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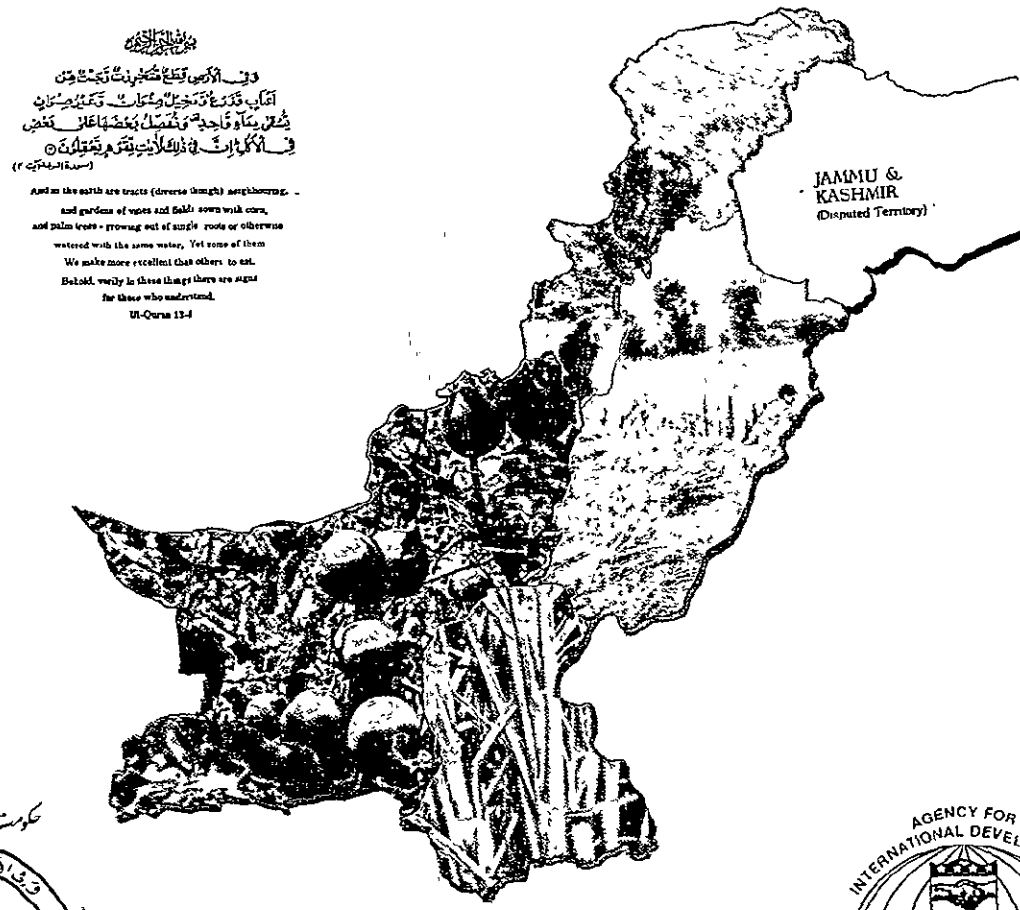
PROCEEDINGS
OF
XII INTERNATIONAL FORUM
ON
SOIL TAXONOMY AND AGROTECHNOLOGY TRANSFER

PAKISTAN

(OCTOBER 9-23, 1985)

FIRST VOLUME: TECHNICAL SESSIONS



And in the earth are tracts (diverse though) neighbouring,
and gardens of vines and fields sown with corn,
and palm trees - growing out of single roots or otherwise
watered with the same water, Yet some of them
We make more excellent than others to eat.
Behold, verily in these things there are signs
for those who understand.
Al-Quran 13-4

SOIL SURVEY OF PAKISTAN

SOIL MANAGEMENT SUPPORT SERVICES U.S.A.

1986

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FIRST VOLUME: TECHNICAL SESSIONS

EDITORS

Mushtaq Ahmad

Muhammad Akram **M. Shabbir Baig**

M. Yasin Javed **Riaz-ul-Amin**

SOIL SURVEY OF PAKISTAN

SOIL MANAGEMENT SUPPORT SERVICES U.S.A.

Lahore, Pakistan

1986

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COLLABORATING ORGANIZATIONS

- Soil Survey of Pakistan (SSP), Lahore
- Soil Management Support Services (SMSS), Washington D.C.
- Pakistan Agricultural Research Council (PARC), Islamabad
- International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT), U.S.A.

FOREWORD

The theme of the XII International Forum on Soil Taxonomy and Agrotechnology Transfer is very pertinent to Pakistan, being an agricultural country. To make the country self reliant in food, feed and fibre, increase in agricultural production is a must. This increase could be achieved by providing scientific basis to agriculture through research and through the transfer of agrotechnology to the end users i.e. the farmers.

Soil is a non-renewable natural resource which should be judiciously used. In the recent past, great advances have been made in the field of soil science and technology in the world including Pakistan. The Soil Survey of Pakistan has collected sufficient basic soils data while other research organizations have carried out research on agronomic and other aspects of agricultural production. Integration of these efforts would definitely be of great benefit. Characterization of Pakistani soils according to Soil Taxonomy, as practised by many developed and developing countries, would enable us to take advantage of the research work carried out in other countries on similar soils under identical environmental conditions. The Forum was arranged to impart training in this field to well drawn participants from all over the country and I hope it has achieved its objective.

Contributions made to the Forum through technical papers and lectures as compiled in this publication are commendable. The information provided is of immense value to the agricultural planners, research scientists and those responsible for agricultural development. They are sure to benefit from it.

Assistance and cooperation of the Soil Management Support Services (SMSS) of USDA for holding this Forum in Pakistan are thankfully acknowledged. The efforts of the Soil Survey of Pakistan and the Pakistan Agricultural Research Council are also appreciated.

KAZI ABDUL MAJID ABID

Minister for Food, Agriculture and Cooperatives
Government of Pakistan, Islamabad.

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- Tour Guide
- Selected Pedon Descriptions and Analytical Data
- Field Excursion Report

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- Principles of Soil Survey Interpretation
- General Principles for Soil Properties and Development of Interpretations
- Procedures Used in the Preparation of Interpretations for Some Pakistan Soils
- Interpretation Record of Some Pakistan Soils
- Concept of Soil Potential Ratings

PREFACE

The XII International Forum was basically a training workshop. It had been organized to create amongst the country's agricultural scientists an awareness of the soil as a vital variable in the plant production enterprise, to familiarize them with the technical language internationally used by pedologists; and to highlight its usefulness in facilitating agrotechnology transfer. Because of the very nature of the workshop, it could accomodate only a limited number of participants. The others would, hopefully, be able to benefit from this compilation of the Forum proceedings. To them it is mainly addressed.

This publication is divided into two volumes to separately cover the two different aspects of the Forum activities. The first volume comprises the indoor proceedings; it contains papers presented in the technical sessions. Detailed profile descriptions, analytical data, prediction of soil behaviour based on data interpretation, and reports of on-site discussions, in respect of the soils examined during field trips make up the second volume. It also includes introduction to some of the basic concepts and categories of Soil Taxonomy—the soil classification system practised in Pakistan.

Most of the write-ups especially those constituting volume one have been subject to a limited degree of editorial modification in consultation with the concerned authors, wherever necessary or possible. The prime reason for effecting these changes was the endeavour of the Publication Committee to relate, as for as possible, the presented material to the conditions prevalent in Pakistan. Credit for pedon descriptions, and related analytical data, interpreted information and photographs of profiles and landscapes goes largely to the SMSS.

Preparation of this publication owes much to the kind patronization and inspiring guidance of Dr. M. Bashir Choudhri, Director General, SSP. On behalf of the Committee, it is my privilege to convey our deep sense of gratitude to him. It is also our pleasure to put on record our appreciation of the cooperation extended to us by the various authors. The services of our colleagues in the SSP for the typing, cartographic and proof reading work are gratefully acknowledged. Personally, I am much obliged to members of the Publication Committee especially the Secretary, for their whole hearted support and untiring efforts during all phases of the work.

MUSHTAQ AHMAD
Chairman
Proceedings Publication Committee

Soil Survey of Pakistan
Lahore.

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20.	Mr. Ghulam Saeed Khan	–do–
21.	Mr. Muhammad Akram	–do–
22.	Mr. Mushtaq Ahmed	–do–
23.	Mr. M. Shabbir Baig	– do –
24.	Mr. M. A. Tahir	– do –
25.	Mr. M. Nawaz Syal	– do –
26.	Mr. Qamar Ali	– do –
27.	Mr. Shams-ul-Haque	– do –
28.	Mr. Abdul Hameed	– do –
29.	Mr. M. Yasin Javed	– do –
30.	Mr. Riaz-ul-Amin	– do –
31.	Mr. Abdul Hameed Sial	– do –
32.	Mr. Muhammad Yousaf	– do –

SOIL MANAGEMENT SUPPORT SERVICES TEAM (USA)

1. Dr. Hari Eswaran, Programme Leader, SMSS
2. Dr. John Witty, National Leader, Soil Taxonomy, USDA-SCS
3. Dr. Fred Beinroth, Department of Agronomy and Soils, University of Puerto Rico
4. Mr. Terry Cook, Soil Management Specialist, SMSS-USDA-SCS
5. Mr. Dennis Lytle, Soil Survey Party Leader, USDA-SCS

PROGRAMME

Wednesday-October 9, 1985

0800	Registration (Conference Room, Hotel Pearl Continental, Lahore)	
1000	Opening Ceremony — Recitation from the Holy Qur'an — Welcome addresses: Dr. M. Bashir Choudhri, Director General, SSP Dr. Hari Eswaran, Programme Leader, SMSS	
1030	Inaugural Address by Minister for Agricutlure, Government of the Punjab	
1045	Reception	

TECHNICAL SESSION I

Hotel Pearl Continetal, Lahore

Chairman: DR. CH. M. ANWAR KHAN

1115	The role of soil surveys in national agriculture development programmes	M. Amjad Hassan
1145	Agriculture research priorities and constraints in Pakistan	M. Anwar Khan
1215	Soil Taxonomy—A technical language of Soil Science (Film)	Hari Eswaran
1245	Lunch	

TECHNICAL SESSION II

Hotel Pearl Continental, Lahore

Chairman: DR. M. AMJAD HASSAN

1400	Scope and purpose of the Forum	Hari Eswaran and M. Alim Mian
1430	Principles and logic of Soil Taxonomy	Hari Eswaran
1600	Diagnostic surface horizons	John Witty
1700	Diagnostic subsurface horizons: cambic, argillic	Terry Cook

Thursday-October 10, 1985

TECHNICAL SESSION III

Hotel Pearl Continental, Lahore

Chairman: DR. M. BASHIR CHOUDHRI

0800	Diagnostic subsurface horizons: oxic, spodic, albic	Hari Eswaran
0900	Diagnostic subsurface horizons: calcic, petrocalcic, gypsic, petrogypsic, salic	Terry Cook
1000	Tea break	
1030	Diagnostic properties	Dennis Lytle
1130	Soil moisture and temperature regimes	John Witty
1230	Lunch	
1400	Alfisols and Ultisols	Hari Eswaran
1500	Aridisols	John Witty
1600	Tea break	
1630	Inceptisols	Dennis Lytle
1730	Vertisols	Terry Cook

Saturday-October 12, 1985

TECHNICAL SESSION IV

Hotel Pearl Continental, Lahore

Chairman: DR. M. AMJAD HASSAN

0800	Entisols	Terry Cook
0900	Mollisols	Dennis Lytle
1000	Tea break	
1030	Soil families	Hari Eswaran
1130	How to classify	John Witty and Terry Cook
1230	Lunch	

TECHNICAL SESSION V

Hotel Pearl Continental, Lahore

Chairman: DR. HARI ESWARAN

1400	An overview of geology of Pakistan	F.A. Shams
1430	Geomorphology of Pakistan	M. Alim Mian
1500	Climate and seasons of Pakistan	Qasim Malik
1530	Ecological zones of Pakistan	Shabbir Baig
1600	Tea break	
1630	Soils of Pakistan	Mushtaq Ahmad
1730	Forum field tour	Aurangzeb Khan

Sunday-October 13, 1985

FIELD TRIP I

0730 Pedon : P10 (Bhalwal)
Pedon : P9 (Lyallpur)

Lunch and Briefing at Rice Research Institute, Kala Shah Kaku

Pedon : P16 (Satghara)

Night at Lahore

Monday-October 14, 1985

FIELD TRIP II

0730 Pedon : P11 (Wazirabad)
Pedon : P12 (Gujranwala)

Lunch at Gujranwala Canal Rest House

Pedon : P15 (Kotli)
Pedon : P13 (Pindorian)

Night at Lahore

Tuesday-October 15, 1985

FIELD TRIP III

Pedon : P5 (Gajiana)
Pedon : P8 (Rasulpur)

Lunch at Farooqabad Canal Rest House

Pedon : P6 (Miranpur)

Night at Lahore

Wednesday-October 16, 1985

FIELD TRIP IV

0730 Travel to Islamabad
1130 Pedon : P20 (Balkassar)

Lunch at Lobani Rest House

TECHNICAL SESSION VI

NARC Auditorium, Islamabad
Chairman : MR. TERRY COOK

1500 Discussion of Field tour

1700 Adjourn

Night at Islamabad

Thursday-October 17, 1985

FIELD TRIP V

0730 Pedon : P17 (Guliana)
Pedon : P21 (Missa)

Lunch at NARC Islamabad

Pedon : P18 (Rajar)

Night at Islamabad

Friday-October 18, 1985

FIELD TRIP VI

0730 Pedon : P19 (Murree)

Lunch at Murree

1600 Return to Islamabad

Saturday-October 19, 1985

FIELD TRIP VII

0600 Travel to Peshawar

Pedon : P22 (Peshawar)
Pedon : P23 (Warsak)

Lunch at Peshawar

1600 Visit to Tarbela Dam

1700 Return to Islamabad

Sunday-October 20, 1985

TECHNICAL SESSION VII

NARC Auditorium, Islamabad
Chairman : MR. A. JAMIL NISHTAR

0800	Principles of agrotechnology transfer	Fred Beinroth
0900	Application of systems analysis for agricultural research and transfer	Fred Beinroth
1030	Soil Capability Assessment Network (SCAN)-History and concepts	Aurangzeb Khan
1130	Soil Capability Assessment Network-Results and achievements	M.I. Nizami

TECHNICAL SESSION VIII

NARC Auditorium, Islamabad
Chairman : DR. FRED BEINROTH

1400	Principles of soil survey interpretation	Dennis Lytle

1500	Interpretation and use of soil survey data in Pakistan	M. Yasin Javed
1600	Tea break	
1630	Exercises in soil survey interpretations	Terry Cook
1730	Transfer of soil technology to agricultural extension service in Pakistan—A pragmatic approach	M. Nawaz Syal

Monday-October 21, 1985

TECHNICAL SESSION IX

NARC Auditorium, Islamabad

Chairman: DR. G.R. SANDHU

0800	Desertification and its assessment	M.A. Tahir
0900	Salinity and reclamation of salt-affected soils	Muhammad Rashid
1030	Concept of soil potential	John Witty
1230	Lunch	

TECHNICAL SESSION X

NARC Auditorium, Islamabad

Chairman: DR. H. NABHAN

1400	Trace elements status of Pakistan soils	Jehangir K. Khattak
1440	Nitrogen use and efficiency	Nazir Ahmad
1520	Phosphorous requirements of Pakistan soils	Kazi S. Memon
1600	Tea break	
1630	Potash status of Pakistan soils	Muhammad Sadiq
1700	Soil fertility and fertilizer use in Pakistan	Tahir Saleem
1730	Need for international cross-checking and correlation in soil analysis for international soil classification system	G. Saeed Khan

Tuesday-October 22, 1985

TECHNICAL SESSION XI

NARC Auditorium, Islamabad

Chairman: DR. IMTIZAJ HUSAIN

0800	Agronomy of wheat	Manzoor Ahmad Bajwa
0845	Agronomy of rice	Abdul Majid
0930	Agronomy of sugarcane	Talib Hussain
1015	Tea break	
1045	Agronomy of maize	M. Qasim Chatha
1130	Agronomy of citrus	Daud Ahmad
1215	Some agrotechnological aspects of cotton production in the Punjab	Waheed Sultan
1245	Lunch	

TECHNICAL SESSION XII

NARC Auditorium, Islamabad

Chairman: DR. MUHAMMAD ASHRAF

1400	Agronomic practices of cotton cultivation in the Punjab	Islam Gill
1445	Agroforestry in Pakistan	M.I. Sheikh
1530	Tea break	
1600	Barani Agricultural Research Development Project	A. Rehman Khan

Wednesday-October 23, 1985

TECHNICAL SESSION XIII

NARC Auditorium, Islamabad

Chairman: DR. M. BASHIR CHOUDHRI

0830	Forum evaluation
0930	Recommendations
1030	Tea break
1245	Lunch

CLOSING SESSION

Islamabad Hotel, Islamabad

Chief Guest: MR. MANZOOR AHMAD

1900	Dinner
2000	Closing addresses: Dr. Hari Eswaran Dr. M. Bashir Choudhri
2100	Award of certificates to participants

PART I
INTRODUCTION
AND
INAUGURATION OF THE FORUM

• Address of Welcome	Dr. M. Bashir Choudhri
• Opening Address	Dr. H. Eswaran
• Inaugural Address	Sardar Arif Rashid

INAUGURATION OF THE FORUM

Pearl Continental Hotel, Lahore

Dr. M. Bashir Choudhri, Director General, Soil Survey of Pakistan, welcoming guests and participants

Dr. Hari Eswaran, Programme Leader, S.M.S.S., presenting the opening address

INAUGURATION OF THE FORUM

Pearl Continental Hotel, Lahore

Sardar Arif Rashid, Minister for Agriculture, Pubjab, inaugurating the Forum

A view of the audience

ADDRESS OF WELCOME

BY

DR. M. BASHIR CHOUDHRI
Director General, Soil Survey of Pakistan

Honourable Minister for Agriculture, Government of the Punjab, Sardar Arif Rashid, Dr. Hari Eswaran, Programme Leader and his colleagues, Soil Management Support Services, Washington DC, distinguished guests, ladies and gentlemen. On behalf of the Soil Survey of Pakistan and other sponsoring organizations, I cordially welcome you all to this Forum on Soil Taxonomy and Agrotechnology Transfer.

This is the 12th programme of its kind organized in different countries on the initiative of the Soil Management Support Services (SMSS) of the United States Agency for International Development, Washington DC. Dr. Hari Eswaran, Programme Leader, SMSS, will throw more light on the concept and objectives of this programme in his succeeding address. Briefly, the purpose of this Forum is to promote the use of soil classification as a vehicle for the transfer of agriculture technology between similar pedo-climatic enviornments. For this purpose it is necessary that a uniform international system of soil characterization and classification is adopted by all countries in their soil survey programmes. A basic and comprehensive system of soil classification is also necessary for detailed interpretation of the soil surveys in farming, forestry, rangeland use and engineering. Moreover, the categories and classes of such a system should be such as to permit us to make precise predictions of soil behaviour under different uses and management practices. The two classification systems most common in use are the Soil Taxonomy developed by the United States Department of Agriculture and the nomenclature used for the soil units in the FAO-UNESCO Soil Map of the World. In our soil surveys, the soils are classified according to the USDA Soil Taxonomy but for correlation purposes we also indicate the corresponding name of the soil unit of the FAO-UNESCO Soil Map of the World.

Since its inception in 1962, the main charter of our department has been the preparation of a comprehensive inventory of the soil resources of the country through reconnaissance soil surveys (1 :250 000) and to compile the findings in the form of reports and maps for the benefit of all organizations concerned with the use, improvement and development of the soil resources of the country. By June this year, about 75 per cent area of the country has been surveyed at reconnaissance level. This includes almost all the irrigated area of the country and a major portion of the rainfed cultivated area as well.

In the history of every soil survey organization, there comes a time when the question is asked, what next? Now that we have completed the reconnaissance soil survey of all the agriculturally important areas of the country, this question is also being faced by us. In many developing countries, particularly those where soil surveys were initiated with external assistance, the question is often answered by terminating the organization or by keeping it in existance with a skeleton staff, mainly for the maintenance of the record. In Pakistan, after the termination of FAO/UNDP assistance, we have not only increased the rate of progress of on-going reconnaissance soil surveys but have also improved the quality of information contained in the soil survey reports. With the extension of surveys to range and forest areas, we modified the format of the reports to give greater emphasis to the evaluation of the potential of the land for grazing and forestry. Our reconnaissance soil survey reports contain information of fundamental value for land development and improvement projects concerning irrigation, drainage, reclamation, soil fertility, afforestation, rangeland development, erosion control etc. Soil survey data is now being increasingly used in these fields because instead of mere supply

of the reports, which the users sometimes find difficult to comprehend, the data is now being interpreted and supplied by us in readily usable form according to the specific requirements of the beneficiary organizations.

One logical answer to the question posed in the preceding paragraph is to initiate detailed soil investigations in selected areas under intensive cultivation for individual farm planning. This we are doing. But detailed soil surveys are expensive and time-consuming. For example, with the manpower that we have in our department, it may take more than 50 years to complete the detailed soil survey of the entire country. Moreover, detailed soil surveys are not needed in many areas. The objectives of the present Forum provide another and a very useful and logical answer to that question. This is to relate the soil survey information to the proper use and management of different soils. This objective can be achieved by carrying out agronomic research on defined and known soils. The research workers are, at present, conducting experiments on undefined soils with the result that the findings of their research may not be applicable to the soils on the farmers' fields. The Soil Survey Department has carried out detailed soil surveys of all the agricultural research institutes and experiment stations of the country. The primary objective of this survey is to enable the research workers to site their experiments on known soils so that their results could be transferred to similar soils on the farmers' fields. Unfortunately, due to the lack of proper coordination between the Soil Survey Department and the agricultural research institutes, the investment made in agricultural research and soil surveys has not produced the desired results. There is an urgent need to restructure the agricultural research organizations including the Soil Survey Department in order to evolve a network for collaborative multi-dsiciplinary approach for solving the farmers' problems.

In 1982, Soil Survey Department, with the assistance of the Pakistan Agricultural Research Council, initiated a small scale project entitled "Soil Capability Assessment Network (SCAN) Project". This project is not meant to duplicate the work of the agricultural research organizations but to test the hypothesis that the crop production technology developed on the basis of soil classification can be transferred to other areas of similar soils, thus not only cutting down the cost of agricultural research but also making the research results more meaningful. The results so far obtained have been very promising which prove that it is possible to relate the recommendations of the research results to specific soils instead of making a blanket recommendation for the whole country, province or district.

We are highly grateful to Dr. Hari Eswaran, Programme Leader and his colleagues of SMSS, Washington DC, for their initiative in holding this Forum in Pakistan. The Forum is being attended by the soil scientists and agronomists from various departments and institutes of the Federal and Provincial Governments. It is our hope that it will create an awareness among these scientists to appreciate soil variability in conducting field experiments and to relate the results of these experiments to properly characterized and classified soils for their extrapolation to areas of similar soils in other parts of the country. Similarly, we can benefit from the experience about the use and management of similar soils in other countries provided we employ the same technical language for description and classification of our soils.

OPENING ADDRESS

OF

DR. HARI ESWARAN

Programme Leader, Soil Management Support Services

Your Excellency, Sardar Arif Rashid, Minister of Agriculture, Government of Punjab, Dr. Bashir Choudhry, Director General of the Soil Survey of Pakistan, distinguished guests, ladies and gentlemen!

The Soil Science Society of Pakistan yesterday concluded its First National Congress and the theme of this Congress was, "Managing Soil Resources to Meet National Challenges." The challenge in Pakistan is to feed the more than 90 million people which has the capacity to double by the next century. The challenge is to increase the food and fiber production and this increase has to be by quantum jumps as the amount of arable land is finite. The challenge is to sustain the national soil resources so that while feeding the current generation it is conserved for the future. These challenges are to be met by managing the soil resource and in fact this Forum addresses the two related questions — where or what is the geographic distribution of these resources and what technology is available to have a sustained high production.

One of the questions that is at the back of every concerned person is how do we prepare for these challenges. The creation of the National Agriculture Research Centre (NARC) is a first positive step. The research and development activities being conducted by all government agencies like the Soil Survey of Pakistan, WAPDA and the Universities are directed to this goal. These efforts must be continued and increased. There is one other way which most countries have not yet exploited for reasons which I will give later. This is called agrotechnology transfer and is defined as the taking of agriculture innovation from one location where it has been tested and proven successful to another location where it is likely to succeed. The transfer of technology from the research stations to the farmer is called the vertical transfer and a commendable job is being done by your extension service. Horizontal transfer is between institutions within a country or world-wide and I do not believe this is fully exploited. The philosophy behind agrotechnology transfer is that if a technology has been developed and tested as in the U.S., it would be a waste of time and money for Pakistan to invest in research to develop the same technology. All Pakistan has to do is to validate the technology and if found useful, extend it to the farmers.

Today we are in the age of information technology. The advent of relatively cheap and rapid computers provides a fantastic tool at the hands of the scientist and if fully utilized will revolutionize agricultural research and agriculture. In the U.S., we have many teams now working on what is called soil-weather-crop simulation techniques and with the use of these models we can monitor the performance of the crop on a daily basis. This technology development is spear-headed by the International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT), a project of the U.S. Agency for International Development of the University of Hawaii and the University of Puerto Rico. These simulation models will become the basic tool of agrotechnology transfer and I am glad to inform you that both the Soil Survey of Pakistan and NARC are collaborating in this project.

A critical assumption in the concept of agrotechnology transfer is that every body speaks the same language. This is where one of the problems lies as scientists in different parts of the world speak a different technical language. However, a decade ago the Soil Conservation Service of the U.S. Department of Agriculture developed a system of soil classification called Soil Taxonomy which is now used by more than 40 countries.

This forum which is the 12th in the series conducted by the Soil Management Support Services has as its general theme "Soil Taxonomy and Agrotechnology Transfer." The Soil Survey of Pakistan is already using Soil Taxonomy and in fact one of their projects, the Soil Capability Assessment Network or SCAN attempts to quantify the interpretations of the soil family category of the system. Many of the papers presented at the First National Congress of the Soil Science Society of Pakistan were excellent but most concerned site specific research as the authors did not characterize and classify their soils. As a result, their research results cannot be extrapolated to other soils or areas thus defeating the basic purpose of research. If all the soils of Pakistan are well characterized and classified, Pakistan can also draw upon the experience of other countries with similar soils. Research need not be duplicated and research becomes very cost-effective.

Your Excellency, ladies and gentlemen, I like to take this opportunity to thank the host institutions, the Soil Survey of Pakistan and the Pakistan Agriculture Research Council for the excellent efforts in preparing this meeting. I have been told that there are many other organizations such as the National Fertilizer Development Center and the Fauji Fertilizer Company who have co-sponsored this meeting and we greatly appreciate their support.

On behalf of the U.S. Agency for International Development, I like to take this opportunity to thank the Government of Pakistan for inviting us here and hosting this Forum. I believe we have an exciting two weeks ahead of us and we all hope to learn much. Thank you all !

INAUGURAL ADDRESS

BY

SARDAR ARIF RASHID
Minister for Agriculture, Government of the Punjab

Dr. Bashir Choudhri, Dr. Hari Eswaran, Delegates from the United States, Participants and Gentlemen!

It is a matter of great pleasure for me to inaugurate this training Forum in which eminent soil scientists and agronomists from all over Pakistan and from abroad are participating. As I understand, the objective of this Forum is the transference of knowledge and experience available about the use of one soil type to similar soils occurring under similar environment in other parts of the country or world wide. Agricultural research is a costly undertaking and can not be carried out for every kind of soil and agro-ecological environment. Duplication of research should be avoided, particularly when the problem is not site-specific. We, therefore, fully subscribe to any concept of agrotechnology transfer within the country as well as between different countries having similar soils and climatic conditions. The classical approach to agricultural research, when scientists carried out routine experiments, such as NPK trials, in isolation from other disciplines, has served its purpose. What we need now is multidisciplinary and collaborative work to reduce costs and increase use efficiency of various inputs, while leading to self-sufficiency in food.

The "green revolution" of mid 1960s and 1970s involving the improvement of wheat is an example of this collaborative approach in agricultural research which resulted in high pay offs. This was not the work of one scientist or institute. The new technology was created by groupings, or networks, of scientists in more than 100 countries. Plant breeders developed new wheat varieties which were shorter, higher yielding, earlier to mature, more resistant to diseases and more responsive to fertilizers. Agronomists worked out suitable production practices for the new varieties such as methods of sowing, irrigating, fertilizing, conserving moisture and controlling weeds. Cereal chemists studied the protein content of the new varieties and their milling and baking qualities, while agricultural engineers developed simple implements for various cultural operations including harvesting and threshing. As a result of these efforts, more progress has been made in raising wheat yields in the last thirty years, than that which occurred since this crop was domesticated.

Land and water are the two most important natural resources, for the agriculture sector in particular and the national economy in general. It is imperative that most efficient use is made of these resources for the development of the rural area of our country where 70 per cent of the population resides and earns its living, directly or indirectly from agriculture.

We are told time and again that the agricultural potential of Pakistan, by way of the production of food and commercial crops, is several times higher than what is being realized today. This is understandable when we look at the wide gap that exists between the yields being obtained on the experimental stations and on the farmers' fields. For example, the top wheat yields on most irrigated research stations are 5 to 6 tons per hectare which are also matched by some progressive farmers. But the average farmer producing irrigated wheat gets only about 2 tons per hectare. Although this subject may be outside the scope of the topic under consideration in this Forum, yet I would request the scientists gathered here to find time to discuss this matter. In my opinion, this gap shows where the potential lies for increasing crop production in the short term.

Another issue which is a matter of great concern for us is that despite strenuous efforts of the government to enhance the availability of farm inputs, there has been no marked increase in yields per hectare of many crops. Since

1966, there has been 14 fold increase in the consumption of fertilizer; supply of credit has increased from less than 100 million to about 7 000 million Rupees; the availability of irrigation water at farm gate has improved by 60 per cent. Similarly, there has been a tremendous increase in the number of tractors and other farm machinery. The adoption of high-yielding crop varieties by the farmers has also been very encouraging. However, it is frustrating to note that the returns, in the form of improved crop yields, have not been commensurate with the investments made in the supply of inputs. To quote one example, a recent study sponsored by the US Agency for International Development showed that response to fertilizer applications was low in Pakistan as compared to similar cropping areas elsewhere. What are the reasons for this low use efficiency of fertilizers and other inputs? This question also I leave as a food for your thought.

While talking to a group of soil scientists, I can not help mentioning the problems of soil salinity and waterlogging. These problems are always in our minds whenever we consider the agricultural and rural development of the country. Enormous expenditure has been incurred on the reclamation of salt-affected soils and on drainage, in the form of Salinity Control and Reclamation Projects (SCARPs), but the improvement has been slow and new areas are being affected with high watertable. As far as waterlogging is concerned, the situation in Sind is quite serious. The Government is fully aware of this menace and the Left Bank Outfall Drain Project is being implemented at a considerable cost. It is designed to improve the drainage in Sind and eventually in the Punjab as well.

In addition, at its last meeting, the Executive Committee of the National Economic Council, has approved a pilot project for the relcamation of 50 000 ha of sodic soils in all the provinces of the country. Under this Project, gypsum will be supplied to the farmers for the reclamation of these soils at 50 per cent of its cost. The sale of the subsidised gypsum to the farmers will cost the Government Rs. 63 million over the next three years.

The holding of this Forum has been made possible because of the work carried out by the Soil Survey of Pakistan. The Department has completed the reconnaissance soil survey of most of the country and has classified the soils according to Soil Taxonomy, an international system of soil classification. They have also completed detailed soil survey of all the important agricultural research institutes and experiment stations in the country. This will make it possible to apply more confidently the results of experiments carried out on specific soils on these stations to similar soils on the farmers' fields.

I am also happy to note that the information contained in the soil survey reports is now being used in the land improvement and development projects. Also, agriculture extension staff is being trained to evaluate the potential and limitations of different soils in order to advise the farmers about their use and management.

There are still many tasks ahead. The first is to apply the soil survey information in all land development and improvement projects. I would like to compliment the Soil Survey of Pakistan for research being undertaken by them with the financial assistance of the PARC, under the Soil Capability Assessment Network (SCAN) Project. The SCAN Project lays the foundation for beneficial soil survey interpretation and greater utilization of the soil survey information. I believe there is an immediate need for a general resource inventory of the whole country. We have many development projects going on and we need a rational basis for national planning. We also need to know how we are conserving the soil resources of the nation. The suggestion of the Director General, Soil Survey Department that our good soils should not be allowed to be diverted to non-agricultural uses will be given a serious consideration by the Government. For these and other reasons, I hope the Soil Survey of Pakistan would consider developing a general resource inventory of the whole country so that we can take stock of what we have and plan judicious use of the soil for the future.

6a

PART II
BASIC AGRICULTURAL RESOURCES

• An Overview of Geology of Pakistan	F.A. Shams
• Geomorphology of Pakistan	M. Alim Mian and M. Nawaz Syal
• Climate and Seasons of Pakistan	Pakistan Meteorological Department
• Soils of Pakistan	Mushtaq Ahmad
• Vegetation Ecological Zones of Pakistan	M. Shabbir Baig and Qamar Ali

AN OVERVIEW OF GEOLOGY OF PAKISTAN

F.A. SHAMS*

INTRODUCTION

Although Earth has been the matter of prime interest to man since time unknown yet due to its vastness he could organise his knowledge (science of geology) not very long ago. For example, the stage for proposing global-level concepts is a rather recent achievement.

It was in 1885 that the Austrian geologist, E. Suess proposed the concept of Gondwanaland, composed of all continents in the southern hemisphere. This supercontinent was separated from Laurasia (North America and Eurasia) by an inland sea, called the Tethys, that occupied south-central Asia (Fig. 1). Such a sea has been mentioned also in many of the Asiatic mythologies, as Ardisura in Iran, as Sut-Ak-Kol in Turkistan, as Marvo in India and as Han Hai in China. In 1893. Suess proposed further that compressional movements between Eurasia and Gondwanaland removed the Tethys and produced the present Alpine-Himalayan mountain chain; he opined that the present oceans represent subsided lands that once connected various continents. An alternative concept was proposed by Wagener in 1912 claiming drift of continents to their present positions.

In mid–20th century, when survey of ocean floors became possible, it was found that the drift concerned rather blocks of crust which moved away from mid–oceanic ridges in response to convection-cells that were active in the earth's mantle. This was proved by magnetic anomalies of ocean floors, ages of oceanic volcanic rocks and of the deep sea sediments. Later studies showed that along the rifting ridge-zones between separating blocks, new crusts is added from depths which spreads almost symmetrically in opposite directions. Such drifting blocks, about 70 km thick, are called lithospheric plates, which carry continents on their back like passengers. For example, the African and S. American continents have moved apart aboard two plates related to mid-Atlantic ridge (Fig. 2). Such motions ultimately bring lithospheric plates in contact so that a drifting plate (Indo-Pak plate) ultimately collides with the passive plate (Eurasia plate) and may even underthrust. In such a case the leading edge of the subducting plate starts melting at depth and generates magma that rising through crustal fractures (Fig. 2) builds volcanic arcs (Island arcs).

In fact, all geological features on the earth are believed to have originated directly or indirectly as a result of plate tectonics.

PLATE TECTONIC DIVISION OF PAKISTAN

The geohistory of Pakistan, as a part of the Indo-Pak Plate, is rooted in the fragmentation of Gondwanaland about 180 m.y. B.P. (Before Present) and its subsequent flight northwards (Fig. 1). Uptil about 80 m.y. B.P., the rate of northwards drift is estimated to be 3-5 om/year. Afterwards, the

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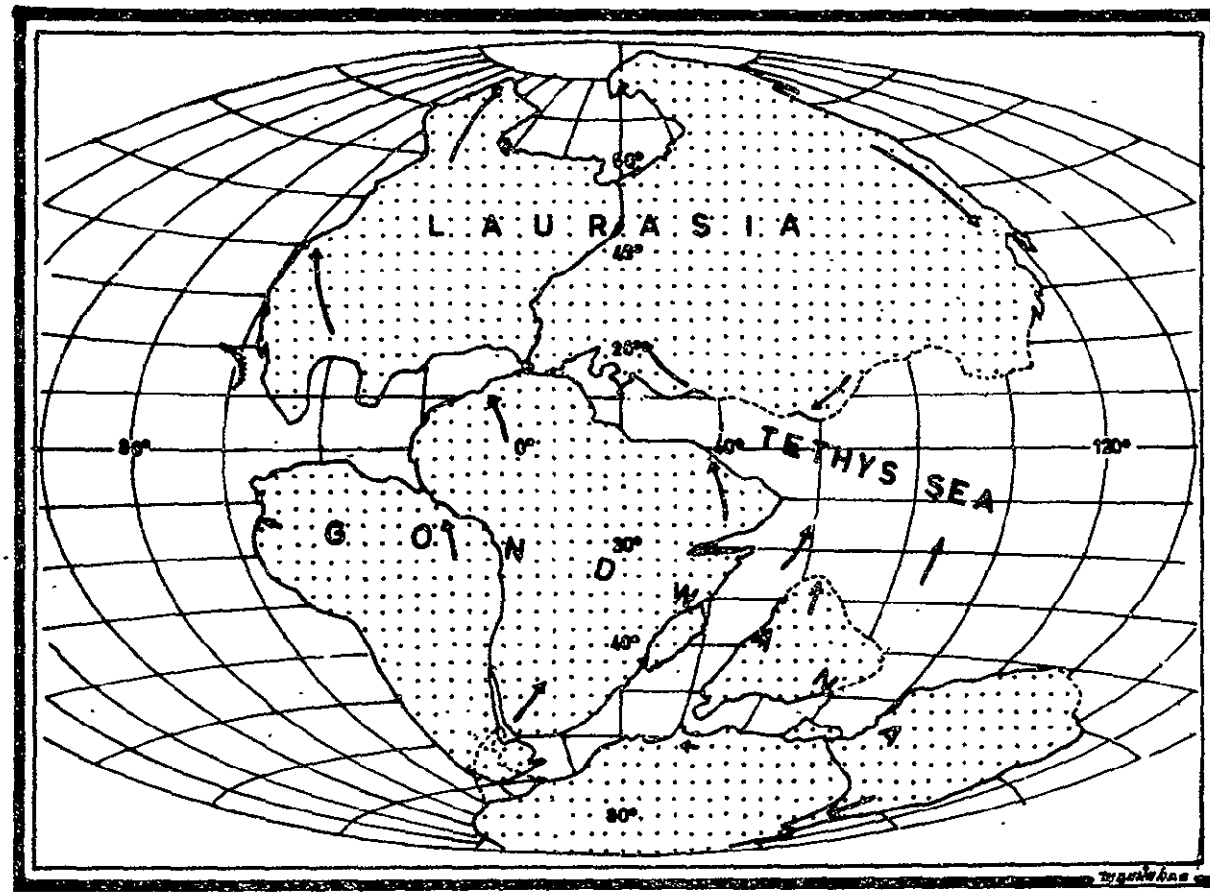

Fig. 1. Showing Split of Gondwanaland from Laurasia 180 m.y. B.P. Arrows show vector motion of continents.

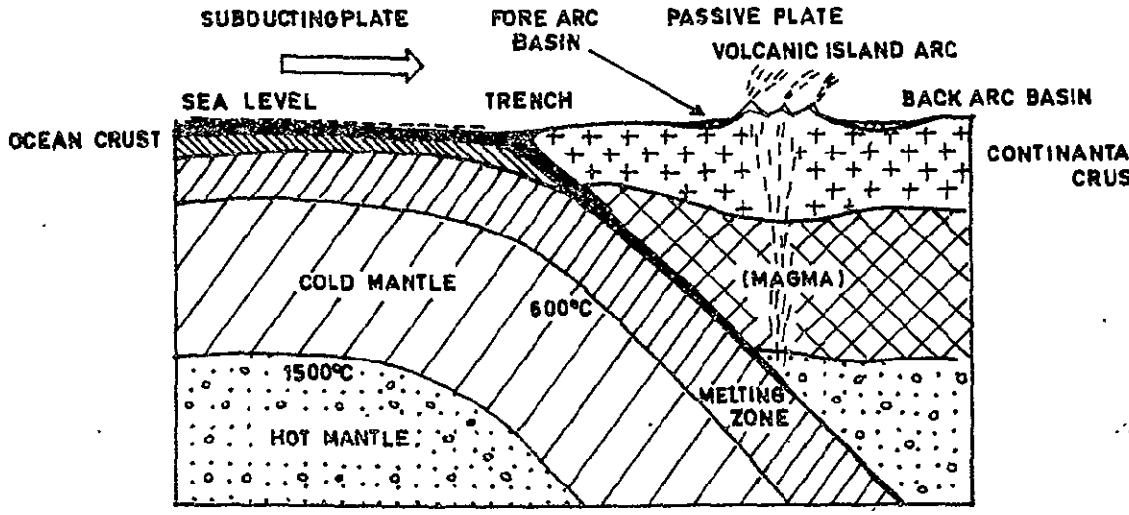

Fig. 2. Model of a plate subduction along a trench zone with volcanic Island arc created by rising magma from the melting zone of the subducting plate.

