SOIL FERTILITY AND INPUTS USE ATLAS OF PAKISTAN

The Khyber Pakhtunkhwa Province

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Note for the Readers

The objective of this Atlas is to present information regarding nutrients and fertilizers, farmers' common practices, crop yields under different nutrient use scenarios and cropping system in Khyber Pakhtunkhwa. The overall trends and inferences drawn are valid (and justified) primarily for a particular crop grown under the respective zone suitable for that crop. However, variations from the normal trends may be noticed for a crop's yield viz-a-viz fertilizer use when grown on a small area in any crop production zone not specific for that crop. Therefore, the stated patterns and conclusions may be viewed in the perspective of the available data sets, assumptions for interpretations and the methodology adopted rather than making comparisons with a given site specific situation. All possible care has been taken in data analysis and presentation; suggestions for improvements are welcome.

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FOREWORD

Khyber Pakhtunkhwa, like other provinces of Pakistan, has an agrarian economy where 80 percent (%) of the population resides in rural areas with agriculture as their major source of livelihoods. Agriculture is the main stay for economy, and thus, overall socio-economic development of Pakistan.The agriculture sector accounts for 42% of the employment equivalent to 37.2 million persons of the national workforce, and 23.4% of the country's GDP. The share of provincial GDP to the National GDP is 13% and the share of agriculture in the provincial GDP is 17%. Adequate and timely use of inputs, such as balanced fertilizers and certified seeds along with mechanization and provision of agricultural credits, are pre-requisites for increasing agricultural outputs. Khyber Pakhtunkhwa province, having a total of about 1.54 million farms, contributes significantly towards the overall national agricultural production in crops including fruits (6%), vegetables (13%), maize (17%) and wheat (5%). Thus, the economic development of the province in the context of ever increasing population largely depends on further growth of agriculture sector.

Sustainable soil management is central to meet overarching human needs including food, raw materials and energy. Imbalanced fertilizer use and high fertilizer prices are dominant factors that are hampering sustainable yields. However, 4R nutrient stewardship, if duly implemented, can help decrease the cost of production and enhance fertilizer use efficiency. The Soil Fertility Atlas is a part of the project '4R Nutrient Stewardship for Sustainable Agriculture Intensification in Pakistan: Baseline Input Atlas and Promotion of Best Soil Management Practices' - GCP/PAK/143/USA. The ultimate objective is to promote the use of appropriately balanced inputs and 4Rs - the Right fertilizer/nutrient at the Right rate at the Right time in the Right place - in partnership with the public and private sectors. The loss of soil fertility in many developing countries poses an immediate threat to food security. Soil nutrients mining due to intensive cultivation and unsustainable soil management practices, is one of the major causes of depletion of the soil fertility. Fertilizers constitute the most important scientific breakthrough in feeding the growing population of Pakistan and elsewhere. The Food and Agriculture Organization, National Fertilizer Development Center, Pakistan Agricultural Research Council and other Research Institutes have reported up to 50% enhanced crop productivity with the use of fertilizers. However, imbalanced use of fertilizers (nitrogenous, phosphatic, potassic and micronutrients) and low fertilizer(s) efficiency still remain the major constraints in enhancing crop productivity in the country. Imbalanced use of fertilizers in Pakistan results in lower incomes for the farmers can be attributed to incorrect ratio of nutrients. Consequently, per unit agricultural production, particularly of grain crops, has remained stagnant in some of the cropping zones. On the other hand, the population is increasing at an alarming rate; which requires sustainable agriculture intensification. Organic manures can help restore soil health and nutrient status, possess a huge potential. However, organic manures alone cannot meet the sizeable nutrient requirements of major crops. Therefore, the concept of integrated plant nutrition management system is need of the hour. This is especially true for soils that have been depleted of their nutrients by intensive cropping for decades.

