. Deterioration of soil pH enhances leaching of bases (Ca, Mg, K) from to soils. Fig. 31 shows Calcium Status Map for Loamy to Clayey Soils, year 2020 and fig. 32 shows the calcium status (% of arable lands) under different fertility class in loamy to clayey soils of both upland crops and wetland rice crops in 2020. Table 14 shows soil calcium status (area and percentage of arable lands) under different fertility class in loamy to clayey soils in 2020.

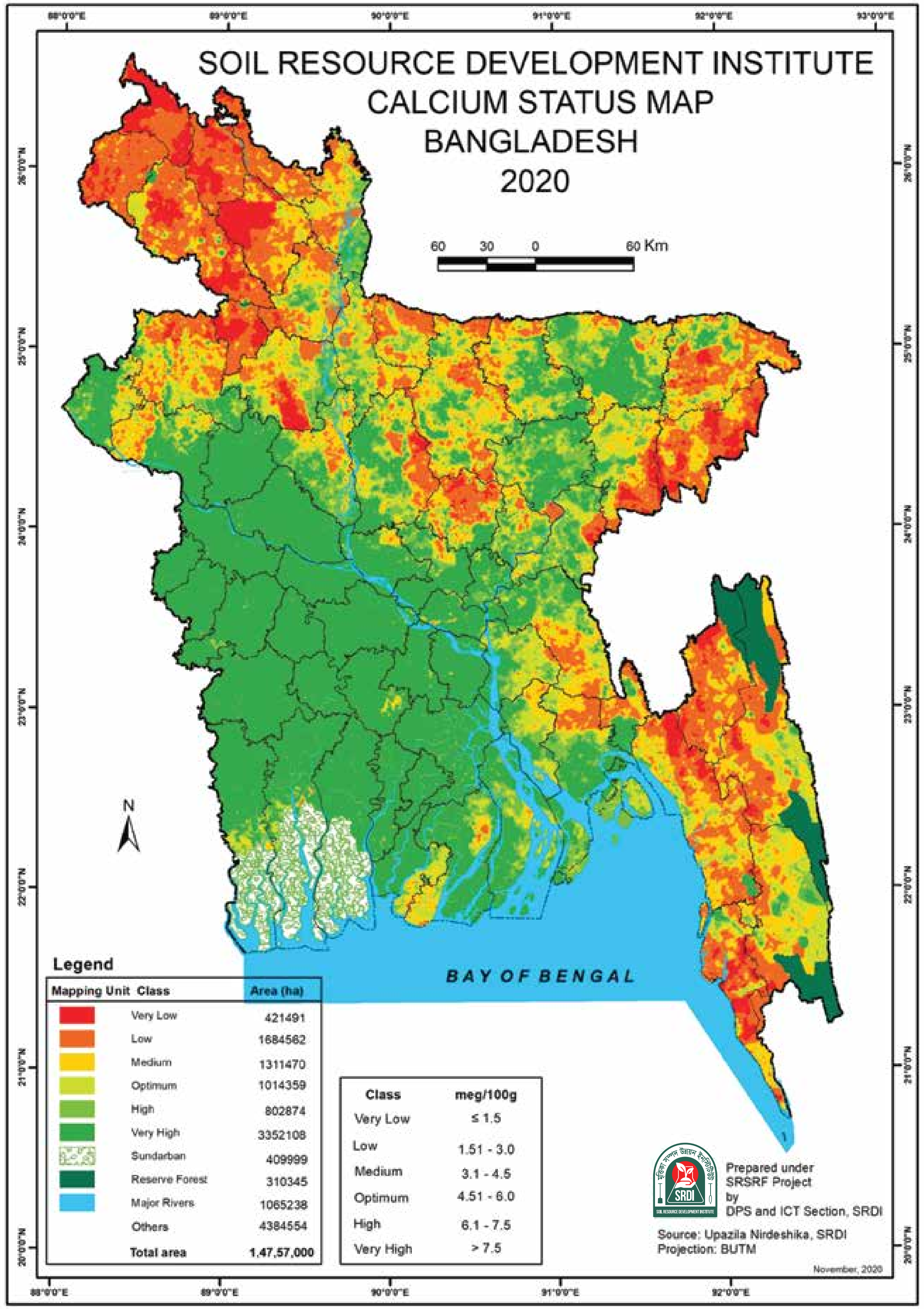

Fig. 31 Calcium Status Map for Loamy to Clayey Soils, Year 2020.