Indo-Pak plate had a rapid flight at an average rate of 15-20 cm/year but slowed down to almost zero about 53 m.y. B.P. This slowing down is believed to mark the time of collision of the Indo-Pak plate with the Eurasian plate, resulting in the consumption of intervening Tethys sea. However, by 24-30 m.y. B.P. the northwards drift was again initiated at a rate of about 4 cm/yr which marks initiation of underthrusting of the Indo-Pak plate beneath the Eurasian plate. The site of underthrusting (tectonic suture) is marked by the Indus-Kohistan line or the Main Mantle Thrust (MMT) in the northern montane region. It is generally believed that the present Indian Ocean opened as a result of northwards drift of the Indo-Pak plate. Another major suture occurs north of MMT which marks southern limit of the Eurasian plate and is called Main Karakorum Thrust (MKT).

The uplift of Himalayan Range is considered a rather recent event. Among various evidences, is the surprising Pleistocene (3.5 m.y. B.P.) uplift alone of Kashmir up to 2000 m (Dainelli, 1922). According to Wager (1937), Himalayan peaks at its northern edge represent simply the upturned edge of the Tibetan Plateau which rose in response to mass erosion by antecedent rivers. Gansser (1964) goes so far as to state that the main uplift of the Himalayas could have been witnessed by the earliest man. Sahni (1936) claimed that early human migration was possible only because the Himalayas was not a formidable barrier in Pleistocene times. This youthful activity of the Himalayas is also supported by occurrence of early human stone implements in highly tilted Siwalik sediments near Jalalpur, District Jhelum (Marks, 1961).

The western boundary of the Indo-Pak plate is marked by the Axial Belt, beyond which the territory belongs to the Lut-Afghan microcontinent, with the Arabian plate underthrusting beneath it. Fig. 3 gives the present situation alongwith plate boundaries and the directions of relative motions.

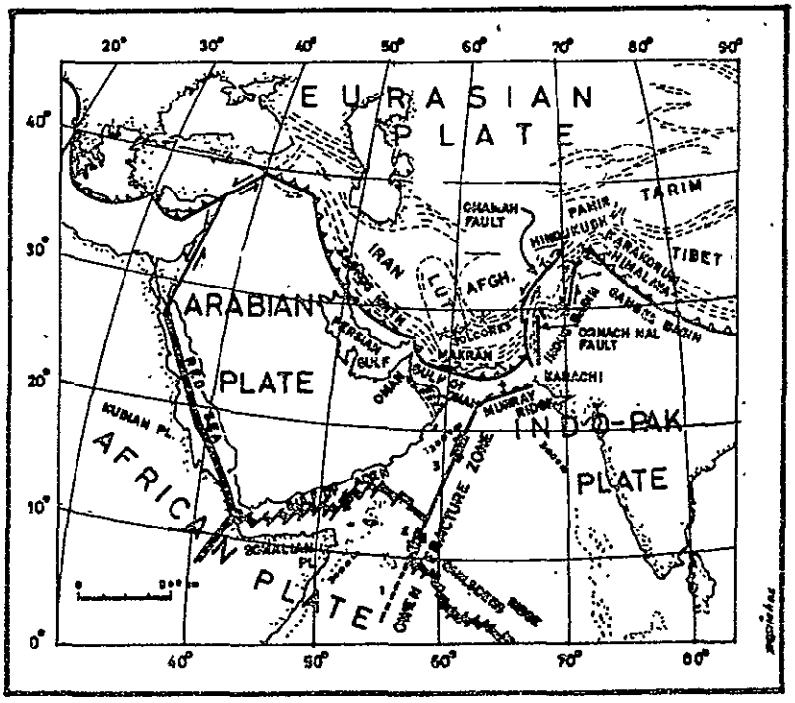

Fig. 3. Plate-tectonic Sketch map of Middle East and South Asia, showing major plate boundaries and relative motions (after Jacob and Quittmeyer, 1979).

The present article is meant to give a sketch outline of geohistory of Pakistan on the basis of plate tectonic subdivisions of the country in relation to its surroundings (Fig. 4).

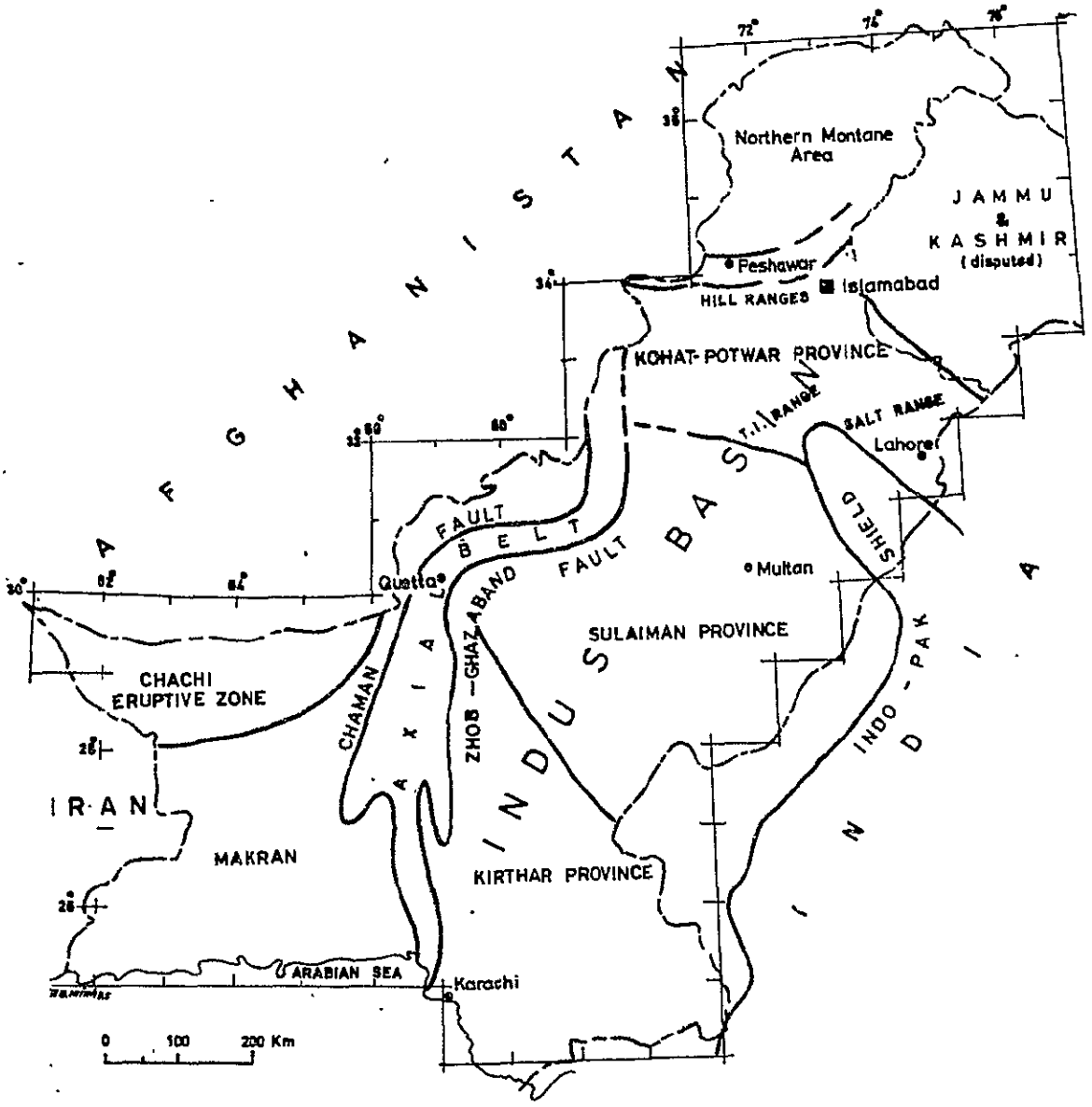

Fig. 4. Showing plate tectonic divisions of Pakistan (after S.M.I. Shah, 1977).

The Baluchistan Basin

As already mentioned, this zone belongs to the Lut-Afghan microcontinent rather than to the Indo-Pak plate, the Axial Belt sedimentation was active on southern shelf of the Iran-Afghan microcontinent and northwest shelf of the Indo-Pak continent. During late Jurassic, Cretaceous and much of the Cenozoic, subduction of Tethyan ocean floor beneath the Iranian plate took place (Dewey et al. 1973). This gave rise to the Chagai Eruptive Zone in northern Baluchistan where Sinjrani Group of

rocks were laid, composed of submarine andesites, and subordinate limestone and clastic sediments. During late Cenozoic, volcanic activity became aerial, and agglomerates and tuffs were ejected. These deposits were succeeded by continental deposits making part of the Saindak-Dalbandin Trough and overlain by alluvial cover. Related plutonic activity concerned intrusion of diorites and granites as stocks. The Chagai Eruptive Zone represents a typical volcanic arc that developed as a result of plate subduction, the tectonic zone presently lying south of the Makran coast, in the gulf of Oman (Oman abyssal plain). In fact, of all the Tethyan realm, this is the only active subduction zone. The chain of Quaternary volcanoes thus generated extends about 450 km westwards into south-east Iran, in the sequence of Koh-i-Sultan, Koh-i-Taftan and Koh-i-Bazman (Fig. 5).

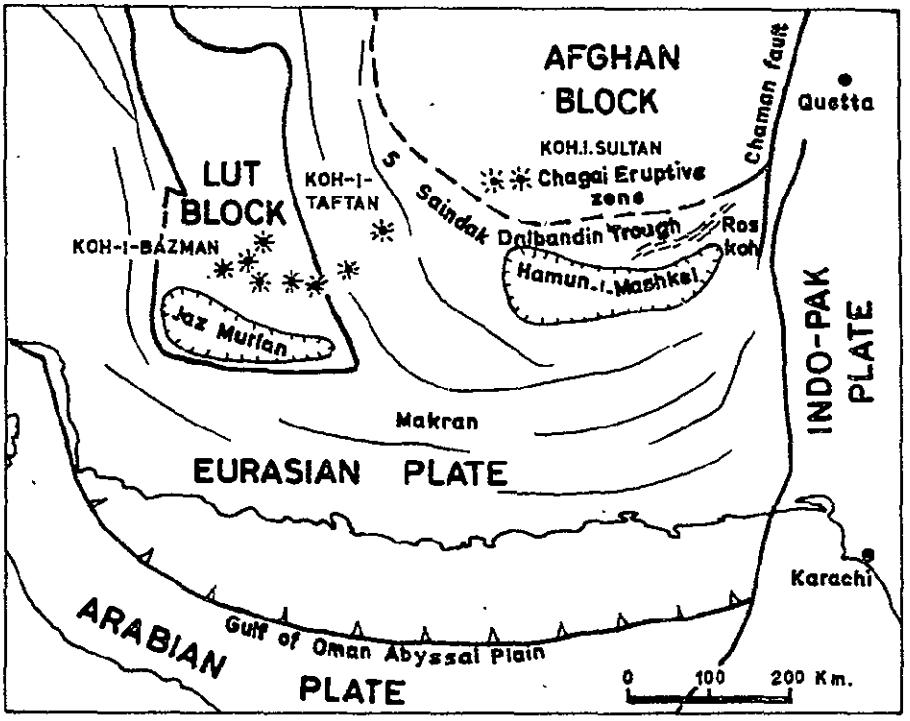

Fig. 5. Tectonic map of Baluchistan, showing various geological features, volcanic chain, depressions and Oman abyssal plain (> 3 000 m deep). Teeth show direction of subduction of the Arabian plate.

The Ras Koh represents an uplifted slice of the Shield rocks, characterised by ultramafic intrusion along its ENE-WSW axis, Cretaceous calc-alkali volcanics and post-middle Eocene intrusions of syenite to diorite composition, Palaeocene sedimentary formations and younger conglomerates. It is notable that of conglomerates and limestones, the former are developed more on the north side while the latter are developed more on the south side of the Koh. This proves geological existence of a barrier to sedimentary environments, may be as a submarine ridge.

South of the Ras Koh, lies a vast crescent shaped plain of wind-blown sand, including the Hamun-i-Mashkhel and the Jaz Murian regional depressions. These belong to the so called fore-arc basins that developed within the trench (Oman abyssel plain) and arc (Chagai Zone) gap and can be

important reservoirs of groundwater and hydrocarbons. Further south, the Makran continental region is characterized by series of E-W ridges. The rocks consist of Upper Cretaceous to Miocene sandstones and shales laid down by turbidity currents into the trench zone (Berberian, 1976). High degree of compression, intense folding and thrusting produced N-S shortening so much that a well drilled near Turbat, continued to a depth of about 4 500 m within the same shale horizon. It is possible that the chain of mud volcanoes along the coast has been produced by mud-eruptions under high pore pressures. May be that the site of subduction zone, now about 100 km south of the Makran coast, is a younger location after its shifting southwards. This may mean that active volcanic activity may some day replace the present mud eruptions.

The Indo-Pak Shield Elements

In Pakistan, although the Indo-Pak Shield extends to northern montane territory yet it is exposed only near Nagarparkar in Sind and in the Kirana Hills about 100 km south of the Salt Range, Punjab. At Karampur, an oil well drilled into the basement rocks recovered material belonging to granitic-metamorphic complex; similar rocks must also form major parts of the Shield in Pakistan.

In Nagarparker, major rocks are pink and grey granites that are cut by basic dyke intrusions. The Kirana Hills Group (Shah, 1977) is, however, composed mainly of quartzites, slates and minor quartzitic and calcareous conglomerates. Interlayered with metasediments are flows of andesites, rhyolites and tuffs with the whole sequence intruded by much altered doleritic rocks (Heren, 1912). These rocks are non-fossiliferous but absolute age found is 870 ± 40 m.y. (Davies and Crawford, 1971), falling in the late-Precambrian. Two strike directions are remarkable, NE-SW of Aravalli type and NW-SE of Himalayan type. The latter component is called the Sargodha Ridge which shows positive gravity anomalies indicating an uplifted block of the crust. It is seismically active and therefore, also called the Punjab Seismic Zone (Seeber and Armbruster, 1979); it may be considered the location of a regional thrust in the making (like those in the Himalayas). This youthful nature of the Kirana Hills is also responsible for their abrupt topographic break with the surrounding alluvial, also appearing as a barrier (Fig. 6).

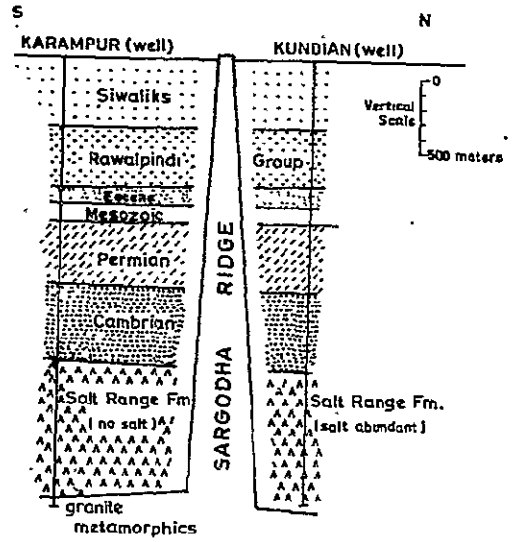

Fig. 6. Subsurface lithologic correlation across Sargodha Ridge, based on information from Karampur and Dhulian Oil-well drillings.

The Salt Range and Trans-Indus Range

Over 200 km long and extending predominantly E-W, the Salt Range occurs only about 100 km south of the Himalayas. It is a pile of sedimentary formations which makes Salt Range world famous as the Field Museum of Geology (Fig. 7).

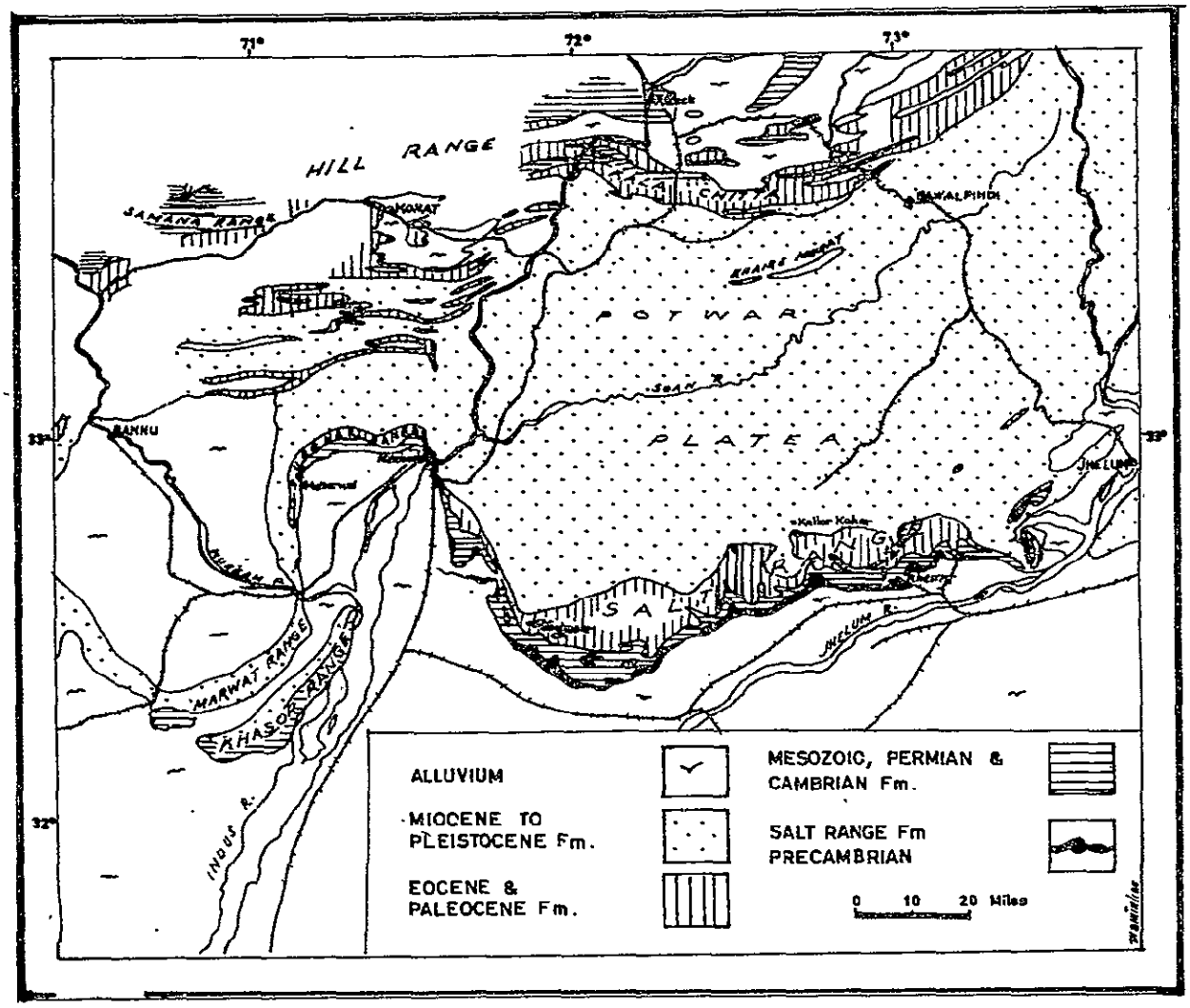

Fig. 7. Generalized geological map of Salt Range, Trans-Indus Ranges, Potwar and Kohat Plateaues and the Hill Ranges

The oldest rocks belong to about 2 000 m thick Salt Range Formation of Precambrian age, laid on crystalline floor of the Indo-Pak Shield. Red marl at its base-horizon contains thick seams of salt with a total thickness of about 650 m. This is followed mainly by gypsum, dolomite and marl, representing evaporites deposited in a shallow, open to restricted marine basin. At nearly top of the Salt Range Formation, occurs about 1 m thick volcanic rock layer, called khewraite, which is a new rock type (Mosebach, 1956) found so far only in Pakistan. This is followed by red shales and purple sand-

stones (Khewra sandstone) that carry ripple marks, rain prints and conglomeratic facies at the top; all hinting towards changing conditions of sedimentation. The overlying shales of the Kussak Formation are important as these carry trails and burrows of trilobite fauna which flourished in the Lower Cambrain sea. In the succeeding sandstone and dolomite successions, we find a sequence of shales (Baghanwala Formation) that are famous for beautiful cubic (sandy) caste of salt crystals. Thus, geohistory of the Salt Range during Precambrian to Lower Cambrian period shows that the area had passed through a complete cycle of continental to marine and again to continental conditions.

A great break in sedimentation occurred due to orogenic uplift and tilting eastwards that caused erosion over a time period of more than 400 m.y. After this, the Salt Range suffered intense glacial activity in the Lower Permian Tobra Formation bringing in rock boulders even from a far as Rajasthan in the south but ultimately coming under marine transgression when sandstones, limestones and clays were deposited. Another break in sedimentation occurred in late Mesozoic when the region was uplifted, tilted westwards, and eroded strongly thereby producing red lateritic beds. This action was followed by marine invasions from south and west when Lower Eocene fossiliferous limestones and shales were deposited and the Kohat (Trans-Indus Range) Salt was emplaced. Once again, there was a break in sedimentation till fresh water and lacustrine Murree rocks of Miocene age were deposited as thousands metres thick sequence followed by a cover of Siwalik Group rocks, Quarternary gravel and soil in the Potwar-Kohat basin (Fig. 8). Eastern extension of the Salt Range has been found in the Indian-held Kashmir where even salt is being mined at Mandi. In the west, tear faults terminate the Salt Range near Indus River, beyond which lies the Trans Indus Range.

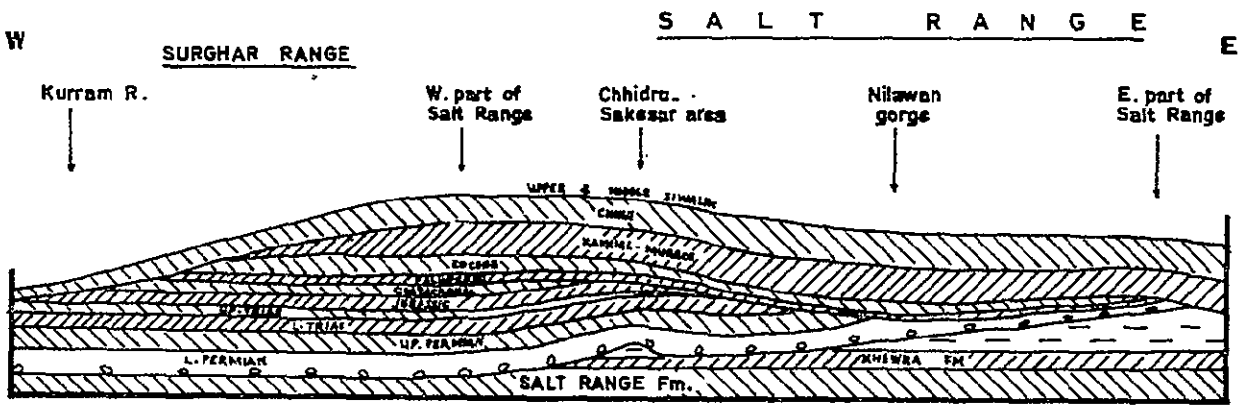

Fig. 8. Sketch Section showing the lithologic successions in the Salt Range and Trans-Indus Surghar Range, including effects of Eastwards and Westwards tilting.

In the Trans-Indus Range, salt belongs to Lower Eocene and shows diapiric intrusions into cores of anticlines (Bahadur Khel-Jatta), which could have been caused by plastic mobilization of older saliferous formations. The Himalayan orogeny in the Late Tertiary—Pleistocene times generated major thrusts and regional folding that affected Surghar and Khisor Ranges and separated the Kala Chitta—Tirah highlands from the Potwar—Kohat region.

According to seismic investigations, the Salt Range appears as the leading edge of a decollement (detachment) thrust (Seeber et. al 1981) rooted in the salt-bearing horizon of the Salt Range

Formation (Fig. 9). The decollement activity is considered to absorb much of the seismic stresses and thereby prohibiting diapiric intrusion of salt (in contrast to Trans-Indus Range) and also damping severity of earthquakes in the region. According to one view, the Salt Range originally had Himalayan trend but suffered anticlockwise rotation and southwards transport along the Jhelum fault to its present location (Crawford, 1974). Southwards transport along the Jhelum fault can be active even presently.

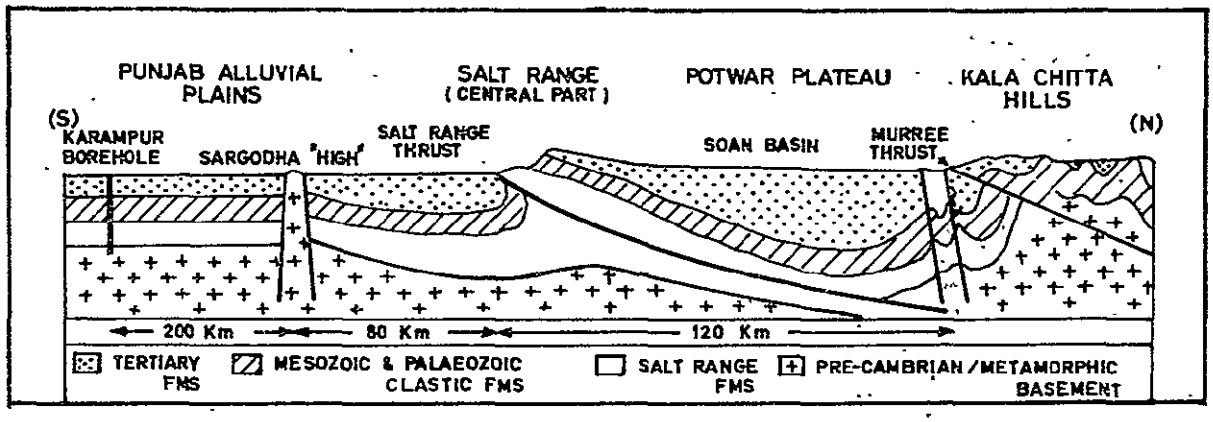

Fig. 9. Showing decollement Thrust (Salt Range Thrust) after E. R. Gee (1963)

The Potwar and Kohat Basins

The Potwar and Kohat Basins with their Siwalik sediments are bounded by Kala Chitta and Margala Ranges in the north and Salt Range and Trans-Indus Range in the south (Fig. 7). Structurally, the Potwar is a folded syncline with the NE-SW axis plunging southwestwards; a large number of synclinal and anticlinal structures run in the same direction. In some of the anticlines, like Khaire-Murat, Bakrala and Cherat, Eocene and older strata are exposed unconformably below Tertiary sediments. Fold intensity increases both towards north as well as towards south, while convergence of folds is seen in the Jhelum re-entrant which provided ease for the river Jhelum to erode its course through sheared rocks. Similarly, Potwar structures terminate in the Kalabagh—Kohat syntaxis in the west. Influence of the Himalayan orogeny is evidenced, not only in terminating Muree deposition of southern provenance but also by increasing its influence on sedimentation successively from Miocene to Pliocene and eliminating in Pleistocene.

The fresh water clastic pile of more than 5 000 m thick is composed of sandstones and mudstones at the Lower stage, sandstones at the Middle stage and changing to conglomerates at the Upper stage. Widespread facies changes and lithologic interfingering were caused by changing drainage directions and regional tectonics. For example, palaecurrent measurements have shown that prior to about 5 m.y. B.P., River Indus flowed towards ENE across the Eastern Potwar and was replaced by a S-flowing River Jhelum between 4.5—5.0 m.y. B.P. It is, therefore, possible that ancestral River Indus was discharging into the Bay of Bengal rather than into the Arabian Sea (Reynolds, 1981). Theis phenomenon happened when a drainage-divide developed between Sutlej and Jamna Rivers. The Plio-Pleistocene sedimentary component is world famous for rich vertebrate fauna that had attracted attention of geologists as early as 1823. Post-Siwalik sedimentation is evidenced by Lei-type conglomerates with

sandy and silty layers, the latter considered as a wind-blown material that coincided with sudden disappearance of old human culture (Soan culture) in Potwar. Presently, the cover of loess-soil is suffering erosion and denudation at an alarming rate.

The magnetic polarity studies (Johnson et al, 1982; Javed, 1984) show that basal sedimentation in the Potwar area was older than in the Kohat basin. Further differences are seen in structural style; for example, in contrast to the Potwar Basin, conformable nature of Siwalik sediments exists in the Trans-Indus Basin which indicates rapid erosion having kept pace with the basinal subsidence.

The Hill Ranges

Structurally, the Hill Ranges north of Potwar-Kohat plateau belong to a single block that extends to southern Kohistan in the north and between Hazara and Safed Koh in the east and west, respectively (Fig. 7). Characterized by a single decollement surface (Seeber, et al., 1981), the Ranges expose older rocks by means of major ramp faults: Precambrian to Palaeozoic in the northern Ranges and Jurassic, Cretaceous and Tertiary in the southern Ranges. These thrust faults close together south of the Safed Koh and join the active Sarobi fault to the west of Waziristan.

The Mesozoic and Tertiary formations of the southerly Ranges are marine and fossiliferous that correlate with the comparable age-units of Sulaiman–Kirthar Ranges but show contrast in the eastern limits. The northerly Ranges, however, correlate satisfactorily with the Hazara Formation of Precambrain age, although former contains quartzite and limestone that differ from that of Hazara as well as of Salt Range. Westwards, however, Attock slates correlate with the Landi Kotal slates. Thus continuations and variations of beds reflect influence of orogenies in this region.

At Nowshera, in the Peshawar Basin, a fossil reef has been discovered (Stauffar, 1967) which has Silurian–Devonian fossils and provides cutstones for building purposes. Extensions of this reef have been found both towards east and west, indicating the wide shores of a Palaeozoic sea.

The Lower Himalayas–Southern Kohistan Zone

Beyond the Plio-Pleistocene basins of Peshawar and Campbellpur (to be discussed later) lies the Lower Himalayas and the Southern Kohistan Zone that extends upto MMT in the NW Pakistan and Indus suture line in Kashmir across the NE-trending Nanga Parbat–Haramosh massif (Fig. 10).

The Salkhala Series of Precambrian age are the oldest rock formation, composed of argillites with characteristic graphitic schist association, that make sporadic outcrops in NW Pakistan upto Mohmand Agency. Succeeding are the pelitic Hazara slates, Manki slates, Landi Kotal slates and the Lower–Swat Buner schists. These are overlain by Tanol quartzites that extend towards west and interfinger with Nowshera reef limestones. It is interesting to note that west of Indus River, thick calcareous formations are prominent that are mainly of Palaeozoic age but, at places, of Mesozoic age as well. The sediments are strongly metamorphosed and intruded by large sheet-like bodies of granites of Lower Palaeozoic age such as the Hazara granite, Lower Swat granite etc. with younger bodies of tourmaline and epidote granites. Aplites and pegmatites are related to heights/stratigraphic levels in the complexes (Shams, 1983).

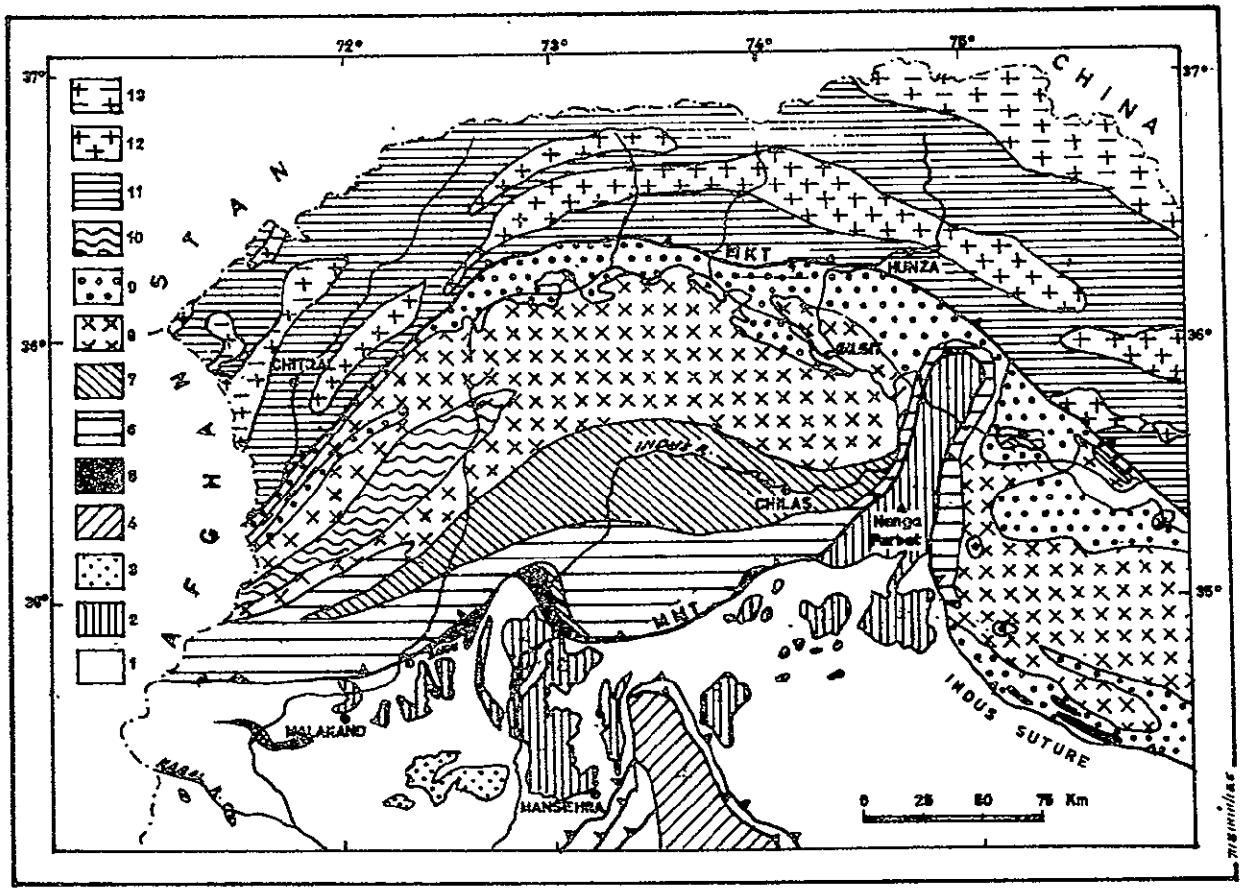

Fig. 10: (1) Precambrian to Mesozoic sedimentary rocks of the Indo-Pakistan Plate; (2) Cambrian granitic rocks; (3) Early Tertiary alkaline to subalkaline igneous rocks; (4) Middle Tertiary clastic sediments; (5) Ultramafic ophiolites; (6) Amphibolite belt; (7) Chilas-Jijal mafic complex; (8) Kohistan-Ladakh (Transhimalayan) granitic rocks; (9) Cretaceous sediments and volcanics of Yasin; (10 Creto-Eocene sediments and volcanics of Kalam-Dir area; (11) Sediments and Metasediments of the Karakorum Plate; (12) Khunjerab-Wakhan Tirichmir granites; and (13) Karakorum granitic belt. MMT: Main Mantle Thrust; MKT: Main Karakorum Thrust.

In Lower Swat, unique outcrops of alkaline complexes are found in the Chamla Valley and Silai Patti in Dir. Igneous carbonatite rocks are associated that contain apatite and rare earths of economic value. It is believed that subducting Indo-Pak plate suffered regional fracturing and upwarping that allowed volatile and gaseous components to concentrate giving rise to alkaline complexes and carbonatites (Shams, 1983). The association of carbonate sediments is characteristic. These complexes of Lower Himalayas were first to be discovered in Pakistan (Siddiqui et al., 1968; Kempe, 1983) before those were identified in India. In certain cases, such as in the Shewa porphyries complex in Mardan, systematic variation in rock compositions had occurred due to repeated extensional and compressional episodes of the subducting Indo-Pak plate (Nawaz & Shams, 1983). This Alkaline Igneous Province is believed to be present also below the Peshawar Plain and extends to the Warsak Dam area on the west and Tarbela Dam area in the east (Kempe, 1983).

The Nanga Parbat—Haramosh Zone

A unique feature of the NW Himalayas is the Nanga Parbat—Haramosh massif that trends NNE, almost transverse to the regional NW trend of the Himalayas; no such feature is seen anywhere in the entire Himalayan Range. North of the Haramosh massif, however, the Karakorum system shows an uninterrupted regional trend similar to the Himalayas. Lithologically, the Nanga Parbat massif is similar to the Higher Himalayas, particularly as regards its migmatitic nature, the occurrence of younger tourmaline granite stocks and minor intrusives. The major rock types are composed of metamorphosed Salkhala sediments, with the grade of metamorphism increasing towards the central zone and ultimately changing migmatitically into gneissic-granitic complex that makes prominent domal structure (Misch, 1949; Shams and Ahmad, 1979). Such a situation is comparable to Higher Himalayas in the east as well as to the Hazara Himalayas in the west (Shams, 1969 and 1983). It is important to note that the Nanga Parbat is rising at a high rate of 1 cm/year (Zeitler et al., 1983). It is probable that the Haramosh massif is also rising at a similar rate; although tectonic interrelationship at its northern end is not known due to permanent snow coverage but northwards tilting of the Shigar river terraces shows its continued activity (Shams et al., 1983). Neotectonics have produced high rate of weathering as an important geomorphic feature of these massifs.

According to Desio (1976), the NP-H massif originally trended NNW but has rotated clockwise to acquire its present NNE-trend. This compares satisfactorily to the eastwards obduction tectonics of the Kohistan zone along the MMT (Coward et al. 1982, Shams, 1983) and shows complexity of tectonic movements in northern Pakistan when we consider that the Salt Range is thought to have rotated anticlockwise (Crawford, 1974).

The Axial Belt Zone

This important zone is bounded by the Chazaband and Zhob Faults in the East and the Chaman Fault in the West. In the north, the Zhob Fault ends against Main Boundary Fault (MBF) while the Chaman Fault joins the Sarobi Fault north of Kabul, with an eastern branch (Gardez Fault) abutting against the Sarobi Fault east of Kabul. The Chaman Fault joins the Ornach-Nal Fault Zone that enters Arabian Sea south of the Makran coast. (Fig. 4).

The Chaman earthquake of December, 1892 brought to light the existence of this left-lateral fault when it offset the Quetta-Chaman railway line (Griesbach, 1893). The fault separates constrasting rock formations and, therefore, can be taken to mark western boundary of the Indo-Pak plate. The fault zone itself is composed of rock gouge, up to 1 km wide, composed of clastic sediments, bosic and ultrabasic rocks, fossiliferous limestones and sheared basement rocks. At many places, it is covered by fan gravel and alluvial. The field survey shows about 200 km slip along the fault, with the magnitude of displacement increasing in segments southwards and therefore having increased seismic activity towards south.

The area east of the Chaman Fault is composed mainly of flysch sediments as a shale-sandstone sequence with associated mafic and ultramafic bodies and dykes that constitute typical ophiolite complexes, mainly the Bela, Muslimbagh and Waziristan complexes. In fact, these bodies lie over ophiolitic melanges that are composed mostly of sedimentary and metamorphic formations and ophiolitic rocks. The exposed ophiolites are considered as fragments of an overthrust sheet that lost its

coherence during final stages of emplacement (Abbas & Ahmad, 1979). Geophysical surveys have shown that basement to the ophiolitic melange is composed of continental crust belonging to Indo-Pak plate. The ophiolitic bodies were emplaced during Paleocene—Lower Eocene times.

The Main Mantle Thrust Zone

As has been mentioned already, northern Pakistan has two prominent palaeo-sutures, MKT and MMT; the MMT is the name given to western continuation of the Indus suture across the Nanga Parbat—Haramosh transverse antiform (Fig. 10). Although occurrence of the Indus suture at the southern edge of the Deosai—Ladakh plateau was known for quite some time, the MMT was recognised only in 1962 but simply as an upthrust fault (Martin et al., 1962). It was in 1971, that occurrence of blue schists was discovered in Swat segment of the MMT zone (Shams, 1972) that established its status as an indicator of subduction zone of the Indo-Pak plate. In 1974, blue schists were discovered also in Kashmir Himalayas (Virdi et al , 1977) after which plate tectonic models for the Himalayas could be proposed on sound basis (Desio, 1977; Tahirkheli et al 1979; Le Fort, 1975; Bard et al , 1980).