The Soil Fertility Atlas for Khyber Pakhtunkhwa provides a comprehensive account of latest soil fertility status, native best management practices, fertilizer use trends at the farm level, and management strategy for normal and constrained soils for resource-based improvement. I am confident that this document will help to understand the soil fertility management changes required for sustainable agricultural intensification in Khyber Pakhtunkhwa province initially, which would also be possibly applicable and extendable to other similar agro-climatic zones across the country. Hopefully, an array of stakeholders will be benefitted from this Atlas including the farmers, extension workers, research scientists, economists and policy makers in the public as well as private sectors. Specifically, the farmers are deemed to benefit the most. Farmers need to get involved for applying the 4R nutrient strategy for ensuring sustainable agriculture as there is a close association between soil fertility management and soil health. Additionally, the soil fertility data-base would provide a basis for the development of an improved capacity for monitoring and management of fertilizer use in Pakistan. This will pave the way to upscale the activities concerning 4R nutrient stewardship across other provinces.

At the end, let me express my deep appreciation of those involved in this undertaking of monumental national importance. I have no doubt that this document will go down as vade mecum for scientists, researchers and policy makers. This will also help develop an assertive vision for progress and prognosis in soil fertility protocol in Khyber Pakhtunkhwa. Model Farm Service Centers (MFSC) are functional throughout KP province which are playing their role quite effectively in the well developed areas for raising awareness regarding cropping patterns and facilitation of the value-chain starting. In addition, there is an opportunity to promote the concept of 4R Nutrient Stewardship and soil and water test based nutrients application through these MFSCs. Such initiatives may also be extended to the relatively remote areas, including the FATA region districts recently merged in KP for the capacity building and guidance of the resource poor farmers.

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The development of Soil Fertility and Inputs Use Atlas of Khyber Pakhtunkhwa Province is the result of the efforts of many institutions and individuals. We acknowledge the US Agency for International Development (USAID) and the US Department of Agriculture (USDA) for providing funds for this task while the Government of Pakistan and the Food and Agriculture Organization of the United Nations (FAO) contributed expertise and knowledge. The FAO implemented the project with close collaboration of the Ministry of National Food Security and Research (MNFS&R) and the Pakistan Agricultural Research Council (PARC). We acknowledge the cooperation and support extended by Dr. Munir Ahmad, Member Natural Resources (PARC) who took keen interest to include fertilizer use assessment at the farm level in this Atlas. The participating team from the Climate, Energy and Water Research Institute (CEWRI) of the National Agricultural Research Center (NARC) included Dr. Munir Ahmad (Director), Dr. Arshad Ashraf and Mr. Muhammad Bilal Iqbal is acknowledged. FAO team including Mr. Muhammad Waheed Anwar (Research Assistant), Mr. Muhammad Afzal and Ms. Mehwish Ali (Information Management Unit), provided support in collection of agricultural related information, preparing maps and layout designing for this Atlas. Mr. Zeeshan Mustafa (Doctoral Fellow School of Economics, Faculty of Economics and Business Administration, University of Szeged, Hungary) is also acknowledged for his support in data analyses and the preparation of graphs for various sections of this Atlas.

The preparation of the Khyber Pakhtunkhwa Soil Fertility Atlas has been led by Dr. Waqar Ahmad (Soil Scientist - Project Lead, The FAO Pakistan; Honorary Associate, School of Life and Environmental Sciences (SOLES) - The University of Sydney, NSW Australia). The kind support extended by Dr. Nisar Ahmad, Ex-Chief of the National Fertilizer Development Center (NFDC), in the form of technical discussions and feedback helped to finalize the fertilizer offtake trends and data interpretation and his help is highly acknowledged. Thanks are also extended to his successor Mr. Abdul Jalil Marwat (Chief NFDC), Dr. Ahmad Ali Khan and Dr. Muhammad Islam (Assistant Chiefs NFDC) for sharing data on fertilizer offtake and postulation of different hypotheses for data interpretation. The support from Professor Dr. Riaz H. Qureshi (Ex-Vice Chancellor, University of Agriculture, Faisalabad; Ex-Advisor to Higher Education Commission of Pakistan), Dr. Muhammad Yaseen and Dr. Ghulam Murtaza (Professors, Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad), Mr. Malik Rahim Bux (Ex-Deputy Director Soil Survey, Punjab), Sheikh Riaz-ul-Amin (Senior Research Officer, Soil Survey) and Prof. Dr. Mohammad Jamal Khan (Chairman, Department of Soil and Environmental Sciences, University of Agriculture, Peshawar, and Soil Expert representing International Technical Panel on Soils of FAO - ITPS) in finalizing district wise dominant soil series, identification of soil parent material and soil classification is highly acknowledged. Thanks, are extended to Dr. Muhammad Salim (Ex-Member Natural Resources, PARC), Dr. Samina Siddiqui (Assistant Professor, National Centre of Excellence in Geology, University of Peshawar) and Dr. Muhammad Aslam (Principal Scientist, NIAB, Faisalabad) for their guidance on the identified soil management problems and development of key messages for the farming community. Thanks to Mr. Yuji Niino (Technical Officer, FAO Rome), Mr. Ronald Vargas (Land and Water Officer, FAO Rome), Ms. Zainab Bazza (Soil Scientist for the Global Soil Partnership, FAO Rome), and other team from GSP who contributed in finalizing key messages. Thanks to National Fertilizer Companies including Fauji Fertilizer Company Limited (FFC), Engro Fertilizers Limited, and Fatima Fertilizers Company Limited/Pak Arab Group shared information on soil and water testing facilities available for farmers in Balochistan. Special thanks are due to the Fauji Fertilizer Company Limited for sharing soil fertility datasets of various districts of Khyber Pakthonwa through Farm Advisory Centers. Dr. Naveed Akhtar (Director General, Agriculture Research, KP) and Mr. Muhammad Nasim Khan (Director General, Agriculture Extension, KP) were proactive in providing information on the existence of district level soil and water testing laboratories and supported the initiative of site specific fertilizer use - an integral part of 4R Nutrient Stewardship.