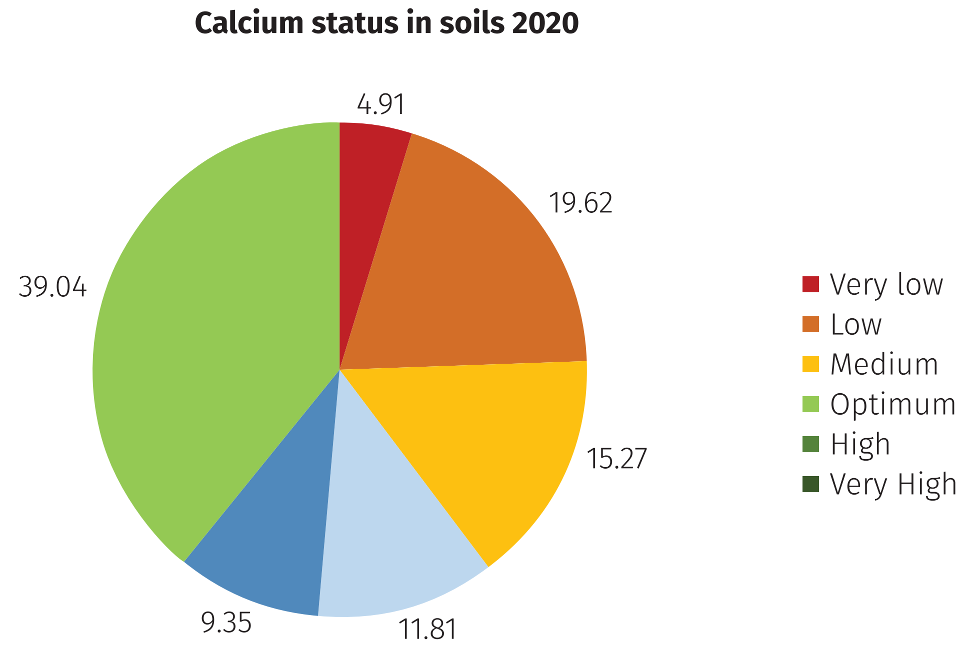

Fig. 32 Soil calcium status (% of arable lands) under different fertility class in loamy to clayey soils in 2020

Table 14 : Soil calcium status (area and percentage of arable lands) under different fertility class in loamy to clayey soils in 2020

Fertility Class	Area (Ha)	Percentage of arable land
Very Low to Low	2106053	24.53
Medium	1311470	15.27
Optimum	1014359	11.81
High to Very High	4154982	48.39
Total	8586864	100.00

5.10 Magnesium

Magnesium is present in chlorophyll which is the key for photosynthesis and is responsible for activating more plant enzymes than any other plant nutrient. Involved in phosphate transfer from ATP and ADP, stabilize ribosome particles, serve as a cofactor of phosphatic enzymes in carbohydrate metabolism. Evaluation of soil analysis is generally satisfactory although care should be taken to also check for excessive K, Ca or Na which can mask the availability of Mg. High risk situation for Mg availability are high or low pH, high potash or calcium levels, sandy soils and poor root architecture. Typically, interveinal chlorosis giving a marbled effect in broad-leaved crops and a speckling in cereals. Always appears first on older leaves and eventually leads to leaf fall.

Magnesium status map never prepared by SRDI or other institution before. There is an estimation made by SRDI in 2010, that magnesium deficient (very low to low) soils of Bangladesh are around 300,000 hectares (Islam Aminul and Md. Nazmul Hasan 2015) and mostly in extreme north-western part of Bangladesh. Estimation was done by SRDI and based on Upazila Nirdeshika database. The first Magnesium status in soil map is prepared in 2020 by SRDI and based on 2nd generation Upazila Nirdeshika database up to 2018.

Critical limit and fertility class values are same for both Loamy to Clayey Soils of upland crops and wetland rice crops (BARC, 2018). In 2020 magnesium status map is prepared considering above. Area under different fertility class is mentioned in the map.

Very low to low content of calcium in loamy to clayey soils in 2020 is about 1,056,740 hectares or 12.31% of the arable land in Bangladesh which is more than 3 fold of 2010's estimation of 300,000 hectares (Islam Aminul and Md. Nazmul Hasan 2015). Medium content of magnesium is about 839,835 hectares or 9.78% of the arable lands. Optimum and high to very high content of magnesium is 10.43% and 67.48% of the arable lands respectively. According to Zahid et.al., it is predicted that soil productivity reduces 50-75% if soil magnesium content is ≤ 0.281 meq/100 g of soil and 25-50% if soil magnesium is between 0.282-0.75 meq/100 g of soil. According to them it may also be predicted that soil productivity may also reduced to 10-25% if soil magnesium is in the range of 0.751-1.125 meq/100 g of soils.