The MMT zone is a pile of many fault—separated tectonic slices of ophiolitic melanges which had developed above the subduction zone that was active during Jurassic—Cretaceous closure of the Tethys. The melange consists of blue schists, Mesozoic fossiliferous carbonates, pillow basalts and serpentinito blocks, the whole complex having obducted on to the northern edge of the Indo-Pak plate (Arshad and Shams, 1983). Absolute age of the blue schists was found to be 84 m.y. B.P. which gave an average rate of 10.7 cm/year for northwards drift of the plate (Shams, 1979). The occurrence of blue shcists shows that the MMT zone represented a fossil trench zone which provided suitable environments for high water vapour pressure and low temperature necessary for the formation fo these unique rocks.

The MMT zone extends westwards, with sporadic occurrences of basic and ophiolitic rocks, till it enters Afghanistan across the Mohmand Agency. In Dargai, a large block of ophiolitic complex had moved southwards over a distance of nearly 40 km (Hussain et al , 1984), while at Jijal a large slab of mantle origin had thrusted up along a shear zone (Jan and Howie, 1981, Lawrence et al 1983). Further east, the MMT swings northeastwards and after swirling around the Haramosh massif trends southeastwards as the Indus suture to join the Dras ophiolitic zone in Kashmir. Further east, the Indus suture zone joins the Shyok suture zone which is the eastwards continuation of the MKT.

The Kohistan—Deosai Zone

This zone is limited by the MMT in the south and the MKT in the north (and between Indus and Shyok sutures east of the Nanga Parbat—Haramosh orogen) that developed during Cretaceous. Seven main rock formations can be recognised (Shams, 1975; Bard et al., 1980), from south to north (Fig. 10).

(1) Southern Amphibolite belt, containing ultramafic intrusions, developed due to metamorphism of basaltic lavas and tuffs, and locally originating from sediments.

(2) Diorite belt, that shows change to granitic components with acid pegmatites and aplites.

(3) Norite belt, originated from a differentiated aluminous basic magma with whole series of basic rocks to pegmatitic bodies and younger ultramafic intrusives. Tectonic metamorphism had changed the rocks into granulites.

(4) Northern Amphibolite belt, as striped rocks having formed from volcanic material, even pillow structure is still seen in the upper parts of the belt.

(5) Metasedimentary series of Kalam and Dir, having transitional relations with amphibolites, and mainly composed of shales, greywackes, tuffs, cherts and marbles.

(6) Calc-alkaline volcanic series of Utror, partly aerial, and having characteristics of an island arc association.

(7) Detrital series, constituting boundary of the Eurasian plate along the MKT, composed of polygenic conglomerates and volcanic flows on the top.

Intrusions of younger granites and diorites are found particularly in the northern part of the Kohistan zone. The region has been explained on the basis of subduction of Indo-Pak plate beneath the Eurasian plate (Fig. 11). The fused edge of the subducting plate gave rise to volcanics and younger plutonic intrusions, a typical form of a volcanic Island arc. Similar situation, both lithologically and tectonically, is found in the Deosai–Ladakh plateau east of the Nanga Parbat–Haramosh transverse antiform. This is a situation comparable to the Chagai Eruptive Zone in Baluchistan, although the subduction zone there lies in the Arabian sea about 100 km south of the Makran coast. Due to obduction processes, the volcanic Island arc of Kohistan has come closer to the fossil trench zone.

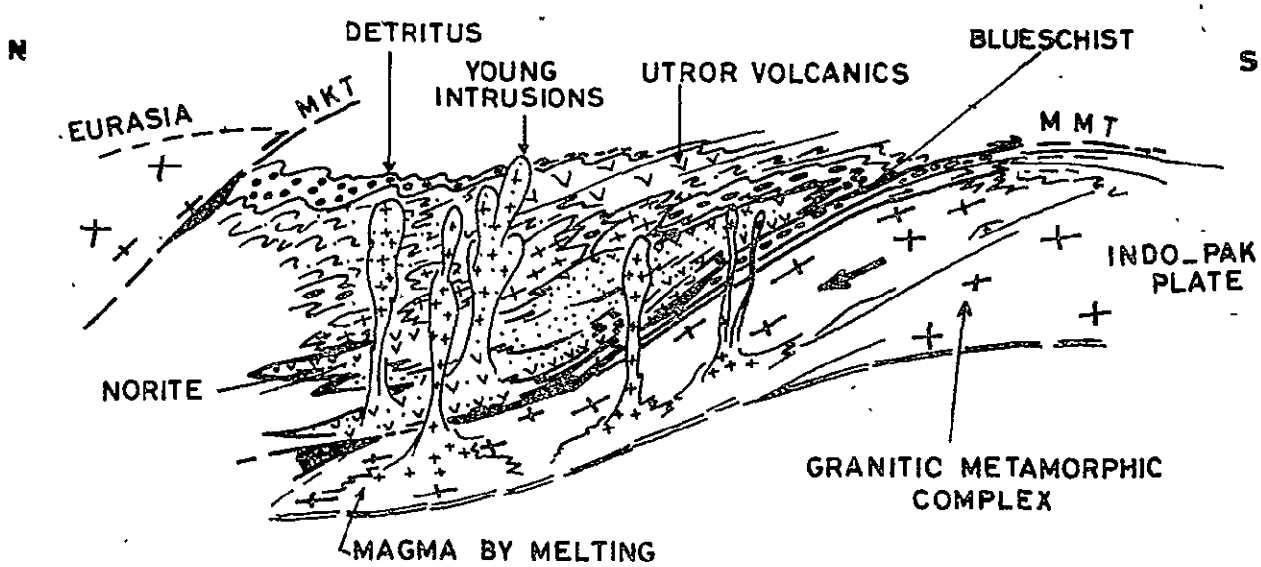

Fig. 11. Plate subduction model for the evolution of the evolution of the Kohistan (fossil) volcanic arc (after Bard *et al.*, 1980).

The Inter-Montane Basins

Although considerable volume of surface and subsurface information on the vast Indus Basin is available yet very little is known about the origin and geohistory of high level Plio-Pleistocene inter-

montane basins of northern Pakistan. Prominent among those are the Peshawar Basin, Pakhli Basin, Campbellpur Basin and Kashmir Basin. These are discussed taking Peshawar Basin as an example.

The Peshawar Basin is bounded by the Attock–Cherat Range in the south which had provided physical barrier to Peshawar depression after the Range was uplifted by N-dipping thrust faults. The basin sediments consist of conglomerates, mudstones, siltstones and volcanic ash beds up to 2 m thick. The deposition of sediments in the Basin started about 2.8 m.y. B.P. at a rate of 15 cm/1 000 yr.; presently, more than 300 m thick sediments are present. After about 0.2 m.y., continued plate compression and uplift of the Attock-Cherat Range caused progradation of alluvial fans towards north at a rate of 2 cm/yr. After increased rate of uplift of the Range, sedimentation was generally stopped about 0.6 m.y. B.P. (Burbank, 1983).

Detailed investigations of sedimentary pile of the Peshawar Basin has shown (Burbank, 1983) that it suffered repeated catastrophic floods; for example, at least 40 such floods had occurred during prehistoric times. Historical records are available of 1826, 1833, 1841 and 1857 floods (Abbott, 1848; Cunningham, 1854; Belcher, 1859). Most of these floods occurred due to outbursts from river Indus after having suffered natural damming by landslides or glaciers. During 1841 flood, the Indus rose by about 30 m at Attock within a period of only 4 hours and brought considerable havoc inundating Nowshera. Repitition of such a phenomenon can happen again which may cause much damage even to the Tarbela Dam.

Comparative studies have shown that age of the Peshawar Basin is intermediate between the Campbellpur and the Kashmir Basins which are 4 m.y. and 2 m.y. B.P. respectively (Burbank et al, 1985); this shows localized effects of Himalayan orogeny within its different segments.

Main Karakorum Thrust Zone

The Kohistan–Deosai fossil Island arc is limited (Fig. 10) in the north by a prominent tectonic scar, the Main Karakorum Thrust (MKT). Like the Indus-Kohistan zone, it is composed of many lithological formations.

From S to N, we first encounter the so called Greenstone Complex (Ivanac et al , 1956) or the Chalt Greenschist Zone (Desio, 1974) which extends from Shyok in the east to beyond Laspur in Chitral and even into Afghanistan. The formation has a typical green to yellowish green colour and is composed of basaltic to andesitic volcanics erupted in a basin, and, therefore, mixed with metamorphosed deep marine sediments; near Chalt, beautiful pillow lavas are present. Fossils present in basal slates give Cretaceous age which is also shown by involvement of the rocks in Alpine orogeny.

Overlying the Greenstone Complex from Baltistan in the east to Chitral in the west are the isolated lensoid bodies of Yasin Group composed of fossiliferous limestones, conglomerates and volcanics of Cretaceous age. The region represents the squeezed linear belt of Tethys between the Eurasian plate in the north and the Kohistan – Deosai complex in the south. As no blueschist rocks are known to occur in the MKT zone, it does not have the status of a subduction zone like the MMT. According to one view, this could be a back-arc basin opened during subduction of the Indo-Pak plate along the MMT.

The Karakorum Zone

North of the MKT, outcrop Palaeozoic carbonatic and shaly-sandy flysch formations of the Darkot Group that represent materials laid in the Hercynian geosyncline. Towards north, these rocks are strongly metamorphosed including the gneiss-marble belt that contains Hunza rubies. Further north, outcrops the so called Karakorum Axial Batholith that makes a long arcuate outcrop extending beyond Baltistan in the east and near to Mastuj in the west, making the Karakorum Mountain Range. It is a composite body of granodioritic to granitic composition with younger aplites and pegmatites. The higher age range is older than the Alpine orogeny, showing that the region had suffered Alpine activity. It is interesting to note that in eastern Karakorum, its intrusive activity cuts through sediments/conglomerates that contain pebbles of the same granite. Thus, polyphase tectonic activity is proved—Alpine over Hercynian. Like the Himalayan zone, grade of metamorphism increases towards higher levels in the lithological sequences, showing inverse metamorphism.

North of the Axial Batholith, Palaeozoic and Mesozoic rocks are again exposed which are, however, very little metamorphosed. At places, beautiful syenite and granite plutons intrude the formations with swarm of dykes and sills.

The Karakorum Range is the home of world famous glaciers and high peaks, including the majestic K_2.

The Eastern Hindu Kush Zone

This Zone is mostly exposed in the Chitral District of N.W.F.P. and consitutes eastern extension of the Hindu Kush Range that mainly lies in Afghanistan. The oldest rocks exposed in Chitral are gneisses, slates and marble of Devonian age, slates merge with the Darkot Group near Mastuj and are similar lithologically to Hazara, Manki and Landikotal slates of Lower Himalayas.

The youngest sediments of Tethyan affinity are grouped as Reshun Formation (Hayden, 1925; Talent et al., 1979) composed of conglomerates, argillites and limestones of Cretaceous—Lower Tertiary age. At least as far as conglomeratic facies are concerned, similar formation is seen in Mount Shanoz in Upper Hunza and in Choga Lungma area NE of Haramosh. Thus, a regional belt of conglomerates is found from Chitral in the west to Baltistan in the east.

Gravity work has shown that in the Hindu Kush, a NE-SW trending anomalous zone has developed due to interaction of upwarping Himalayan trend and the downwarping Chaman Fault trend (Marussi, 1979). The interaction zone is the nest of intermediate earthquakes that shake NW of Pakistan, including the devastating Pattan earthquake of 1973. It is considered that the zone may represent downgoing region of disrupted leading edge of the Indo-Pak plate.

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GEOMORPHOLOGY OF PAKISTAN

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ABSTRACT

Before the inception of Soil Survey of Pakistan, country-wide orderly investigation and classification of landscapes had not been undertaken by any organisation. For the purpose of identification and mapping of soils, study of landforms has been a prerequisite. Keeping in view all the available information on geology and landforms, the geomorphology of the entire country has been systematically studied using aerial photo-interpretation and extensive ground check.

The hierarchal system used to study geomorphology of the area includes three categories: the landtypes, landforms and landform units. According to this system, six major landtypes have been recognised throughout the country. They are River Plains and Terraces, Indus Delta, Loess Plains, Piedmont Plains, Rock Plains and Mountains. The geomorphological units are shown on the accompanying map at a scale of 1: 5 000 000.

The River Terraces include well-defined Bar Uplands of the eastern Punjab, Modified Sandy Terraces of Peshawar Vale and Attock, and Dissected Silty Terraces of Soan river catchment. In addition, all the components of the floodplains, and the Indus Delta have been identified as separate landtypes.

Loess Plains are formed in distinct, highly erodible silty aeolian materials deposited in three sequential stages during the Pleistocene. Depending upon the configuration of the basement rocks, the climatic conditions and past erosion, this landtype has acquired a very peculiar configuration. Four component units have been defined: Level Plains, Dissected Plains, Gullied Land and Fluviated Loess Plains. The latter has formed in erosion products deposited in structural troughs situated in the vicinity of the eroding Loess Plains.

The Piedmont Plains are the major landtype occurring at the foot of the mountains. Depending upon the age, three types of surfaces have been identified: Pleistocene, Subrecent and Recent. The surface configuration in all the three cases is similar but the nature of sediments varies. The Pleistocene sediments have been subjected to severe geologic erosion and at present some surfaces have been carved out as terraces, which are sandy, stony or conglomeratic in nature. The Subrecent Plains represent the entire sequence of Piedmont surfaces: Alluvial Fans, Alluvial Plains and Basins. In arid part the basins are undrained and have developed Playa Lakes.

Rock Plains consist of rocky area with subdued relief. In arid parts the rockplains show no significant weathering. In semiarid and subhumid parts they have weathered

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to varying degrees depending upon the angle of dip and effective precipitation. Two landforms have been distinguished: Undulating Rock Plains and Ridge-and-Trough Plains. Both have very peculiar configuration.

Northern and north-western parts of the country are largely covered by mountains. Depending upon the nature of the formations, several landtypes have been identified in this region. But due to low intensity of ground check only two types of mountains have been mentioned: Mountains with strong structural control and Mountains with strong slope control.

All the inaccessible areas or areas not considered feasible for study have been mapped as Miscellaneous Areas.

INTRODUCTION

Diversity and conspicuousness of landscapes are the two outstanding physiographic features of Pakistan. Prolonged orogenic disturbances, changing climates, unique hydrologic features and human activity have played significant roles in the sculpture of the landmass of Pakistan. Exclusively for the purpose of landscape classification and mapping of soils, the methodology adopted by the Soil Survey of Pakistan (Soil Survey Staff, 1963-83) includes landscape identification as a procedural entry based on the nature of the parent materials.

This presentation collates physiographic data obtained during the reconnaissance soil surveys undertaken utp 1983. It also incorporates an earlier attempt on the subject (Brinkman and Rafiq, 1971). The work of several other geologists, geomorphologists and geographers (Fraser, 1958; Hunting Survey Corporation Limited, 1960; Abu Bakr and Jackson, 1964; and Wadia, 1966); have also been duly considered. Landscapes have been studied by these researchers both as a spatial phenomenon and as a subject of classification and mapping. In this study, the morpho-genetic aspects of landscape evolution have been considered to develop a chronological hierarchy and hence the terminalogy for the landforms.

In this hierarchy, landtype is considered as the highest order of generalisation indicating positions on earth's surface which are geogenically and chronologically similar. Within each landtypes, there are several main landforms representing features which are morphologically similar and fall within the defined range of macro relief. The lowest category is landform units representing maximum homogeneity of surface conditions and similary micro relief.

METHODOLOGY

The study makes use of 1: 40 000 scale aerial photographs, taken under the Colombo Plan Project during 1953-54 and the systematic aerial photographic interpretation procedures (Goosen 1967 and Vink, 1963). Initially, "the pattern analysis" procedure was used for the study as the photo patterns are the picturesque representations of several soil conditions. Later, when the reference level of the field surveyors was gradually enhanced, the "physiographic procedure" of photo-interpretation was generally followed. The procedure includes the study of the processes involved in the formation of various landscapes. In both procedures, systematic stereoscopic study of aerial photographs was carried out to determine genesis and classification of the landscapes before undertaking regional field sur-

veys. Uncontrolled mosaics were used to obtain synoptic views of various main landtypes and to study the general lay of land as determined by the drainage patterns and relief. Field data was transferred from aerial photographs to 1:50 000 topographic sheets obtained from the Survey of Pakistan, with the help of sketchmasters or by matching features in case of poor quality photos. Final maps were printed at 1:250 000 scale.

Authenticity of the photo-interpretation units was checked in the field. Ground truthing was more intensive in the plains. In the hilly areas, consideration was also given to the secondary data collected from other agencies. Locally, the information on geology and geomorphology was improved, corrected and updated on the basis of direct observations. The approachable parts i.e. the colluvial slopes were studied in a little more detail.

It may be mentioned here that Soil Taxonomy (USDA, 1975), is primarily designed to stress morphological aspects of soils giving less attention to physiographic aspects. The present study directly correlates the soil categories with the physiographic features. Consequently, all the soils information is presented on the basis of well-structured physiographic format, keeping in view the significance of geological formations.

DESCRIPTION OF GEOMORPHIC UNITS

The following account is based on the surface configuration of the land surface, relative elevation, mode of deposition of the sediments, and the degree and kind of soil profile development as investigated during the course of reconnaissance soil surveys. The identification of stratigraphic sequence and ages assigned to different sediments were correlated with photo-image characteristics and the soil boundaries extrapolated accordingly. The geomorphic units described below are shown on the accompanying map at a scale of 1: 5 000 000

PLEISTOCENE RIVER TERRACES

The Indus River system has developed several kinds of terraces all along its longitudinal profile from the Himalayas to the sea. During the main part of the Last Glacial, this river system deposited mainly sandy material which largely served as the base of the terraces. Fines of this material were blown out to form loess. Late part of the Last Glacial is the period of deposition of mainly silty material, derived from eroding loess of the highlands of the Himalayas, on the existing sandy base of the river terraces. Partial down-cutting by the rivers started during the Early Holocene. As a result of river bank erosion, the silty material was removed and the rivers deposited fresh loamy and silty materials along their courses, with the concurrent onset of salinization of margins of basinal sites and channel infills. With the continued, severe, down-cutting as a result of sudden lowering of the base levels, probably by tectonics, the rivers were shifted to their present courses. As a result, the Old river terraces (Bar Uplands) were carved out. The rivers started building up their new floodplains, which is still continuous, resulting in the formation of three more subterraces: The Active floodplains, the Recent meander floodplains and the Subrecent (partly) covered floodplains. These terraces are discussed here as floodplains.

The terraces of the upper reaches of the Indus system are different in respect of the nature of sediments and their mode of deposition. These terraces have been developed in coarser materials deposited by flash floods during the Last Glacials. They are spread over relatively narrow stretches marked by sharp bluffs and very low existing stream courses.

Subrecent mesa type terraces have been developed in the alluvial plains of Peshawar Vale, Bannu Basin and Kohat. Gypsiferous mesas are encountered as tablelands in the Subrecent terraces of the lower reaches of the Indus beyond Multan. Most of these terraces are of negligible extent.

Level Bar Uplands (silty and loamy terraces)

The river terraces, occurring south-west of the vast Himalayan piedmont plains extending upto eastern part of the Multan District, are locally called as 'Bars' and occupy the central highest platforms lying between the courses of the adjoining rivers (Refer to map). In strict geomorphological terms these terraces represent flat tablelands characteristics of 'mesas'. These terraces are separated from the adjoining lower terraces by sharp bluffs of varying height from a few centimetres to about 9 metres. At places, these terraces merge with the younger terraces so insiginficantly that the old surfaces get buried under the Subrecent sediments.

The surface of the terraces is generally level and the old riverain features such as covered levees covered channels and indistinct basins, are barely discernible. Micro-relief differences owing to these features have a marked effect on the degree and direction of soil formation due to unequal distribution of rainfall and chances of salinization on convex and gently sloping sites. The following are the main component of this landform.

– Level plains: They are generally characterized by advanced stage of soil development, well developed soil structure, stronger and brighter soil colours and presence of generally a thick kanker zone. Slightly higher and convex parts are loamy and level to very gently sloping parts are silty.

– Broad indistinct basins: Level but very indistinctly concave parts collect run-off during heavy downpours. The soils are fine textured. In subhumid zones they are non-saline but in semiarid parts the basins have developed salinity/sodicity.

– Covered channel–levee remnants: Assemblage of partly covered channels and levees are the most conspicuous features of the terraces. They break the monotony of the landscape because of not only relief but also the associated problems of salinity, waterlogging and locally by falling out of the canal commands.

– Terrace escarpments: These represent eroded edges of the terraces and include bluffs and assoicated gullied land facing the level Subrecent terraces downwards. Kankar zone is at or near the surface. Soils are generally saline-sodic.

Dissected Silty Terraces

During the Pleistocene epoch, Kurram and its tributaries deposited fine silty material in the Bannu Basin (Refer to map). The process of down-cutting starting in the Holocene period dissected

this terrace and imparted it the present configuration. The uneroded parts provide evidence of erosional cycles. Soils have lime accumulation zone and are well-structured, showing advanced stage of development on level parts. However, on sloping parts the direction of soil development turned to form saline soils. Small patches of dissected terrace occur in catchment areas of the Soan river and its other tributaries.

Undulating Sandy Terraces

The mighty Indus deposited enormous sandy materials as a result of flash floods during the Pleistocene (Refer to map). Three major terrace sites are discussed: Swabi Maira in Peshawar Vale, north-western part of the Attock and north-estern part of Kohat. A fourth terrace is located near Talagang. Its material is deposited by Soan river and its tributaries. The terraces are marked by high escarpments. The surface is generally gently undulating to undulating. Wind action has modified the surface of these terraces considerably. Rolling relief in the Swabi Maira is, in addition, attributed to tectonic disturbances as, locally, big boulders are found on the surface, indicative of uplifted river bed material.

The sediments of these terraces may have some admixture of loess. Major part of these terraces has been severely dissected. Soils in the remaining parts show advanced stage of soil development. Several subdivisions of these terraces have been recognised: level plains, basins and channel infills, Subrecent valleys, rolling and undulating plains, and outwash aprons.

SUBRECENT LEVEL TERRACES

Although not very significant extent-wise, these terraces are unique specimens of geomorphological interest.

Kabul and Swat Terraces

Kabul and Swat rivers have peculiar longitudinal profiles in the Peshawar Vale. Upon emergence from the mountain gorges, the rivers are split into well-defined courses which have not shifted so frequently. It appears that the branches follow some fault lines in the basement rocks. As a result of regular flooding and truncation process, these tributaries have sculptured small very prominent terraces flanked by characteristic floodplains. Profile development indicates that the maximum age of these terraces could be Subrecent. Such terraces are mapped in some other valleys also but the extent is too small.

Gypsiferous Terraces

Another important member of the Subrecent terraces is the Gypsiferous terraces mapped in several areas in Sind (Khairpur, Tharparkar, Sanghar and Hyderabad districts) and in some areas in the Punjab (Vehari, Muzaffargarh and Rahim Yar Khan districts). They always occur higher than the adjoining floodplains. In their surface configuration, they resemble the Bar uplands of the Punjab although these terraces are not separated by high escarpments. Nevertheless, the elevation differences are very conspicuous. The terraces gradually disappear under the flood plains. At places an escarpment as high as one metre is observed. Because of scale limitation these terraces are included in map unit 'Subrecent Flood Plains'.

FLOOD PLAINS

This landform is characterized by presence of relatively exquisite riverain features scuh as levees, backslopes, backswamps, meander scars and abandoned channels. Generally, three main surfaces have been observed in the country, depending upon elevation and relative conspicuousness or obscruity of the constituent riverain features. As a result of differential moisture distribution (from run-off collection and floods), the salient features of floodplains are clearly discernible visually and on the aerial photographs. Relief conditions can be easily perceived under the stereoscope.

Characteristic floodplains are only mapped in the Punjab and Sind provinces. In the remaining areas the floodplains represent minor areas along the streams which have attained their local base levels. Very often the landform units associated with these floodplains are neither prominent nor mapable.

Three major subdivisions are observed on the basis of criteria mentioned above. Recent floodplains, Subrecent floodplains and Subrecent deposits on old river terraces. They are discussed below chronologically.

Recent Floodplains

Generally speaking, this landform can be distinguished into active river channels, flooded land and Recent meander floodplain (Refer to map). The former two elements are too unstable and are subject to river erosion and sedimentation and hence to continual geographical changes. The other component occurring as a narrow belt along the river, has attained certain degree of stability from seasonal floods. This belt covers areas lying above seasonal flood level. The surface configuration is almost similar to the actively inundated parts. Proportion of sandy levees is relatively lower than that of flat suface. Soil formation processes have, however, not yet started.

Subrecent Floodplains

This is invariably the most extensive landform of the irrigated parts of the country (Refer to map). River flooding is very infrequent although run-off collection and effect of seepage water is consistently inducing an lement of instability and mode of soil formation towards negative direction. On the basis of the surface configuration and the nature of sediments the following subdivisions are observed:

- Level plains: They have been formed through sedimentation by slow-moving spill water during high floods in the past. The material is predominantly silty and fine silty. Evidences of lime redistribution are absent. On the parts having insignificant relief variations, situation is favourable for salinization and poor drainage. Phenomenon of polycyclic profiles is observed in several areas indicating at least two-stage depositional cycles.

- Shallow basins and infilled channels: They occupy low general position in the landform. It has been formed by vertical accretion of fine soil particles from stagnant water collected from high floods. All the abandoned riverain features like backswamps, backslopes and river beds have been filled up to form this unit. The surface is nearly level but concave.

Soil material is fine silty and clayey. Due to collection of run-off during high rainfall season, the unit remains wet for considerable periods. Fringes of such units or slightly raised parts within it, are favourable sites for salinization/sodication.

Channel-infills are different from basins in being narrow and meander-like in nature. Higher parts of the channels have locally been completely filled up as level plains. As a result, all the abandoned channels cannot be traced even on aerial photographs. Margins of channels have been exclusively salinized.

Levee remnants: Larger parts of the original levees have been covered; only the highest crests are observable. As such, the surface of the unit is highest in the landform. Locally the levees have been completely covered by slow-moving silty sediments leaving only the convex level plains. Margins of the covered levees are locally saline.

In some areas the levees were too high to be covered by sheet flood sediments. As a result the sandy deposits have been subject to wind action raising the level of the natural levees too high to be used for any agricultural purposes.

INDUS DELTA

The Indus delta comprises the southernmost part of the vast Indus basin. Its landforms are markedly different from those of the river floodplains. Both fresh-water and salt-water tides have influenced the sedimentation pattern in this part. The delta comprises two main divisions: an estuary plain formed of tidal river spill deposits, and a coastal belt constituted of marine tidal sediments (Jalaluddin et al 1970).

Estuary Plain

It (Refer to map) is constituted of a variety of distinctly different landform units: vast spill flats, and numerous basins, spill heads, meander bars and levees. The spill flats are level to nearly level and are made up of extremely well sorted, silty materials. The basins are occupied by deep clayey sediments. The levees and bars are nearly level to gently sloping and predominantly silty. Along with the spill heads, they occupy highest positions in the landscape. The spill heads and a few high meander bars are fine sandy.

The sedimentation sequence in the estuary plain consists of very fine sands at the spill heads, silty materials on the flats and silty clays/clays in the basins, each separated from the other by a relatively abrupt boundary. The spill sediments making up the flats contain higher proportion of silt and less clay than their counterparts in the normal river plains. This extreme sorting occurs during sedimentation under fresh-water tidal flooding. It happens when high river discharge is blocked by rising sea tides, causing release of large volume of river spill flowing overland at an even speed and inundating the whole surrounding. During this flow, mainly the silt fraction with little very fine sand or clay settles on the spill flats.

Coastal Belt

The coastal belt (Refer to map) is subject to regular tidal flooding ranging from twice a day in the depressions to fortnightly on higher sites. Most of the area is covered by clayey tidal flats with some silty tidal ridges. A small part comprises clayey tidal basins. Tidal lakes, coastal playas and channels/creeks account for the rest of the area.

The river water at the lower reaches of the estuary plain contains mainly dispersed clay and fine silt. As it comes in contact with the salt water of sea tides, the fine sediments coagulate to form fine silt-sized aggregates. The clay, thus, ceases to behave like clay in sedimentation. This gives rise to extensive, level, clayey tidal flats in comparison with the silty estuarine flats.

LOESS PLAINS

In the highlands, the most striking Upper Pleistocene material is loess. It is unconsolidated, nonstratified and largely homogeneous. The particles are dominantly silt-sized, yellowish brown in colour and nearly rounded in shape.

The main source of this material is postulated to be the extensive sand plains occurring along the main ancient rivers. The material had been annually picked up by the cyclonic winds during the Older Glacials before the outbreak of seasonal monsoons and deposited probably together with snow.

During this study, two distinct loess covers were recognized, the lower one denser and mottled and the upper more porous and softer. A third deposit has also been identified in certain exposures. The loesses are intercalated with thick piedmont or river bed materials. At places the upper loess rests directly on the bed-rock. At the time of deposition the periodic loess mantles covered all the existing land surface like a blanket. The present relief is however, attributed to later erosion and subterranean surface conditions of the basement rocks. In general, the loess mantle was eroded swiftly and easily from the sloping surfaces. During the following summers, the frozen loess thawed and moved down. Melt water acted as lubricant over the frozen ground for the movement of migrating loess.

The conditions mentioned above are supported by the presence of a fragipan in the loess deposits. It is one to two metres thick and has essentially been formed by alternate freezing and thawing over a permanently frozen substratum. Polygonal pattern of permafrostic surface has also been locally observed.

Erosion of the loess landscapes due to torrential rains continued during the Holocene period and is active even at present. Consequently the following three landforms have been recognized.

Level Plains

The level table lands (mesas) represent the parts of loess landscapes which escaped from gully and/or sheet erosion (Refer to map). In humid parts the soils show an advanced stage of soil development: decalcification, presence of argillic horizon and a thick lime accumulation zone. On the other hand soils in the subhumid and semiarid zone are not completely decalcified.

Locally, gently sloping plains are also included in this landform. Sheet erosion is active and has removed a part of the soil material from the surface. The lime accumulation zone is encountered at a shallower depth.

Dissected Plains

These are by far the most extensive plains of the loess landscape. This landform (Refer to map) occurs on a relatively lower elevation than the level plains. The surface is gently undulating to undulating. On different slopes, degree of soil formation varies considerably. On the basis of past erosion and topography, this landform can be split into the following units.

– Gently undulating/sloping plains: The topography of this unit is possibly controlled by the unevenness of the basement rocks. Periodic tectonics have also played their role in shaping this unit. Rill erosion is common although gully erosion is also moderately active. The soil mantle is still intact but the variability of the degree of soil formation is suggestive of the fact that erosion is most active on lower slopes, moderate on middle slopes and least on the upper flat parts. Catenary relationships of soils of this unit are very well established throughout the country.

– Undulating plains: This unit is characterized by presence of numerous gullies. The interfluves between the adjacent gullies are subject to sheet erosion, whereas, the areas adjacent to gullies are eroded by undermining action of the local channels which have nearly reached their local base levels. In certain areas where peneplanation is active, the streams have developed their narrow floodplains. Included in this unit are patches wherein width of the less eroded interfluves have been reduced so drastically that cultivation has become impracticable. However, the extensive parts of the severely dissected unit have been excluded and treated as miscellaneous areas.

Fluviated Plains

Commonly called as water reworked loess plains, this unit occurs in the loess areas in the vicinity of which structural depressions are present in the basement rocks – (Included in Dissected Plains). The Subrecent erosion products from the adjoining loess plains are deposited here. The material may have admixture of other materials from the eroding piedmont plains and outwash aprons etc. Generally, the surface is concave and seasonal run-off collection is a common phenomenon. Impervious substratum has resulted in poor drainage conditions. The material is generally clayey. The soils indicate characteristics associated with bad drainage. This landform unit is present in almost all the loess areas but the most extensive basins are observed in Peshawar, Hangu and Tal valleys.

SANDY DESERTS

Throughout the country, four main sandy deserts are encountered: Thal, Cholistan, Thar and Kharan. In addition, small sandy deserts are situated in 'Derajat' (Piedmont sandy terraces of Sulaiman and Kirthar Ranges) and in Chagai District. Of these, Cholistan and Thar Deserts represent the north-western parts of the great Indian Rajputana Desert. In this study, the Thal, Cholistan, Derajat and north-western fringes of Thar Desert have been considered. The remaining areas have not been studied, nor adequate secondary information is available about their geomorphology. In the following, the

available data is presented about the areas investigated. Sandy piedmont terraces will be discussed under the respective landtypes.

Thal Desert

The Thal Desert (Refer to map) represents a complex geomorphological pattern of alluvial sedimentation of sand mass by a westerly drifting Indus River, progressively followed by several surface modifications such as (a) wind resorting of the sediments into various forms of sand ridges (b) modification of sand ridges by river action and by deposition in spill channels, (c) deposition of outwash aprons and (d) present day continued wind resorting and dune formation (Ahmad et al, 1968; and Baig et al, 1968).

The braided nature of the Indus River has resulted in deposition of enormous amount of essentially sandy material throughout the desert. More than 95 per cent of Thal is shallowly underlain by great depth of mainly fine sands. Geological cross sections (WAPDA, 1963), reveal no extensive or continuous silt or clay deposits to depths of more than 150 metres. Concurrent with the sedimentation, it is assumed, the fines of the sediments were blown out by the winds to form loess. Four main landform units have been identified in this desert, depending upon the relative velocity and direction of seasonal winds and presence of interspersed river channels.

— Longitudinal ridges are comparable to stabilized Seif dunes which are widespread in all the deserts of the world. They develop in the areas where wind regime is predominantly unidirectional and stronger. In the Thal desert, longitudinal dunes of diagonally opposite direction are encountered in different regions. They are several kilometres long and five to ten metres high separated by inter-ridge valleys approximately of the same width as the ridges. Several other common morphological features and differences have been described.

— Transverse ridges are located in parts of the Thal where the wind regimes are relatively gentle and directly opposing in direction but are of equal strength. Consequently, the ridges are at right angles to the prevailing winds. They are rake shaped, five to ten metres high 100 to 200 metres wide and are separated by inter-ridge hollows of approximately the same width. General slope is of the order of four to twelve per cent. Occasionally, some blow out streamers are encountered due to weaker nature of the modifying winds.

— Alveolar ridges represent the transitional zones between the above two sand ridge systems. Alveolar (honeycombed) sands occur where one of the opposing winds is slightly predominant over the other. In this system the orientation of transverse ridges is maintained but the parallel ridges are joined by cross ridges giving the system a honeycombed appearance. Inter-ridge hollows are enclosed.

— Barchan sands are symmetrical crescentic dunes with the apex pointing towards the direction of the prevailing wind and the wings extend downwind. In Thal, windward slope is ten to fifteen per cent and is longer. The leeward slope is shorter and steeper. The barchan sands represent the only sand relief that can be called as true dunes. They are mobile in nature and are found on flat surfaces which are clayey or silty and quantity of sand mass available is small.

— Abandoned channels: Spill channels occur throughout the Thal and represent the remnants of the previous main river channels. They play important role in shaping the Thal landscapes and

admixing fresh sediments with the sand mass. As these channels went on receding, dune formation become more and more active due to prevailing dryness. During the soil survey investigations, three types of abandoned channels were recognised: (i) exposed channel remnants, (ii) covered channel remnants and (iii) modified covered channel remnants. The latter are the type which represent areas where subsequent water movement has reoriented the alignment of the covering sand ridges.

Cholistan Desert

The types of sandy landform units present in Cholistan (Refer to map) are comparable to Thal Desert. However, there are several important features of Cholistan Desert which need to be mentioned. There has been a lot of controversy in the origin of the parent material of Cholistan. Investigations have revealed that three types of surficial materials which markedly differ from each other in mineralogical composition, have been encountered in the area deposited both by wind and water and in different geological periods.

From the south-western sea coast and the Rann of Kutch, aeolian sands were carried to a considerable distance upto the southern part of Cholistan by the south-western coastal winds. A small portion of the sand is contributed by weathered debris of Aravalli hills occurring in the Rajputana Desert. The central part of Cholistan was formed in sandy alluvium deposited by one or more of the eastern rivers. Whereas, in the northern part of Cholistan, clayey alluvium is encountered, possibly derived from Middle and Lower Himalayas.

Unlike the Thal Desert, the Cholistan area displays more interesting geomorphological history. In addition to the geomorphic processes described for Thal landforms, other episodes are westerly drifting of the rivers of the area and lowering of the base levels of these rivers possibly as a result of tectonics. They have resulted in a number of well defined terraces. Depositional and erosional stages have been exquisitely illustrated in the nature of soil material and degree of soil development/truncation. Each terrace is separated from the other by an escarpment ranging in height from less than one to about seven metres. In all as many as six stages of deposition have been distinguished (Baig et al, 1975).

Generally, three types of sand ridges have been distinguished. The transverse ridges occurring in the western part (Middle Pleistocene), the longitudinal ridges occurring in the northern and southern parts (latest part of Late Pleistocene) and the alveolar ridges occurring in the centre (earlier part of the Late Pleistocene). All these dune formations are stabilized and have sparse vegetation on them. At places where devegation has taken place, sands have been activated to form shifting sand dunes.

– **Transverse ridges:** In Cholistan, the transverse sand ridges are subdivided into two landform units based on height and size of the ridges. They occur as parallel and non-connecting system of ridges (different from Thal). The higher transverse ridges have long wavelengths and are of Middle Pleistocene age and about a kilometre wide. Maximum height is about 100 metres above the general land level. The lower ridges have a shorter wave length and rise three to five metres higher than the surrounding general land level. Their repetitive occurrence is at 50 to 100 metre interval. The height and size decreases from south-west to north-east, possibly due to gradual decrease in the supply of sand.

– Longitudinal ridges: The mechanism of formation of ridges is similar to those studied in the Thal Desert. They are three to five metres high, 30 to 50 metres wide and are essentially uniform in cross-section.

– Alveolar ridges represent the transitional zones between the above mentioned ridge systems as in case of Thal Desert. In this system, the transverse ridges are older and are five to eight metres high, whereas the longitudinal ridges are younger and steeper. The inter-ridge hollows are enclosed. The lowest parts of the hollows accumulate outwash fines from the adjoining ridges.

– Old spill channels constitute a prominent feature of Cholistan and represent remnants of previous main river channels, at present acting as drainageways for disposing run-off during years of exceptional rainfall. These areas generally remain more moist as compared to the hinterlands. The channels lie three to ten metres lower than the general land level and vary in width from one to three kilometres. At places the channels have Barchan-dunes or irregular hummocks.

– Clayey terraces are formed in very peculiar sediments of the Hakra River which had since long been a braided river. The change in sediments is attributed to downwarping of land surface towards the end i.e. Late Pleistocene period.

Thar Desert Margins

Thar Desert (Refer to map) represents small stretches of areas occurring along the irrigated areas of Sind Province. These stretches have been studied partially. Information about hinterlands of Thar is not available. The sources of sand material are the same as discussed in Cholistan. The landform units are also similar, only locally the relief is greater than Cholistan.

Thar Desert margins have occasionally intruded upon by the Indus and its antecedents. Sandplains occurring near Rohri rockplains contain some gravel admixture.

Kharan/Chagai Deserts

These deserts (Refer to map) are unexplored. According to the secondary information available, the sand deserts of Kharan and Chagai are younger. Active sand dune proportion is higher and inter-dunal valleys are small.

Hab Sand Plain

The material was probably deposited in the Late Pleistocene and occurs along the entire course of the Hab River (Refer to map). Two surfaces have been identified: level to nearly level plains and dissected plains with considerable proportion of interspersed torrents.

PIEDMONT PLAINS

Piedmont plains are developed in material derived from the local hills and mountains and deposited by the torrential streams emanating from them. The material reflects the mineral composition of the adjoining rock formations. It has been repeatedly confirmed that the material was deposited in three definite stages: Pleistocene, Subrecent and Recent periods. Mode of deposition had been

characteristically similar. The sequence of constituent landform units, however, locally varies depending upon tectonic activities in the past, climatic conditions and hydrologic environments mainly during Last Glacials and Holocene periods.

In the northern high rainfall areas, the piedmont plains are restricted to very narrow belts along the colluvial footslopes and valley margins. In the semiarid zones, these plains are quite extensive and are generally abutting the major rivers or their tributaries or end up in basins which have always some drainage outlets. In the arid regions, on the other hand, the lowest components of the piedmont plains are the playas, salty lakes with hydromorphic conditions. The following are the main landforms and their constituent units.