The editorial comments on the final product were provided by Dr. Waqar Ahmad, Dr. Mohammad Jamal Khan, Mr. Zeeshan Mustafa, Dr. Khalid Mahmood (Ex-Deputy Chief Scientist, Nuclear Institute for Agriculture and Biology (NIAB), Faisalabad), ,Dr. Balwant Singh (Professor, School of Life and Environmental Sciences (SOLES - The University of Sydney, NSW Australia), Dr. Munir H. Zia (FFC, and Chair Pillar-2 GSP), Dr. Arshad Ali (Senior Director, Land Resources Research Institute, NARC) and Mr. Abdul Jalil Marwat. The development of this Atlas would have been difficult, if not impossible, without the leadership and oversight of Mr. Farrukh Toirov (Deputy Representative, FAO Pakistan) and Mr. Anthony Bennett (Project Lead Technical Officer, FAO Bangkok) and we are thankful for your support.

INTRODUCTION

Agro-ecology of Khyber Pakhtunkhwa (KP) is quite diverse ranging from flat, uneven undulating to widely distributed hilly areas, with an extremely dry climate in the south and rainfall gradually increasing to the humid and cold towards the north. Out of the total land area of 5.62 million hectares (Mha), only 30% is cultivated and more than 50% of the cultivated is rainfed. Most of the farmers (90%) have small subsistence land holdings. Approximately, 50% of the cultivated soils have low fertility level due to intensive cropping over the years. Ensuring sustainable agriculture intensification through efficient inputs management while maintaining environmental quality is a major challenge for the agriculture sector. Sustainable practices for soil, water, nutrient and crop management at different stages of agricultural production systems are important and must be promoted to raise the awareness of stakeholders. A sustainable production system requires efficient use of the natural and other resources, may involve recycling of organic wastes without causing any negative impact on the soil and environment. In relation to plant nutrition, the objective is to replenish nutrients that have been removed by crops and minimize nutrient losses through various processes, such as fixation in the soil, ammonia volatilization, denitrification, leaching and run off. To address these concerns, the Food and Agriculture Organization of the United Nations (FAO), in partnership with the Ministry of National Food Security and Research (MNFS&R), Pakistan Agricultural Research Council (PARC) and US Department of Agriculture (USDA), implemented a project entitled '4R Nutrient Stewardship for Sustainable Agriculture Intensification in Pakistan: Baseline Input Atlas and Promotion of Best Soil Management Practices' - GCP/PAK/143/USA. For this, the FAO collaborated with public and private sector partners to:

- Identify current soil management practices commonly adopted by farmers for the selected crops;
- Enhance cooperation between the public and private sectors and present common core messages on the 4Rs (the Right source, at the Right rate, at the Right time, in the Right place) that help farmers to use fertilizer inputs efficiently, improve soil health, soil fertility and reduce the probability of losses;
- Strengthen the capacity of relevant provincial and national agricultural organizations for the implementation of sustainable soil management practices focusing on soil fertility, plant nutrition, and data visualization;
- Prepare the baseline Atlas of current soil fertility status and soil health management practices; and
- Use outputs of the above activities for decision making at various levels and setting provincial frame-works for agriculture and natural resources management.