Over all impresssion is that soil magnesium content in loamy to clayey soils both of upland crops and wetland rice crops accross the country declined alarmingly over the years. Though the earlier estimation is made only in Old Himalayan Piedmontplain (AEZ-1), Active Tista Floodplain (AEZ-2) and Tista Meander Floodplain (AEZ-3) floodplan. It may be because of increasing cropping intensity and inadequate replelishment of magnesium through fertilization (application of dolomite). Hasan et.al. 2015, reported that there is a considerable leaching of base materials such as Ca, Mg and K from top soils and subsequent accumulation in sub soils of Birganj upazila of Dinajpur and Hatibanda upazila of Lalmonirhat district. Deterioration of soil pH enhances leaching of bases (Ca, Mg, K) from to soils. Fig. 33 shows the magnesium status map for loamy to clayey soils of both upland crops and wetland rice crops in 2020 and fig. 34 shows the soil magnesium status (% of arable lands) under different fertility classs in loamy to clayey soils in 2020. Table 15 shows soil magnesium status (area and percentage of arable lands) under different fertility class in loamy to clayey soils in 2020.

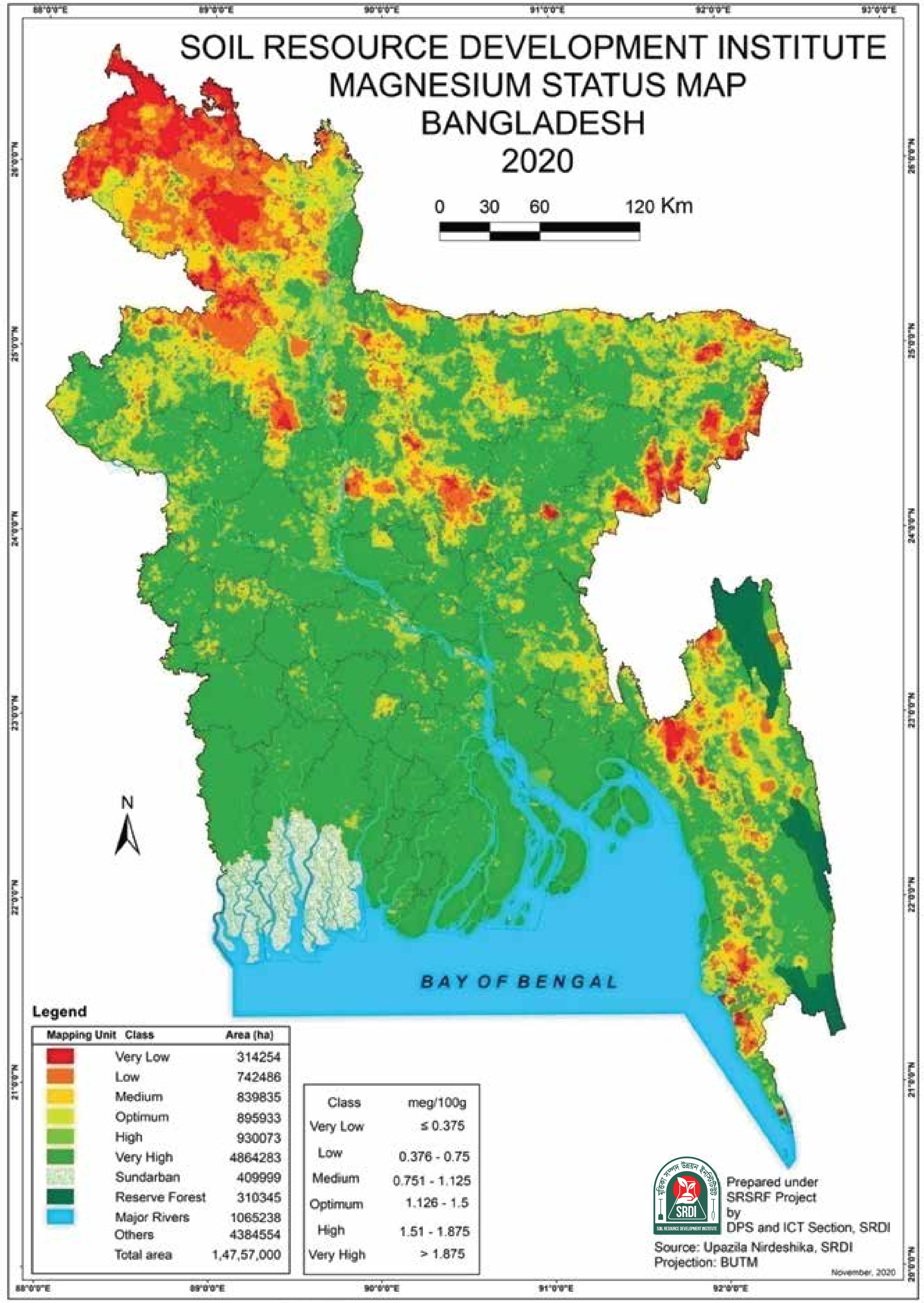

Fig.33 Magnesium Status Map for Loamy to Clayey Soils, Year 2020.

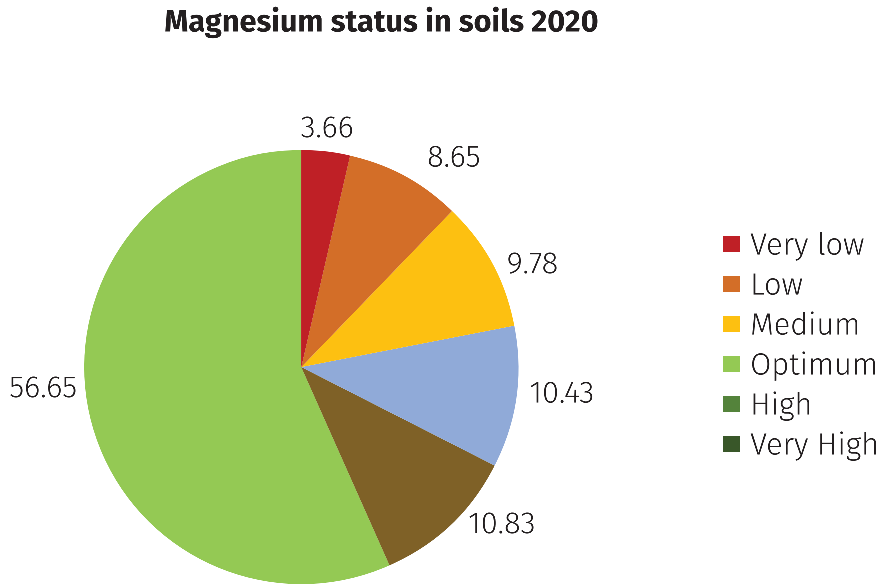

Fig. 34 Soil magnesium status (% of arable lands) under different fertility class in loamy to clayey soils in 2020

Table 15 : Soil magnesium status (area and percentage of arable lands) under different fertility class in loamy to clayey soils in 2020