Bahadas/Bajadas

Bahadas or Bajadas (Refer to map) are the characteristic continuous piedmont slopes starting from the foot of the mountains to the level plains or basins excluding pediment slopes which are almost absent in the country. Three main units have been identified in the main landform :

– Alluvial fans represent the upper most slopes of the Bahadas. As a result of sudden decrease in gradients of the streams the transporting energy drops and the extremely heterogeneous sediments carried by them are deposited in front of the gorges within the stream beds in the form of triangular cone-like features called fans, with apex located in the gorges. The streams thus get clogged and are forced to seek alternate courses. Continual changes in stream courses keep the surface of the fans generally unstable and rugged. At places the fans occur in isolated form but generally they are coalesced together. The alluvial fans of north-western and western areas are generally stony and gravelly. Locally, however, sandy fans are extensive (Derajat, Bannu areas). Some loess pockets have also been observed on the alluvial fan remnants (Peshawar Vale, Tarbela Watershed). Most of the alluvial fans are preserved from erosion due to presence of a stony, gravelly or coarse sandy covers or desert pavements.

– Alluvial plains: This landform unit is by far the most extensive landscape mapped in the piedmont plains. Based on age, the plains can be split into Recent, Subrecent and Late Pleistocene. But in this study, emphasis is given to the surface configuration and elevation of the terraces. In many areas loess and piedmont alluvium generally alternate with each other in the profile. Gravel veneers always mark the point of contact. Generally, the piedmont alluvial plains can be subdivided into level and dissected sub-units.

- The level parts have been formed in the lower parts of the coalescing alluvial fans where the slope is almost imperceptible. The material is coarser on the higher parts occurring towards the alluvial fans, whereas it is fine silty towards the lower slopes. Generally, fine gravel or coarse sandy material has accumulated at the surface as a result of removal of fine particles by sheet erosion.

- The Dissected parts occur generally on the middle slopes where petered out piedmont streams start erosion in a ramified pattern. Along lower slopes of the piedmont plains, down cutting activities accelerate till they traverse the piedmont basins, again in a coalesced form. In some areas (Rawalpindi) the dissected plains are severely eroded and the pro-

portion of intact plains is relatively low. The entire surface is erosional. Interfluves are convex and have a desert pavement where not cultivated.

Piedmont Terraces

The terraces generally occur in the upper and middle reaches of the piedmont plains. The material ranges from gravelly and stony to clayey. They are formed by lowering of local base levels. The surface is generally gashed by torrential streams. Several relief forms have been encountered on the basis of the nature of sediments and surface configuration. The following landform units have been observed. They occur as scattered small patches that cannot be shown separately on the map due to scale limitations. Part of them especially the sandy areas are included in Bahadas (Refer to map). The remainder mostly form part of the map unit: Mountains.

– Dissected stony terraces occur normally at the foot of the mountains and consist of thick gravelly and stony outwash deposits. The surface is several metres higher than the adjoining piedmont plains; stream beds are very low. Locally the material has been tilted and may partially be consolidated as conglomerate. In some areas, these terraces have been mapped as gravelly and stony land (Peshawar, Kohat).

In western arid regions, locally the entire piedmont plain sequence of Pleistocene periods has been dissected deeply during Recent times to form terraces: gravelly, loamy and clayey (Quetta-Pishin valley). Locally, parts of the basins are uplifted by tectonic activities (faulting or tilting) of Middle Pleistocene. In addition, as a result of 'river piracy' a stream draining from one basin into another cuts down into the separating rocks and base levels are unusually lowered, ultimately giving rise to characteristic terraces in the upper basins. In many places the stony parts of the terrace system are intact, whereas the rest of the terraces have completely disappeared by dissection. Prolonged erosion brings the stream beds to new (lower) base level (Kohat, Lasbela areas). Accelerated dissection resulted in formation of talus slopes, a common physical feature of these regions. The terraces assume a height of about 60 metres with a slope range from 25 to 55 per cent.

– Dissected sandy terraces have been formed in thick Late Pleistocene deposits of sandy outwashes derived from weakly consolidated Siwalik arenaceous rocks. The surface is gently undulating to undulating and is traversed by numerous deeply incised channels (Bannu, D.G.Khan and D.I. Khan areas).

– Gently sloping silty terraces usually occur in the form of high interfluves (mesas) lying between deeply entrenched channels. The central parts of the land mass are level to nearly level. Sheet erosion progressively increases towards the main gullies. Locally, these terraces are subject to severe headward erosion by intricate pattern of gullies (Peshawar, Bannu areas).

Basins and Playas

Mountain ringed plains which have derived sediments from the surrounding mountains (Rash plain, Abbottabad) are typical basin plains. These basins are linked with the main river streams through some drainage outlet. Generally, on the other hand, the basins of the piedmont plains are directly bordering the main drainage streams (Peshawar, Kohat and entire sequence of piedmont

basins of Sulaiman and Kirthar Ranges). The surface is flat, but locally concave and is largely depositional. The interspersed streams provided drainage. Along these streams, extensive Recent plains have developed like floodplains but the surface of the former is very flat and riverain features are absent.

Playas occur in the western inter-mountain closed arid valleys having small, non-perennial streams. Generally they have no external drainage. The entire valley catchment drains out in the playas, which have acquired the form of intermittent salt lakes. The sediments reaching playas are fine silty or clayey. Since all the water reaching the playas eventually evaporates, thick salt crusts are present at the surface during dry part of the year.

WEATHERED BEDROCK PLAINS

Potwar plateau and its suburbs are the main homeland of weathered bedrock plains. In addition, rockplains with very little in-situ weathered material have been mapped in Dadu, Kohistan Mahal, Karachi and Thatta areas. They are excluded from this unit.

In Potwar region, weathered rock plains have formed where exposed surfaces, predominantly of Siwalik and Murree formations, have weathered to form a mantle of soil cover of varying depths. Siwalik represents loosely cemented grey sandstone whereas the Murree formation consists of alternate beds of grey sandstone and purple shales.

Depending upon the angle of dip of the strata, mainly two types of landform units have been explored:

Undulating Plains

This landform unit (Refer to map) has been mapped both in the Siwalik sandstones and the Murree shales which are either tilted or have a dome shaped stratigraphic deformation. Dipping strata display various agnles. The product of weathering is yellowish loams or sandy loams on soft grey sandstones, whereas it is red or purple clays on Murree shales. At places, the outcrops at the higher edge of the slopes represent cuesta like features with gentle dip slopes and steep face slopes. The process of soil formation has extended deeper on gently sloping to nearly level shales than on sandstones with similar surface. The general topography is gently undulating to undulating.

In Zhob, this unit has developed on Shaighalu sandstone with the similar topography.

Ridge-and Trough Plains

This is very characteristic landfrom unit developed on vertically or steeply dipping Murree formation. The sandstone part is resistant to weathering and forms, steep, parallel, narrow and long ridges alternating with shallow troughs developed on shales, which are soft and easily weatherable and yield clayey material. The thickness of the weathered material usually increases from the edge represented by sandstone outcrop to the centre of the trough where there are more favourable situations for weathering.

MOUNTAINS

Northern and north-western parts of the country are largely covered by mountains (Refer to map). Their orogenic history has been authenticated and compiled by several authors with a concensus at

large. The present rocks and surficial, material consists of rocks or products of rocks of limestones, calcareous shales and sandstones, igneous, mainly granitic material, some calcareous slates, and locally patches or volcanic rocks. Strong folding, faulting and tilting associated with drastic down-cutting activities of the streams resulting in large relief variation, are the outstanding features of the mountainou regions.

Hard limestones represent largely bare rocks. Sandstones and shales, on the other hand, are less exposed and have a much higher amount of scree and colluvial deposits.

The rock formations are, though of Tertiary age or older, the present land surfaces of mountains largely represents Holocene and Pleistocene ages, the only-reason being continuous rejuvenation by erosion.

During the course of this study the mountainous regions have been split into a large number of physiographic units representing unique portions of land surface, although according to the Soil Taxonomy the soil types do not show variations of the same order.

Regardless of the nature of the parent materials, the categories of the mountainous region have been generalized on the basis of photo-image characteristics studied under the stereoscope, ground check along selected transverses and extrapolation of information in the remaining areas. According to a much generalized form, the mountainous region can be split into the following landform units :

Structurally Controlled Mountains

This unit has a regular alignment of rock formations. The ridges are generally parallel and oriented according to the defined orogenic history of the respective formations. The ridges have a wide range of elevation. The slopes are generally steep and very steep, associated with occasional deep gorges, bluffs and hogbacks. The slopes become gradually gentler towards mountain bases. Alignment of granitic areas (Swat) is not well defined, the side slopes are bouldry and crevasses are present in the bedrock. Parts occupied by shales, schists and phyllites have flat peaks and side slopes in the form of catsteps tilted terraces produced by slumping action downslope.

Generally, the easily accessible and gentler slopes are terraced and represent regions of human activities relating to obliteration of the natural land surface. On the older slopes which are protected from erosion, the process of soil formation has advanced considerably.

Hills with Poor Structural but Strong Slope Control

This unit is comprised of generally rounded hills i.e., hills with no regular alignment. Generally, the constituent rock material is soft (clay, grit, conglomerate etc.) and is susceptible to erosion. Geologic erosion has provided this unit with extreme irregularity, ruggedness and complexity.

In most of the survey areas this unit has been mapped as rough broken land. It has small enclosed valleys, locally having some drainage outlets. All the Siwalik formations are included in this unit.

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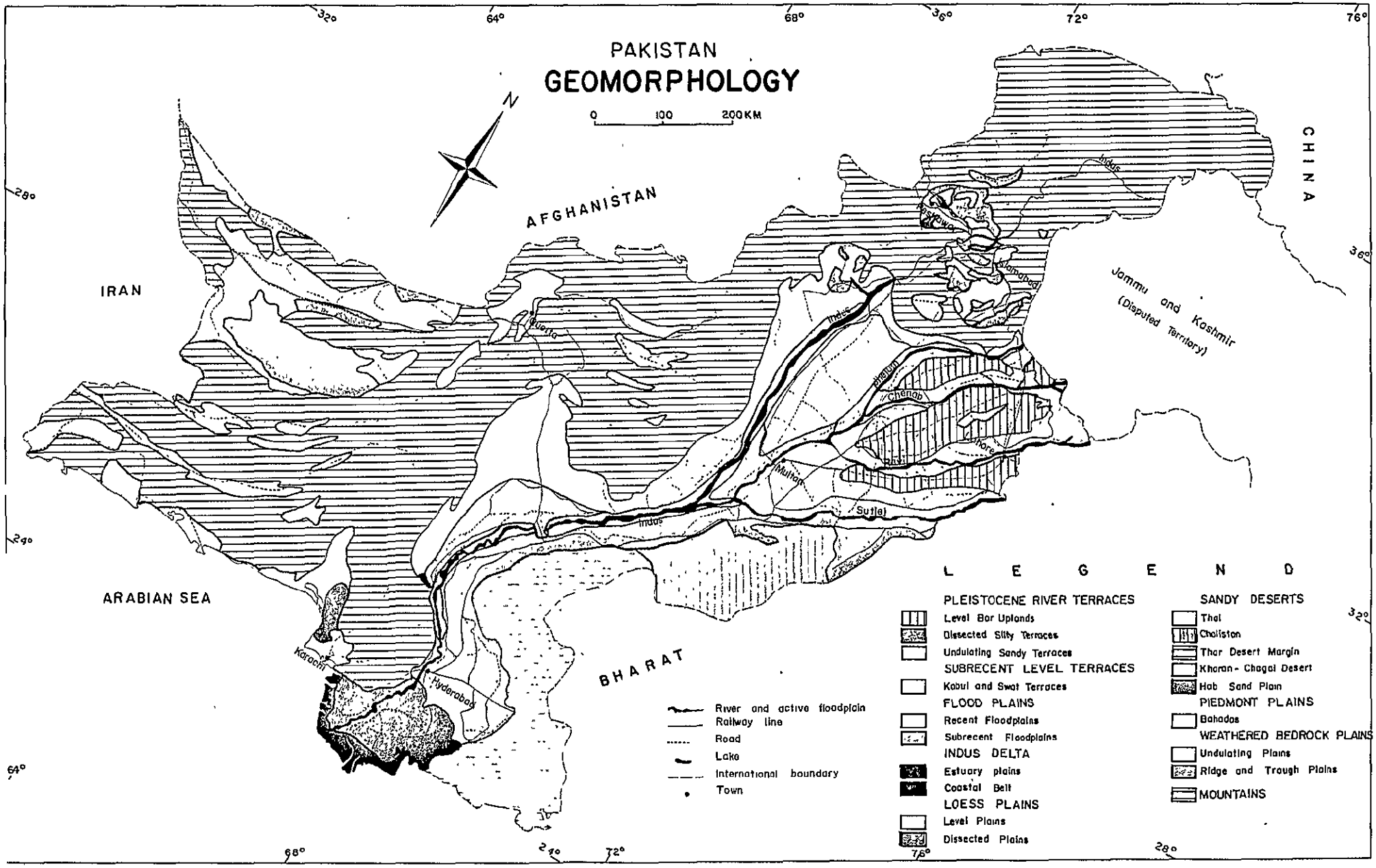

PAKISTAN
GEOMORPHOLOGY
0 100 200KM
N
AFGHANISTAN
IRAN
CHINA
BHARAT
ARABIAN SEA
Jammu and Kashmir
(Disputed Territory)
Indus
Kabul
Peshawar
Islamabad
Quetta
Jhelum
Chenab
Ravi
Lahore
Multan
Sutlej
Karachi
Hyderabad
LEGEND
PLEISTOCENE RIVER TERRACES
Level Bar Uplands
Dissected Silty Terraces
Undulating Sandy Terraces
SUBRECENT LEVEL TERRACES
Kabul and Swat Terraces
FLOOD PLAINS
Recent Floodplains
Subrecent Floodplains
INDUS DELTA
Estuary plains
Coastal Belt
LOESS PLAINS
Level Plains
Dissected Plains
SANDY DESERTS
Thal
Cholistan
Thar Desert Margin
Kharan - Chagai Desert
Hab Sand Plain
PIEDMONT PLAINS
Bahadas
WEATHERED BEDROCK PLAINS
Undulating Plains
Ridge and Trough Plains
MOUNTAINS
River and active floodplain
Railway line
Road
Lake
International boundary
Town

CLIMATE AND SEASONS OF PAKISTAN*

INTRODUCTION

Pakistan lies approximately between latitudes 24° and 37°N, and longitudes 61° and 76°E. To its north and north-east are situated the worlds' loftiest mountain ranges: Hindukush, Karakorams and Himalayas. For the most part, its western border with Afghanistan and Iran too, is a rugged mountainous country that steadily loses elevation southward. Its northern section is crossed by a number of passes. All these physical features have a great bearing not only on the temperature and rainfall pattern of Pakistan but also on general circulation of the atmosphere over southern Asia.

CLIMATE OF PAKISTAN

The climate of Pakistan according to Koppen's classification falls under the following five climatic types.

- Tropical semi-arid climate with dry winter. This includes Karachi, Hyderabad and southern Khairpur divisions. The mean annual temperature is above 18°C.
- Tropical arid climate with average annual temperature about 18°C and dry winter. This includes southern Kalat and the whole of Indus Plains from Lahore, Rawalpindi and D.I. Khan divisions to the northern half of Khairpur Division.
- Cold semi-arid climate with dry summer. This includes hilly regions of southern and central Kashmir, Peshawar, D.I. Khan, Quetta and northern half of Kalat Division.
- Snow forest climate with the average temperature of coldest month below –30°C, warm summer with mean temperature of the warmest month between 10° and 22°C. It includes northern mountainous areas and part of Kashmir.
- Extreme cold climate with average temperature of the warmest month between 10° and 0°C. It comprises eastern and northern parts of Kashmir including Leddakh, Baltistan, Gilgit and north Chitral.

SEASONS OF PAKISTAN

Broadly, there are four well marked seasons in Pakistan:

Cold/Winter season (December to March)
Hot/Summer season (April to June)
Monsoon season (July to September)
Post-Monsoon season/Autumn (October and November)

*Contribution from Pakistan Meteorological Department, Regional Meteorological Centre, Lahore.

Cold/Winter season

The cold season sets in Pakistan by the middle of December and lasts till March. The weather during this period is influenced by the frequent passing of western disturbances originating over the Mediterranean Sea. The Mediterranean Sea is one of the worlds' major centres of cyclogenesis. Few depressions actually travel from the Atlantic Zone either through the Caracassone Gap or the Straits of Gibraltar as recognizable disturbances. These disturbances advance eastward over Saudi Arabia, Iran and Afghanistan to Pakistan. Their average number according to official data, are:

December	4
January	5
February	5
March	5

In the valley of Peshawar, they cause considerable rain in January, February, March and April, the maximum being in the month of March. In Kashmir the maximum is in April but March has almost as much as in April. In November and December, the western disturbance may bring clouds without much rain. In March and April, with the increasing heat of the sun, a strong, local, thermal effect is added, and the thunderstorms, hail-storms and occasionally tornadoes mark their passage. The rain is heaviest on the North-West Frontier and in the Punjab. The precipitation on the mountain tops in the N.W.F.P. and occasionally in the valleys is in the form of snow which at times falls to a height of 300 metres. A failure of the winter rains causes considerable distress among the farming community. In the Indus Basin, the amount of winter rainfall is not large as compared to the amount received during the monsoon period. In Quetta and Kalat divisions, however, more than 75 per cent of the total annual rainfall is received during this season. In general, low temperatures, occasional rain, and poor visibility in the mornings and evenings due to mist, smoke, haze and occasionally fog, are common in the northern parts of Pakistan. Frost also occurs in some areas. During extraordinarily cold spells, the lowest temperature has been recorded as minus 22°C at Kalat, minus 19°C at Parachinar and minus 17°C at Samungli (Quetta).

Hot/Summer season

The period from April to June is the period of increasing temperatures, the sun being almost overhead. The mean daily range of temperature is of the order of 16-17°C. Relative humidity in May and June varies from about 50% in the morning to about 25% or less in the afternoon.

The highest day temperatures have been recorded in May and June when the hot weather continues unabated for days together with the mean daily maximum temperature ranging from 41° to 46°C, while temperatures of 50°C or above are not uncommon. The highest recorded temperature at Jacobabad in June is 53°C, at Sibi and Reti is 52°C, and at Lasbela, Turbet, Chhor, Nawabshah. Padidan, Khushab, Multan and Sargodha is 51°C.

While the interior is blazing hot in May and June, areas along the Sind-Mekran coast are under the influence of sea breeze in the afternoons which keeps the maximum temperature down to about 35°C. However, when a trough of low pressure appears over northern Arabian Sea or over Sind-Gujerat coast, the sea breeze is cut off and hot desert winds from Rajasthan blow over Hyderabad and

Karachi divisions. The temperatures of 45°C and above, and the sultry weather along the coast which then results is most uncomfortable. Temperatures as high as 50°C at Hyderabad and 48°C at Karachi have been recorded. Such heat waves, however, do not last for long and it is the mild climate of Karachi which has been a factor in the development of this city during the last few decades.

Any description of the hot season would be incomplete without a brief reference to the pleasant climates of hill stations. The mean daily maximum and minimum temperatures at Murree in June are 27°C and 16°C respectively. Once in a while, Murree too gets a hot spell when the maximum temperature may shoot up to 35°C. Quetta is another hill station where summer might get a bit hot. The mean daily maximum and minimum temperatures at Quetta in July are 34°C and 10°C respectively. Maximum temperatures of higher than 35°C are not infrequent during June, July and August. Temperature as high as 41°C has been recorded at Quetta during summer.

The months of April to June are usually dry in Pakistan. The total rainfall of this period at different stations in the plains varies between 27 and 76 mm and is of the order of 102 to 127 mm in the submontane districts. In Kashmir and Peshawar Division, however, the total rainfall of April and May forms an appreciable percentage of the annual total. This is received generally in the wake of western disturbances which move over the northern latitudes and are accompanied by dust/thunderstorms and hail. At times, though rarely, tropical cyclones affect the Sind-Mekran coast resulting in short spells of heavy rain.

Monsoon season

For hundreds of years Arab merchants plying their trade across the Indian Ocean were well aware of the striking seasonal changes in wind direction. They termed this wind reversal "mausim" from which we derive our word monsoon. The current usage describes the monsoon as a seasonal change in the direction of winds. This is a simple descriptive statement and is not meant in any way to be explanatory.

Prior to the onset of monsoon, the area over Pakistan is very dry and the maximum temperature exceeds 44°C in the plains. By the beginning of June, a thermal low called Indus low establishes over Hyderabad, Khairpur, Multan and Quetta divisions, which is to some extent responsible for the onset of southwest monsoon over the Indo-Pakistan subcontinent.

Radiation from the sun reaches the ground day after day through nearly cloudless skies. During May and June, a shallow area of low pressure forms close to the surface. Since daytime heating exceeds radiation cooling at night, the heat low becomes a permanent summer feature. Two conditions prevent the heat low from dissipating. First, very dry air must exist at the surface otherwise clouds would form in the warm ascending thermals. The persence of cloud would lessen surface absorption of energy and lower the day time temperatures. This does not occur even though a ready source of moisture is close by in the warm waters of the Arabian Sea. Second, the condensation level would eventually be reached by convection currents if they ascended high enough. They are prevented from doing so by an inversion at about 2 000 m. Above this inversion, subsidence from a midtropospheric STHP maintains an outflow of dry warm air. Any clouds that do form are quickly evaporated in this very dry environment.

The Indus low is consequently associated with hot and dry weather. During May, an associated trough of low pressure develops along the Ganges Valley. Though shallow and thermal in origin, its character changes as moist air is fed into the weak cyclonic circulation over eastern India from the Bay of Bengal. At the beginning of June the inversion disappears over the eastern end of the trough but is maintained further west.

Further changes in the structure of the upper air notably the shift of the westerly jet stream to the north of the Himalayas, allow further invasion of moist air from the Bay of Bengal in July. The trough, therefore, becomes associated with disturbed weather. Each breakdown of the inversion allows a further advance of monsoon air. When this stage is reached, many climatologists call the trough a monsoon trough and regard it as the inter-tropical convergence zone. It is a zone into which warm moist air is advected in surges producing periods of heavy rain and storms.

The monsoon normally appears in Sri Lanka in the second or third week of May, and a little later in lower Burma. It spreads northwards generally in series of pulses. The west Punjab is reached by the end of June/early July. The provinces of Sind and Baluchistan never come under the regular sway of the moist currents; they are affected by monsoon incursions occasionally in July and August. The rainfall in the monsoon season in any part of the country, does not take place uniformly. It occurs in spells. The monsoon current remains steady in July and begins retreating towards the end of August, but occasionally it continues to be active even in September when some of the highest floods of the Indus Basin have been recorded.

A series of tropical depressions during the monsoon season causeheavy rainfall in the catchment areas of the Indus Basin rivers causing high floods in them. Some also cause widspread rainfall in Khairpur, Hyderabad and Karachi divisions, over the Kirthar ranges and some times even in the Quetta Kalat region. A few of the depressions that emerge from the northeastern Arabian Sea, intensify and affect the Sind-Mekran coast. The normal rainfall over Pakistan for the period June to September (monsoon season) is 145.0 millimetres.

Post-Monsoon season

From the middle of September to the middle of November is the transitory period. The retreat of the monsoon from the Arabian Sea is marked by the disappearance of the stratus cloud over the Sind-Mekran coast and by the general rise in day temperatures over the coastal belt in September. In October, the maximum temperature is of the order of 34° to 37°C all over Pakistan, while the nights are fairly cool and the minimum temperature remains near about 16°C. In the month of November, the maximum and minimum temperatures fall by about 6°C and the weather bacomes pleasant. October and November are by far the driest months characterized by clear skies, and light and variable winds all over the plains of Pakistan.

SOILS OF PAKISTAN

MUSHTAQ AHMAD*

GENERAL

Soil in any one location has developed through a genetic process whose nature is determined by the following factors related to that particular site and environment.

- Climate
- Living organisms (both plants and animals)
- Relief i.e. configuration of the land surface
- Soil parent material
- Water above, within and below the soil
- Man's presence and use of the land
- Span of time over which the above mentioned six elements have interacted.

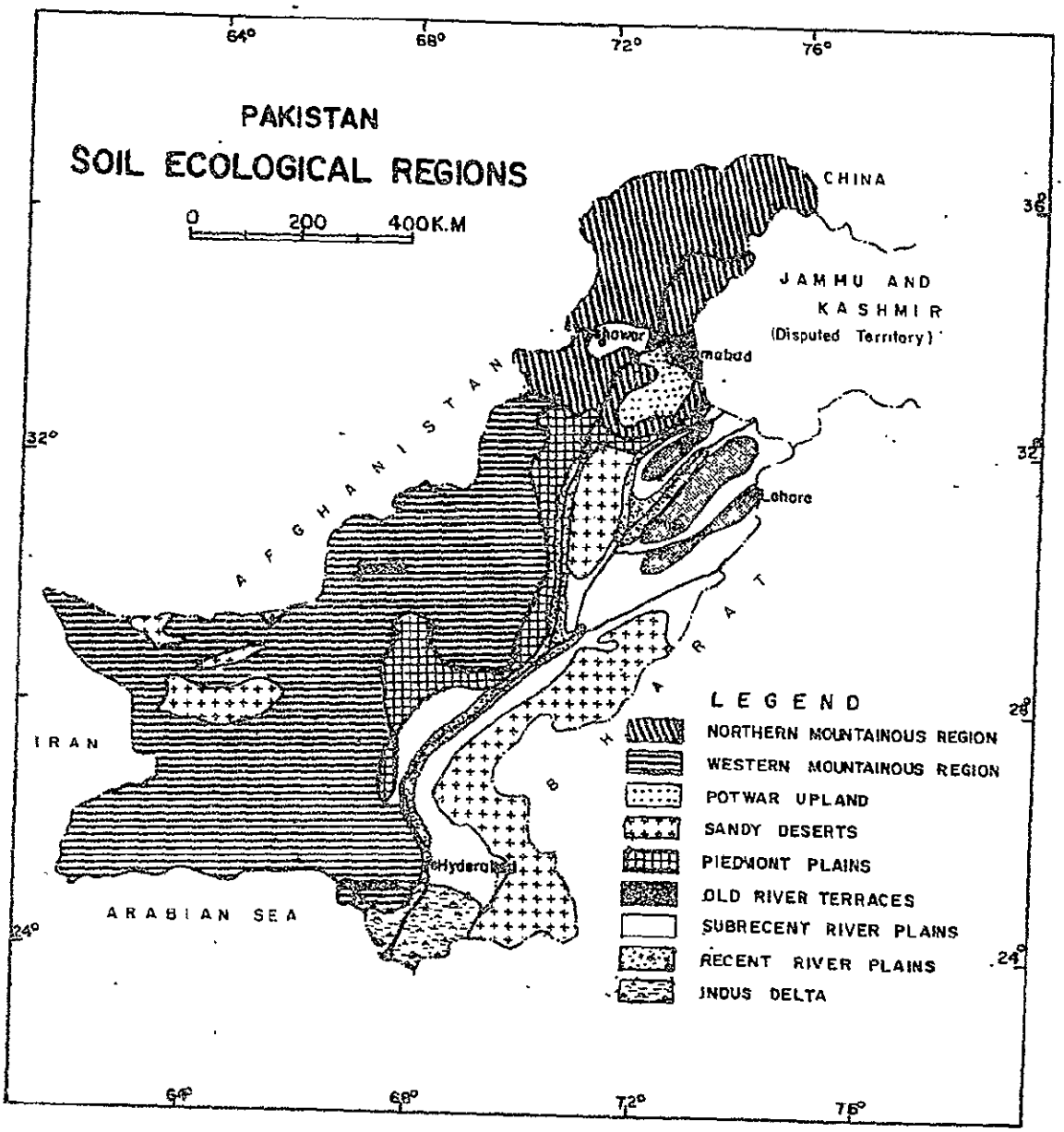
A change in any of these variables causes a different kind of soil genesis producing different soil characteristics.

Geographically, Pakistan has a highly diversified landscape and environment. Lofty snow-clad mountains, vast sandy deserts and extensive river and piedmont plains have combined to give rise to a country where variations in the soil-forming factors are quite common. This is conspicuously reflected in the variety of soil characteristics encountered here.

This expose is an attempt to present a generalized account of the different kinds of soil that are found in Pakistan. For this purpose, the country has been divided into nine broad ecologic zones.

- Northern Mountainous Region
- Western Mountainous Region
- Potwar Upland
- Sandy Deserts
- Piedmont Plains
- Old River Terraces
- Subrecent River Plains
- Recent River Plains
- Indus Delta

*Soil Survey of Pakistan, Lahore.


PAKISTAN
SOIL ECOLOGICAL REGIONS
0 200 400K.M
64°
68°
72°
76°
32°
24°
CHINA
JAMMU AND KASHMIR
(Disputed Territory)
AFGHANISTAN
IRAN
ARABIAN SEA
Lahore
Hyderabad
LEGEND
NORTHERN MOUNTAINOUS REGION
WESTERN MOUNTAINOUS REGION
POTWAR UPLAND
SANDY DESERTS
PIEDMONT PLAINS
OLD RIVER TERRACES
SUBRECENT RIVER PLAINS
RECENT RIVER PLAINS
INDUS DELTA

The following account has been divided into separate sections in respect of each region, describing the physiography, soil parent materials, climate, vegetation/land use, soil-forming processes and typical soils.

NORTHERN MOUNTAINOUS REGION

It includes the mountainous country comprising the Himalayas, the Karakorams and the Hindu Kush. The Salt Range area also represents somewhat similar conditions. Physiographically, it is constituted of a series of high mountain ranges and narrow intervening valleys. The land surface steadily rises northward where some of the loftiest peaks of the world are situated. A wide variety of sedimentary, igneous and metamorphic rocks is exposed in the area. Since these rocks are the source of the soil materials, the latter exhibit large variations in mineralogic make-up etc from place to place.

Climatically too, the region has considerable diversity. Alongside its eastern periphery, Muree and its surroundings are the wettest part of the country receiving an annual precipitation of about 1 800 mm. Towards north, west and south, the climate steadily becomes drier. The northernmost portion is the driest part with an average annual precipitation of 125 mm or so. Due to its peculiar surface configuration, there is lot of temperature variation spatially. A number of temperature zones are easily distinguishable along the altitudinal axis. Beginning with the valleys and foot-slopes that are seldom frozen, the temperature shows steady gradation with elevation until finally perennial snows are reached.

This climatic zonation is distinctly manifest in the natural vegetation distribution over the area. Generally, the lowest parts of the terrain are occupied by open scrub. Above that, there is the coniferous trees zone. This gives way to seasonally frozen areas of alpine pastures whose upper limit is marked by the perpetual snow.

Over major portion of the region, higher precipitation and lower temperatures with consequent variations in the type and the density of the flora distinctly set it apart from the rest of the country. Littering and humification, leaching, and decalcification are the important pedogenic processes in the region. Its soils, characteristically, have a higher content of organic matter and are humified to deeper depths. The climate and the vegetation have been instrumental in effecting considerable leaching of the soils. Generally, their base saturation and pH values are lower, and they are more decalcified. The pronouncement of these characteristics gradually diminshes towards the drier margins. Absence of soil salinity or sodicity is a universal peculiarity of this region.

The region is constituted of two distinctly different landform divisions each with its own typical soil pattern. The mountain slopes are occupied by residual-colluvial, shallow (on the average about 50 cm thick), loamy soils with lot of rock fragments. Generally, their organic matter content is fairly high. Depending upon parent rock type, local climate and kind of vegetation, and soil age, the soil reaction varies from moderately alkaline to medium acid (pH 8.0 to 5.6). The substratum comprises partially weathered bedrock.

The valleys are either nearly level or have only gentle slopes. Here, the soil materials are mostly of alluvial origin and considerably deeper. Their texture as well as the proportion of stones/gravel is

variable depending upon physiographic position and distance from the source. Common polycyclic profiles with conspicuous discontinuities point towards frequently as well as drastically changing sedimentation conditions in the bygone times. Nature of the parent material, physiographic position and soil age are the chief soil-differentiating agents determining the kind, degree and depth of soil development.

Mollic and ochric are the most commonly occurring epipedons in the region. The subsurface horizons are generally cambic and calcic. Argillic horizon may be present in some old valley soils. Lithic/paralithic contact characterizes soils of the mountain slopes. Mollisols, Inceptisols and Entisols are the major soil orders of the region. Aridisols are encountered only in the very dry (arid) peripheral parts. A minor extent of Alfisols may also be present.

WESTERN MOUNTAINOUS REGION

This is the most extensive geographic division of Pakistan encompassing most of Baluchistan, Waziristan Agencies and the Kirthar Plateau. Generally, it is composed of mountain ranges of moderate height separated by fairly wide elongate valleys. The outcropping starta are dominated by calcareous sedimentary rocks. Consequently, the soil parent materials in the region contain varying proportions of calcite. There is lot of diversity in soil materials inherited from the parent rocks.

Except for some semi-arid pockets surrounding Bannu, Zhob, Loralai and Quetta, the region is arid. The aridity accentuates westward culminating in the most dessicated part of the country comprising the Dalbandin-Nokundi tract. Low atmospheric humidity also causes wide seasonal as well as diurnal fluctuations in temperatures. Harsh winters and relatively mild summers characterize the central and the northern parts of the area. This region is not much influenced by the monsoon stream. Late summer rains over major expanse of the area are comparatively less important compared with the winter-spring precipitation. Part of the latter is in the form of snow which varies in bulk as well as duration of stay depending upon altitude. The temperature regimes also exhibit considerable variation from place to place. Locally, temperature variation associated with altitude difference becomes quite visible.

The native vegetation presumed to have been composed of a varied mix of trees, shrubs, and grasses, in equilibrium with the environment, has undergone drastic modification because of prolonged severe biotic disturbance. The tree-tall shrub population has suffered most adversely; it survives only in small reserves. The present vegetation cover mainly comprises low shrubs and grasses of low grazing or other economic value.

Limited moisture effectivenesss is the most outstanding characteristic of the region. The consequent restricted biologic activity is well reflected in the existing soil pattern. The mountain slopes are subject to severe erosion and have only patchy, thin and too variable a soil cover. The valleys comprise alluvial fill constituted of outwash from the flanking mountains brought down and deposited by the torrents. Stones/gravel admixed with heterogeneous soil materials occur at the mountain bases. The soil materials become progressively finer with distance from the mountains; the flat areas are occupied by deep silty deposits whereas central concave depressions of internally drained valleys contain fine silty to clayey sediments.

The soils generally belong to Subrecent and later periods. They exhibit only weak profile development characterized by homogenization, weak soil structure formation and slight colour development. Very little leaching has generally taken place and soils are 100% base saturated. Their organic matter content is quite low, averaging about 0.5 per cent in the surface horizons.

In environments conducive to net upward movement of moisture through the soil profile, saline/saline-sodic soils occur depending upon the kind of salts in the evaporating moisture. The processes of salinization etc are especially active in the enclosed central depressions of the valleys, creating playas. The soils are invariably calcareous; only the Pleistocene soils contain a zone of secondary lime accumulation in the lower solum.

Weathering accompanied by homogenization and formation of soil structure is the ubiquitous pedogenic process in the area. Redistribution of lime and soluble salts become important, locally. Humification and leaching show only very slight effect on soil profile development. Ochric epipedon and cambic horizon are the genetic features characteristic of the region. The Pleistocene soils are likely to have a calcic horizon. A salic horizon may occur in some severely salinized soils like those formed in playas. Aridisols are by far the largest group of soils in the region, followed by Inceptisols and Entisols.

POTWAR UPLAND

The Potwar Plateau is part of the great Indo-gangetic synclinorium separated from it and elevated at the end of the Tertiary period. The Plateau generally has a flat to gently undulating surface locally broken by gullies and low hills/ranges. The surface soil materials are: loess deposits, residual mantle on sandstones and shale bedrocks, or narrow strips of silty/loamy alluvium along major streams like Soan, Haro, Kanshi etc. The hills are mostly bare, shale and sandstone outcrops. Because of its raised position with respect to the drainage system, dissection is the most prominent feature of the area. In fact, the present landscape has been shaped exclusively by eroding waters.

The Potwar Plateau has a semi-arid to subhumid subtropical continental climate. The northern part situated at the foot of the Outer Himalayas receives greater amount of precipitation. With distance from the mountains, rainfall steadily decreases. The rainfall is a twin-peak type with the two maxima occurring in the late summer and during the winter-spring period. Temperatures are favourable for plant growth throughout the year. Frost might occur during December and January.

The Potwar area once supported a fairly dense scrub dominated by tall thorny shrubs, scattered trees, and an under-cover of a variety of grasses. With the exception of some reserve areas, the native vegetation has since long been cleared for cultivation. The area is at present extensively used for dry-farmed arable cropping. The cropping pattern and intensity vary spatially as well as temporally with the moisture availability.

Apart from homogenization, braunification and soil structure development, leaching, redistribution of lime, eluviation and illuviation are the important pedogenic processes operating under the Potwar environment. The soil characteristics vary within the area depending upon the parent material and the soil age. Climatic variation mainly the amount of precipitation is clearly reflected in the degree of soil development; it is more pronounced in the wetter areas.

Loess plains are a very characteristic landform of this region. These comprise thick deposits of calcareous, fine, wind-laid sediments that have undergone strong profile development followed by erosion and a second cycle of pedogenesis. The oldest (Pleistocene) surface (least affected by subsequent erosion) occurs as almost flat topped table lands occupied by strongly developed, very deep soil profiles. They are well humified, strongly structured, considerably leached, silty clays/silty clay loams w ·h lot of lime redistribution. Some eluviation and accompanying illuviation of clay etc are also evident in these soils.

The soils on the sloping margins of the table lands represent truncated remains i.e. lower solum, of the Pleistocene soil surface, in which a second cycle of pedogenesis is operative. In these soils, the Pleistocene morphological characteristics have a superimposition of later horizon differentiation. These soils show weaker profile development in every respect as compared to the main table land soils.

The next lower level of the loess landscape comprises steep gully banks. Here, severest truncation of the soils has taken place. What is expoxed on the surface comprises the substrata of the earlier table land profile. It is mainly composed of partly altered/unaltered loess material.

The second important group of soils has formed in residuum derived from sandstones and shales. Wherever the slopes permit, these rocks have a mantle of unconsolidated materials resulting from rock distintegration and soil genesis. Its thickness varies with physiographic position. Climate and soil age are the major soil differentiating agents. Soil development is stronger on the older soil surfaces and under more humid environs.

Soils developed on sandstones range from very shallow, loose, clacareous, undeveloped sands/loamy sands on sloping, semi-arid parts subject to active erosion, to very deep, humified, moderately structured, non-calcareous, sandy clay loams/clay loams on Old, stable, flat to slightly concave surfaces in the subhumid climatic zone.

The soils derived from shales are generally moderately deep, weakly developed, calcareous, clays/sility clays.

Alluvium, the third kind of soil-producing sediments, occurs as narrow belts of floodplain along all the major Potwar streams. The soil materials are mainly loamy and calcareous. They are of relatively recent age. The soils show weak morphological development without appreciable redistribution of soluble constituents. The substrata have conspicuous depositional stratification.

The most common diagnostic soil features in the Potwar Plateau are ochric epipedon, and cambic and calcic horizons. Fargipan has been observed in the Pleistocene silty soils. Argillic horizon is likely to occur in Old stable surface soils. Its presence is subject to confirmation by further laboratory investigations. Inceptisols, Entisols and Aridisols are the dominant soil types. Small extent of Alfisols is also present.

SANDY DESERTS

This division includes vast areas of aeolian sand deposits occurring in three different locations in the country i.e. Thal, Thar-Cholistan and Chagai-Kharan Desert. The sands underwent intensive

sorting out by the wind before deposition during the Pleistocene epoch. The landscape is essentially constituted of an intricate pattern of ridges and hollows formed by systematic wind action. The ridge-valley pattern i.e. shape and size of the valleys and ridges and the relief difference, varies from place to place depending upon speed, direction and duration of seasonal winds, sand supply and surface characteristics of the original terrain. Origins of the sands are different in the three localities mentioned above. The Thal sands are derived from the shifting floodplain deposits of the Indus River during its gradual migration from a much easterly older course to its present day location. Sands forming the Thar-Cholistan Desert are presumed to be combination of materials derived from: the alluvium of the Indus River system, weathered rock debris of the Aravallis and marine sediments of the Rann of Kutch. The Chagai–Kharan Desert is presumably constituted of sands from the weathering products of the sandstone formations surrounding the area. All the wind blown sands are calcareous and rich in quartz.

Dominant part of this unit has an arid subtropical continental type of climate. The southern part of the Thar Desert, however, is influenced by nearness to the sea and may be characterized as a marine tropical type. Salient features of the climate are low rainfall and atmospheric humidity, large seasonal and diurnal variations in temperature and a few frosty days. The marine tropical part, on the other hand, has high humidity, no frost or major changes in seasonal and diurnal temperatures.

The area generally supports a desert scrub type of vegetation dominated by shrubs and bunch grasses. There is a surface layer of perennial grasses. Few trees also occur scattered over the area. The natural plant cover is used extensively for grazing and livestock production and as a consequence has been drastically modified. In some areas, especially around habitation centres and the drier parts, the protective plant cover has totally disapperaed resulting in severe wind erosion and heaps of shifting sand.