Under the project, input of balanced fertilizers and 4R Nutrient Stewardship were promoted through a series of objective-oriented events (awareness raising and commodity-specific workshops, consultative meetings, seminars and dialogues) at different places in Khyber Pakhtunkhwa and Balochistan provinces; similar tasks have been already undertaken in Punjab and Sindh, the other two provinces in Pakistan.

Key recommendations coming out of these events are:

- Development of a nutrient stewardship frame-work and a Manual on 4R Nutrient Stewardship for the farming community of Pakistan;
- Establish a public-private partnership for sustainable agriculture intensification in the country;
- Farmers' experiences sharing in devising soil and nutrient management strategy for sustainable agricultural productivity; and
- Make collaborative efforts to address such issues in the best interest of the farming community.

This Soil Fertility and Inputs Use Atlas of Khyber Pakhtunkhwa Province includes:

1) General Maps, 2) Inputs Use Assessment, 3) Mapping of NFDC Nutrient Offtake Data,

4) District Profiles, 5) Soil Fertility Status, and 6) Key Messages.

Besides, several annexures show details of other relevant information. The FAO's Voluntary Guidelines for Sustainable Soil Management (VGSSM) and various infographs are included to highlight the significance of healthy soils. The baseline Atlas provides information on the use of different fertilizers/nutrients for major crops grown in the province. Yield of different crops varies under different nutrient use scenarios. Also, in different cropping zones, inconsistent relationship between crop yields and application of inputs / fertilizers exists. This indicates the impact of factors, other than the material fertilizer, such as soil constraints and inappropriate crop management practices. Soil fertility management practices desired for sustainable agriculture intensification could thus be better understood through the identification of hot spots with regard to non-judicious use of nutrient applications (over or less than required) coupled with other low efficiency factors.

Minà Dowlatchahi
FAO Representative
Pakistan

METHODOLOGY

The information presented in the Atlas pertains to the provincial agricultural statistics, field-based assessment and source data collected from the provincial and federal departments and other government agencies. To collect information and experience from national and provincial stakeholders, several workshops/consultations were conducted at different locations across the province. Based on the contribution of major crops in agricultural production, wheat, maize, sugarcane, tobacco and horticultural crops were selected to examine the fertilizer usages and yield trends. Economically important crops/commodities were considered in analyzing various trends, such as crop productivity in relation to fertilizer inputs, management practices, and soil quality parameters. The consultations were aspired to emphasis the significance of 4R Nutrient Stewardship and differentiate this relatively new concept from the balanced fertilization, to identify soil and crop management constraints, and to identify best soil health management practices for sustainable agricultural intensification in the province. Major steps involved in the Atlas preparation are described below.

Inputs Use Assessment

The assessment is based on the assumption that fertilizer offtake data (a term used by NFDC Pakistan to describe fertilizer consumption based on the marketing of products) does not necessarily reflect the actual application of fertilizers at the farm level. This assessment was conducted with the involvement of the Khyber Pakhtunkhwa Agriculture Research, Extension and Information Department. All national fertilizer companies including Fauji Fertilizer Company Limited, Fatima Fertilizer Company Limited/Pak Arab Group, and Engro Fertilizers Limited played a vital role in conducting this assessment. A questionnaire was developed in consultation with different stakeholders and farmers' interviews were conducted across three crop production zones (CPZs). Khyber Pakhtunkhwa (KP) province has 25 districts namely Abbottabad, Bannu, Batagram, Buner, Chitral, Charsadda, Dera Ismail Khan, Dir Lower, Dir Upper, Hangu, Haripur, Karak, Kohat, Kohistan, Lakki Marwat, Malakand, Mansehra, Mardan, Nowshera, Peshawar, Swat, Shangla, Swabi, Tank and Tor ghar. Progressive, medium and small farmers from different CPZs of KP were gathered at Peshawar. The number of farmers selected from each CPZ was based on the trends of fertilizers offtake during the last ten years. More farmers were selected from areas of proportionately higher fertilizers offtake. The data collected were deemed representative for a group of farmers, as rural communities often follow similar practices as elders decide after consultation within the family. The information through this assessment pertains to the use of various fertilizers, yield of major crops, major soil constraints hampering productivity, and numbers of farmers availing soil and water testing facility in each district of KP. The validation of such trends in each district was based on field surveys, follow up interviews, and interactions with famers during commodity workshops and discussions with public and private sector experts/individuals.