Fertility Class	Area (Ha)	Percentage of arable land
Very Low to Low	1056740	12.31
Medium	839835	9.78
Optimum	895933	10.43
High to Very High	5794356	67.48
Total	8586864	100.00

6. Weakness of the study

Soil fertility mapping is based on the data generated for the preparation of Land and Soil Resources Utilization Guides popularly known as Upazila Nirdeshika for every upazilas of the country. First phase of the preparation of Upazila Nirdeshika started in 1985 and ends in 2002. It means data generation for first phase of the preparation of Upazila Nirdeshika took about 17 years. Based on this database, Soil Fertility Maps 2010 is prepared. Thus, Soil Fertility Maps 2010 does not actually represent the status of soil nutrients of 2010. Second phase of the preparation of Upazila Nirdeshika starts in 2005 and continues till today. So far 245 Upazila Nirdeshika has been prepared and published. Based on the data base of these updated Upazila Nirdeshika, Soil Fertility Maps 2020 were prepared. Similarly Soil Fertility Maps 2020 does not represent actual soil nutrient status of 2020.

7. Conclusion

Soil fertility does not mean only the status plant nutrients in the soil but it is the combination of soil physical properties such as soil texture, bulk density, aggregate stability; chemical properties such as pH, EC, CEC, plant nutrients; and biological properties such as soil organic carbon, microbial biomass carbon, microbial biomass nitrogen, soil biodiversity etc.