Arid and hot climate with mainly late summer monsoon rains, highly permeable soil materials, fair amount of plant cover and an adequately long period for soil development have given rise to the soils of these areas. Homogenization, braunification and redistribution of soluble constituents including lime are the most important soil-forming processes. Soil structure development is evident wherever texture has been favourable. Wind erosion is ubiquitous but it is most conspicuous on devegetated sites. Relief or the surface configuration has played the most important role in soil distribution over the area. It has drastically modified the pedo-climate through moisture redistribution and consequent variation in the type and amount of vegetation cover. The soil pattern is constituted of a series of classical catenas repeating at a small amplitude.

A typical example of the soil pattern of ridge-hollow landscape is Thal-Bhakkar soil association occurring in arid part of the Thal Desert. This part has longitudinal sand ridges separated by narrow valleys. Stable parts of ridges, mainly crests and windward slopes are occupied by sands/loamy snads developed to moderate depths. The soil profile shows considerable colour development and scattered fine lime segregations. The soil surface is deflated wherever bare. The higher, nearly level peripheries of the valleys have loamy fine sands that show greater degree of profile development as compared to the ridge soils. The concave central parts of the valleys have very deeply developed, fine sandy loams having a bright coloured subsoil with a weak zone of lime accumulation at the bottom. The soil profile has a fine textural gradation from a heavy fine sandy loam in the subsoil which gradually

lightens with depth to original fine sands in the substratum. The leeward sides of the ridges are steep, and covered with shifting sand blown from the windward faces. Where ridges are of the transverse type, the shifting sands form streamers at right angle to the main ridge orientation. Similar kind of soil distribution pattern exists in other ridge-hollow systems too. The ridge soils are akin to the loamy sands described above but the valley bottom may have lighter or heavier soils depending upon the size of valley with respect to the runoff producing ridges.

An ochric epipedon and a cambic horizon are the most commonly present diagnostic features. Aridisols and Entisols account for the soils of the area.

PIEDMONT PLAINS

This region is constituted of the vast, gently sloping plain between the Sulaiman Range and the Indus River, the Kachhi Plain and the plain parts of the Bannu Basin. All these areas are made up of alluvial sediments brought down from the adjoining mountains by the torrents and deposited in the depressional parts at their front. During deposition, sorting out of the sediments has taken place in accordance with the transportation capacity of the carrying water.

The upper reaches of the piedmont landforms comprise fans constituted of stones, boulders and gravel admixed with some sandy to loamy materials. These represent the first load shedding by the stream as it loses energy on immediately leaving the mountains. The fan surface is uneven and has a littering of stones and boulders. It has a steady dip away from the mountains. At their lower tips, the fans are bordered by sandy deposits that have in places blown into shifting dunes. The sandy materials give way to silty sediments futher down slope. The materials become progressively finer with distance from the source so that the lower aprons of these plains are made up of moderately fine/fine textured soil materials.

The sediments are derived from a variety of rocks but dominant contribution is from calcareous Tertiary rocks mainly limestones, shales and sandstones. They are very deep and invariably calcareous. At places very fine gypsum crystals are present uniformly distributed in the sediment. There is also indication of the presence ofexpanding-lattice clays inthe form of wide cracks at the surface extending well into the subsoil.

Due to their higher position and limited availability of water, considerable part of the piedmont plains is uncultivated. A part receives irrigation from the canals taken off from the Kurram-Gambila or the Indus River. Strips along torrents are used for seasonal cropping wherever flash flows in the torrents can be tapped for diversion onto embanked fields. Small dam irrigation schemes also cover some portions of the landform. Alluvial fans support natural vegetation comprising low shrubs and grasses with few scattered trees providing forage and fuel.

The region has mostly an arid subtropical continental climate characterized by hot summers, mild winters, low humidity, mainly late summer rains and a few frosty days. The Bannu Basin is slightly more moist and cooler in winters. About one-half of the annual precipitation is received during winter.

Little moisture and sparse vegetation are mainly responsible for weak soil profile development in the main (Subrecent) part of the plains. These soils have developed to moderate depths with weak

structure and colour development. They are moderately to strongly calcareous and may be slightly saline under virgin conditions. The salinity is easily got rid of by a few irrigations. The soils show textural variation inherited from the deposition. Generally, the lowest parts of the plain have silty clays and silty clay loams, the mid reaches are occupied by silty/loamy soils, the uppermost belt is coarse textured.

In the Kachhi Plain, the hemline contains super clays. These soils exhibit wide and deep cracks, slickensides and wedge-shaped structural aggregates in the solum. They need especially adapted management techniques as well as an appropriate crop choice.

The Subrecent fans have shallow, stony/gravelly loams that have been only slightly modified by pedogenesis. These are associated with the present day drainage systems. Side by side with these, there is considerably higher and dissected land surface comprising Pleistocene fan deposits. These are occupied by shallow, well structured, brighter coloured clay loams/sandy clay loams with a zone of secondary lime accumulation as soft segregations and coatings on the underside of stones.

As is evident, homogenization and structure and colour development are the universally active processes in the region. Lime redistribution is conspicuous only in the Pleistocene soils. Slickensiding and salinization are operative wherever the conditions are conducive.

Ochric epipedon and cambic horizon are the most commonly occurring genetic soil features in the region. The Pleistocene soils may have a calcic horizon. Wide and deep cracks, slickensides and wedge-shaped aggregates characterize soils having adequate quantities of swelling clays. Aridisols are the dominant kind of soils. They rather typify the region. Entisols are also common. Vertisols are important, locally.

OLD RIVER TERRACES

This unit comprises the scalloped interfluves (locally called 'bars') occupying the middle parts of the land between major rivers ('doabs') of Punjab. The unit has generally a flat surface interrupted only by some natural levees or channel remants. It is made up of river alluvia brought down from the Himalayas and deposited during the Pleistocene epoch. In general, the sediments are loamy in the northern reaches and become silty southward. Locally, physiographic position has played a very important part in textural differentiation within the sediments. Finer materials settled in the depressional parts and coarse materials on higher undulations, the intermediate level areas received the particle-size fractions in between. The sediments are characteristically calcareous and of mixed mineral make-up.

The region has a subtropical continental type of climate, gradually changing from subhumid in the north to arid in the southern extremity. The temperatures show the reverse gradation. Incidence of frost is likely throughout the areas but number of days vary in accordance with the temperature means. The rainfall is dominated by the late summer monsoon downpours.

Native vegetation of the region has been classified as open thorn forest but is non-existent at present because of clearance consequent upon canal colonization. Diversified irrigated cropping is the dominant kind of use.

Limited moisture and warm climatic conditions have mainly influenced the pedogenesis. Weathering, homogenization, braunifications, leaching, lime redistribution and structure development are the important soil-forming processes. Despite a weak pedogenic environment, the soils show some pronounced morphologic features mainly because of long period of soil development.

The soils are typically deep, calcareous, weakly structured, bright coloured and with a zone of secondary lime accumulation at or near 1 metre depth. In the subhumid part, upper part of solum has been decalcified. Here, some eluviation and illuviation of clay has also taken place. In this part, some basins are occupied by soils formed under the influence of expanding lattice clays.

Slightly raised areas adjoining depressions that were flooded, became the salinization sites. Saline-sodic soils are encountered in these locations. Mottling and gleying have affected areas of seasonally fluctuating water-table or impeded drainage.

Ochric epipedon and cambic, clacic and argillic horizons, slickensiding and wedge-shaped structural aggregates are important features. Inceptisols and Aridisols with some Alfisols and Vertisols are soil categories occurring in this region.

SUBRECENT RIVER PLAINS

This unit consists of the areas between the Old River Terraces and the present day floodplains of the rivers. The nature of sediments, depositional pattern and their surface configuration are similar to the 'bar' areas. Age-wise, however, these are much younger having been deposited during the Subrecent times.

The age difference is mainly responsible for the weaker development in these soils, although there is the same trend in pedogenesis. Calcic horizon, vertic characteristics and features due to eluviation or illuviation of clay are absent in the soils of this area. These soils are developed to moderate depths only. Generally, only ochric epipedon and cambic horizon are encountered in the soils. Mottling, gleying and salinization/sodication are locally important. Inceptisols, Aridisols and Entisols dominate in the area.

RECENT RIVER PLAINS

These consist of the present floodplains of the major rivers occurring as narrow belts along the river streams. The area is subject to periodic flooding. Sedimentation is still going on in some parts especially those overlooking the river. Burial underneath fresh deposits and erosion are concurrently active in this landform.

Because of youth, soil-forming processes have not produced any significant alteration in the soil materials. The area is generally free of salinity/sodicity. No diagnostic feature/horizon except for ochric epipedon in some location is present. The soils are stratified and laminated and fall in the Entisols order.

INDUS DELTA

This unit comprises the deposits of the Indus River extending from a little south of Hyderabad to the sea. Major part of the area is constituted of estuary deposits. A narrow coastal fringe forms its border with the sea.

The estuary plain has different kind of sedimentation as compared to the normal river plains. Here, deposition by the river is greatly modified by sea tides inflow into the river mouth. It contains a large proportion of extensive, extremely well sorted spill flats. Its surface gradient is considerably smaller and has a different degree and kind (gypsiferous) of salinity. Clayey basins and channel infills occupy the rest of the area.

The coastal fringe consists of strongly saline, clayey tidal flats with some narrow tidal ridges.

The region has an arid to semiarid marine type climate characterized by high humidity and slight diurnal/seasonal changes in temperature.

Due to peculiar sediments and a low gradient, the area has impeded drainage conditions. Under these conditions salinization is the most active process here. Dominant soils of the area are severely saline, silt loams with weak structural development. These soils are very difficult to irrigate because of very rapid resalinization process. The basins and channel infills have moderately deeply developed silty clays. Where these soils have been under old irrigated cultivation, they are non-saline. The uncultivated parts are saline but salinity can be got rid of by leaching as the clayey soils do not have as acute a drainage problem as the silty soils.

Ochric epipedon and cambic and salic horizons are the most common features in these soils. Aridisols and Entisols include most of the soils in the area.

VEGETATION ECOLOGICAL ZONES OF PAKISTAN

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ABSTRACT

Following an integrated multidisciplinary approach, an attempt has been made to delineate ecological zones of Pakistan by integrating information on vegetation, climate, physiography and soils.

At the highest level of hierarchy, three distinctly contrasting Ecological Territories differing from each other in lithological and geomorphological history, climatic personality, hydrological conditions, soil characteristics, flora and fauna and even in mineralogical resources as well as in cultural and socio-economic aspects, have been delimited. At the middle level, three Ecological Territories are divided into eighteen Bioclimatic Regions on the basis of vegetation indicated climate. At the lowest level, the Bioclimatic Regions are broken up into thirty six Vegetation Ecological Zones using the cirteria of physiography and soils.

The hierarchy is described at the Region Level that covers Ecological Territories at higher level and Ecological Zones at lower level, by giving briefly the distribution of each Ecological Region, climax vegetation, characteristic plant species, climate, terrain, soils, its potential use and the associated wildlife. At the end of each Ecological Region are given the Ecological Zones occurring therein. Two maps showing Vegetation Ecological Zones at 1 : 2 000 000 scale and Bioclimatic Regions at 1 : 5 000 000 scale have been prepared. The latter is appended with this paper.

INTRODUCTION

The ecological zones provide solid frame work for land use planning and management of natural resources of a country. Vegetation, climate, physiography and soils are the major components that integrate to constitute different ecological zones.

Many workers have divided Pakistan into ecological regions or zones using mainly the criteria of climate and physiography but none has so far integrated the criterion of vegetation with other components of land in his delineations.

Ahmed (1951) presented a classification of Pakistan into regions based on climates. Champion et al (1965) defined forest types of Pakistan considering the vegetation component only. Rafiq (1976) divided Pakistan into crop ecological zones, but he based his delineation on physiography and climate. PARC (1980) put forth agro-ecological zones of Pakistan based on physiography alone.

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Much of the information on climate which has been central in these delineations is either unreliable or based on such climatic indices and formulae which can give only an approximate value and cannot provide a sound basis for describing the ecological conditions of the relevant areas. On the contrary, vegetation which, besides being an important land forming factor and an attribute, is also a sensitive expression of the environment and can be used as a tool for accurate and sound ecological zoning. Moreover, vegetation has the advantage that it can be seen on the ground and can be identified on the aerial photographs and thus can guide in the delineation of ecological zones. The type of vegetation occurring in any area depends on both the physical and biotic environments. The factors of the physical environment are rock type/parent material, climate, physiography, soil and hydrological conditions. The variations in any of these environmental factors cause differences in the characteristics of a site which result in different vegetation type. Conversely, different vegetation type would grow in different environments i.e., ecological zones, thus forming a sound basis of their delineation.

MATERIALS AND METHODS

Available information on vegetation, climate, relief, geology, landforms, parent materials and soils was transformed into 1 : 2 000 000 scale maps separately.

The vegetation map was prepared by consolidating information from Champion et al (1965), Selod (1969), Rafi (1978) and Beg et al (1985). The climatic zone map of Pakistan by Ahmed (1951) was then superimposed on the vegetation map and by making necessary adjustments, various vegetation indicated climatic regions (bioclimatic regions) were sorted out.

The transparencies of generalized landforms, parent materials and soils maps prepared by the Soil Survey of Pakistan (1970, 78, 82) were combined together and a consolidated map showing uniform lithologic-physiographic-soils regions, was made.

By overlaying the bioclimatic region map on to the lithologic physiographic-soils map, an integrated map of vegetation-ecological zones, showing homogeneous areas within which the vegetation, climatic, lithologic, physiographic and soils conditions are known, was produced. The boundaries of the vegetation ecological zones correspond with the physiographic-soil units.

RESULTS AND DISCUSSION

In all three Ecological Territories, eighteen Bioclimatic Regions constituting the Ecological Territories and thirty six Ecological Zones occurring in the Bioclimatic Regions, have been recognized. They are described in the following pages.

HIGHLAND TERRITORY

Snow Desert Region

This region comprises the highest mountainous ranges in the world and includes the K-2, Nanga Parbat, Raka Poshi and Trichmir peaks. These mountains bear at about 4 600 m above mean sea-level, ice caps, glaciers, and permanent snow fields which may rise to thousands of meters above snow line. The edges of these vast ice masses constitute a special habitat, cold and arid, called snow desert. During summer which is of short duration, these deserts are covered, although sparsely, with herbaceous vegetation, the typical plant species of which include *Primula macrophylla, Sibbaldia*

cuneata, Sedum recticaule, Cerastium cerastioides, C. tibeticum, Minuartia biflora, Oxyria digyna, Potentilla flabellate, P. tephroleuca, Draba sp., Thlaspi alpestris, Waldheimia tridactylites, Gnaphalium stewartii, Arenaria orbiculata, Oxytropis immersa and Luzula spicata.

This region makes the most important water resource of the country in summer.

The wildlife associated with this region includes : snow pigeon, Himalayan snowcock, Alpine cough, Royleshigh mountain vole, long tailed narmot, Himalayan ibex, snow leopard.

Dry Cold Temperate Continental Winter Rains Region

This region occurs in the northern high mountainous tracts of Pakistan lying between 3 400 and 4 000 m altitude above mean sea-level. Record of rainfall within this region is not available. However, snowfall of 2 to 6 m depth falling in the region, is of greater importance. The gradual melting of the accumulated snow ensures adequate soil moisture for most of summer growing season. The mean annual temperature remains below 10°C with monthly means below 0°C for 5 to 6 months. Maximum temperatures do no exceed 15°C while the minimum touches –10°C. Due to high altitude, solar radiation is intense and sun temperature correspondingly high.

This region includes two types of vegetation

- Alpine scrub, and
- Subalpine forest

The alpine scrub zone lies above the subalpine zone between 3 800 and 4 000 m altitude. The alpine vegetation consists of shrub formations composed of a limited number of species, mostly deciduous (Lonicera spp.), but including some evergreen Juniper and sometimes Rhododendron, Ephedra and dwarf, prostrate Salix. There is also a rich herbaceous growth including a variety of palatable grasses and forbs. The typical plant species included in this type are *Juniperus squamata, Rhododendron collettianum, Salix himalayensis S. lindleyana, Lonicera korolkovii, Berberis sp., Cotoneaster sp., Polygonum affine, Sibbaldia cuneata* and numerous other forbs and grasses.

The alpine scrub makes the most important summer grazing lands in the high mountainous part of Pakistan for a large number of sheep, goats and cattle.

The wild life associated with this zone includes: Hodgson's mountain finch, Hodgson's pipit, snow pigeon, snow partridge, white winged grosbeak, blue fronted redstart, Himalayan ibex and red bear.

The subalpine forests make the uppermost forests in the northern high mountainous tracts between 3 400 and 3 800m above sea-level.

The forests consist of the following species, *Betula utilis, Pinus wallichiana, Salix sp., Lonicera sp., Lonicera sp., Juniperus squamata, J. communis* and *Rhododendron anthopogon* and other species including herbaceous vegetation.

Wildlife associated with this zone includes. Hodgson's moutain finch, common corefinch, chukor, snow pigeon, western tragopan, monal pheasant, stone marten, large eared pika, Royles pika, Chinese birch mouse and musk deer.

The region includes two ecological zones, based on differences in vegetation. They are:

- Alpine scrub, Lithic/Typic Cryochrepts very high altitudinal montane zone
- Subalpine forest, Lithic/Typic Cryochrepts high to very high altitudinal montane zone

Dry Cool Temperate Continental Winter Rains Region

This region occurs in the high mountainous tracts of Baluchistan, N.W.F.P and Northern Areas lying between 1 800 and 3 400 m altitude above mean sea-level.

The climax vegetation of this region is dry temperate coniferous forests. There are two main types of forests occurring in this region almost in pure stands:

- Juniperus macropoda type, and
- Pinus gerardiana type

The main associates of these forests are *Fraxinus xanthoxyloides,* and *Pistacia khinjuk* among the trees, while *Prunus eburnes, Cotoneaster racemiflora, Crataegus songarica, Ephedra nebrodensis, Caragana ulicina, C. ambigua, Berberis vulgaris, Lonicers quinquelocurs, Spiraea brahuica* and *Rosa lacerans* are important shrubs.

The mean annual precipitation is about 275-375 mm of which about 60 per cent falls during winter and spring while the remaining in summer, with a part of winter component occurring in the form of snow. The mean annual temperature is about 9°C. Winters are very severe, temperature goes down to below 0°C, while summers are dry and mild. The mean minimum temperature for January is-–0.6°C while the mean maximum for July, the hottest month, is 37°C.

The terrain comprises high mountains with steep slopes and narrow valleys in between them. The slopes, in the main, are bare without soil cover, locally containing Lithic/Typic Xerorthents (shallow loamy skeletal soils). The valleys contain Xerollic Camborthids (deep loamy soils) in their lower parts and Lithic Xerollic Camborthids (shallow loamy soils) in their upper parts.

The region makes the most important watersheds and the summer grazing ground for the nomadic livestock including sheep and goats. Besides timber and fuelwood, it also provides valuable medicinal plants such as *Ephedra nebrodensis* and *Artemisia maritima. Pinus gerardiana* forests are valuable due to their edible pine-nuts.

The lower parts of the valleys are locally used for raising cryophilous fruit orchards including apples, apricots, plums, grapes, peaches and cherry with torrent-watering. Besides, potatoes are also grown.

The region provides habitat for the following wildlife: white capped bunting, redmantled rose-finch, black throated jay, magpie, white winged grosbeak,chukor, Himalayan black bear, stone marten, leopard, markhor and Persian wild goat.

Dry Temperate Continental Winter Rains Region

This region predominates in the mountainous area of Baluchistan, N.W.F.P and Northern Areas between 1 200 and 1 800 m altitude.

The climax vegetation is dry temperate semi-evergreen and evergreen forests. There are two main types of forests occurring in this region. They are:

- Olea-Pistacia type, and
- Quercus ilex type.

The mean annual precipitation in the region varies from 175 to 300 mm, received mostly during winter. Mean annual temperature is about 15.5°C. Winters are severe, temperature goes down below 0°C, while summers are dry and warm.

The region occurs throughout the inner mountain ranges beyond the effective reach of the south-west monsoon. The terrain comprises steep mountain slopes, and alluvial valleys in between them. The mountain slopes contain locally Lithic Xerorthents (shallow loamy skeletal soils), that are mainly bare. In the lower parts of the valleys occur Xerollic Camborthids (deep loamy soils) whereas in the upper parts Lithic Xerollic Camborthids (shallow loamy skeletal soils).

This region apart from supplying some timber and fuelwood and wild Pistacia nuts, constitutes the best livestock producing region since it grows nutritious grasses such as Chrysopogon, in addition to the forage from Olive, Pistacia, Fraxinus, Prunus, Cotoneaster and other shrubs. It also produces some medicinal plants such as Ephedra.

The region provides habitat for grey partridge, see see partridge, chukor, lammergeier, Afghan pika, marbled pole cat, Persian wild goat and Persian jird.

The region is suitable for a wide variety of fruit orchards notably apples, almonds, apricots, peaches, plums, cherries, for vegetables such as chillies, onions, tomatoes, as well as for crops like maize, sorghum, millets, mong, rice and sunflower under irrigation.

Semi-arid Warm Subtropical Continental Winter/Monsoon Rains Region

This region is typical of the foothills and lower slopes of the Himalayas, the Salt Range, Kala Chitta Hills, the Sulaiman Range and the Kirthar Range occurring at elevation between 600 and 1 200m above mean sea-level.

The climax vegetation is dry subtropical semi-evergreen scrub. The typical plant species of this type are *Olea cuspidata* occupying cooler sites and *Acacia modesta* flourishing on warmer sites. *Reptonia* buxifolia is a typical indicator of this type.

The rainfall of this region is about 250 to 375 mm and is distributed evenly between winter and summer. Summers are fairly hot while winters are mild.

This is a transitional region, merging downwards with the lowlands subtropical thorn forests and upwards with the highlands dry temperate evergreen forests or subtropical pine forests, and thus contains flora of both the regions.

It occurs mainly on Teritary shales, sandstones and limestones overlain by shallow gravelly loamy soils classified as Lithic Torriorthents.

The region besides providing some timber and fuelwood could be an excellent cattle producing tract because of its richness in highly nutritive grasses. The leaves of *Nannorrhops ritchieana* (dwarf palm) are valued for manufacturing of mats, ropes, baskets, and for various other uses.

Being transitional between tropical and temperate regions and containing mixed flora of both the regions, this zone makes a highly important agricultural area permitting a wide variety of both the cryophilous and non-cryophilous crops to grow. Fruit orchards of temperate climate such as almonds, apples, pomegranates and apricots as well as crops of tropical climate including cotton, sugarcane, rice, maize, millets, sorghum, wheat, gram, groundnuts, phaseolus beans, sunflower etc. could be grown successfully under irrigation.

This region also provides habitat for a wide variety of wildlife including white cheeked bulbul, Hume's nightjar, chukor, grey partridge, red jungle fowl, barking deer, yellow throated marten and leopard.

The following two ecological zones have been recognized within this region.

- Olea-Acacia modesta, Lithic Torriorthents low altitudinal montane/plateau zone
- Olea-Acacia senegal, Lithic Torriorthents low altitudinal montane zone

Semi-arid Hot subtropical Continental Winter/Monsoon Rains Region

This region occurs in the southern part of the Potwar plateau and in the Peshawar Basin between 250 and 600 m altitude above mean sea-level.

The region is characterized by a low dry subtropical mixed thorny climax vegetation comprising *Acacia modesta, Acacia nilotica, Prosopis cineraria* and *Zizyphus mauritiana* as evidenced from the remnants of these species throughout the region.

The mean annual rainfall in the region ranges from 250 to 350 mm, most of which is received during winter. The mean anuual temperature is 23.5°C. The mean maximum temperature of the hottest month and the mean minimum of the coldest month are 42°C and 4.5°C respectively.

The terrain comprises piedmont and loess plains, severely dissected in patches. The soils are deep, well drained, dominantly fine-silty and clayey with weak to moderate structure in the B horizon. The older soils are non-calcareous whereas the younger ones are calcareous. They are mainly Typic Camborthids.

The region has mostly been cleared of its natural vegetation and is dominantly used for the cultivation of rainfed wheat, pulses, millets, mustard, gram, groundnut and sorghum.

Associated widlife with this region comprises: white cheeked bulbul, Humes' nightijar, grey partridge, yellow throated marten, little brown dove, common babbler, India crested porcupine, pangolin, desert cat, fox, jackal.

Only one ecological zone has been recognized in the region.

- Acacia-Prospis-Zizyphus, Typic Camborthids low altitudinal piedmont/loess plains zone

Arid Hot Subtropical Continental Winter Rains Region

This region occupies the low mountainous tract in Mekran District between 600 and 1 200m altitude above mean sea-level.

The climax vegetation of this region is dry tropical desert thorn scrub. The typical plant species of this type are *Maerua crassifolia, Salvadora oleoides, Nannorrhops ritchieana.*

Rainfall in this region is about 100-125 mm, most of which occurs in winter and spring. The distribution of rainfall is very erratic. However, spring showers are a prominent feature. Winter are cold and summers are hot.

It occurs mainly on Siwalik shales and sandstones containing shallow loamy skeletal soils classified as Lithic Torriorthents.

Owing to harsh climate with low rainfall and high summer temperatures, and irregular terrain with shallow gravelly soils, the region is essentially pastoral. Locally in the intermountain valleys receiving flash floods during rainy season, maize, millets, sorghum and date-palm trees are grown. Besides, *Nannorrhops ritchieana* growing along seasonal streams provides raw material for making mats.

The region provides habitat for wildlife such as: grey partridge, see see partridge, desert cat, caracal, Indian chinkara, Baluchistan urial, Persian wild goat, Baluchistan black bear, Arabian hare, Cape hare, Lybian jird, leopard.

Only one ecological zone within this region has been recognized.

—Maerua—Salvadora—Nannorrhops, Lithic Torriorthents low altitudinal montane zone

Arid Hot Subtropical Continental Monsoon/Winter Rains Region

This region is represented by low hill tracts in the eastern parts of Lasbela and Kalat districts occurring between 600 and 1 200 m altitude.

The climax vegetation of this region is dry tropical thorn scrub occurring as transitional merging downwards with arid tropical thorn forest and upward with the dry temperate evergreen type. There are three main types occurring in this region. They are:

- Olea-Acacia senegal
- Acacia senegal-Salvadora-Capparis, and
- Salvadora-Capparis-Acacia jacquemontii

As regards climate, it forms a transitional area between the arid tropical coastlands, arid subtropical lowlands and dry-temperate highlands. The mean annual rainfall varies from 125 to 200 mm with maxima both in summer and winter. It is very capricious and uncertain. Summers are very hot whereas winters are mild with only occasional frost.

The terrain comprises low mountains consisting mainly of Siwalik shales and sandstones with gentler slopes containing shallow loamy skeletal soils (Typic Torriorthents), locally. They are mainly bare without any soil cover.

Because of its harsh climatic and terrain conditions i.e. low rainfall, high summer temperatures and irregular slopes with patchy and poor soils, the region has only a low potential for winter grazing of sheep and goat, besides providing some fuelwood to the local population.

The region provides habitat for grey partridge, see see partridge, desert cat, caracal, Indian chinkara, bear, Arabian hare, Cape hare, Lybian jird, leopard.

Depending upon differences is vegetation type, the region has been split up into the following two ecological zones.

- Acacia senegal-Salvadora-Capparis, Lithic Torriorthents low altitudinal montane zone
- Salvadora-Capparis-Acacia jacquemontii, Lithic Torriorthents low altitudinal montane zone

Very Arid Hot Subtropical Continental Winter Rains Region

This region is found in the sandy deserts of Chagai and Kharan districts between 600m and 1 200 m altitude.

The climax vegetation of this region is desert scrub. Three main types occurring in this region are:

- Haloxylon salicornicum-Rhazya type
- Haloxylon persicum type
- Alhagi-Desmostachya type

Extreme aridity, high temperatures and frequent dust storms are the chief characteristcs of this region. The rainfall is less than 50 mm of which about 30 mm falls in January and February. The mean minimum temperature for January is about 4°C whereas the mean maximum for July is about 40°C.

The terrain comprises three sets of physiographic-soils units: (i) nearly level to gently sloping intermontane piedmont plains containing Typic Camborthids in the lower parts of the plains and Lithic Camborthids in their upper parts, (ii) undulating to rolling sand dunes comprising Typic Torripsamments, and (iii) playas consisting of Typic Salorthids.

The region is valued for providing very good browse for camels and for fuelwood. Owing to the harsh climatic and terrain conditions, the region has no potential for any other agricultural use.

The wildlife associated with this region comprises: brown necked raven, Lichtensteins desert finch; Hutton's owlet, desert finch lark, hoopoe lark, desert cat, caracal, Lybian Jird.

Based on differences in physiography and soils, the following three ecological zones have been recognized in this region.

- Haloxylon salicornicum-Rhazya, Typic Camborthids/Lithic Camborthids low altitudinal intermontane piedmont plains zone
- Haloxylon persicum, Typic Torripsamments low altitudinal intermontane sandy desert zone
- Alhagi-Desmostachya, Typic Salorthids low altitudinal intermontane playas zone

Subhumid Warm Subtropical Continental Monsoon Rains Region

This region is confined to the northern part of Potwar Plateau and the adjoining lower Siwalik hills lying between 450 and 900 m altitude.

The climax vegetation is a dry subtropical chir pine-broad leaved forest, represented by *Olea cuspidata, Pinus roxburghii, Acacia modesta* and numerous other species. The forest also contains elements of dry deciduous forests, as a type non-existent in the area but penetrating from the east such as *Butea monosperma, Salmalia malabarica, Emblica officinalis, Acacia catechu, Bauhinia variegata, Lannea coromandelica, Ficus roxburghii, Sterculia villose, Flacourtia indica, and Dendrocalamus strictus* generally occurring on gentle topography. This floristic composition is because of its biogeographic topography.

The rainfall in this region ranges between 650 and 1 000mm of which about 70 per cent is received in summer. The temperatures rise towards the month of June. The mean annual temperatures range between 18°C and 24°C, while the mean maximum of the hottest month and mean minimum of the coldest month are 40°C and 3.9°C.

This region comprises the northern submontane slopes consisting mainly of shales and sandstones and the northern part of Potwar Plateau consisting of piedmont and loesss plains. In the submontane slopes the soils are dominantly Lithic/Typic Ustochrepts whereas in the piedmont and loess plains they are Typic Ustochrepts and Haplustalfs.

Most of this region has been cleared of its natural vegetation for rainfed cultivation. The length of growing periods in summer and winter allow for the cultivation of wheat, maize, pulses, groundnut, sorghum, millets, mustard and gram.

The region provides potential habitat for the following wildlife. European roller, barred owlet, chukor, grey goral and leopard.

Depending upon the difference in physiography and soils, the following two ecological zones have been recognized in this region.

- Olea-dry chir pine, Lithic/Typic Ustochrepts low altitudinal montane zone
- Olea-dry chir pine, Typic Ustochrepts/Haplustalfs low altitudinal piedmont plains zone

Humid Cool Temperate Continental Monsoon/Winter Rains Region

This region occupies the northern and north-eastern mountainous tract lying between 1 400 and 3 100m above mean sea-level.

The climax vegetation of this region is Himalayan moist temperate forests. Two main types are commonly present in the region.

The characteristic plant species of type (i) comprise *Pinus wallichiane, Taxus wallichiana, Abies pindrow* and *P. ciliata*

The typical plant species of type (ii) are *Cedrus deodare, Abies pindrow, Picea smithiana* and *Pinus vallichiana.*

The rainfall in this region is above 1 400mm, of which one-half is received during summer season, while the other half is distributed over the cold period, with a part of the winter component occurring in the form of snow. The temperatures rise towards the month of June. The mean annual temperature is 12.5°C, while the mean maximum of the hottest month and mean minimum of the coldest month are 26°C and 0.5°C respectively.

The terrain is mountainous with steep slopes consisting of mafic and ultramafic intrusive and some igneous and metamorphic rocks containing Lithic/Typic Hapludolls and Eutrochrepts.

The blue pine and deodar forests constitute the most important timber and fuel reserves, pastures and watersheds in the region. The length of growing period in winter due to low temperatures is less than 90 days, therefore, winter cropping is not possible in this region. In summer, however, the length of growing period is 120 days where rainfed cultivation of only maize is possible.

The region is a potential habitat for the following wildlife: black and yellow grosbeak, rufous turtle dove, short billed minivet, chestnut mantled koklas pheasant, white crested kallej pheasant, grey goral, Himalayan black bear, yellow throated marten, leopard, leopard cat.

Depending upon the difference in vegetation types, two ecological zones have been recognized in this region:

- Moist blue pine, Lithic/Typic Hapludolls and Eutrochrepts moderately high to high altitudinal montane zone
- Mixed coniferous, Lithic/Typic Hapludolls and Eutrochrepts moderately high to high altitudinal montane zone

Humid Moderately Cool Subtropical Continental Monsoon/Winter Rains Region

This region is confined to the north-eastern middle mountainous belt covering Murree and Kahuta ranges at an altitude between 900 and 1500 m.

The climax vegetation of this region is subtropical moist chir pine forest which is hitherto still intact. The forests include also many elements of the moist temperate flora. The characteristic species of this forest type are: *Pinus roxburghii, Gedrela serrata, Fraxinus excelsior, Pistacia integerima, Olea ferrugines* and *Quercus incana.*

The rainfall in this region ranges from 1 000 to 1 400 mm, half of which is received during summer, while the other half is spread over the cold period, partly as snow. The snow, however, does not stay long. The temperatures tend to rise towards the month of June. The mean annual temperature is about 18°C, while the mean maximum of the hottest month and the mean minimum of the coldest month are respectively about 28°C and 2.2°C.

The terrain is mountainous with steep and very steep slopes and comprises shale, sandstone and limestone rock types. The soils on the slopes are under forests.

The chir pine forests are valued for providing timber and fuelwood and for constituting important waterhseds as well in the region. The length of growing periods both in summer and winter are

110 and 180 days respectively, permitting cultivation of wheat, maize, groundnuts, millet and sorghum under rainfed conditions.

The wildlife associated with this region includes. chukor, jungle fowl, cheer pheasant, white crested kaleej pheasant, grey goral, yellow throated marten, leopard.

The region includes only one ecological zone, namely :

- Moist chir pine, Lithic/Typic Eutrochrepts and Hapludolls low to moderately high altitudinal nontane zone

LOWLANDS TERRITORY

Arid Hot Subtropical Continental Monsoon Rains Region

This region includes the south-western Punjab and the middle and the upper Sind covering Thal, Cholistan, northern Tharparkar, piedmont plains of D.G.Khan, D.I.Khan, Sibi and Kachhi districts and Subrecent and Recent river plains of the Indus, Jhelum, Chenab, Ravi and Sutlej rivers. This region makes the driest part of the Lowlands Territory.

The climax vegetation of this region is arid tropical plains thorn scrub (Champion, 1965). The typical species of this type are *Propsois spicigera, Capparis decidua, Salvadora eloeoides, Tamarix aphylla, Zizyphus mauritiana, Z. nummularia, Tecoma undulata, Phoenix dactylifera* etc. found as remanants here and there.

Rainfall is less than 250 mm, about 80 per cent of which falls in summer. Length of growing period is less than 75 days, therefore no cultivation is possible without irrigation. Summers are very hot and winters mild but not frost-free. In summer, dust storms are frequent and scorching winds blow in May and June when temperature rises to 47°C.

The terrain comprises rolling to hilly sand plains. (Thal, Cholistan and northern Tahrparkar), piedmont plains and Subrecent and Recent river plains. The soils in the sand plains are dominated by Typic Torripsamments, whereas in piedmont plains and Subrecent river plains they are Typic Camborthids, although locally Typic Salorthids and saline phase of Typic Camborthids are also met with. In the Recent river plains, the soils are predominantly Typic Torriorthents.

The temperatures are highly conducive for the growth of a wide variety of crops both cryophilous and non-cryophilous under irrigation. The most suitable crops are cotton, gram, alfalfa, wheat, sorghum (fodder) and onions. Sugarcane, maize and rapeseed have moderate suitability. Dates are highly suitable, but mangoes moderately suitable due to likelihood of frost damage.

The wildlife assoicated with this region includes: white throated munis, little brown dove, common babbler, collared turtle dove, Indian hare, jungle cat, Indian chinkara, grey partridge, black partridge, Hog deer, wild boar, Houbara bustard, Bengal fox, desert warbler, cock pythos, Indian coarser, Hoopoe lark, Night hereon, coucal, yellow eyed babbler, spotted sand grouse, black buck and grey mongoose.

The following six ecological zones, each indicating a definite set of ecological conditions, have been recognized within this region.

- Calligonum, Typic Torripsamments sandy desert zone
- Capparis-Suaeda-Tamarix Typic Camborthids piedmont plains zone
- Salvadora, saline Typic Camborthids piedmont plains zone
- Prosopis-Capparis, Typic Camborthids Subrecent river/piedmont plains zone
- Tamarix-Phoenix dactylifera, Typic Camborthids Subrecent river plains zone
- Acacia-Populus, Typic Torriorthents Recent river plains zone

Semi-arid Hot Subtropical Continental Monsoon Rains Region

The region includes central Punjab covering Subrecent and Old river plains and occurs as transition between arid hot subtropical region in the west and south-west, and subhumid warm sub-tropical region in the north-east.

It has been categorized as arid tropical plains thorn forest (Champion, 1965). The characteristic plant species are. *Salvadora oleoides, Tamarix aphylla. Acacia nilotica, Zizyphus mauritiana, Z. numularia, Prosopis cineraria* and *Capparis aphylla.*

The rainfall in this region veries from 250 mm in the south-west to 500 mm in the north-east. Both the summer and winter rainy seasons are well-marked, although the former is longer. Summers are intense while the winters are cold with occasional frost. The mean maximum temperature for June, the hottest month, remains below 43°C.

The terrain comprises level to nearly level Subrecent and Old river plains. The soils are loamy to clayey and well drained. They are mainly Typic Camborthids. although locally, some Typic Salorthids and saline phase of Typic Camborthids are also present.

Most of the area in this region is irrigated. Temperatures are highly suitable for a wide variety of cryophilous and non-cryophilous crops. The most suitable crops of this region are wheat, maize, soyabean, berseem and summer pulses. Sugarcane, cotton, citrus especially Kinnow, mango and guava are moderately suitable. Under rainfed conditions, hardier and drier crops like sorghum, millets, gram, water-melon could be grown in the northern part of the region.

The associated wildlife of this region includes; white throated munis, little brown dove, common babbler, collared turtle dove, Indian hare, jungle cat, Indian chinkara, leopard.

In this region only one ecological zone has been recognized.

- Salvadora-Prosopis, Typic Camborthids Subrecent/Old river plains

Subhumid Warm Subtropical Continental Monsoon Rains Region

This region forms the northern strip of Punjab adjoining the Himalayan foothills. It is comprised of Old piedmont plains and Subrecent river plains.

The climax vegetation of this region according to Champion et al (1965) is tropical dry decidutus forest, composed dominantly of deciduous trees, with a few trees of the thorn forest type. An important feature of this forest type is that it is leafless during dry season, and attains an almost luxu-

riant appearance in the monsoon season. These forests have almost been cleared for cultivation, only a few remnants are present here and there which provide a fair indication of this bioclimatic region. *Butea monosperma* and *Dalbergia sissoo* are the predominating species with a few other species of the dry deciduous or thorn forest.

The rainfall in this region is quite reliable and increases rapidly from 500 mm in the south 1 000 mm in the north and is received mostly in monsoon. The winter rains are also greater than in the plains southwards and are quite significant to encourage barani rabi cultivation. The area suffers more from floods than from droughts. The annual range of temperature is great; the mean maximum for June is 40°C, and the mean minimum for January is 5.5°C. Frost is unusual but may occur.

The terrain comprises Old piedmont plains and Subrecent river plains containing mainly loamy and clayey Typic Ustochrepts/Typic Haplustalfs.

The region is mainly used for irrigated and to a lesser extent for rainfed cultivation. Under irrigated cultivation, the most suitable crops are fine rice, wheat and berseem whereas under rainfed cultivation, groundnuts, wheat, rapeseed, millets and pulses are suitable. Besides, guava and mango are also suitable.

The wildlife associated with this region comprises. black partridge, white crested kaleej pheasant, peafowl, barking deer and nilgai.

Basaed on differences in physiography and soils, the following two ecological zones have been recognized in this region.

- Butea, Typic Ustochrepts/Typic Haplustalfs piedmont plains zone
- Butea, Typic Ustochrepts/Typic Haplustalfs river plains zone

COASTLANDS TERRITORY

Arid Warm Tropical Maritime Monsoon/Winter Rains Region

This region occurs along the coast, south-east of Karachi, covering tidal flats, and estuarine plains.