Crops data are arranged district wise according to the following CPZs. The respective fertilizer use (offtake kg/ha) is based on the cumulative offtake of NPK in kg per hectare. The fertilizer offtake values were calculated from reviewing annual reports of NFDC from several years:

- **Zone-1**
  Districts: Peshawar, Charsadda, Nowshera, Mardan and Swabi
  Cropped area: 394,000 ha
  Fertilizer use (kg/ha): 287
- **Zone-2**
  Districts: Kohat, Karak, Dera Ismail Khan, Bannu, Tank, Lakki Marwat
  Cropped area: 278,000 ha
  Fertilizer use (kg/ha): 143
- **Zone-3**
  Districts: Abbottabad, Mansehra, Haripur, Malakand, Swat, Dir, Buner, Koshistan
  Cropped area: 567,000 ha
  Fertilizer use (kg/ha): 75

NFDC Offtake Data

The NFDC offtake for the period 2008-2017 was used for product wise usage of the fertilizers across the province. The nutrient use for ten years was averaged, and trends were compared with the averages for 5 years. Overall trends for 5 and 10 years outlook (offtake of fertilizers) remained comparable across past several years although minor fluctuations were observed. Therefore, the used data sets suffice for the objectives of the Atlas. The agricultural statistics data and addresses of soil and water testing facilities in KP have also been document which provide a fundamental baseline for future management and planning for nutrient(s) use and overall soil health/quality in the province.

Data Mapping and Analysis

Initially, a base map of the province containing the district boundaries was prepared in ArcGIS software to aid geo-spatial mapping and analysis. The results of the Inputs Use Assessment and the fertilizer offtake data presented in tabular forms were linked with vector data of the districts for spatial cum attribute data analysis. Scenarios of fertilizer use were developed and matched with yield responses of various crops at CPZs and/or district level in the province.

METHODOLOGY

Data Visualization

The layout of the Atlas was prepared by incorporating all necessary mapping details. Fertilizer offtake was mapped under different sections of the Atlas for a general overview and presentation. Fertilizer use information is illustrated in the Atlas in aggregated and cartographic forms as well as tabular statistics is presented for each crop and district.

Soil Fertility Status

For increasing crop production and economic returns at farm level, Fauji Fertilizer Company Limited (FFC) is providing free Advisory Services to the farming community throughout Pakistan since 1981. The company provides soil and water testing facilities through its five mobile Farm Advisory Centers (FACs). Currently, these centers are located at Sargodha, Sheikhupura, Multan, Rahim Yar Khan, and Hyderabad. The laboratories are frequently moved around to facilitate the farming community in each district. Soil fertility data, which included soil electrical conductivity (EC), soil reaction (pH), organic matter (OM), plant available phosphorus (P) and extractable potassium (K), were obtained from 2001 to 2018. It was assumed that EC, pH, OM, P and K values are indicative of the overall soil fertility status of each district, and for the defined CPZs when aggregated. Farmers of a district may plan nutrient management practices according to the guidelines provided for their respective district. However, farmers are advised to consult with the nearest soil and water testing laboratories and agriculture advisory services before sowing crop(s).

SUMMARY AND WAY FORWARD

Agriculture is the backbone of Pakistan's economy. Economic development is possible through the efficient use and conservation of natural resources, particularly the soil/land (non-renewable) and water. Unfortunately, the mismanagement of soil resources has led to a decline in soil fertility and health, compelling the sufficient use of chemical fertilizers which are not utilized efficiently. The resource base of raw materials for inorganic fertilizer production is also depleting fast. These scenarios warrant adoption of best management practices (BMPs) to enhance fertilizer use efficiency and improve soil fertility on a sustainable basis. The Soil Fertility Atlas of Khyber Pakhtunkhwa (KP) province is a comprehensive document that provides detailed information of cropping patterns, management practices, soil fertility status, trends of fertilizer use, advisory services/facilities available to the farmers in the province and suggests strategies to optimize productivity while sustaining the soil health and environmental quality.