Lack of sufficient data on soil physical, chemical and biological properties, this soil fertility trends study, concentrated with available plant nutrients status such as phosphorus, potassium, sulphur, zinc, boron, calcium and magnesium; organic matter and soil pH. Total nitrogen is not included in this study as its status is very low to low across the country over the years. Other plant nutrients such as copper, iron, manganese is not included in the study as there is no information of deficiencies of these elements. Chlorine and molybdenum is also not included in the study as because the unavailability of the data. Land use changes over the years is included in this study to understand how much crop land is shifted to non-crop uses.

There is a significant change in land use since 2010 to 2020. Crop land or arable land decreases from 65.05% of Bangladesh in 2010 to 58.19% in 2020. Average annual loss of crop land is about 0.685%. Area under homestead, rivers, urban etc., increases from 30.13% to 36.93% over the years.

Area under very strongly acidic to strongly acidic soils increase from 41.23% of total arable land to 45.67% over the years and decreases area under slightly acidic and neutral soils from 28.53% to 25.42% and 15.02% to 11.71% over the years respectively. This indicates soil pH decreases since 2010 to 2020.

There is an increase of organic matter since 2010 to 2020. Area under very low to low content of soil organic matter decreases from 37.94% in 2010 to 34.83% in 2020 and increase of area under medium content from 55.57% to 59.19% over the years indicates the build of organic matter.

Phosphorus status in soil decreases from 2010 to 2020 considerably. Area under very low to low status soil phosphorus in loamy to clayey soils of wetland rice crops increases from 38.60% to 50.27% over the years indicates the decrease of soil phosphorus.

Potassium status in soil decreases from 2010 to 2020 significantly. Area under very low to low status soil potassium in loamy to clayey soils of wetland rice crops increases from 28.34% to 43.23% over the years indicates the decrease of soil potassium over the years.

Sulphur status in soil also decreases from 2010 to 2020 significantly. Area under very low to low status soil sulphur in loamy to clayey soils of wetland rice crops increases from 34.45% to 46.41% over the years indicates the significant decrease of soil sulphur over the years.

Zinc status in soil decreases from 2010 to 2020 sharply. Area under very low to low status of soil zinc in loamy to clayey soils of upland crops and wetland rice crops increases from 28.71% to 78.84% and medium status decreases from 18.99% to 11.54% over the years indicates the sharp decrease of soil zinc over the years.

Boron status in soil decreases from 2010 to 2020 considerably. Area under very low to low status soil boron in loamy to clayey soils of upland crops and wetland rice crops increases from 25.99% to 30.78 over the years indicates the considerable decrease of soil boron over the years.

Calcium status in soil decreases from 2010 to 2020 sharply. Area under very low to low status of soil calcium in loamy to clayey soils of upland crops and wetland rice crops increases from 3.13% (300,000 hectares as estimated by SRDI) of crop land to 24.53% over the years indicates the sharp decrease of soil calcium over the years.

Magnesium status in soil decreases from 2010 to 2020 sharply. Area under very low to low status of soil magnesium in loamy to clayey soils of upland crops and wetland rice crops increases from 3.13% (300,000 hectares as estimated by SRDI) of crop land to 12.31% over the years indicates the sharp decrease of soil magnesium over the years.

8. Recommendations

Soil fertility mapping is based on the data generated for the preparation of Land and Soil Resources Utilization Guides popularly known as Upazila Nirdeshika for every upazilas of the country. First phase of the preparation of Upazila Nirdeshika started in 1985 and ended in 2002. It means data generation for first phase of the preparation of Upazila Nirdeshika took about 17 years. Based on this database, Soil Fertility Maps 2010 prepared. Thus, Soil Fertility Maps 2010 does not actually represent the status of soil nutrients of 2010. Second phase of the preparation of Upazila Nirdeshika starts in 2005 and continues till today. So far 245 Upazila Nirdeshika has been prepared and published. Based on the data base of these updated Upazila Nirdeshika Soil Fertility Maps 2020 were prepared. Similarly Soil Fertility Maps 2020 does not represent actual soil nutrient status of 2020.

Thus, it is recommended to conducting special program to prepare soil fertility status of the country. This program may conduct through soil sampling using grid method of survey. At least 25 soil samples may be collected from each upazila covering every physiography, agro-ecological zones, land type and soil series or groups. Sample volume may not exceed 15000. These sample will be analyzed for pH, EC, OM, Nitrogen, Phosphorus, Potassium, Sulfur, Zinc, Boron, Calcium and Magnesium and if possible, Molybdenum. Moreover, routine analysis for Fe, Cu, Mn and exchangeable acidity may be done. Determination Cation Exchange Capacity (CEC) and texture (may be done through finger feelings) must be done for every sample. Determination of Bulk density may add precious value. Based on these analytical data base a real time soil fertility status and mapping may be prepared on regional and national level. Every sample should have geo-reference.