This region is represented by mangrove forest/scrub and saline scrub. The former is associated with the tidal flats where *Avicennia officinalis, Ceriops tagal, Rhizophora mucronata* and *Bruguiera conjugata* are the characteristic species, and the latter with the saline estuarine plains where *Suaeda fruticosa, S. nodiflora, Salsola foetida, Tamarix troupii, Salvadora persica* and *Calotropis procers* are the main species.

The rainfall in this region does not exceed 175 mm, summer rainfall increases in amount towards the east, while the winter rains are higher towards the west. The mean annual temperature is above 29°C, May and June being the hottest months with a secondary maximum in October. This

region is characterized by a steady inflow of sea-breeze throughout the summer, high humidity (75% or more), and low ranges of both the annual and diurnal temperatures.

The terrain comprises mainly tidal flats and estuarine plains. The former typically contains compact saline clayey soils submerged by salt water at every rise in tide. The soils of this terrain are dominated by Typic Salorthids.

The region is predominantly used for grazing of sheep, goats and camels.

The region provides habitat for wildlife such as reef heron, little green heron, curlew, whimbrel, terek sand piper, painted stork, large sand plover, fishing cat and smooth coated India otter. Besides, it serves as a resting ground for a large number of migratory birds.

Arid Warm Tropical Maritime Monsoon Rains Region

This region covers the southern part of the Tharparkar Desert and the adjoining Subrecent plains of the Indus River.

The climax vegetation of this region is arid tropical coastland mixed thorn scrub. The typical plant species of this type are *Acacia senegal, Acacia jacquemnotii, Euphorbia caducifolia, Commiphra mukul, Cordia rothii, Prosopis spicigera, Zizyphus nummularia, Salvadora oleoides, S. persica, Crewis tenex, Blepharis sindica, Avera javanica, Cassia angustifolia, Calligonum polygonoides, Crotolaris burhia, Panicum antidotale, Eleonurus spp.* etc.

The rainfall in the region varies from 175 mm in the west to 250 mm in the east, most of which is concentrated in the months of July and August. Both the annual and diurnal ranges of temperature are great. May and June are the hottest months. The mean maximum temperature for May is about 42°C and the mean minimum temperature for January, the coldest month, is about 10°C. Sea breeze blows throughout summer and is accompanied by dust-storms which are most frequent in the month of June. The region is free from frost.

The terrain comprises: i) rolling to hilly sandy desert with sand ridges aligned parallel to the south-western winds containing mainly Typic Torripsamment soils, and ii) Subrecent river plains containing mainly Typic Camborthids and locally Typic Salorthids.

The sandy desert provides a natural grazing ground for large herds of sheep, goats, cattle and camels. In the eastern part adjoining Indian border, where the rainfall is higher, rainfed cultivation of sorghum, millets and guar is done.

In the Subrecent river palins, the most suitable crops under irrigation are. sugaroane, maize, soyabean, rapeseed, wheat, lentils, sorghum (fodder), alfalfa, berseem and onion. Among fruits, mango and guava are highly suitable but banana and papaya have moderate suitability.

The associated wildlife of this region is little brown dove, painted sand grouse, streaked scrub warbler, common babbler, white throated munia, grey partridge, Houbara partridge, peafowl, desert cat, caracal, Indian chinkara, black buck, Indian hare, Baluchistan gerbil and leopard.

Based on marked differences in physiography and soils, the following two ecological zones have been recognized in this region.

- Acacia senegal-Calligonum, Typic Torripsamments sandy desert zone
- Acaica senegal, Typic Camborthids river plains zone

Arid Warm Tropical Maritime Winter Rains Region

This region makes the southern most part of Baluchistan plateau comprising mainly low hills of less than 500 meters altitude, and their piedmont plains occurring along the Makran coast.

The climax vegetation of this region is arid tropical coastland thorn scrub characterized by *Acacia jacquemontii, Acacia senegal, Euphoriba daducifolia, Commiphora mukul, Salsola foetida* and *Saueda spp.*

Two types have been recognized in this region:

- Acacia jacquemontii-Acacia senegal
- Suaeda-Salsola

The former is confined to the low hills part whereas the latter occurs in the saline piedmont plains.

The rainfall of this region is about 150 mm, about two-thirds of which falls in December to February, January being the rainiest month. The weather is generally mild, except during the months from May be July, when the mean maximum temperature is above 37°C. Hot winds descending from the interior occasionally raise the temperature still higher. Winters are mild, the mean minimum temperature of the coldest month is about 13°C.

The terrain comprises mainly low hills composed of shales and sandstones which aie mainly bare, locally containing Lithic Torriorthents. Part is made up of saline piedmont plains, where the soils are Typic Salorthids.

The region serves as a poor grazing ground for goats and camels only. Because of the harsh terrain and climatic conditions, and poor soils it has no potential for agriculture. Depending on physiography and soils the following two ecological zones have been recognized in this region.

- Acacia jacquemontii-Acacia senegal, Lithic Torriorthents montane zone
- Saueda-Salsola, Typic Salorthids piedmont plains zone

The wildlife associated with the first zone consists of little brown dove, painted sand grouse, streaked scrub wabler, common babbler, white throated munia, grey partridge, Houbara bustard, peafowl, desert cat, caracal, Indian Chinkara, Indian hare, Baluchistan gerbil and leopard. Piedmont plains zone provides habitat for Indian Chinkara and Indian wild ass.

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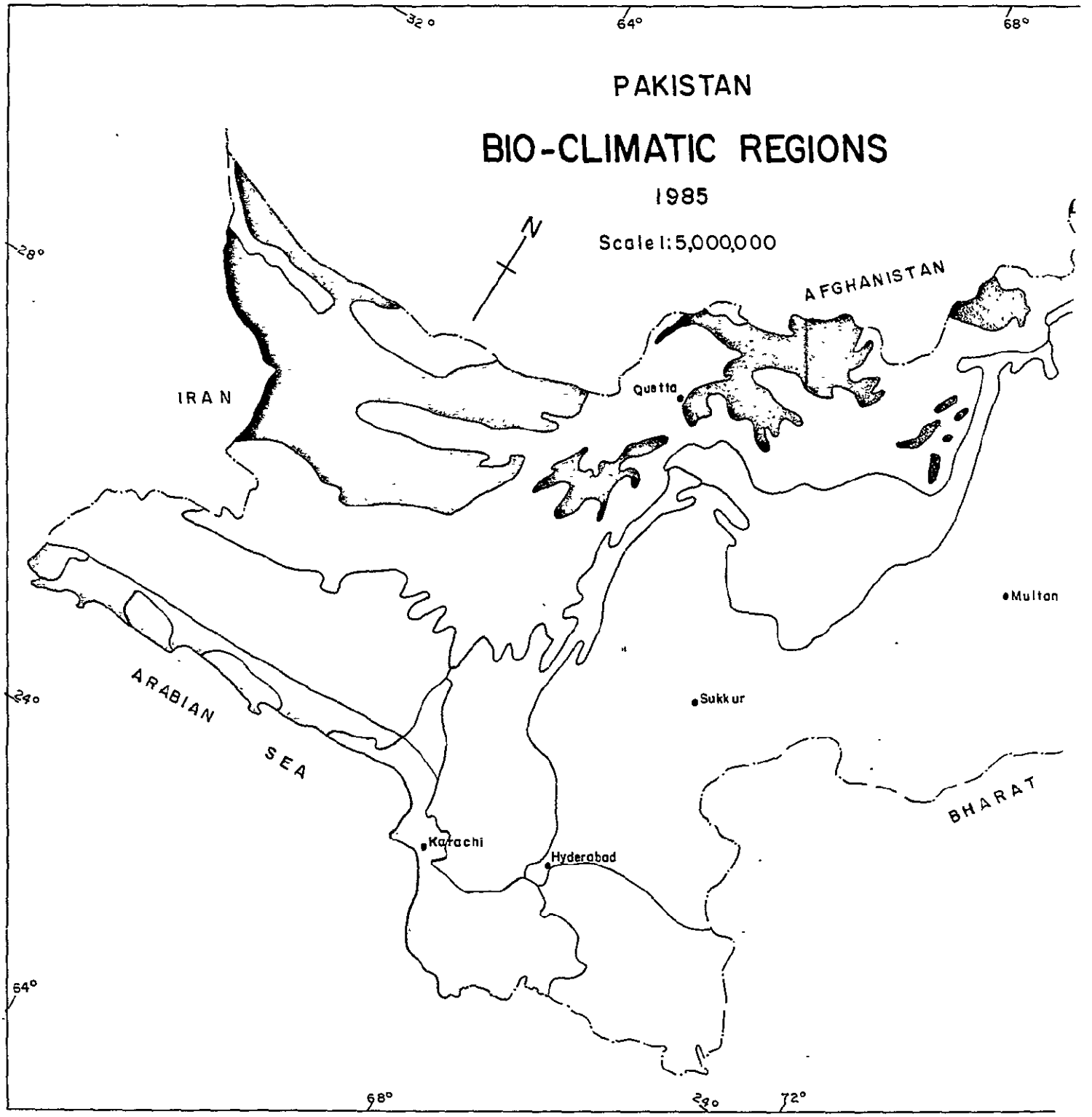
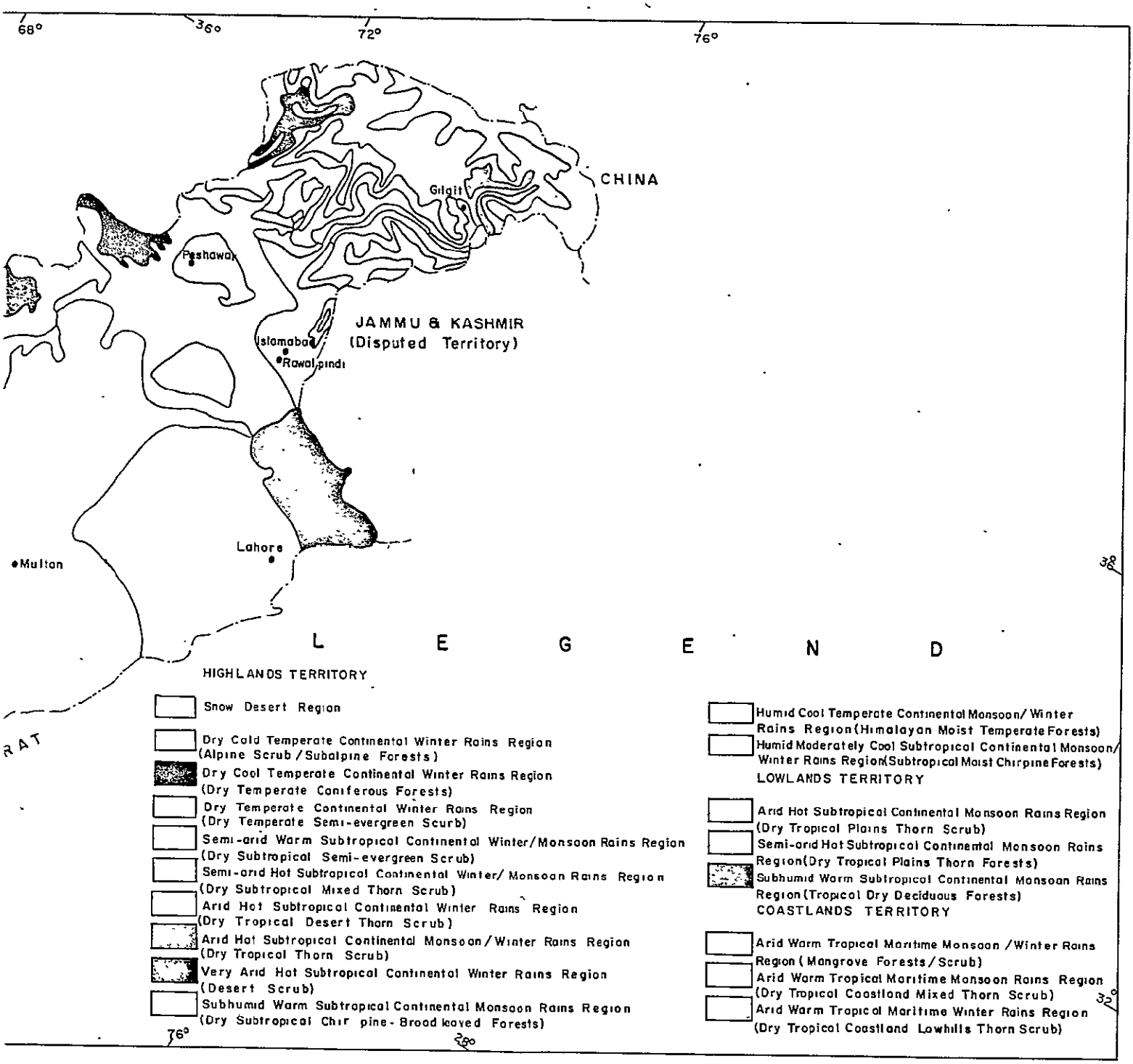

PAKISTAN
BIO-CLIMATIC REGIONS
1985
Scale 1:5,000,000
N
32°
64°
68°
28°
24°
64°
68°
28°
72°
IRAN
AFGHANISTAN
Quetta
Multan
Sukkur
ARABIAN
SEA
BHARAT
Karachi
Hyderabad

72A


68°
36°
72°
76°
CHINA
Gilgit
Peshawar
JAMMU & KASHMIR
(Disputed Territory)
Islamabad
Rawalpindi
Lahore
Multan
32
L E G E N D
HIGHLANDS TERRITORY
Snow Desert Region
Dry Cold Temperate Continental Winter Rains Region (Alpine Scrub / Subalpine Forests)
Dry Cool Temperate Continental Winter Rains Region (Dry Temperate Coniferous Forests)
Dry Temperate Continental Winter Rains Region (Dry Temperate Semi-evergreen Scurb)
Semi-arid Warm Subtropical Continental Winter/Monsoon Rains Region (Dry Subtropical Semi-evergreen Scrub)
Semi-arid Hot Subtropical Continental Winter/ Monsoon Rains Region (Dry Subtropical Mixed Thorn Scrub)
Arid Hot Subtropical Continental Winter Rains Region (Dry Tropical Desert Thorn Scrub)
Arid Hot Subtropical Continental Monsoon/Winter Rains Region (Dry Tropical Thorn Scrub)
Very Arid Hot Subtropical Continental Winter Rains Region (Desert Scrub)
Subhumid Warm Subtropical Continental Monsoon Rains Region (Dry Subtropical Chir pine - Broad leaved Forests)
Humid Cool Temperate Continental Monsoon/ Winter Rains Region (Himalayan Moist Temperate Forests)
Humid Moderately Cool Subtropical Continental Monsoon/ Winter Rains Region (Subtropical Moist Chirpine Forests)
LOWLANDS TERRITORY
Arid Hot Subtropical Continental Monsoon Rains Region (Dry Tropical Plains Thorn Scrub)
Semi-arid Hot Subtropical Continental Monsoon Rains Region (Dry Tropical Plains Thorn Forests)
Subhumid Warm Subtropical Continental Monsoon Rains Region (Tropical Dry Deciduous Forests)
COASTLANDS TERRITORY
Arid Warm Tropical Maritime Monsoon /Winter Rains Region (Mangrove Forests / Scrub)
Arid Warm Tropical Maritime Monsoon Rains Region (Dry Tropical Coastland Mixed Thorn Scrub)
Arid Warm Tropical Maritime Winter Rains Region (Dry Tropical Coastland Lowhills Thorn Scrub)
32°
76°
280

726

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PART III
SOIL SURVEY INTERPRETATION AND LAND EVALUATION

- The Role of Soil Survey in National Agriculture Davelopment Programme — M. Amjad Hassan
- Desertification and its Assessment — M.A. Tahir
- Interpretation and Use of Soil Survey Data in Pakistan — M. Yasin Javed

THE ROLE OF SOIL SURVEYS IN NATIONAL AGRICULTURE DEVELOPMENT PROGRAMMES

M. AMJAD HASSAN*

INTRODUCTION

Before 1962, relatively little was known about the soil resources of Pakistan, apart from the experience gained over several centuries of grazing and irrigated/rainfed agriculture on a traditional pattern, and some sixty years of large scale canal irrigation.

In the absence of modern soil surveys it was assumed that soils in the plains of Pakistan were 'Alluvial" and genetically undeveloped; and that texture was the single most important variable. This view was further stregthened by the report "Landforms and Soils of Indus Plains" by Fraser et al 1957, published by the Government of Canada for the Government of Pakistan. In the early 'thirties' the increasingly high water-table, and consequent water-logging as a result of extensive canal irrigation development, caught the attention of the Government in some areas. Also at about the same time, erosion in the foothills and rainfed uplands of Pakistan was recognized as a danger. This resulted in the creation of two organizations, "Directorate of Land Reclamation" and "Central Soil Conservation Organization", for the control of the problems of soil salinity and soil erosion. The Land Reclamation Directorate carried out salinity surveys. Some soil surveys of small areas were carried out by the Soil Conservation Directorate.

Various kinds of surveys concerning land and soils, conducted in the past by various agencies in selected areas, were single-value surveys meant to serve a limited purpose. Moreover, the information, for the most part even in local areas, was not available to other concerned agencies as, in most cases, published reports were not produced. It was difficult to correlate the information as the methods used by various agencies were different. The Soil Survey Project of Pakistan was set up in 1962 in order to remove the afore-mentioned drawbacks and to provide, through regular basic soil survey operations, a comprehensive body of knowledge about the soils of Pakistan.

NATURE OF SOIL SURVEYS

There is a general belief in our country that the main purpose of soil survey is to collect soil samples for laboratory analysis in order to assess their nutrient content and thereby make recommendations for the use of fertilizers. This is not correct. The purpose of soil survey is to describe, identify, classify and map soils, through airphoto interpretation, field work and soil profile examination. The field work includes the study of soil profiles, the surface features, drainage, natural vegetation and the land use. As natural bodies the soils are classified into defined units: soil series, families, subgroups,

*Soil Survey of Pakistan, Lahore.

great soil groups etc. The field data is subsequently processed to produce the soil survey report and maps which contain the description and distribution of the soils besides other information. Soil samples are collected from representative sites of each soil and are analysed in the laboratory. The soil analyses data and the field data are used as complementary to each other for the description of the soils.

Special purpose surveys

Soil surveys are sometimes carried out for a special purpose and only those soil properties are noted which concern that purpose. The soil surveys carried out by the Directorate of Land Reclamation are of this type as these surveys were conducted for the purpose of investigating the extent of salinity problem and the soils were classified on the basis of texture and salt content. Similar surveys were carried out by the 'Water and Soil Investigation Division' of WAPDA. Such surveys are useful but only for the limited purpose. Additional field work is needed if the surveys are to be used for some other purpose.

Basic soil surveys

A basic soil survey is designed to collect data on all soil properties and to classify soils on the basis of all significant differences in properties. As it contains all the information about soil properties, it can be interpreted for many different purposes without any additional field work. Such soil surveys are now carried out in most of the advanced countries as they are more economical in the long run than the special purpose surveys.

DETAIL OF MAPPING

With respect to the detail of soil mapping there are three main kinds of soil surveys, i.e. exploratory, reconnaissance and detailed. The exploratory soil survey is done to get a general idea about the soil resources of a large region or the whole country. It is used for agricultural development planning at various levels. It supplies information about the kinds of soils and their extent but the individual soils are not shown separately on the soil map.

Reconnaissance soil surveys

The Soil Survey of Pakistan is carrying out "Reconnaissance" soil surveys. In this survey, individual soils are described and classified but they are mapped as soil associations which are groups of soils naturally occurring together in a distinct pattern. In the soil survey report the soil associations are described in terms of the component soils, their important properties, their relative proportion and position in the landscape, together with their present land use, their limitations and suggestions for specific improvement. Different soils have different potential for various uses. The reconnaissance soil survey reports and maps, will serve as a comprehensive "INVENTORY OF THE SOIL RESOURCES" of the country in terms of potential for agricultural development. With accurate soil maps and accompanying reports, the land users can make full use of the technology to realise the true potentialities of the soil for sustained production.

The total area of Pakistan (869 000 square kilometres) has been split up, for the purpose of reconnaissance soil survey, into two categories, 'A' and 'B' according to the suitability and importance for agricultural use. The Category 'A' includes the agriculturally important area and comprises the Indus Plains including the Peshawar Valley. It has been given priority for soil surveys and by June, 1985, all the 'A' level area and most of the 'B' level area have been surveyed. Most of the survey reports have been published. Each soil survey report contains descriptions of various soils of the survey area, their land capability classification and present land use. Due to the reconnaissance nature of the survey the soil maps show only soil associations which are groups of soils occurring together in a landscape, in a definite geographic pattern. In the report, each soil association is described in terms of its component soils, their proportion, important properties, limitations and specific improvements which are needed to realise their potential. The position of each soil in the landscape is also indicated. The soil associations are interpreted into land capability associations for agricultural use and these are shown on separate maps accompanying the report. The land capability associations are also described in terms of the component capability subclasses, their proportions, limitations and suggested improvements. The soil survey report also contains the description of the present land use in terms of land use assoications which are also shown on a map. The suitability of each soil for various crops is also given in the reports. Thus the soil survey reports give information not only about the potential of the area but also about the present situation.

Detailed soil surveys

Whereas the reconnaissance soil surveys provide data for planning development projects, detailed soil surveys are needed for the execution of development projects, for individual farm planning and for the orientation of agricultural research by soil types. The detailed soil surveys of all the agricultural research stations in the country have been carried out. In addition, the Tehsils of Peshawar and Hyderabad, and part of Multan have also been surveyed at detailed level.

The detailed soil surveys of research stations show whether the soils are representative of that area or not. By reconnaissance surveys the major soils of these research stations are already known and the detailed surveys show whether their soils are representative of the major soils that occur in that area or not. For instance, the Rice Research Institute, Kala Shah Kaku has been found to be located on very unrepresentative soils and so the hard work of the research workers is not fully rewarded.

SOIL SURVEY INTERPRETATION

The reconnaissance soil survey has been completed for the major part of Pakistan. Now the question arises—How to use this information? The answer is—through interpretation of the soil survey data. The reconnaissance soil survey reports contain basic data on soils, their properties, their relationship, the drainage and the climate. This basic data can be interpreted for many uses. Land capability classification and crop suitability ratings are the two interpretations included in the survey reports but many more interpretations can be made for various uses.

USE OF RECONNAISSANCE SOIL SURVEYS

The data provided by the reconnaissance soil survey is meant primarily for planning agricultural

development at various levels—national, provincial, district, tehsil and development projects. The main uses of this survey are mentioned below:

- Planning of agricultural development. In this regard soil survey data is interpreted to assess the land capability, and crop suitability of the soils. The area of various land capability subclasses in a province, district or project can be worked out to find areas where development will be most rewarding and quick. Costly failures can thus be avoided. The survey data will help to find out the economic feasibility of a development project.
- Planning for conservation of soil and water resources on the basis of land capability classification.
- Planning of irrigation and reclamation projects. For centuries, land settlement has been on a trial and error basis. This approach was successful in areas with high proportion of good land but it utterly failed in Kotri Barrage Command where about 50 per cent land is unfit for agriculture.
- Planning of towns and selection of sites for factories on land not suitable for agriculture, so that good agricultural land is saved.
- Planning development of forest and range areas on land not suitable for agriculture. For example, the class IV and VI land in the subhumid areas and very sandy soils of riverain areas with sweet water at shallow depths can be used for forests.
- Providing information for engineering purpose, e.g. alignment of roads, location of construction material (sand, gravel, clay etc.) and location of airports and buildings.
- Providing basis for the suitable location of agricultural research stations. Recently the soil survey information was used for locating suitable sites for tea research trials in Pakistan.
- Providing teaching material for courses in Soil Science, Soil Morphology, Soil Genesis, Soil Classification, Geography etc. in educational institutions of the country.
- Providing a framework for detailed soil surveys which are needed for planning at individual farm level.

PRACTICAL EXAMPLES OF VARIOUS USES OF SOIL SURVEY IN PAKISTAN

As a result of the activities of Soil Survey Department many aspects of soil resources in Pakistan have become much better understood than before and the soil survey data has been actually used by various organizations in many different ways. These uses were, however, possible by interpretation of the soil survey data. The following are just few examples, to show the utility of soil survey data in the development of the country. They show that the scientific soils information leads to considerable economy of capital and helps to avoid costly failures.

Planning of agricultural development projects

The Shadab Project, a pilot project of integrated rural development, used the soil survey data for planning the development programme. The survey data was interpreted to suit the requirements

of the project. Also, detailed soil surveys were carried out for the preparation of plans of Model Farms within the project area.

The reconnaissance soil survey data have been used for planning of agricultural development of the riverain areas of Sind. The development was planned by the Project Planning Directorate, Southern Zone, WAPDA, for installation of tubewells.

Planning of salinity control and reclamation projects

The detailed study of the genesis of saline-sodic soils, during the soil survey opertaions, revealed that saline-sodic soils are of two main kinds i.e. (i) porous and (ii) dense or without porosity. The dense saline-sodic soils are not economically reclaimable because in the absence of porosity the permeability of these soils is very low, almost zero, and the water either does not move down or moves so slowly that the reclamation process is very slow and uneconomic. Some of the salinity control and reclamation projects have been planned on the basis of soil survey data (Example: SCARP-5-Lahore District).

Reclamation experiments

In Khairpur area experiments* on reclamation of various kinds of saline and saline-sodic soils were conducted by the Reclamation Expert, SCARP–Khairpur, using the soil survey data. The results of these experiments confirmed the findings of the Soil Survey of Pakistan and helped to refine the limits of the economically reclaimable soils. This was the first time that the reclamation experiments on saline soils were conducted by kinds of soils in Pakistan. Now that the area of various kinds of soils is known through soil surveys, the results of these experiments can be applied with greater certainty of success.

Planning of irrigation projects

An exploratory soil survey of the Hab Dam Irrigation Project area was made by the Soil Survey Department at the request of the Agricultural Development Corporation. The survey showed that half of the area, planned to be irrigated, comprised poor land with very shallow soils underlain by gravel or rock. The smooth surface of the land was deceptive. The timely soil survey helped to avoid the wastage of millions of rupees.

It was planned to irrigate an area near Karachi by constructing a high level canal from Kotri Barrage and the water was to be lifted by about 15 metres. A timely exploratory soil survey showed that the area to be irrigated was mostly unfit for irrigated agriculture due to very shallow soils; hardly one-third area had suitable soils. The wastage of millions of rupees was thus avoided.

Suitability of agricultural research stations

The detailed soil survey of Kala Shah Kaku Rice Research Institute has shown that almost whole of it has unrepresentative soils. The major area has a reclaimed phase of a severely saline-sodic soil and has at present 20 to 40 cm of reclaimed surface soil underlain by impervious saline-sodic layers. Thus the hard work of the research scientists working there is not fully rewarded.

* de Vos, J.H. Reclamation Report 1969-71, SCARP, Khairpur.

The reconnaissance soil surveys show that some agricultural research stations are located on unrepresentative soils. Agricultural Research Station, Rawalpindi is another example as it represents a soil which occurs only in the vicinity of Rawalpindi. So a new research station near Rewat or Gujar Khan and an additional station near Pindi Gheb are needed. The research station near Chakwal is not representative as it is in the trasitional zone between subhumid and semiarid climate. No research station is located in the main arid zone, from Multan to Nawab Shah. At Multan and Khanpur stations research is conducted only on cotton and fruits. So new research stations are needed in the following areas:

- Rewat or Gujar Khan, Rawalpindi District.
- Pindi Gheb, Attock District.
- Sukkur or Khairpur District.
- Indus delta area.

Fertilizer experiments

Soil fertility trials on farmer's fields have been carried out throughout Pakistan for many years, but without regard to soils. No recommendations could, therefore, be given for specific soils and only general fertilizer recommendations are made for a region. Being averages, these recommendations hold good for few soils but on others they do not give the desired results; in some cases they produce even negative response.

The Soil Survey Department started identification of soils of the fields in which the Soil Fertility Directorate staff conducted fertilizer experiments. The soil survey information was also used to select experimental fields so that the experiments were done on main soils and the results were applicable on large areas.

The trials are being conducted under the Soil Capability Assessment Network (SCAN) to evolve optimum management requirements of soils grouped together on the basis of similarity in important characteristics i.e. soil families. Soils of major soil families have been selected in the irrigated as well as barani areas and research is in progress on farmer's fields. In the first instance the fertilizer response of major crops is being studied to formulate recommendations for each soil family.

Irrigation planning

To date, development and allocation of irrigation water have been planned on the basis of projected average cropping intensities and average yields, without considering the variability of soils. The Soil Survey Department of Pakistan have produced land capability classification on a uniform standard for nearly whole of the Indus plains. This shows that: (i) generally the proportion of very good and good irrigated and irrigable land in the Indus Plains is quite high but its full capacity for crop production is not being realized due to shortage of water, (ii) the proportion of very good, good, moderate and poor land varies a great deal between canal commands: for example, Thal and Kotri Barrage commands contain much lower proportion of very good and good land than other commands. This information will help in the allocation of new irrigation water between canal commands, so that water is first allocated to meet the demands of very good and good land on which it gives much higher return than the moderate or poor land. If water is surplus, then it may be allocated to the moderate land. The poor land gives so low returns that the scarce water should not be wasted on it.

In view of the shortage of irrigation water, extension of cultivation on to the poor land should be discouraged and we should try to increase production per unit of water instead of per unit of land. The farmer should be encouraged to concentrate on good land instead of spreading his limited water supply on all his land.

Problems of the Indus delta

The soils of Indus delta (the Kotri Barrage command) have formed under conditions quite different from the other parts of the Indus Plains, and so they present unique problems. Large areas of extremely silty soils formed by massive spills of the river under the influence of sea tides have low clay content but very high percentage of silt, resulting in very high capillary porosity favouring upward movement of water from more than ten feet. In these soils the water moves down through them only when water is standing on the surface. So the downward movement of water takes place only during the irrigation, for a few hours, and then the moisture moves upward under the influence of capillary pull created by evaporation. There is a severe salinity problem which cannot be solved unless the water-table is lowered to more than twelve feet —an impossible task.

The good soils of the Indus delta are clayey and have good porosity. Their pores are such that the downward movement of water and salts predominates over the upward movement. So once reclaimed, these soils remain nonsaline if the water-table is kept below three feet. When the drainage network is completed in the area, these soils will form good irrigated land and give high net returns. But these cover only about half of the delta area. The remainder, covered by very silty soils, should not be brought under cultivation.

The substratum of the clayey soils is also very silty with very slow permeability. The drains should, therefore, be placed in clayey layer above the silty substratum. It is expected that mole drains made at short intervals will be most useful. Drainage by tubewells has failed because perched water-table remains above the impervious silty layer.

Problems of Potwar Upland

The soil survey has shown that there are two climatic zones in the Potwar Upland—one is subhumid with rainfall of more than 500 mm The best soils in the subhumid area form class III land (moderate agricultural land) and the best soils in the semiarid zone form class IV land (poor agricultural land). It may be mentioned that the class I and class II lands occur only under irrigation in Pakistan. The class IV is economically marginal land on which agriculture is barely profitable.

It has been found by soil surveys that there is an extensive area of class III land on which improvements are quite feasible and economic. This should receive prime attention in the development programme. The class IV land that is already under cultivation should be improved next.

Soil erosion is a problem on about 51% in Rawalpindi and Jhelum districts, 28% in Attock district and in areas falling in Gujrat district on about 20 per cent of the cultivated land, the rest being almost free of erosion hazard. The problem of soil erosion is of different magnitude on different soils. For example, the silty soils are much more vulnerable to erosion than the loamy soils. The major cause of soil erosion is the practice of leaving the land vacant during summer and emphasis on wheat

production. Cultivation of groundnuts on loamy soils and sorghum on clayey soils would help to check soil erosion but this is possible only if wheat supply is assured from the irrigated areas.

The reconnaissance soil survey shows areas of different types of soils and land capability classes and subclasses. Now the foremost need is to evolve suitable cropping pattersn for various land subclasses so that maximum potential of the land is realized and soil erosion is kept under check. The suitable erosion control practices can also be evolved for various types of land.

Deep ploughing and levelling

Deep ploughing has been found to increase crop yields in some soils but on the Kala Shah Kaku Rice Research Station it resulted in total crop failure. The soil survey information shows that the soil has only about 25 cm thick good surface layer underlain by strongly alkaline layers. The deep ploughing mixed the bad subsoil layer with the good surface layer which had been created by reclamation and cropping for 50 years.

Deep ploughing gave good results during the first year at Faisalabad but later the water intake rate decreased. A look at the soil layers showed that deep ploughing had destroyed the natural propsity. It has been found that some soils have impervious and dense layer below the plough layer (at 10 to 25 cm depth). Deep ploughing is useful only in such cases and the depth of ploughing should be enough only to break the dense layer.

For land levelling also, the soil survey information is necessary. Shallow soils over sand or gravel or rock may be destroyed by levelling in the absence of such information.

Alignment of roads

On the basis of soils data, the alignment of the following roads were proposed to the Highway Departments.

–Road between Ahmadpur East and Feroza in Bahawalpur Circle. The road section between Channi Goth and Feroza was previously located in an area with very high water-table caused by the seepage from the Panjnad Main Canal. Realignment of this road in the light of the soil survey informattion solved this problem.

–Road between D.G.Khan and Loralai. The help of the Soil Survey Department in the alignment of this road not only helped in avoiding sharp bends, steep slopes and higher elevation spots, but also reduced the length of the road as much as by 65 km.

– Road between Kharian and Jalalpur Jattan. The existing road is unmetalled and crosses a number of streams coming from the adjoining hills. Help was rendered in selecting suitable sites for bridges on the streams in order to reduce the cost of bridges, and to avoid road bends.

–Road between Muridke and Qila Suba Singh. According to the first plan the road was located on very good agricultural land. The road alignment was shifted to the dense saline-sodic land which is worthless for agricultural use.

–Road between Qila Suba Singh and Narowal and between Badiana and Zafarwal. These roads had problems of failure in certain sections. The soil survey data showed that these points were the

areas of seasonally wet and swelling clays. In new alignments of these roads the trouble spots were avoided.

Town planning

All the cities and towns are rapidly expanding. The soil surveys show that in most cases, very good agricultural land is being used for the prupose which is lost for ever. There are areas of poor land which has no economic potential for irrigated agriculture and at many places they are not very far from the cities and towns. The expansion of Lahore, for example, is on very good agricultural land on the southern side. This is the only land that can be used to produce fresh vegetable, fruit and milk, and can also form a green belt around the city. With proper integrated planning on the basis of the soil survey data, the city of Lahore could be transformed into a city of gardens with intensive cultivation of vegetables and fruits on good land to the south-east, south and west.

Forestry planning

The soil survey shows that the irrigated forest planatations are located mostly on very good agricultural land. It has been estimated that the net returns from the land under these forest planatations is about one-third to one half of what it would be under agriculture. Good forest can be grown even on poor land with very sandy soils (example: forest planatation a few miles north of Sargodha). So in future the poor land with very sandy soils occurring in riverain areas and having sweet ground water within 3 to 5 meters depth can be utilized for forest planatations. In such areas, irrigation will be needed only for the first few years and later the trees will thrive on the ground moisture.

Miscellaneous

A light weight concrete made by firing of balls made from certain clayey soils is used in special buildings structure. The Soil Survey Department provided samples of various clayey soils to a foreign expert of engineering for this purpose. It was found that one clayey soil which is useless for agriculture, is good for making light weight concrete.

DESERTIFICATION AND ITS ASSESSMENT

M. A. TAHIR*

INTRODUCTION

Desertification is comparatively a new word but the process has been active since historical times. Destruction of some old civilizations has been attributed to desertification processes. It can be tracted in the literature that a commission was appointed as early as 1922 to investigate the effects of drought in South Africa. The findings and recommendations of the commission were almost similar with the present day results. Despite extensive past human miseries the problem of desertification was considered of localized nature in areas like the Great Sahara, Gobi, Rajastan and Australian deserts until about a decade ago when the catastropic drought occurred for five years (1968-73) in the Sahara taking a heavy toll of 100 000 to 250 000 human and innumberable animal lives. This tragedy attracted world attention and through a United Nations General Assembly Resolution, World Conference on Desertification was held in 1977. Since then the problem is under active consideration at international and national levels but it is a general consensus that the fight against desertification is not being won. The Executive Director of the United Nations Environment Programme confessed in May, 1984 that the war against desertification is being lost. Similarly a headline in a leading western newspaper appeared 'March of Deserts unstoppable'. Hunger strucken people of Ethiopia is a daily news item. This situation is a matter of great concern for the soil scientists, the agronomists, the environmentologists and the range managers and demands for realistic plans; proper motivation of people and governments.

It has been estimated that one-third (about 47 billion ha) of the earth surface falling in arid & semi-arid zones and populated by 850 million people (19 per cent of the world's population) and consisting of parts or whole of some 91 countries, is prone to the danger of desertification and some 190 million people are immediately menaced. It has also been estimated that about 20 million ha are deteriorating each year through the desertification process to the point where they produce zero or negative returns.

UNESCO prepared a world map (Fig. 1) showing distribution of arid regions, based partly on aridity indices and partly on temperature, soil, relief, vegetation, etc. Following criteria for aridity were used.

Hyperarid when P/Etp is less than 0.03
Arid when P/Etp is from 0.03 to 0.20
Semi-arid when P/Etp is from 0.20 to 0.50
Sub-humid, when P/Etp is from 0.50 to 0.75

*Soil Survey of Pakistan, Lahore.

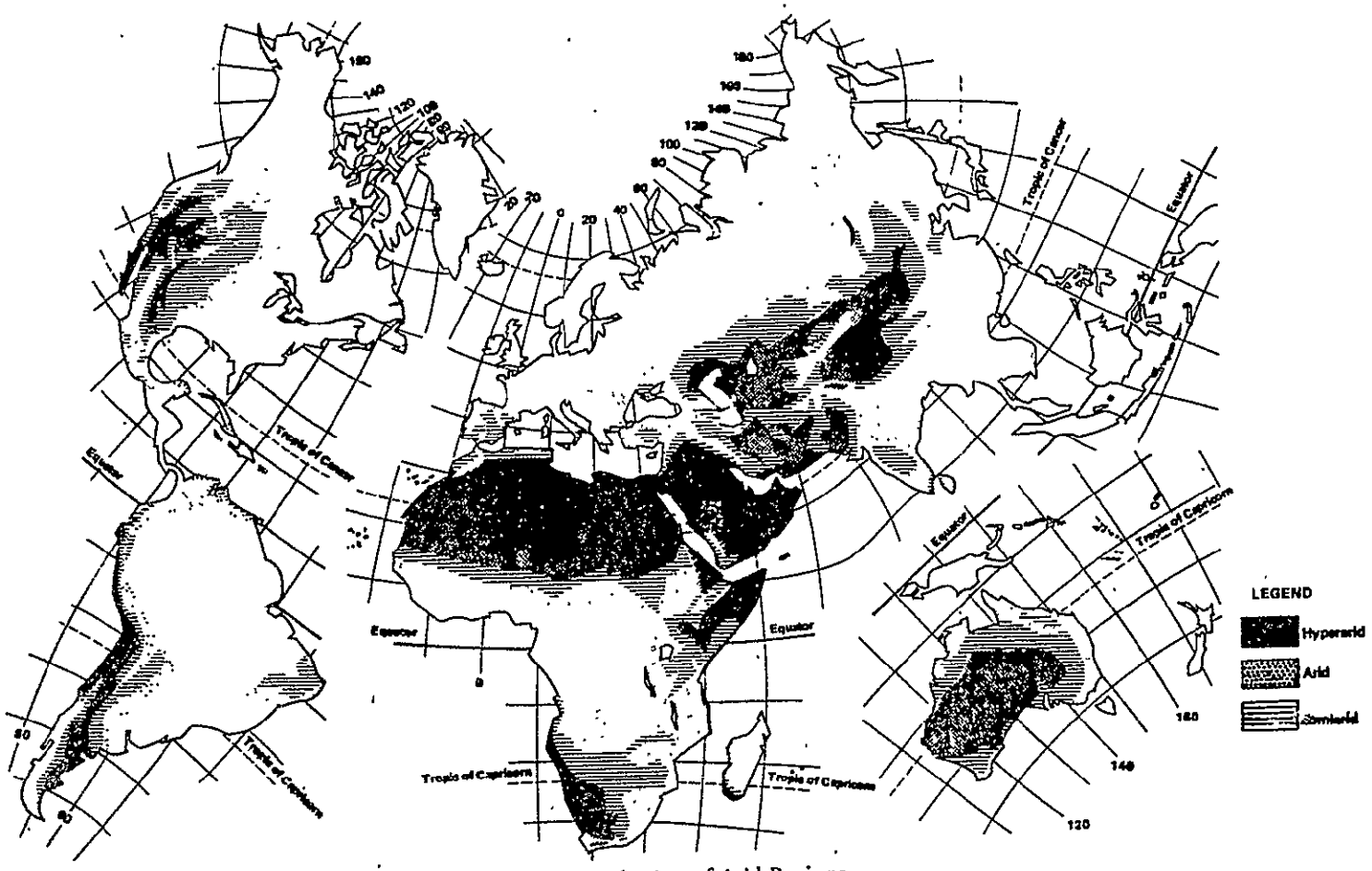

Fig. 1 World Distribution of Arid Regions

where P is average annual precipitation and Etp is potential evapotranspiration. Based on the above mentioned factors three degrees of desertification hazard were defined:

Very high: The region will be subject to very rapid desertification if existing conditions do not change.