KP province has a diversified array of ecologies ranging from an extension of Thal desert in the south zone to high rainfall, cold hilly areas in the north. Central part is the main irrigated agriculture zone, while upper zone has a mix of irrigated and rainfed cropping. The districts Abbottabad, Mansehra and upward are hilly terrain with evergreen natural forests and scattered croplands. The extreme north of Chitral and Gilgit are the cold areas with very sparse natural grasslands and agriculture activity. On the other extreme in south part is the dry, bare hilly belt. This Atlas summarizes information of three distinct Crop Production Zones (CPZs) namely, central zone (Zone-1), south zone (Zone-2) and north zone (Zone-3). The CPZ-1 is a prime agricultural area has comparatively level canal irrigated fields. Main crops are wheat, maize, tobacco, sugarcane, peach, citrus and plum. Application of farmyard manure is a common practice along with the phosphatic fertilizers. The farm size is highly variable with land holdings starting from very large to very small subsistence levels. The application of potassic fertilizers on tobacco is a common practice and to some extent in sugarcane as well. Nitrogenous fertilizers are abundantly used on all agricultural crops whereas micronutrient application is negligible. The CPZ-2 is adjacent to the Thal desert area of Punjab and starts with Dera Ismail Khan and extends upward through Bannu and Kohat. The area is mostly arid hilly terrain. Soils are generally coarse-textured with very low soil organic matter content, and thus, are prone to erosion. Only 5% of the cropped area is irrigated while the rest of the area depends on rainfall for any crop production. The source of irrigation water is underground water via pumping, except in some parts of Dera Ismail Khan that are irrigated from Chashma Right Bank canal. Majority farmers have small land holdings and thus practice subsistence agriculture. Major crops are wheat, chickpea and groundnut, followed by mustard, pulses and fodder crops. In irrigated areas, rice, cotton and vegetable crops are grown as well. The use of chemical fertilizers is low by small farmers, while progressive farmers apply adequate nutrients on irrigated crops and especially the vegetables. In Karak and Kohat districts, agriculture practices are more like those in the adjoining upper districts and vegetables are commonly grown. Overall, the application of organic sources of nutrients is negligible due to limited availability of organic manures.

While, commonly cultivated crops in CPZ-3 are the vegetables' However, cereals like wheat are mainly grown for domestic use and maize for grain and animal fodder. Poultry farming is a common business and readily available poultry manure is regularly used for crop production. However, due to lack of awareness, the farmers using poultry manures often omit the use of P fertilizers. Therefore, soil test-based application of NPK fertilizers and the integration of organic sources of nutrients should be adopted. Marketing of perishable commodities, particularly vegetables, is a major concern with reference to the profitability of the farmers. Canal water supply is insufficient which is supplemented with ground water pumping. In this regard, the government is subsidizing drip irrigation systems as well as solar tube-wells through the water management department under various schemes. Apart from soil and water related constraints, termites and wild boars are major threats to some field crops.

Farmers of the KP province reported nutrient(s) application in ten different combinations (N only; Organic amendments only; N + Organic amendments; N + P; N + P + Organic amendments; N + P + K + Organic amendments; N + K + Organic amendments; N + P + Zinc; N + P + Zinc + Organic amendments; N + P + K + Organic amendments). Moreover, the addition of each nutrient to individual nutrient use scenario was not translated, in general, into the increased yield for the selected cereal, fruit and vegetable crops. However, the increased use of nutrients variably enhanced yield in case of wheat across the three CPZs. The same trend is noted for fruits and vegetable crops. Therefore, further investigations are required in the specific CPZ(s) to determine the optimum efficient nutrient application rate for improved crop yield(s).

Fertilizer offtake values for the KP Province for both N and P nutrients during the last decade (2008 – 2017) do not indicate systematic trends. Nevertheless, the maximum offtake of the two nutrients invariably corresponds with the intensive agricultural activities in the districts of Mansehra and Abbottabad in north cropping zone, Peshawar and Nowshera districts in central cropping zone whereas in Dera Ismail Khan district of south cropping zone. By far, urea as an N source and DAP as a source of P supply occupy the principal place in

SUMMARY AND WAY FORWARD

the KP province. Higher N and P fertilizers use in vegetable growing areas of north and central zones of KP also complements with higher use of organic sources mainly the poultry manure. Although in some districts of the three cropping zones, a decreasing trend in fertilizer offtake in the second half of the last decade has been reported; but it does not necessary reflect the decreased fertilizer use on agricultural crops in these districts as a number of marketing and socio-economic factors come into play.