9. Guideline for soil fertility trends study

Soil fertility does not mean only the status plant nutrients in the soil but it is the combination of soil physical properties such as soil texture, bulk density, aggregate stability; chemical properties such as pH, EC, CEC, plant nutrients; and biological properties such as soil organic carbon, microbial biomass carbon, microbial biomass nitrogen, soil biodiversity etc.

Soil fertility mapping in SRDI is based on the data generated for the preparation of Land and Soil Resources Utilization Guides popularly known as Upazila Nirdeshika for every upazilas of the country. First phase of the preparation of Upazila Nirdeshika started in 1985 and ends in 2002. It means data generation for first phase of the preparation of Upazila Nirdeshika took about 17 years. Based on this database, Soil Fertility Maps 2010 prepared. Thus, Soil Fertility Maps 2010 does not actually represent the status of soil nutrients of 2010. Second phase of the preparation of Upazila Nirdeshika starts in 2005 and continues till today. So far 245 Upazila Nirdeshika has been prepared and published. Based on the data base of these updated Upazila Nirdeshika Soil Fertility Maps 2020 were prepared. Similarly Soil Fertility Maps 2020 does not represent actual soil nutrient status of 2020.

For soil fertility trends study, we need a base line study and subsequent mapping. For this SRDI may conduct a special program to understand soil fertility status of the country, not to depends of Upazila Nirdeshika, which took 15-17 years for one round.

SRDI can collect soil sample from every upazila following grid method of soil survey within a year through its 33 regional and 07 divisional offices. At least 30 soil samples be collected from each upazila. Every sample should have geo-reference. Number of soil samples may increase depending on the number of physiography, AEZ, land type, soil series etc. If possible, surveyors may open mini pit or collect samples from each horizon for future study. The sample volume (top soil) may be 15000 to 16000.

Collected soil samples be analyzed through SRDI's 16 regional, 07 divisional laboratories and Central laboratory for pH, EC, OM, Nitrogen, Phosphorus, Potassium, Sulfur, Zinc, Boron, Calcium and Magnesium and if possible, Molybdenum. Moreover, routine analysis for Fe, Cu, Mn and exchangeable acidity may be done. Determination Cation Exchange Capacity (CEC), texture (may be done through finger feelings method) and bulk density must be done for every soil sample. If possible microbial biomass carbon, microbial biomass nitrogen may also be analyzed. These whole activities may be completed within a year or two.

These geo-referenced databases be digitized in the GIS platform. Based on these analytical data base a real time soil fertility mapping may be prepared. SRDI can update these databases and maps in every five years interval. These databases and maps may be used for soil fertility study, fertility changing trends analysis and planning for appropriate measures to be taken.

10. References

Aryal, J. P., Sapkota, T. B., Rahut, D. B. and Jat, M. L. 2019. Agricultural Sustainability under emerging climatic variability: Role of climate smart agriculture and relevant policies in India. Int.J. Innov. Sust. Dev., https ://www.inder science.com/info/ingeneral/forth coming.php?jcode =IJISD.

BARC,2018. Ahmed et al.,2018. Fertilizer Recommendation Guide-2018. Bangladesh Agricultural Research Council (BARC), Farmgate, Dhaka 1215. 223pp.

Bangladesh Economic Review, 2019. Bangladesh Economic Review, 2019. Ministry of Finance, Bangladesh.

Hasan, M. N., Hossain, M. S., Bari, M. A and Islam, M. R, 2013. Agricultural land availability in Bangladesh. SRDI. Bangladesh, 42pp.

Hasan, M. Nazmul. and M. Lutfar Rahman, 2015. A Comparative Assessment of Soil Fertility in Birganj Upazilla of Dinajpur District and Hatibandha Upazilala of Lalmonorhat District of Bangladesh. "FAO suppoeted research work" 73pp.

Hasan, M. N. and M. L. Rahman, 2016. Changing Land Use and Soil Fertility over Time: Perspective Hatibandha Upazilla. Daffodil International University Journal of Science and Technology. 11: 43-53.