High: The desertification hazard lies between the two conditions mentioned in very high and moderate.

Moderate: The region will change only slowly from its present state to a more degraded stage if existing conditions do not change.

Hence estimates of dry land areas of the world and the risk of desertification incurred has been given in table 1. Similar calculations for Pakistan were made which are presented in table 2.

Table 1. Dryland areas of the world including Antarctica

ARIDITY	Hyperarid		Arid		Semiarid		Subhumid		Aridity Total	
Desertification Risk	Km²	%	Km²	%	Km²	%	Km²	%	Km²	%
Very high	By definition desertification		1 173 497	0.8	2 017 892	1.3	165 252	0.1	3 356 641	2.2
High	does not exist		14 856 563	9.9	2 798 457	1.9	615 282	0.4	18 270 302	12.2
Moderate	in hyperarid		2 370 746	1.6	11 803 973	7.9	3 578 544	2.4	17 753 263	11.9
	regions.									
Desertification Totals			18 400 806	12.3	16 620 322	11.1	4 359 078	2.9	39 380 206	26.3
No Desertification	9 181 052	6.1	859 955	0.6	1 085 988	0.7	10 514 060	7.0	21 641 055	14.4
Total Drylands	9 181 052	6.1	19 260 761	12.9	17 706 310	11.8	14 873 138	9.9	61 021 261	40.7
							Non-dryland		88 699 184	59.3
							Total Area of the Territory		149 720 445	100.0

Table 2. Dryland areas of Pakistan

ARIDITY	Hyperarid		Arid		Semiarid		Subhumid		Aridity Total	
Desertification Risk	Km²	%	Km²	%	Km²	%	Km²	%	Km²	%
Very High	By definition, desertification		2 145	0.3					2 145	0.3
High	does not exist in hyperarid		247 750	30.3	83 307	9.4	11 998	1.4	363 055	41.1
Moderate	regions.				75 357	8.5			75 357	8.5
Desertification Totals			269 895	30.6	158 614	17.9	11 998	1.4	440 557	49.9

No Desertification								
Total Drylands	269 895	30.6	158 614	17.9	11 998	1.4	440 557	49.9
					Non-dryland		442 318	50.1
					Total Area of the Territory		882 875	100.0

DEFINITION

Before defining desertification it may be useful to define desert. A quantitative definition of desert has been given as: A region of the earth where ten hectare would fail to produce sufficient pasture to nourish one cow and a calf. Desert has also been defined as a dryland almost totally devoid of vegetation. A more compreheensive definition may be, "Deserts can be hot or cold, clayey, sandy or stony, waterlogged or saline but highly deficient in rainfall with high rate of evaporation and scarce or absence of vegetation".

Regarding desertification some one hundred definitions appear in the literature. Here only two are cited. The first reflects the substance of the problem. 'Desertification is a natural or man-induced process of irreversible change of soil and vegetation of dry land in the direction of aridization and diminution of biological productivity, which in extreme cases may lead to total destruction of biological potential and conversion of the land into desert.

Thc second is the one accepted by the 1977 United Nations Conference on Desertification (UNCOD). 'Diminution or destruction of the biological potential of the land which can lead ultimately to desert–like conditions'.

The potential danger of the problem can be judged from the proceedings of UNCOD which describes desertification as a self–accelerating process, feeding on itself with rehabilitation costs rising exponentially with time, if allowed to continue unchecked, reaching economically and technically irreversible limits.

CAUSATIVE ELEMENTS

"We have here a degeneration that is the result of too severe struggle for existence. When a man, cold, hungry and sick simply to save what is left of life, to keep his children alive. . . . clutches at anything to satisfy his hunger and destroys everything headless of the morrow" (Dr. Astrov).

The statement points towards the factor–man and the other major factor is severity of climate. So there are two factors or causative elements i.e. the man–induced causes and the natural causes. Their listing may include: overgrazing, soil compaction, increase in rainfed cultivated areas, firewood cutting, pressure of human and livestock population, use of soil for unproductive uses, irrational utilization of water resources, extension of irrigation on unsuitable lands, cultivation of steep slopes etc. and on the other hand drought, strong winds, sporadic heavy showers, excess of evaporation over precipitation, mineralization of water, low rainfall, albedo, salt spray, topography, type of soil, floods, loss of top soil, advance and encroachment of sand dunes, depletion of water supplies, lowering of

ground water, sea water intrusion, reduction in biological activities, excess of toxic substances, suspended dust etc.

DESERTIFICATION PROCESSES

For practical purposes the induced or natural processes leading to desertification are considered to be:

- Degradation of the vegetation cover
- Water erosion
- Wind erosion.
- Salinization
- Reduction in soil organic matter
- Soil crusting and compaction
- Accumulation of substances toxic to plants or animals.

CRITERIA FOR ASSESSING

UNEP in collaboration with FAO (Food and Agriculture Organization of the UN) held three expert consultations to develop parameters and their limits for the assessment of the dynamics of desertification in respect of the processes involved and the hazards. A provisional methodology was developed and tested in twelve countries including Pakistan. Consequent upon the field tests, the methodology was modified. The recommended factors and the class limits by aspects of desertification for degradation of vegetation cover, water erosion, wind erosion, salinization, soil crusting and compaction and organic matter reduction are given in tables 3 to 8.

Table 3. Criteria for assessing degradation of vegetative cover

Desertification Aspect	Assessment Factor	Class Limits			
		Slight	Moderate	Severe	Very Severe
Status	Canopy cover of pernnial plants (%)	>50	50 – 20	20 – 5	<5
	Range condition (%) of desirable vegetation	>75	50 – 75	25 – 50	<25
	Present productivity (%) of potential productivity	85–100	65 – 85	25 – 65	<25
Rate	Decline (%) of biomass production/ha	<10	10 – 25	25 – 50	> 50
	Range condition degradation (%) per year	<2.5	2.5 – 5	5 – 7.5	>7.5
	Harvest of woodlands. (%) per year without replacement	<2.5	2.5 – 5	5 – 7.5	>7.5

	Decrease in fodder production (%) per year	<1.5	1.5 – 3.5	3.5 – 7.5	>7.5
Inherent Risk	Climatic conditions for biological productivity (Kg of Dm/ha/yr/mm of rain)	roductivity >5	2 – 2.5	2.5 – 1	<1
	Potential for reclamation (year)	<3	3 – 5	5 – 10	>10

Table 4. Criteria for assissing water erosion

Desertification Aspect	Assessment Factor	Class limits			
		Slight	Moderate	Severe	Very Severe
Status	Surface status (%)	Gravel and Stones	Stones and boulders	Boulders and rocks	Boulders, exposures of rocks
		<10	10 – 25	25 – 50	>50
	Type of erosion	In sheet and rill (Slight to moderate)	In sheet and rill (Moderate to severe)	In sheet, rill and gully (severe)	In sheet, rill and deep gully (very severe)
	Subsoil exposed (%) of area	<10	10 – 25	25 – 50	>50
	Gully area, (%) of total area	<10	10 – 25	25 – 50	>50
	Soil thickness (cm)	> 90	90 – 50	50 – 10	<10
	Loss of soil depth over root inibiting layer, %				
	Original soil depth <lm	<25	25 – 50	50 – 75	>75
	Original soil depth >lm	<30	30 – 60	60 – 90	>90
	Present productivity (%) of potential productivity	85 – 100	65 – 85	25 – 65	<25
Rate	Increase in eroded area (%) per year	<1	1 – 2	2 – 5	>5
	Soil loss, Mt/ha/year	<2.0	2.0–3.5	3.5–5.0	>5.0
	Decrease in annual biomass production (%) per year	<1.5	1.5–3.5	3.5–7.5	>7.5
	Sediment deposition in reservoirs, watershed 500 km^2 (m^3/km2/yr)	<60	60 –200	200 – 500	>500
	Watershed > 500 km^2	<40	40 –100	100 –250	>250
	Annual loss of storage (%)	<0.2	0.2–0.4	0.4–1.0	>1.0

Inherent Risk	Rating of climatic aggressivity	<0.03	0.03–0.06	0.06–0.10	> 0.10
	Rating of pedo-topographical conditions	<1	1 – 2	2 – 3	>3
	Rating of potential soil loss in t/ha/hr	<5	5 – 12	15 – 25	>25

Table 5. Criteria for assessing wind erosion

Desertification Aspect	Assessement Factor	Class Limits			
		Slight	Moderate	Severe	Very Severe
Status	Surface area covered by hummocks, (%) of area	<5	5 – 15	15 – 30	>30
	Loss of soil depth over orrt inibiting layer, %				
	Original soil depth < 1 m	<25	25 – 50	50 – 75	>75
	Original soil depth > 1 m	<30	30 – 60	60 – 90	>90
	Present productivity, % of potential productivity	85 – 100	65 – 85	25 – 65	<25
	Soil thickness (cm)	<90	90 – 50	50 – 10	<10
	Surface gravel (%) of surface covered	<15	15 – 30	30 – 50	>50
Rate	Increase in area, (%) per year	< 1	1 – 2	2 – 5	>5
	Soil loss, Mt/ha/yr	<2.0	2 – 3.5	3.5 – 5.0	>5
	Decrease in annual biomass production, (%) per year	<1.5	1.5–3.5	3.5–7.5	>7.5
	Amount of sand per year transported over the 1 m line, m^3	<5	5 – 10	10 – 20	>20
Inherent Risk	Wind erodibility groups (texture of soil)	sand clay loam, sandy clay, silt	rest of the textural classess	loamy sand	sand
	Mean annual wind speed at 2 metre height, m/s	<2	2 – 3.5	3.5 – 4.5	>4.5
	Active wind ($v \geqslant 6$ m/s) frequency (in % of total number of winds per year)	<5	5 – 20	20 – 33	>33
	Rating of potential sand movement	<5	5 – 15	15–25	>25

Table 6. Criteria for assessing salinization

Desertification Aspect	Assessment Factors	Class Limits Slight	Moderate	Severe	Very Severe
Status	Morphological indications indications	no salts	spots of salts	spots and micelles of salt	Crystals afflorescence, pseudo sand salt crust or salt puff
	ECe x 10^3, maximum level in any 15 cm layer within 75 cm of soil surface	<4	4 – 8	8 – 16	>16
	ESP, maximum level in any 15 cm layer within 75 cm of soil surface	<5	5 – 20	20 – 45	>45
	Crop yields, (%) of potential productivity	85 – 100	65 – 85	25 – 65	>25
	Surface area affected adversely, (%) of delineated area	< 5	5 – 20	20 – 50	>50
	Boron, parts per million in soil saturation extract	<0.25	0.25–0.5	0.5–1.0	>1.0
	Mineralization of the water ECe x 10^3	<4	4 – 8	8 – 16	>16
	g/l	<2.5	2.5 – 5.0	5 – 10	>10
Rate	Increase in salt affected area (%) per year	<1	1 – 2	2 – 5	>5
	Increase in ECe x 10^3 in any 15 cm layer within 75 cm of soil surface, per year	<0.4	0.4 – 0.8	0.8 – 1.6	>1.6
	Increase in ESP in any 15 cm layer within 75 cm of soil surface, per year	< 0.5	0.5 – 2.0	2.0 – 4.5	>4.5
	Increase in boron in soil saturation extract, parts per million per year	<0.025	0.025–0.05	0.05–0.1	>0.1
	Decrease in crop yield (%) per year	<1.5	1.5–3.5	3.5 – 7.5	>7.5

Inherent Risk	Average depth to groundwater table, cm	>300	300 – 100	100 – 50	<50
	Quality of irrigation water				
	Salt content, g/l	0.5	0.5 – 1.5	1.5 – 3.0	>3.0
	ECe x 10^3	0.75	0.75 – 2.25	2.25 – 5.0	>5.0
	SAR	4	4 – 7	7 – 10	>10
	RSC	1.25	1.25 – 2.5	2.5 – 4.0	>4.0
	Boron, mg/l	0.75	0.75 – 1.5	1.5 – 3.0	>3.0
	Physiography/landform	Level plains	Level plains	Basins and channel remnants	Basins and channel remnants
	General drainage	good	imperfect	poor	poor
	Internal drainage	moderate	slow	very slow	very slow
	Soil management practices and drainage system	good/ special	moderate	poor	poor
	Rating of potential soil salinization	<0.6	0.6 – 2.4	2.4 – 15	>15

Table 7. Criteria for assessing status of soil crusting and compaction

Assessment Factor	Class Limits			
	Slight	Moderate	Severe	Very Severe
Calcic accumulation and 1 cementation form (depth in cm)	Generalized accumulations and/or nodules (30 – 50)	Crusting (30 – 50) or generalized accumulations and/or nodules (< 30)	Crust (10 – 30) or crusting (< 30)	Crust (< 10)
Gypsic accumulation and cementation form (depth in cm)	Gypsum accumulation (50 – 100)	Gypsum sand or powder (30 – 50)	Gypsum powder (< 30)	Crust (< 10)
Ferric accumulation and cementation form (depth in cm)	Nodules and concertion (30 – 50)	Crusting (30 – 50) or nodules and concertion (< 30)	Ironstone (10 – 30) or crusting (< 30)	Ironstone (< 10)
Silicon dioxide accumulation and cementation form (depth in cm)	Crusting (< 50)	Crusting (30 – 50)	Crusting (10 – 30)	Crusting (< 10)

Table 8. Criteria for assessing organic matter reduction

Class limits	Status Criteria	Rate Criteria
Slight	90 – 100% of maximum natural level	Organic matter in suface reduced <1%/Year
Moderate	70 – 90% of maximum natural level	Organic matter in surface reduced 3–7%/year
Severe	30 – 70% of maximum natural level	Organic matter in surface reduced 3–7%/year
Very Severe	< 30% of maximum natural level	Organic matter in surface reduced < 7%/year

Criteria for assessing toxic substances

The reduction in productivity, as an indicator of desertification due to excess of toxic substances in the soil, in the air and in the water is suggested. The limits for reduction in productivity are the same as for the other processes of desertification.

DESERTIFICATION ASSESSMENT IN PAKISTAN

In view of the criteria internationally accepted only a little work on desertification assessment has been carried out in Pakistan. The results in Thal are presented in table 9.

Table 9. Desertification Assessment in Thal

Mapping unit	Extent (km^2)	Per cent
E – 1 E3	7 582	39.2
E1 – V2	2 567	13.3
E2	2 008	10.4
E2 – V2	1 081	5.6
E2 – V2 – E4 – V4	5 554	28.8
E4 – V4	146	0.8
E4 – E1	372	1.9
Total	1 9310	100.0

where E stands for erosion, V for vegetation and S for salinity/sodicity. The numerals 1 to 4 indicate the degree of desertification i.e. 1 for slight, 2 for moderate, 3 for severe and 4 for very severe.

Similar work has been undertaken at two sites namely Din Garh and Fortabbas in Bahawalpur Division. Each site comprises 100 sq. km. in Cholistan. The overall results of these sites based on the various factors are presented in tables 10 and 11.

Table 10. Extent of desertification classes in Din Garh

Classes	Extent (ha)	Percentage
Moderate	1 253	12.5
Severe	7 601	76.0
Very severe	1 146	11.5
Total	10 000	100.0

Table 11. Extent of Desertification classes in Fortabbas

Classes	Extent (ha)	Percentage
Slight	1 647	16.5
Moderate	1 426	14.2
Severe	4 609	46.1
Very severe	2 318	23.2
Total	10 000	100.0

These sites and a third site at Islamgarh where the field work has been completed and the report preparation is in hand will form the basis of assessing the extent of various desertification classes in Cholistan.

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INTERPRETATIONS AND USE OF SOIL SURVEY DATA IN PAKISTAN

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ABSTRACT

The primary interpretations of soil survey data in Pakistan are land capability classification and crop suitability rating of soils in qualitative terms. These are general-purpose interpretations related to common agricultural use of land. Special-purpose interpretations are made for planning and execution of various land development projects, agricultural as well as non-agricultural, when required by the concerned organizations or by the government. Important fields of soil survey data utilization include assessment of general agricultural potential, integrated rural development planning, development, of new agricultural lands, irrigation extension and water management, agronomic research, formulation of cropping patterns, improvement of soil management, fertilizer use and production, reclamation of saline lands, erosion control, drainage planning, agro-ecological zoning, forest improvement, range and dairy development, land consolidation, siting of agro-based industries, town planning, alignment of roads and trafficability assessment etc. Future use of soil survey data in many disciplines is likely to increase with further development of the data interpretation techniques and with the availability of more detailed soils and climatic data.

INTRODUCTION

The primary objective of soil surveys is to provide data about the characteristics, distribution and extent of various kinds of soils occurring in an area. The soil characteristics considered are closely related to the performance of land under agricultural as well as nonagricultural use and are, therefore, of fundamental value for land use planning. The soil survey data form the basis of land resource assessment for various development projects. Efficient utilization of the data, however, depends on their purposeful interpretations which should have relevance with the environments and socio-economic conditions of the project areas. The quality of interpretations is largely determined by the type and adequacy of additional knowledge available with the interpretor. The interpretations may be changed or modified with the growth of scientific knowledge and technological developments. The other data required for land resource assessment include climate, hydrology, relief, vegetation and competetive types of land utilization.

The most commonly used interpretations of soil survey data in Pakistan are the land capability classification for general agricultural purposes and land suitability assessment for individual crops. Such interpretations are included in the routine soil survey reports published by the department of Soil Survey of Pakistan. The capability classification basically considers the adaptability of land for general arable use, forestry and range development but also indirectly guides in planning of various engineering

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works and rural structures, such as designing of irrigation and drainage channels, urbanization and siting of agro-based industries. The suitability ratings are helpful in determining the most suitable cropping patterns for different areas.

The intension behind these common interpretations was that the soil survey data should be used by the officials and technologists involved in research, planning and development of land resources. The data, however, remained a Greek to most of its prospective users until recently. We, therefore, adopted to impart training to the technical staff of the concerned departments with a view to help them understand and interpret the data for specific purposes while, at the same time, started issuing simplified and elaborated versions of the soil survey reports by modifying their data in directly usable forms. Some special-purpose reports were prepared on demand from various departments and agencies. In addition, the post-graduate students of the universities and colleges were introduced to the importance of soil survey data and the scope of their application in various fields. This was accomplished with the help of special field excursions, showing practical examples. The results were quite encouraging so that over a dozen of different departments, institutes and agencies are now not only efficiently using the soil survey data but also, of necessity, requesting the collaboration of soil survey staff in their various projects.

This paper presents a review of how the soil survey data interpretations are currently applied or can be applied in Pakistan for various pruposes.

METHODOLOGY

The interpretations of soil survey data for specific kinds of land use are based partly on the Land Capability Classification followed by the United States Department of Agriculture (USDA, 1961) and partly on matching the characteristics of soils and other related environmental factors with the requirements of the land use which follows the procedure recommended by FAO (1976) and Beek (1978).

The soil characteristics are studied in the field, by adopting the standards of USDA's Soil Survey Manual (1951) and FAO's Guidelines for Soil Description, and correlated with different kinds of land use under known conditions of relief, climate, hydrology, natural vegetation and socio-economic structure etc. This correlation helps in determining the optimal and minimal requirements of any land use in terms of land characteristics and in identifying the important limitations that play role in classification of land according to suitability for the intended use. The available data on land resources are then matched with these requirements to assess land suitability under certain assumed conditions. The tracts of land satisfying optimal requirements of a land use and having no significant limitations are classified as highly suitable while those fulfilling only the minimal requirements or having severe limitations are assessed as marginally suitable for purposes of the relevant use. Where even the minimal requirements are not satisfied, the land is regarded as unsuitable for the purpose. The intermediate categories of land are classified accordingly.

The interpretations of soil survey data are primarily done in terms of relative suitability for the purpose of a land use, indicating the important limitations that affect the use in the form of increasing costs or decreasing returns. Economic analyses of the land suitability classes then leads to their defini-

tion in quantitative terms. The kinds and severity of limitations are interpreted to suggest specific management measures for best performance of land under a certain use or for best service of the purpose.

INTERPRETATIONS AND USE OF SOIL SURVEY DATA FOR AGRICULTURE

Agriculture is the most related and widest field of soil survey data use. For this purpose, the data are primarily interpreted to classify land according to its capability for sustained production of common agricultural crops or forest trees, or for range development. This classification is based on the expected relative response to inputs and the net returns obtainable under an assumed medium level of management. There are four classes (i.e. class I to IV) to define the land capability for arable farming and another four classes (i.e class V to VIII) to define the land potential for forestry or range. The highest class, i.e. class I for arable farming and class V for forestry or range, would give the highest relative response to inputs and would bring the highest returns at the same inputs and management level from the respective land use. The lower classes will have correspondingly lower response and returns.

On the same grounds, the soil data are interpreted to classify land according to its suitability for different crops so that, for any tract of land, the most suitable crops would be the most economical to grow and the most feasible to conserve the soils as a natural resource.

The soil data interpretations in terms of land capability and crop suitability are integral parts of the routine soil survey reports issued by the Soil Survey of Pakistan. In addition, widely different interpretations are made to satisfy the requirements of various agricultural organizations. These are special-purpose interpretations adapted to the requirements of the organizations. The important agricultural fields in which interpretations of soil survey data are of fundamental importance and most commonly applied are discussed below.

Assessment of general agricultural potential and integrated development planning

The soil survey data of an area interpreted in the form of land capability provide an estimate of general agricultural potential of the area and help in planning for integrated rural development. The data have been widely used for that purpose under the IRDP (Integrated Rural Development Programme) during 1970's. The data are used also by the international agencies including IFDA (International Fund for Agricultural Development) and FAO (Food and Agriculture Organization of the United Nations) for planning of agricultural development and determining the magnitude and kind of aid required by Pakistan in the agricultural sector. The PARC (Pakistan Agricultural Research Council) and Soil Survey of Pakistan are currently collaborating in a project of SCAN (Soil Capability Assessment Network) to identify the constraints in soil management and to have an overall assessment of the potential for agricultural production. This project is entirely based on the soil survey data collected by Soil Survey of Pakistan.

Development of new agricultural lands

Land differs considerably from place to place in its response to agricultural use. The new lands which are to be developed now for agriculture are mainly those which have no or only a low potential for that purpose, so that very low or negative returns are expected from most of them. The proportion

of potentially productive land is rather small. This proportion must be sorted out to delimit area and justify cost of any development project on new lands. For that purpose, soil survey data are interpreted to classify land according to its suitability for agriculture. The extent and potential productivity of each land suitability class are then exploited to estimate gross returns from the project and match them with the project costs to see the feasibility of such projects. Various land development agencies, including NESPAK (National Engineering Services Pak. Ltd.), WAPDA (Water and Power Development Authority) and PLUA (Punjab Land Utilization Authority) are making good use of soil survey data interpretations for this purpose.

Irrigation extension, water distribution and management

The irrigation water is a limited resource in Pakistan. The canal water which has a high quality and is the cheapest source of irrigation is especially short and must be used economically on lands which are capable of giving high returns. So, the irrigation projects involving construction of dams and extension of canals require, for their feasibility reports, the land suitability classification based on expected net returns per unit area and per unit of irrigation water in quantitiative terms. Interpretations of soil survey data can be made for such classifications too. In a case study made by the author (Javed, 1981) in two different ecological zones of Pakistan i.e. Lahore zone and Multan zone, net returns per ha and per ha–m of irrigation water use on 4 different classes of land are estimated as in Fig. 1. The NESPAK and other relevant agencies make good use of such interpretations.

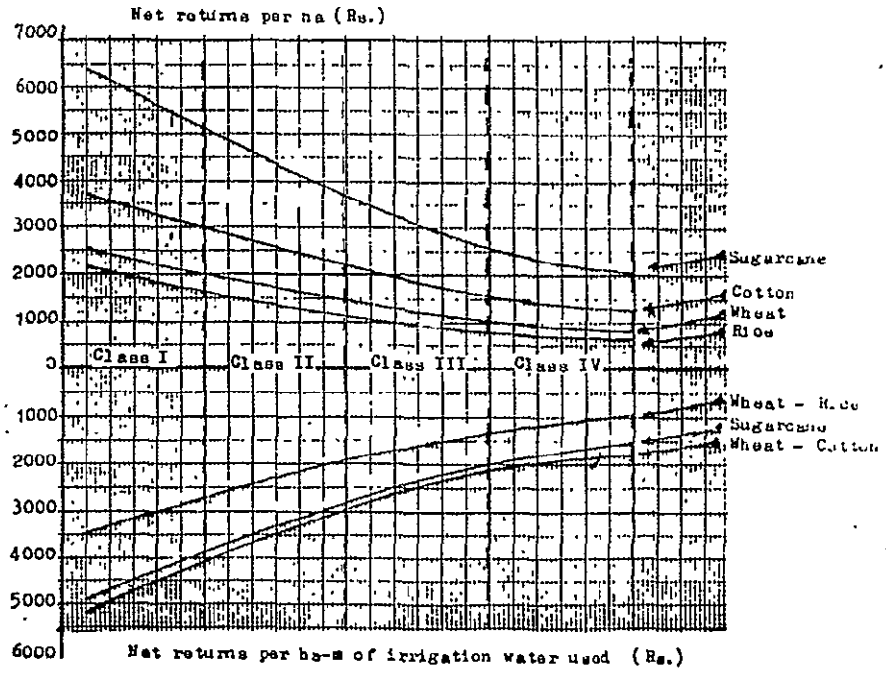

Fig. 1 Net return per ha and per ha-m of irrigation water from different land capability classes at 1979-80 price level and under a medium level of inputs.

Every tract of land covered by an irrigation project naturally has soils that differ in their rate of water intake, available moisture capacity and susceptibility to waterlogging and salinization; so vary

their requirements of irrigation to economize water, conserve soils and get maximum agricultural production. The soil survey data interpretations help in deciding the optimum amount of water to be applied for irrigation, the allowable irrigation intervals for any crop and the quality of irrigation water that can be safely used. Such interpretations are of prime importance for planning as well as execution of the irrigation and water management projects and for optimum utilization of the available water resources on currently irrigated land. For this purpose, research is being carried out on many important soils in some experimental farms and in the field. We hope, the application of the research will lead to considerable increase in returns per unit of irrigation water and conserve the soil and water resources against deterioration.

Agronomic research

Soil Survey of Pakistan has conducted very detailed to ultra detailed soil survey of all the important agricultural research stations so that the results of research may be presented according to well defined soils and applied on similar soils in Pakistan. There has been a high response from the research stations in this respect. Many research organizations including Ayub. Agricultural Research Institute and Agricultural University at Faisalabad, Maize Research Institute Yousafwala, Rice Research Institute Kala Kaku, Agricultural Research Institute Tando Jam, Sugarcane Research Station Tarnab and Soil Fertility Research and Soil Testing Institute Lahore are making good use of the soil survey data for that purpose.

Formulation of cropping patterns

Field investigations have indicated that lime-free clayey soils are best suited to produce fine-quality rice. Cotton, sugarcane, maize, potato, wheat and vegetables give high yields on well drained loamy soils while millets, sorghum, gram, groundnuts, sesame and phaseolus pulses can give high production even on somewhat sandy soil with no other limitation. The data of distribution of various kinds of soils, and their interpretation in terms of crop suitability, guide in selecting the most suitable crops for an area to obtain maximum agricultural production. Such interpretations of soil survey data are helpful in formulating cropping patterns at farm level and crop zoning at national or provincial level. The agricultural extension staff are being trained by the Soil Survey of Pakistan to identify soils of varying potential for crops to achieve that end.

Improvement of soil management

The soil survey data are interpretable for selection of specific cultural practices required by certain soils for their satisfactory performance under intensive agricultural use. The problems like plough pan formation, subsoil cementation, surface crusting, clod formation and appearance of slick spots are the consequences of injudicious soil management and had so far been overlooked by the farmer due to his ignorance. Such problems are in fact peculiar to certain soils. Field investigations have shown that the soils with high silt content and with a high percentage of exchangeable sodium are the most susceptible to surface crusting and plough pan formation; those with high clay content pose difficulty in seedbed preparation and favour clod formation; and those with high lime content are prone to subsoil cementation and appearance of slick spots. Any of these problems can reduce crop yield considerably if not properly tackled. The soil data interpretations help in choosing appropriate/

preventive measures against such problems. For example, casual chiselling is a requirement of lime-cemented subsoils as in case of Potwar Plateau while it is hazardous for good structured, noncalcareous soils. The slowly permeable clayey or sodic soils require a higher tractor power and a longer waiting period for tillage after irrigation and must be tilled within a short period for good seedbed preparation, while the moderately permeable loamy soils have no such limitations. The soil survey data thus provide a base for developing an appropriate soil management technology and selecting the type and quantum of farm machinery for any project area of agricultural development. Such interpretations are being taught to the agricultural extension staff under a programme of 'Transfer of Soil Technology' for general improvement of cultural practices in Pakistan.

Fertilizer use and production

The soil survey data provide a sound basis for deciding the kinds of fertilizers to be used as well as their appropriate doses and methods of application, as these requirements are dependent on the soil types. For this purpose, the data are interpreted to predict the nutrient losses by leaching, risks of nitrogen loss by volatilization, fixation of phosphate and availability of micronutrients etc. from which estimates of fertilizer response can be made. These predictions guide in streamlining the government policies regarding production and import of fertilizers on one hand and in increasing the efficiency of fertilizer use by curtailing its losses through appropriate measure on the other hand. Currently, the policy of the Government of Pakistan to import various blended fertilizers from developed countries is greatly influenced by the opinions of Soil Survey of Pakistan which are based on interpretations of soil survey data. Field experiments are being conducted by some organizations and institutes, including the Directorate of Soil Fertility, fertilizer companies/corporations and agricultural universities, who are using these data for research and application in the field. Pakistan Tobacco Board is using the interpretations of soil survey data for use of fertilizers on the tobacco crop.

Reclamation of saline lands

The soil surveys have discovered that there are several kinds of saline soils occurring in Pakistan which differ from each other in the ease and cost of reclamation. The soil data are interpreted to classify these soils in terms of their reclaimability. The following reclaimability classes are recognized:

a. Soils which are easy to reclaim by simple leaching
   - highly permeable soils affected by slight salinity and gypsiferous soils having no problems of sodicity or drainage

b. Soils which are easy to reclaim by leaching with a moderate amount of gypsum
   - well drained, porous loamy soils having a sodicity problem

c. Soils which are somewhat difficult to reclaim; requiring drainage and leaching with a moderate amount of gypsum
   - imperfectly drained, porous, loamy soils and gypsiferous clayey soils having sodicity problem

d. Soils which are difficult to reclaim; requiring drainage and leaching with a high amount of gypsum

- moderately permeable clayey soils and slowly permeable silty soils with a sodicity problem

e. Soils which are very difficult to reclaim requiring chiselling or deep ploughing, provision of a drainage system and leaching with a very high amount of gypsum
   - impermeable clayey soils with a severe sodicity problem

The differentiation of these soils helps in the selection of priority areas for reclamation on economic basis. Such interpretations of soil survey data are being used for formulation of various reclamation projects at national and provincial levels. A latest example in that respect is the sanction of a Rs. 63 million project by the Government of Pakistan to reclaim about 48 500 ha of good agricultural land proposed by the Soil Survey of Pakistan on the basis of soil survey data. The data are utilized also by many land development and reclamation agencies including WAPDA, Punjab Land Utilization Authority and the Land Reclamation Directorate of the Irrigation Department.

Soil conservation

The interpretations of soil survey data are made also to classify soils according to their susceptibility to erosion. These interpretations are widely used in Pakistan to plan different soil conservation schemes and choose appropriate measures to control erosion. On request of the concerned agencies or organizations, various kinds of potentially erodable soils are delimited on the maps and suitable measures suggested to control erosion, keeping regard of their characteristics and agricultural potential. For example, the steeply dissected parts of the Potwar Plateau have no potential for arable use and their protection by levelling or terracing for that purpose is not advised. Conversely, the protection of table lands having a high agricultural potential is strongly pleaded. The Directorates of Soil Conservation, the Forest departments and the Federal Forest Research Institute are effectively using the soil survey data for planning and execution of their soil conservation schemes. In addition, the program of controlling desertification of sandy areas in Pakistan run by the Desertification Monitoring Unit of the Federal Irrigation Research Council is also making a good use of the interpretations of soil survey data to control soil erosion by winds.

Drainage of waterlogged land

Soil surveys have found out that the land areas affected by waterlogging have a close relationship with the depositional pattern of soil material. It has been discovered that there are only narrow strips of certain soils in Pakistan which are most affected by impeded drainage because of their specific physiographic positions and that the discharge of excess water from these strips would improve drainage of all the surrounding land. It is therefore imperative that the drainage systems are planned by keeping regard of these strips which would serve as best sites for the collector drains. Moreover, the abandoned beds of river streams which are mostly linked with the currently active river streams and are responsible for rise of groundwater through subsurface flow from these streams are clearly indicated on the soil survey maps. So, the maps help in the alignment of interceptor drains to check groundwater recharge of the interior areas. The soil data on the content of silt, lime and salts and on permeability etc. help in deciding the type of drainage system to be installed and effectiveness of the system. For example, the soils high in content of silt, salts and lime and having a low permeability, as

of the Indus delta, are not suitable for tile drainage or even for tubewell drainage. Their drainage by means of open ditches will also involve high maintenance costs. The interpretations of soil survey maps for that purpose are used by a few agencies including WAPDA and DRIP (Drainage and Reclamation Institute of Pakistan) but it would probably form the most important basis for drainage planning in future.

Agro-ecological zoning

Soils constitute the most important part of an ecological environment. Their characteristics reflect the effects of climate, hydrology, lithology, relief and biosphere which are other important components of the eco-system. It is mainly the data on soils and climate which decide the type of vegetation that can be established or the crops that can be grown in a certain area. The soil survey data are, therefore, universally employed as the main basis of agro-ecological zoning. The Pakistan Agricultural Research Council, Pakistan Forest Institute and Soil Survey of Pakistan are currently collaborating in differentiating various agro-ecological zones in Pakistan by interpreting the soil survey data.

Forest improvement

Soil surveys have a wide application in planning and improvement of forests. The interpretations of soil survey data are made firstly to isolate the potentially suitable forest land, secondly to classify the land according to its adaptability for different plant species, thirdly to suggest improvement measures and fourthly to predict returns from various classes of forest land for the development projects. Many planatations have so far been surveyed at semidetailed level on requests received from the Forest departments. The interpretations of soil survey data now form an essential part of the working plans for these plantations. The development of natural forests in highland areas by the Forest departments and Pakistan Forest Research Institute also take much initiative from the soil survey reports of the relevant parts.

Range and dairy development

A large proportion of land in Pakistan is not suitable for arable use or forestry but has a potential for development of ranges. Soil surveys have sorted out such parts of land which can be improved by reseeding with palatable plant species and used for large-scale production of livestock in the relevant parts. The feasibility reports of range development projects by various agencies like NESPAK, Pakistan Forest Institute and provincial Forest departments, are guided by the soil data interpretations in this regard. In addition, the potential fodder producing areas are also delimited by interpreting soil survey data aor establishment of dairy industries in the suburbs of metropolitan cities like Karachi, Islamabad and Lahore.

Land consolidation

There are currently a large number of agricultural holdings in Pakistan which exist in scattered patches and are not easily manageable by the farmers. An efficient utilization of land for agricultural production necessitates that these patches are consolidated into contiguous blocks. To do a good justice with the land owners, the exchanges of land need to be made on equitable basis. The soil

survey data interpretations in terms of land capability classes provide the most reliable tool to achieve that end, so that a certain class of land be exchanged with the same class. This will, however, require detailed soil surveys of the relevant areas.

Agricultural taxation

The soil survey data are interpretable for determining income tax on agricultural lands. These data enable us to estimate the net annual income of a land owner, given with a specific land use pattern and inputs level, from which the amount of income tax recoverable can be determined at farm level. The income tax assessment made in this way would have a scientific basis but that end is still remote as it requires some more details of soil survey.

Siting of agro-based industries

To establish an industry in a certain area, the basic requirement to be met is that the supply of raw material is adequate and regular. The industries like textile mills, sugar factories and vegetable oil industries depend on the raw material from agricultural sector and function well only when located in areas having extensive land resources suitable for producing cotton, sugarcane/sugarbeet and oilseeds respectively. The soil survey data help in demarcating the potential productive areas of these crops and are, therefore, of fundamental importance for siting of such industries. The government as well as the private sector is making use of the soil survey data for that purpose.

NON-AGRICULTURAL USES OF SOIL SURVEY DATA

The non-agricultural uses of land for which the soil survey data are interpreted mostly relate to the field of soil engineering where soils play a vital role as foundation materials for different structures. The data interpretations help the engineers in locating stable areas for planning of industrial and social structures on one hand and avoiding the misuse of good agricultural lands for these purposes, on the other hand. The land characteristics which have close relationship with the engineering uses include drainage, soil texture (especially with respect to clay content), clay mineralogy, salinity, sodicity, soil permeability, depth to bedrock and relief. These characteristics form an essential part of the soil survey data and are interpretable in terms of bearing capacity of land and its stability against natural forces and processes such as swelling pressure of clays, corrosion by salts, subsidence and damping etc. The important engineering fields in which the soil survey data are applied are as follows.

Town planning and industrial settlements

The major guidance rendered by the soil survey data in planning of towns and other settlements is the economic value of land with respect to its agricultural use. Since the prime agricultural land is of limited extent and an irreplaceable natural resource, it must not be brought under housing or industry. Instead, low-quality agricultural lands which occur abundantly are usable for that purpose. The expansion of towns and industrial areas should be directed towards these lands. The soil survey maps indicate the distribution of these lands and their data can be interpreted to identify problems connected with house construction, underground systems of pipelines, surface drainage and vegetating recreation parks and play grounds etc. The area distribution of the proposed town for various purposes and the design of buildings are also guided by the soil survey data. The data are also interpreted

to locate suitable sites for mining of building materials like sand, clay, stones and gravel near the towns. The Soil Survey of Pakistan has been extending necessary guidance in this regard to the Lahore Development Authority, Capital Development Authority and Faisalabad Development Authority etc.

Alignment of roads

The soil survey maps can be interpreted to indicate areas which are fairly stable for construction of roads and railway lines and the sections where maintenance of these communication systems is likely to be problematic. The problem areas are represented by soils which are too clayey, sodic, saline or waterlogged etc. The clayey soils generally shows great differences in volume by swelling when wet and contracting when dry. This process results in producing large cracks and undulations at the soil surface, affecting the roads and railway lines. The saline and sodic soils damage these structures because of their very low stability when wet. The waterlogged soils also have a low bearing capacity and pose maintenance problems. A few of such problems experienced in Pakistan have been solved either by realignment of roads or by construction of bridges over the relevant sections on suggestions by the Soil Survey of Pakistan.

Trafficability assessment

The soil survey data are interpretable for assessment of trafficability of any tract of land under dry or wet weather conditions. The assessment is made on the same principles as road alignment by using more detailed climatic and hydrological data. Such interpretations are of special significance for cross-country movement of heavy machinery. A training course for trafficability assessment is annually arranged by the Soil Survey of Pakistan.

Teaching material

The latest information contained in the soil survey reports published so far has been of tremendous help to the soil scientists, agronomists, teachers and research scientists in updating their knowledge about soils and agricultural land resources of Pakistan. It has greatly improved the syllabi at universities and colleges level. As a result, the new students generation is going to be increasingly better equiped with the background knowledge required for research and planning of overall agricultural development in Pakistan.

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PART IV
SOIL FERTILITY AND FERTILIZER USE

- Phosphorus Requirements of Pakistani Soils — Kazi Suleman Memon
- Potash Status of Soils in Pakistan — Muhammad Sadiq
- Trace Element Status of Pakistan Soils — Jehangir Khan Khattak and Sajida Perveen
- Nitrogen Use and Efficiency — Nazir Ahmed
- The Need to Review Recommendations for Efficient Use of Fertilizer in Pakistan — M. Tahir Saleem

PHOSPHRUS REQUIREMENTS OF PAKISTAN SOILS

KAZI SULEMAN MEMON*

ABSTRACT

Current knowledge about soils of Pakistan indicates widespread deficiencies of phosphorus with continuing underfertilization practices. Soil test method (Olsen) followed in the country has not been well calibrated against crop response to P fertilization. Fertilizer recommendation generally range from 50 to 100 kg P_2O_5/ha depending upon the fertility status of the soil and the nature of crop grown. However, much of the fertilizer recommendation as practiced today is generalized one and is based on the experience gained from thousands of fertilizer trials performed in farmers' fields. It is high time that research efforts are focused on formulation of site specific fertilizers recommendations taking into account the variations in soil, climate and management aspects. In view of the influence of soil texture, mineralogy, lime contents, pH, soil moisture and temperature regimes etc. on P supply properties of soils, it has been suggested that future P fertilizer research be undertaken on the basis of soil family/series. The results of these studies can then be transferred with reasonable confidence to other sites having similar soil and climatic conditions.