Soil and water related constraints weighted 71% in the constraints matrix for hampering crop productivity. Water scarcity is the major constraint hampering agricultural activities throughout the province as reported by majority of the farmers (67%), whereas the extent of this constraint varied by zones. Soil salinity and sodicity were reported by 10% of the farmers. Most of the farmers (>90%) were not satisfied with fertilizers (higher prices) and commodity prices (comparatively low price vs. cost of production). Unavailability of good quality seed was also reported by 68% of the farmers whereas access to agricultural loans was reported by 34% farmers. Soil maps to identify soil constraints that limit crop yield in the consistently poor performing areas may be helpful. The spatial distribution of soil constraints at similar scale could also be used to get the cost of lost production using a soil constraint matrix. Although crop production on fertile soil with no constraints is preferred obviously, due consideration should also be given to marginal lands under the changing climate scenarios.

In summary, the first 2Rs, i.e., Right source and Right rate of the desirable 4R Nutrient Stewardship (the Right source at the Right rate at the Right time in the Right place) are usually practiced, but the latter 2Rs are rarely followed by the farming communities that results in low nutrient use efficiencies and poor economic returns. This is the first step forward in the right direction and similar activities should be undertaken in other provinces of the country for achieving a sustainable food security for growing population and socio-economic uplift of rural communities in the country. For this purpose, a network of soil, plant, water, and fertilizer testing facilities needs to be established for the benefit of farmers. The existing soil and water testing laboratories are inadequate to serve one and half million farmers in the KP province. At present, not a single soil and water testing laboratory of the private sector is functional even in the economically important CPZs of Khyber Pakhtunkhwa. Outreach linkages with the farmers may be strengthened for extensive surveys/assessments at the farm level and applying Best Management Practies according to the 4R soil constraint based commodity specific packages. All the partner organizations are encouraged for collaborative efforts to address the adoption of best methodology for nutrient use, and mapping of most responsive crop growth stage(s). Certainly, this effort would contribute towards setting up of a national framework and policy intervention for Agriculture and Natural Resources Management in the Sustainable Development Goals (SDGs) agenda (specifically Crop Production, Environment, and Soil and Water for agriculture related activities). All federal and provincial agencies and the private sector should join hands for collaborative initiatives to achieve sustainable development not only in KP and all over Pakistan.

ACRONYMS

4Rs Right Source, Right Rate, Rate Time and Right Place

AZRI Arid Zone Research Center

BMPs Best Management Practices

CPEC China-Pakistan Economic Corridor

CEWRI Climate Energy and Water Research Institute

CAN Calcium Ammonium Nitrate

DAP Di-Ammonium Phosphate

dS m^{-1} DeciSiemens per meter

FAO Food and Agriculture Organization of the United Nations

FAC Farmer Advisory Center

FFC Fauji Fertilizer Company Limited

FYM Farm Yard Manure

FBMPs Fertilizer Best Management Practices

GAUL Global Administrative Unit Layers

GSP Global Soil Partnership

HEC Higher Education Commission of Pakistan

ICARDA International Center for Agricultural Research in the Dry Areas

ISFM Integrated Soil Fertility Management

ITPS International Technical Panel on Soils

IUA Inputs Use Assessment

LRRI Land Resources Research Institute

MFSC Model Farm Service Center

MARC Mountain Agricultural Research Center

NTHRI National Tea and High Value Crops Research Institute

NIFA Nuclear Institute for Food and Agriculture

NARC National Agricultural Research Center

NFDC National Fertilizer Development Center

NIAB Nuclear Institute for Agriculture and Biology

PCRWR Pakistan Council of Research in Water Resources

PARC Pakistan Agricultural Research Council

SDGs Sustainable Development Goals

SARS Summer Agricultural Research Station

USDA United States Department of Agriculture

USAID United States Agency for International Development

VGSSM Voluntary Guidelines for Sustainable Soil Management

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