Islam Aminul and Md. Nazmul Hasan 2015. Paper presented in the seminaron "Healthy Soils for a Healthy Life" on 13 December,2015 at Bangladesh Agricultural Research Council (BARC), in observance of "International Year of Soil, 2015' organized by Soil Resource Development Institute (SRDI), Ministry of Agriculture and Food and Agriculture Organization of the United Nations, Bangladesh. (Research Publications. Professor Dr. Aminul Islam. Department of Soil Science, University of Dhaka.

Jahiruddin, M. 2015. Zinc and Boron Deficiency in Crops and Their Management in Bangladesh, 28p.

Karlen, D. L., Doran, J. W., Andrew, S. S. and Wiehold B. J. 2003. Soil quality - humankinds' foundation for survival. J. Soil Water Conservation. 58: 171-+179.

Land and Soil Statistical Appraisal Book of Bangladesh, 2010. SRMAF Project, Soil Resource Development Institute (SRDI), Ministry of Agriculture, Bangladesh.

Lal, R. 2011. Soil health and climate change: an overview. In book: B. P. Singh, A. L. Cowie and K. Y. Chan ed., Soil Health and Climate Change. Springer - Verlag Berlin Heidelberg. pp. 3-24.

Mandal, L. N. and S. K. Khan.1972. Release of Phosphorus from Insoluble Phosphatic Materials in Acidic Low Land Rice Soils. Journal of the Indian Society of Soil Science. 20: 19-25.

Prasad and Power, 1997. Soil Fertility Management for Sustainable Agriculture—Rajendra Prasad and James E. Power.1997. CRC Lewis Publishers, New York.

Ranjit, R., G. S. Dasog and P. L. Patil. 2000. Effect of Lime and Phosphorus Levels on Nutrient Uptake by Groundnut Genotypes in Acid Soils of Coastal Agro Eco System of Karnataka. Karnataka Journal of Agricultural Sciences. 20: 631-633.

Rijpma, J. and Jahiruddin, M. 2004. National Strategy and Plan for Use of soil Nutrient Balance in Bangladesh. SFFP Consultancy Report. DAE, Khamarbari, Dhaka.

.World Bank. 2010. Economics of Adaptation to Climate Change – Synthesis Report (English). Washington, D.C. World Bank.

World Development Indicators. 2016. Bangladesh Fertilizer Consumption. https://knoema.com/WBWDIGDF2016Jul/world-development-indicators-wdi-july-2016

Yuan, T. L., W. K. Robertson and J. R. Neller.1960. Form of Newly Fixed Phosphorus in 3 Acid Soils. Soil Science Society of America Proceedings. 24: 447-450.

Zahid, A. M., Kohinoor, N. A., Hossain, M. A. and Shoaib, J. U. 2020. Land Degradation in Bangladesh: Baseline Study of Land Degradation Processes 1985-2000. FAO supported Research Report, SRDI, Dhaka.

11. Annexure

Annexure-1 Changes in land use since 2010 to 2020

Land Use Type	Year 2010		Year 2020	
	Area (Ha)	% of BD	Area (Ha)	% of BD
Arable Land	9598381	65.04	8586864	58.19
Sundarban	427418	2.90	409999	2.78
Reserve Forest	284210	1.93	310345	2.10
Major Rivers	*	*	1065238	7.22
Homestead, urban and others	4446991	30.13	4384554	29.71
Total	14757000	100.00	14757000	100.00

• Not measured separately. BD=Bangladesh

Annexte-2 Changes in soil pH status of arable land of Bangladesh since 2010 to 2020

Soil pH Class	Year 2010		Year 2020	
	Area	% of Arable Land	Area	% of Arable Land
Very Strongly Acidic	250270	2.61	277544	3.23
Strongly Acidic	3707269	38.62	3644449	42.44
Slightly Acidic	2737997	28.53	2182698	25.42
Neutral	1441908	15.02	1005558	11.71
Slightly Alkaline	1435378	14.95	1459510	17.00
Strongly Alkaline	25559	0.27	17039	0.20
Very Strongly Alkaline	0	0.00	65	0.00
Total	9598381	100.00	8586863	100.00

Annexure-3 Changes in soil organic matter status of arable land since 2010 to 2020

Fertility Class	Year 2010		Year 2020	
	Area	% of Arable Land	Area	% of Arable Land
Very Low	762073	7.94	407570	4.75
Low	2879893	30.00	2582784	30.08
Medium	5333558	55.57	5082396	59.19
High	506882	5.28	393512	4.58
Very High	115975	1.21	120601	1.40
Total	9598381	100.00	8586863	100.00

Annexure-4 Soil phosphorus (upland crops) status in arable land in 2020.

Fertility Class	Year 2020	
	Area	% of Arable Land
Very Low	1293150	15.06
Low	3529203	41.10
Medium	1781569	20.75
Optimum	887376	10.33
High	700825	8.16
Very High	394741	4.60
Total	8586864	100.00

Annexure-5 Changes in soil phosphorus status (wetland rice crop) in arable land since 2010 to 2020

Fertility Class	Year 2010		Year 2020	
	Area	% of Arable Land	Area	% of Arable Land
Very Low	1188871	12.39	888964	10.35
Low	2515687	26.21	3427491	39.92
Medium	2029146	21.14	1840200	21.43
Optimum	1097564	11.43	1063152	12.38
High	782848	8.16	805726	9.38
Very High	1984265	20.67	561330	6.54
Total	9598381	100.00	8586864	100.00

Annexure-6 Soil potassium (upland crops) status in arable land in 2020.

Fertility Class	Year 2020	
	Area	% of Arable Land
Very Low	135647	1.58
Low	5003692	58.27
Medium	2018590	23.51
Optimum	805010	9.37
High	336075	3.91
Very High	287850	3.35
Total	8586864	100.00

Annexure-7 Changes in soil potassium status (wetland rice crop) in arable land since 2010 to 2020

Fertility Class	Year 2010		Year 2020	
	Area	% of Arable Land	Area	% of Arable Land
Very Low	287628	3.00	36782	0.43
Low	2432313	25.34	3675469	42.80
Medium	2122073	22.11	2650264	30.86
Optimum	1945245	20.27	1147473	13.36
High	779666	8.12	532102	6.20
Very High	2031456	21.16	544773	6.34
Total	9598381	100.00	8586864	100.00

Annexure-8 Soil sulphur (upland crops) status in arable land in 2020.

Fertility Class	Year 2020	
	Area	% of Arable Land
Very Low	350880	4.09
Low	2710343	31.56
Medium	1927100	22.44
Optimum	1265155	14.73
High	1173837	13.67
Very High	1159549	13.50
Total	8586864	100.00

Anneure-9 Changes in soil sulphur status (wetland rice crop) in arable land since 2010 to 2020

Fertility Class	Year 2010		Year 2020	
	Area	% of Arable Land	Area	% of Arable Land
Very Low	726260	7.57	350880	4.09
Low	2580659	26.89	2710343	31.56
Medium	1790221	18.65	1927100	22.44
Optimum	1093299	11.39	1265155	14.73
High	762178	7.94	1173837	13.67
Very High	2645764	27.56	1159549	13.50
Total	9598381	100.00	8586864	100.00

Anneure-10 Changes in soil zinc status in arable land since 2010 to 2020

Fertility Class	Year 2010		Year 2020	
	Area	% of Arable Land	Area	% of Arable Land
Very Low	749392	7.81	2478969	28.87
Low	2006122	20.90	4291006	49.97
Medium	1822941	18.99	990510	11.54
Optimum	1407845	14.67	399444	4.65
High	1032177	10.75	195282	2.27
Very High	2579904	26.88	231653	2.70
Total	9598381	100.00	8586864	100.00

Anneure-11 Changes in soil boron status in arable land since 2010 to 2020

Fertility Class	Year 2010		Year 2020	
	Area	% of Arable Land	Area	% of Arable Land
Very Low	833807	8.69	544362	6.34
Low	1660386	17.30	2098585	24.44
Medium	2006311	20.90	2350285	27.37
Optimum	1542449	16.07	1365198	15.90
High	988737	10.30	810891	9.44
Very High	2566691	26.74	1417543	16.51
Total	9598381	100.00	8586864	100.00

Annexure-12 Soil calcium status in arable land in 2020.

Fertility Class	Year 2020	
	Area	% of Arable Land
Very Low	421491	4.91
Low	1684562	19.62
Medium	1311470	15.27
Optimum	1014359	11.81
High	802874	9.35
Very High	3352108	39.04
Total	8586864	100.00

Annexure-13 Soil magnesium status in arable land in 2020.

Fertility Class	Year 2020	
	Area	% of Arable Land
Very Low	314254	3.66
Low	742486	8.65
Medium	839835	9.78
Optimum	895933	10.43
High	930073	10.83
Very High	4864283	56.65
Total	8586864	100.00