INTRODUCTION

The discussion about phosphorus requirements of soils should include the considerations about the following three aspects of P management: P content of soil, level of soil P associated with near maximum yield of crops and, finally, how much fertilizer P to apply to achieve the required level of soil P for various soil-crop combinations. Soil P status can be determined by extracting P from soil with an appropriate extracting solution.

Next step is to determine the level of soil test P required for optimum yield of various crops and establish the levels of deficiency and adequacy for various soil crop combinations through well-planned soil-test calibration studies. The knowledge of soil P contents in relation to the levels required for maximum yields and how various soil, plant and management factors influence P requirements should lead to formulation of sound P fertilizer recommendations for different soil, crop and agro-climatic conditions. This paper presents a brief account of the issues related to P fertilizer requirements of soils with special reference to Pakistan.

CATEGORIZATION OF SOIL TEST VALUES

Irrespective of the method of soil test P followed, it is important to know what do the analytical data convey? What level of soil test P be considered as low or adequate for growing different

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crops? Such information is to be derived from well-managed soil P test-calibration studies. Somehow this aspect has not received much attention in Pakistan. The need for such studies is now being emphasized throughout the country.

In case of Olsen method which is followed for soil P analysis in Pakistan and in many other countries, grouping of soil test data suggested by various sources is given below:

Olsen et al, (1954)

< 5.5 mg P/kg – a response
5.5 – 11 mg P/kg – probable response
> 11 mg P/kg – response unlikely

FAO Soils Buletin 48/2 (Cottenie, 1980)

< 5 mg P/kg	Very low
5–9 mg P/kg	Low
10–17 mg P/kg	Medium
18–25 mg P/kg	High
> 25 mg P/kg	Very high

For Pakistan, the figures available for deficiency and adequacy levels of Olsen P are only tentative (Choudhry and Memon, 1969; Wahab, 1985) because of limited studies on calibration of soil-test values.

Chaudhry and Memon (1969)

< 15 mg P/kg	–	Low (positive response)
15–25 mg P/kg	–	Medium (probable response)
25–32 mg P/kg	–	Medium high
> 32 mg P/kg	–	High (no response)

Wahab (1985)

Punjab

< 5 mg P/kg	–	Positive response to P expected
5–10 mg P/kg	–	Positive response to P likely
> 10 mg P/kg	–	Response to P not likely (depends on the crop)

Sind

Phosphate recommendation for wheat (Kg/ha)

Olsen P (mg P/kg)	Clay and clay loam soils	Sandy loam soil
< 10	90 – 112	67 – 90
10 – 20	67 – 90	56 – 67
20 – 30	45 – 67	45 – 56
> 30	0 – 45	0 – 34

It is relevant to point out that categorization of soil values for Sind soils is based upon pot studies. In general, concentration of soil nutrients required for optimum growth of plants would be higher when grown in pots than when grown in field. Therefore, fertilizer P application to wheat has been recommended even when soil P is 30 mg P/kg.

Based on the experience of various workers in and outside the country, soil level of 12 – 15 mg P/kg may be considered as cut off level beyond which crop responses to added P may be less likely for majority of crops. However, there is a great need to establish deficiency and adequacy levels of soil test P in the country on the basis of well-planned and well-managed soil test–correlation and calibration experiments.

PHOSPHORUS CONTENTS OF SOILS OF PAKISTAN

The soils of Pakistan are generally deficient in P. Ansiaux (1977) conducted an enquiry about P fertilization practices followed in various countries. The results of the enquiry showed that approximately two-third of Pakistani soils were low (less than 2.6 mg P/kg), one-fourth medium (2.6-4.4 mg P/kg) and the rest high (more than 4.4 mg P/kg) in available (Olsen) P.

In another study, Bhatti (1973) reported that out of 1 110 soils samples taken from 13 districts of Punjab, 61% contained less than 3 mg P/kg, 34% contained between 3 and 12 mg P/kg and 5% contained more than 12 mg P/kg. Malik et al. (1973) similarly showed that 86% of 6 207 soils samples taken from Punjab were low (less than 5 mg P/kg), 24% were medium (5 – 10 mg P/kg) and 8% were adequate (more than 10 mg P/kg) in available P by Olsen method. Qayyum (1984) analysed 240 samples collected from Rawalpindi-Islamabad districts and reported that 52% soils contained less than 10 mg P/kg, 38% soils contained between 10 and 20 mg P/kg and only 10% soils contained more than 20 mg P/kg.

Recently, Wahab (1985) attempted to represent the P status of 200 soils of Punjab by a histogram which showed that Olsen P ranged from less than 2 mg P/kg to over 25 mg P/kg with a mode of 4 to 5 mg P/kg. Majority of the soils were, however, deficient in P with values below 10 mg P/kg. A recent survey of district Hyderabad soils (Memon, 1985 b), showed that 50% of the 125 soils contained less than 10 mg P/kg.

FACTORS INFLUENCING PHOSPHORUS REQUIREMENTS

The data available on soil P status can only tell as to whether the soil is deficient, moderate or adequate with respect to P. But our ultimate interest is to know how much fertilizer P the deficient soils need to bring them to level of adequacy. The fertilizer P requirements, however, depend upon many factors. For example, two soils differing in their clay mineralogy and texture but having same level of soil P may not require same quantity of fertilizer P to bring them to a given level of soil P. The differences in P requirements will be attributed to differences in their P-buffering capacity. Similarly, plants also vary in their requirements for P. Thus P requirements of soils for plant uptake depend upon many factors which can be grouped into soil, plant and management categories (Peaslee and Fox, 1978; Fox, 1979, 1981) as given below.

Soil factors

- Buffering capacity of the soil and quantity of labile P.
- Cross section area for diffusion of P to roots and tortuosity of the diffusion path.
- Soil factors associated with root development, especially root hair proliferation and mycorrhizal associations.
- Mineralization of organic P.
- Species and concentration of salts in soil solution.
- Temperature
- Nature of solid phase P as this influences the rate of dissolution of P compounds.

Plant factors

- Yield potential
- Effectiveness of roots and associated mycorrhiza in P uptake.
- Interaction of roots with solid phase P.
- Threshold P concentration for P uptake by roots.
- Solution concentration at which roots are saturated with respect to P uptake.
- Differential uptake of cations by plants.

Management factors

- Volume of soil fertilized and placement of fertilizer with respect to roots
- Time of fertilization in relation to expected time of utilization.
- Use of organic manures.

Phosphorus requirements would therefore, depend how various factors interact with each other under a given set of soil conditions, plant factors and management practices.

FACTORS INFLUENCING PHOSPHORUS SORPTION

Phosphorus sorption characteristics of soils depend primarily on proportion and nature of clay minerals and soil texture. Different clay minerals react differently to the phosphates around them. The mechanism of reaction between soil minerals and P also depends upon whether the soil is acid or alkaline in reaction.

In acid soils, P is rendered unavailable through formation of insoluble Fe and Al phosphates. In highly weathered acid soils of tropics, the presence of Fe and Al oxides and hydroxides constitute the major group of clay minerals. These minerals fix large quantities of P through ligand exchange.

Soils of Pakistan are much less weathered, alkaline in reaction and generally calcareous in nature. Thus, they sorb much less quantity of P compared to highly weathered acid soils of the tropics.

Possible reactions leading to P retention in calcareous soils are: precipitation of relatively insoluble calcium phosphates such as orthocalcium phosphate, hydroxyapatite and carbonato-apatite favoured by high calcium activity and high pH, surface precipitation with free calcium carbonate and fixation of phosphate by clays saturated with calcium. Therefore, it is frequently stated that soils of Pakistan have high P sorption capacity. The work of Memon and Fox (1983), however, suggests that soils of Pakistan may not have strong P fixing capacity compared to some soils from India, Tanzania and the USA. In fact, these soils would be categorized as low-P sorbing according to the following scheme suggested by Juo and Fox (1977) for soils of different mineralogies.

Standard P sorption mg P/kg soil	P sorption scale	Usual soil mineralogy encountered
< 10	Very low	Quartz, organic materials
10 to 100	Low	2:1 clays, quartz, 1:1 clays
100 to 500	Medium	1:1 clays – oxides
500 to 1 000	High	Crystalline oxides, moderately weathered ash
< 1 000	Very high	Desilicated amorphous materials

The data available on clay mineralogy of some soils of Pakistan show presence of minerals like mica, montmorillonite, kaolinite, vermiculite, calcite etc. to varying degree depending upon the conditions under which these soils are developed.

Soil materials capable of reacting with fertilizer P evidently increase in amount as the clay content rises for soils subjected to the same degree of weathering processes and containing similar parent materials. Thus equal applications of fertilizer P to soils with different texture often produce unequal effects on plant growth. The concentration of soil solution P required for a given uptake of P by crops is also influenced by soil texture. For the same amount of P uptake by plants, higher concentrations of soil solution P are needed in coarse textured soils as compared to fine textured soils because coarse textured soils are poorly buffered, the cross-section for diffusion is small because of low moisture contents and the path for diffusion is crooked.

Other factors which influence P sorption are time, temperature, water content, mixing, supporting electrolyte, soil pH, competition for adsorption sites and surface area for adsorption.

PHOSPHORUS FERTILIZER REQUIREMENTS

Phosphorus requirements of crops have been a subject of study for the last 25 years or so in Pakistan. Numerous experiments have been conducted during this period on a number of field crops. These experiments have generated voluminous data which have not been properly utilized to fully realize the objectives of such an extensive effort. However, it is very encouraging that National Fertilizer Development Centre (NFDC) of Pakistan is taking keen interest in the matter and is already busy with consolidation and interpretation of the data available from various agricultural research institutes

of the country. The task is the challenging one because the experiments were performed under a variety of soil, climate and management factors. This coupled with widely different experimental designs makes it very complex to develop response curves for various soil-crop-management conditions. In a number of studies two or more elements have been varied at a time making it difficult to separate the effect of one element from the other.

Inspite of the shortcomings, the available data and experience has served as a basis for making generalized fertilizer recommendations to the farmers for growing various crops. The recommendattions which are currently in practice in Sind and Punjab are given in table 1.

Table 1. Fertilizer recommendations (kg P_2O_2/ha)

Crop	Sind	Punjab
Wheat	67 – 112 (Irrigated)	0 – 112 (Irrigated) 56 – 67 (Barani)
Cotton	0 – 67	27 – 56
Sugarcane	56 – 100	67 – 112
Rice	67 – 100 (IRRI)	67 – 84 (IRRI) 36 – 57 (Basmati)
Maize	67 (Hybrid)	67 – 100 (Hybrid) 45 – 57 (Local)
Potato	84	112
Sorghum	67	Not reported
Millet	55	36
Soybean	90	Not reported
Groundnut	34	57
Clover and Alfalfa	Not reported	112 – 136
Sunflower	45	74

Source: Chaudhry, 1985: Bhatti et al. 1985.

It is apparent that fertilizer P recommendations generally range from 50 to 100 kg P_2O_5/ha depending upon soil P status and the kind of crop grown.

The practice of generalized fertilizer recommendations cannot be continued indefinitely. The stage of fertilizer P utilization demands that the fertilizer recommendations be made site specific. We cannot be content with uniform fertilizer recommendations for all the soil, climate and management practices. Such considerations require well planned replicated trials. Unfortunately, number of studies involving one replicate are still underway which are not well suited for soil test-calibration studies. A country-wide systematic approach is required to perform such studies under various ecological zones and on various soil types.

PHOSPHORUS RESEARCH ON THE BASIS OF SOIL FAMILY/SERIES

As discussed already, soil mineralogy, texture, moisture, temperature etc. influence P rentention and P supply properties of soil. Grouping of soils on the basis of these factors should result in relatively more homogeneous units and thus provide a viable basis for sound P fertilization programmes. Soil Taxonomy groups soils into such units called "Soil Families" which takes into account the variations in soil texture, mineralogy, soil temperature and moisture regimes and various other aspects.

The concept of soil P research on the basis of soil families is new to Pakistan. The project SCAN (Soil Capability Assessment Network) recently initiated by Pakistan Agricultural Research Council in collaboration with Soil Survey of Pakistan can be termed as a pilot project in this behalf. Reporting on the results of this project, Nizami (1984) states that the work done on five families indicates that the soil classification holds and the need for considering soil as a variable in soil fertility and soil management research is evident. These studies should form a basis for further research in this direction.

In the absence of soil classification to soil family level, one may group similar soil series on the basis of the soil characteristics playing key role in supply of nutrients to the plant. For soils of Pakistan, soil texture, mineralogy and degree of calcareousness constitute important factors in P fertilization program. With these considerations in mind, Mian (1985) identified the following soil series with diverse textural and lime contents and suggested fertility research on these basis.

Soil group	Representative soil series
Noncalcareous loamy soils	Pindorian
Noncalcareous silty soils	Gujranwala
Noncalcareous clayey soils	Kotli
Noncalcareous silty soils of river Swat	Charsadda
Calcareous loamy soils	Hafizabad
Clacareous silty soils	Bhalwal
Calcareous clayey soils	Matli
Strongly calcareous silty soils of loess deposits.	Rajar
Strongly calcareous silty soils of Sulaiman piedmont	Surab
Strongly calcareous clayey soils of Sulaiman piedmont	Jhatpat

Phosphorus fertilizer trials on the basis of soil families/series should help a great deal in determining P fertilizer requirements under different soil and climatic conditions. The data so generated can then be transferred with reasonable confidence to other sites having similar soils and climatic conditions.

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POTASH STATUS OF SOILS IN PAKISTAN

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ABSTRACT

Fauji Fertilizer Company Limited has a soil testing laboratory at their plant site. This facility is used for developing fertilizer recommendations for different crops. This laboratory has during its operation of about two years, analysed 4 583 soil samples, collected from various farms throughout the country based on requests received from the farmers. Although these analyses of soils are undertaken for a number of physical as well as chemical characteristics of the soil, yet this paper presents only a summary of the potash level in the soils. The potassium contents of soils were grouped into seven categories of less than 50 ppm K_2O, 50 to 75, 75 to 100, 100 to 125, 125 to 150, 150 to 200 and more than 200 ppm K_2O. It has been found that 10.89% soils in Pakistan contain less than 100 ppm of available potash extracted with ammonium acetate solution. The frequency distribution of potash deficient soils (less than 100 ppm) has been different in different provinces. In Sind and Baluchistan, it is only 4.2%, in NWFP it is 8.19% and in Punjab it is 15.32%. It appears that the intensity of cropping which is more in Punjab, is directly related to the present status of available potash in various soils.

INTRODUCTION

Soils in Pakistan are usually known to contain plentiful of potash. In the past widespread deficiency of nitrogen and phosphorus in Pakistan led to a major emphasis of scientists as well as policy makers on research and promotion of their use. Nitrogen which is deficient in almost all the soils of Pakistan was the first to be adopted by the farmers. Its use during the last about 30 years has increased manifold and has reached a level of about 1 million tons. Increase in the intensity of cropping has caused the depletion of phosphate in the soils and their consumption in Pakistan, although started late compared with the nitrogen, has grown considerably to about 0.3 million tons. The use of potash in Pakistan has been almost negligible and that too has been quite erratic. In the recent past potash consumption has grown slightly but it can hardly be compared with nitrogen or for that matter even with phosphorus.

Field research to establish the deficiency of potash has been undertaken by some scientists in Pakistan but their efforts have been limited to very small number of locations. Although some scientists did report response to the application of potash by some crops at some places yet their frequency was so small that most of the scientists were not convinced of the results. In view of the fact that the results of the experiments did not reveal any potassium deficiency, the policy makers also did not take necessary decisions to promote the use of potash. Although the government has been subsidizing

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potash even more than other fertilizers in terms of percent subsidy yet the whole hearted efforts in promoting the use of potash were always lacking. There were controversies regarding the response to the application of potash even by a crop like sugarcane which is known to have a high demand for potash. Very little work to find out the overall potash status of Pakistan soils has been undertaken by any agency in an organized manner.

Food and Agriculture Organization of the United Nations did make an effort to describe the potassium level of Pakistan soils in their Soils Bulletin No. 48 on "Micronutrients and the Nutrient Status of Soils: a global study" by Mikko Sillanpaa published in 1982. Their results are also reported in this paper which indicate very similar findings.

The soil test results of FFCL laboratory, have been used as a basis for describing the potash status of Pakistan soils in this report.

MATERIALS AND METHODS

Collection of soil samples

The Fauji Fertilizer Co. Ltd., is a fertilizer manufacturing and marketing organization which supplies chemical fertilizers throughout the country. This Company provides advisory services to the farmers through trained agriculture experts spread throughout the four provinces. One of the services for the farmers is helping them to use optimum doses of fertilizer for best returns. Soil testing is used to determine the quantity of nutrients present in the soil and is then used as a basis for developing fertilizer recommendations for the farmers and this facility of the company is promoted through mass media as well as through personal contacts of company's agriculture experts. Those farmers who are interested in getting their soils tested approach FFCL for this purpose. The Company agronomists reach the farms themselves and collect representative soil samples from the fields. The soil samples thus collected are dried and then sent to the Soil Testing Laboratory at Goth Machhi, District Rahim Yar Khan. During the last about two years 4 583 such soil samples were collected and analysed.

These samples may not be considered to have been collected strictly on a random basis since the company is entertaining almost all requests for soil testing. Secondly, it is felt that soil testing is requested usually by more progressive and relatively educated farmers and as such these samples may not represent all types of farmers in the country. However, since the number of samples is relatively large we feel these results can be used to draw fairly precise conclusions regarding the overall ptash status of soils in Pakistan.

Soil analysis

Available potash is determined in this laboratory with the help of a flame photometer after extracting potash with 1.0 N ammonium acetate with its pH adjusted to 7.0. All the soil samples are once again dried in the laboratory, and are ground to pass through a 2.0 mm sieve. Duplicate tests are run on each sample in order to minimize error. The soil to extractant ratio used in this laboratory is 1 to 10. The available potash in the soil is expressed as parts per million of soil.

Data Compilation

The data collected from soil test results in respect of available potash was categorised as under:

Category No. 1 – less than 50 ppm K_2O.
Category No. 2 – 50 and above but less than 75 ppm K_2O.
Category No. 3 – 75 and above but less than 100 ppm K_2O.
Category No. 4 – 100 and above but less than 125 ppm K_2O.
Category No. 5 – 125 and above but less than 150 ppm K_2O.
Category No. 6 – 150 and above but less than 200 ppm K_2O.
Category No. 7 – 200 ppm and above.

These data were stratified on provincial basis. Since number of samples from Baluchistan were very small, these were grouped with the province of Sind and the total number of samples collected from these two provinces were 1 593. The soils of NWFP were treated separately. The total number of samples that came from NWFP were 366 only. Maximum number of soils came from the province of Punjab with a total number of 2 624.

RESULTS AND DISCUSSION

The critical level of potash in soils is usually considered to be different for different crops. It is also known to vary with soil texture. Although for a crop like cotton the potash level of as low as 75 ppm may be sufficient yet for a sugarcane crop the minimum potash level can be as high as 125 ppm. For crops like potato it can go as high as 200 ppm. For fruit trees like mango and banana potash is usually recommended even if the available potash in the soil is as high as 400 ppm. In order to find out the quantum of probable potash deficient soils we have in this article taken 100 ppm to be an average critical threshold for available potash in the soil. The results given in Table 1, and then

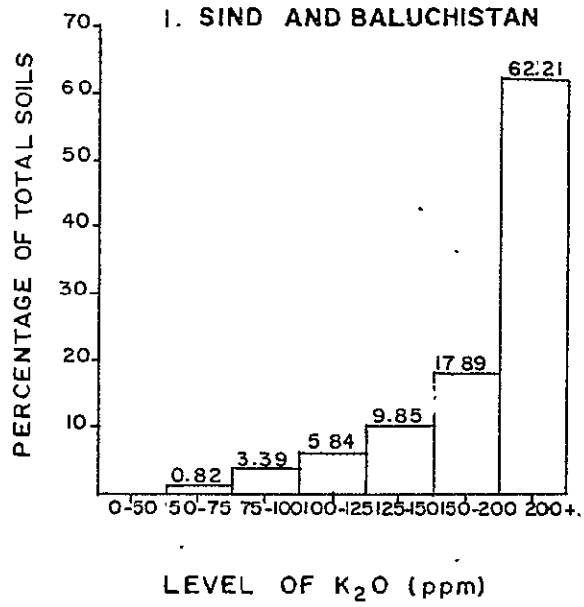
Table 1. Potash Status of Soils

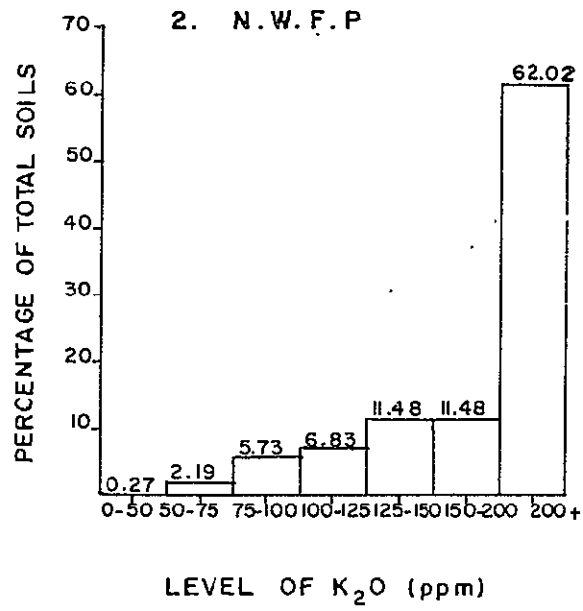
Level of K_2O (ppm)	Sind & Baluchistan		N.W.F.P.		Punjab		Pakistan	
	No. of samples	%	No. of samples	%	No. of samples	%	No. of samples	%
50	0	0.00	1	0.27	36	1.37	37	0.81
50 – 75	13	0.82	8	2.19	139	5.30	160	3.49
75 – 100	54	5.39	21	5.73	227	8.65	302	6.59
100 – 125	93	5.84	25	6.83	289	11.01	407	8.88
125 – 150	157	9.85	42	11.48	340	12.96	539	11.76
150 – 200	285	17.89	42	11.48	491	18.71	818	17.85
200	991	62.21	227	62.02	1 102	42.00	2 320	50.62
Total:	1 593		366		2 624		4 583	

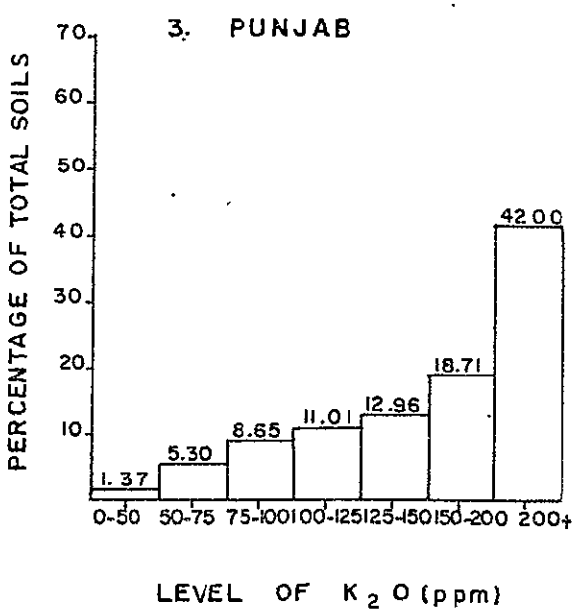
depicted in the form of diagrams 1 to 4 indicate that on country basis 10.89% soils may respond to the application of potash and the balance about 89% will not give economic returns to the application of potassic fertilizer in the country. The frequency distribution of soils is very interesting for different provinces. Sind and Baluchistan soils are better supplied with potash compared with the soils of NWFP and the Punjab. Whereas only 4.21% soils in Sind and Baluchistan have potash contents of less than

DIAGRAMS 1-4

POTASH STATUS OF SOILS







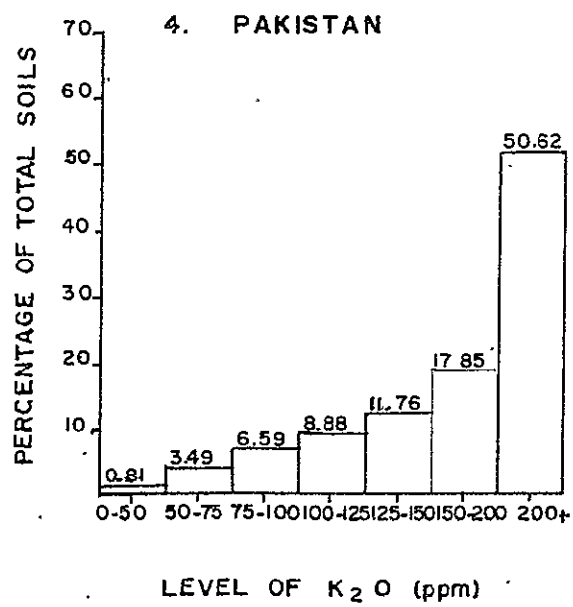
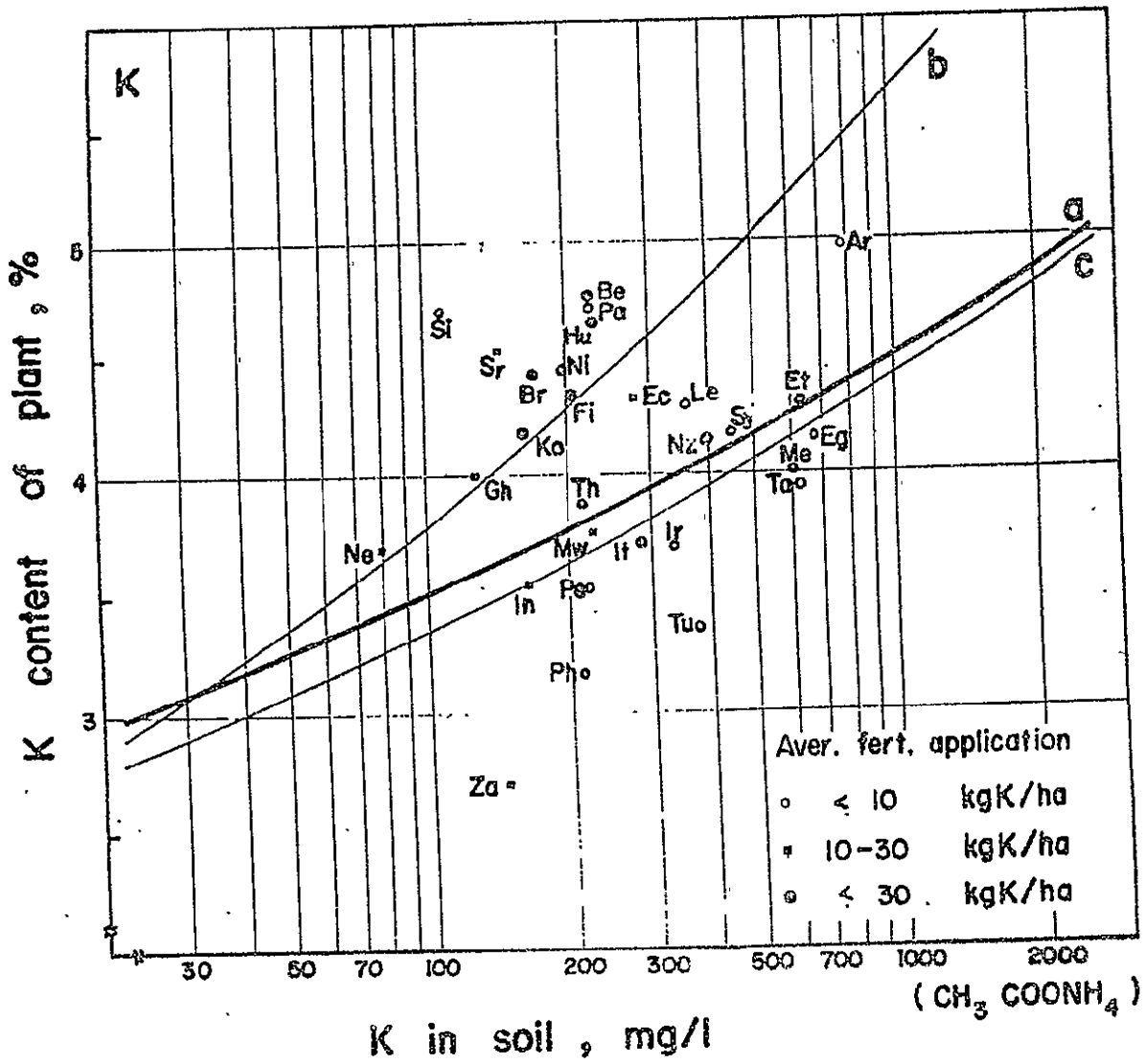


DIAGRAM - 5



Be - Belgium
Br - Brazil
Ec - Ecuador
Eg - Egypt
Et - Ethiopia
Fi - Finland
Gh - Ghana
Hu - Hungary
In - India
Ir - Iraq
It - Italy
Ko - Korea
Le - Lebnan
Me - Mexico
Mw - Malawi
Ne - Nepal
Ni - Ningeria
Nz New Zealand
Za Zambia
Pa - Pakistan
Pe - Peru
Ph - Philippines
Si - Sierra Leone
Sr - Sri Lanka
Sy - Syria
Ta - Tanzania
Th - Thailand
Tu - Turkey

100 ppm, 8.19% soils have less than 100 ppm available potash in NWFP soils and 15.32% soils have less than 100 ppm potash in Punjab soils. This shows that the Punjab soils which are under cultivation for a longer period than the soils of other three provinces have developed potash deficiency relatively to a greater extent. Sind and Baluchistan soils which came under cultivation rather recently are still containing sufficient levels of available potash. Another explanation for higher available potash in Sind soils could be the fact that Sind soils are usually heavier than Punjab soils which have a higher capacity to hold on to their potash contents.

The results reported by FAO Soils Bulletin No. 48 support the findings of this study. Although FAO study is based only on the analysis of 242 samples yet their frequency distribution of K in wheat soils in Pakistan shows that 5% of the soils are deficient in available potash. Another factor revealed by the FAO study indicates that potash uptake by plants in Pakistan is comparatively high under similar soil K level when compared with other countries. Diagram No. 5 which is quoted from FAO Soils Bulletin No. 48 indicates that the K content of plants in Pakistan soils is relatively high compared to many other countries with similar soil K values. This indicates that the soil and climatic conditions in Pakistan encourage better uptake of potash by the plants and as such the crops may not respond to the application of potash even where the K_2O level in the soil is low. Such a rapid uptake would also indicate a relatively faster depletion of soils in Pakistan of their potash contents.

CONCLUSIONS

Although only 10.89% soils of Pakistan are deficient in potash yet it is quite likely that they would be playing an important role in depressing the overall yields in the country. It also points to the fact that a blanket application of potash to the soils would not produce economic results since there are only 10.89% chances of the positive response as against over 89% for no response. It is, therefore, felt that potash application should not be resorted to without first identifying a specific K deficiency which can be done through soil testing. Pakistan has however, yet to establish precise fertilizer – crop response curves for potash application in order to make the best use of the available soil testing facilities.

It has been observed that some organized sectors like sugar industry in the province of Sind and tobacco industry in the province of NWFP have been instrumental in ecouraging the Government of Pakistan to import potash for meeting their local requirements. No such efforts have ever been made in the province of Punjab which happens to be relatively more deficient in potash than other three provinces.

TRACE ELEMENT STATUS OF PAKISTAN SOILS

JEHANGIR KHAN KHATTAK AND SAJIDA PERVEEN*

ABSTRACT

Literature review, and plant and soil analysis resutls revealed that there are widespread deficiencies of Zn and B throughout the country. In most areas Cu and Fe are usually within normal range. Highest B values are found in Multan, Sind and elsewhere. High Mo values are scattered all over the country, but somewhat less frequent in Rawalpindi and Peshawar than elsewhere. Moreover, due to the calcareous nature of the soil and high pH, the availabilities of Zn, Mn, Fe and Cu are generally low. Deficiency symptoms in various crops have been described. Various doses of micronutrients for different crops are tentatively suggested.

INTRODUCTION

Micronutrients play vital role in plant nutrition and are essential for various enzymatic reactions and metabolic processes. However, boron which is not a metal and unlike other metallic trace elements (Zn, Cu, Fe, Mn and Mo) is not an enzyme component or enzyme activator, plays a highly specific role in plant life processes.

The soil and climatic conditions of Pakistan are quite conducive to micronutrient deficiencies in plants. Majority of our soils are generally light to medium textured, high in pH, low in organic matter, deficient in nitrogen and phosphorus and calcareous to varying degrees where Zn, Cu, Fe and Mn may form insoluble compounds and become unavailable to the plants. Moreover, heavy application of N and P fertilizers and introduction of high yielding crop varieties and intensive crop production system may also induce the deficiency of micronutrients. Though our soils and soil conditions are conducive to micronutrient deficiency, yet the role of micronutrients in crop production has not been properly understood in Pakistan. To meet the demand of rapidly increasing population of the country, more and more food and fiber must be produced from each hectare of country's arable land by introducing proper plant nutrients.

MICRONUTRIENT RESEARCH IN PAKISTAN

(Wahab, 1958) was the first scientist to determine trace elements in some soils of Pakistan. Later on, the Government of Finland through its Institute of Soil Science and FAO started systematic studies about the micronutrient deficiencies in developing countries and in this connection a project "Trace Element Study" was initiated in Pakistan in 1974. Soils and crops samples were collected from

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various locations of the country for analysis. During 1974-1975, a second project on the availability of micronutrients in the soils of Pakistan at NIAB, Faisalabad, was started under PL-480 programme. The High Powered Agricultural Committee in its 24th meeting held on 25th August, 1977 also decided that Agricultural Research Council should start research scheme on the use of micronutrients in Sind, N.W.F.P. and if possible in Azad Jammu & Kashmir. Thus, a third project entitled "Co-operative Research Programme on Micronutrients" was implemented in July, 1978 by PARC throughout Pakistan and is still in operation in various institutions of the country. The fourth project entitled "Standardization of Methods for the Determination of Available Copper using Maize as a Test Crop" was sponsored by Pakistan Science Foundation and N.W.F.P. Agricultural University, Peshawar during the period 1982-84. In addition to these four projecrs, some individual studies by various scientists were also carried out in different locations of the country during the past two decades. At present a significant amount of information is available regarding the micronutrient status of Pakistan. The objective of this paper is to summarize all the available important and relevant information regarding micronutrients status of Pakistan soils and their response to various crops for effective utilization by the farmers and for future research studies on micronutrients.

MICRONUTRIENT STATUS OF PAKISTAN SOILS

As pointed out earlier, during the year 1974 in co-operation with FAO and Government of Finalnd, 242 soil samples were collected, covering relatively most important agricultural areas of the country, (Sillanpaa, 1982), and it was found that 49% of the soils in Punjab, 25% in Sind and 55% in N.W.F.P. were deficient in boron. This study showed that Pakistan is among the countries occupying the highest position in respect to boron content. The correlation between plant B and soil boron were very high. About eleven percent of the B valuefall on highest position. Many of the highest B values were found in Multan, but there were also soils which were rich in B in Sind and elsewhere. Low B values were often recorded in samples from unirrigated sites. If soil values of 0.3–0.5 ppm were considered as critical, a number of Pakistan soils can be suspected of B deficiency. About 62% of the soils in Punjab, 100% soils in Sind and 77% in N.W.F.P. were deficient in zinc. Only a few samples showed an abundance of zinc. The low Zn values were more typical for Sind, Multan and Peshawar. Almost all the Cu values measured from plant and soil samples are within the normal range. The present analytical data indicate neither Cu deficiency nor excess. Iron situation in Pakistan is relatively normal against the international status. About 10% of the Fe values are marginal. Dry weather during the growing season may lead ferrous to ferric due to excess soil aeration and so decrease the availability of Fe to plant and induce Fe deficiency. Most of the lowest values were in Peshawar, Faisalabad, Sheikhupura and Lahore. Nearly all Mn values are marginal. On the basis of analytical data it seems likely that Mn deficiency, acute or hidden, is relatively common in Pakistan. About 40% of Pakistan plant-soil Mo values fall on highest range. The origin of high Mo values were scattered all over the sampled area. They were somewhat less frequent, however, in Rawalpindi and Peshawar than elsewhere. The deficiency levels were differentiated according to FAO Soil Bulletin 48, (1982). The levels in ppm are: 0.8–1.0 for Cu, 2–5 for Mn, 30–35 for Fe, 0.4–0.6 for Zn, and 0.3–0.5 for H.W.S.B.

Kausar et al (1979) analysed 151 soil samples representing the four provinces and found that 86% of the soils were deficient in Zn. The adequate levels in ppm are 0.2, 1.0, 4.5 and 1.0 for Cu, Mn, Fe and Zn respectively (Lindsay and Norvell, 1978). The deficiency level for H.W.S.B. is less than 1 ppm, according to Walsh and Beaton, 1973.

Khattak and Perveen (1986) reported that out of 320 soils from Hazara, D.I.Khan, Mardan, Peshawar, Kohat, Bannu and Malakand, 98, 3, 46, 23 and 4% were deficient in B, Cu, Fe, Zn and Mo respectively and further reported that there are widespread deficiency of Zn in the country. Rice and citrus responded to Zn, Cu, Fe and Mn. Wheat responded to Zn, Cu and B. Maize sorghum, cotton, sunflower and sugar beet responded to Zn and B and Potatoes to Mn and Fe.

MICRONUTRIENT DEFICIENCY IN VARIOUS CROPS

The normal range of zinc in most crops is between 20 and 100 ppm. Zinc deficiency is possible when plant contains less than 200 ppm of Zn (Plank, 1980; Shorrocks, 1984, Katyal and Randhawa, 1983).

Zinc deficiency may depress plant yields by as much as 50% without producing any symptoms. Where visible Zn deficiency symptoms appear mostly on the 2nd or 3rd fully mature leaves from the top plants.

In corn, older leaves have yellow streak or chlorotic strip between veins. When the deficiency is severe, it shows a broad yellow or entirely white band between the mid rib and edge of the leaf. In severe cases undfolding young leaves may be white or yellow, hence the name "white bud" in corn.

In wheat, a longitudinal band of white or yellow leaf tissue, followed by interveinal chlorotic motlling and white to brown necrotic lesions in the middle of the real blade, eventual collapse of the affected leaves near the middle.

In rice, after 15 – 20 days of transplanting, small scattered light yellow spots appear on the older leaves which later enlarge, coalesce and turn deep brown in colour. The leaves dry out within a month.

In citrus, irregular interveinal chlorosis, terminal leaves become small and narrowed (little leaf), fruit bud formation is severely reduced, twigs die back.

In apple, Zn deficiency is frequently known as rosette disease. Young leaves become chlorotic between veins. Veins stay green. Leaves become crinkled are narrow and characteristic rosettes are formed at the shoot tip.

In black gram, zinc deficiency is shown in the leaves by the chlorotic areas between the veins.

The noraml range of copper in many plants is from 5 to 20 ppm. When the Cu concentration in plants is less than 4 ppm in dry matter, deficiencies are likely to occur.

In case of copper deficiency in wheat, new leaves are pale yellow, lack turgor and become rolled and yellow. Older leaves become limp and bent at the ligule. The leaves die and dry to a bleached grey. Wheat grain shows poor pigmentation.

In oats terminal or new leaves roll at the tips, are narrow and become chlorotic. Yellow grey spots appear which turn yellow white, ears are not fully developed and may be partially blind. Seed is light or shrivelled.

In apple, terminal shoots die back. Top leaves develop necrotic spots and brown areas, followed by withering and death of the shoot tips. Repetition of die back over the years leads to a bushy stunted appearance.

In orange, like apple the terminal growth dies back. There are sometimes reddish excrescences over large portion of the twig bark. Fruits may be bumpy, have a rind covered with reddish brown excrescences, there are gumpockets around the core and may split. The juice is low in acid and the pulp dries out early in the season.

In sugarbeet, old leaves show severe discoloration and scroching of interior leaf margin, due to Cu deficiency. Later, these effects spread to the entire interveinal areas and the affected tissue dries up. Young leaves are puckered.

Carrot root and onion bulbs show poor pigmentation.

In plants Fe concentration usually ranges between 50 and 250 ppm. Iron deficiency is likely to occur when Fe content in plant leaves ranges from 10 to 80 ppm. The grasses and corn have a lower Fe requirement, the critical level being 20 ppm.

The deficiency symptoms of different species of plants are quite uniform. Fruit trees, ornamentals and grain sorghum are affected more generally than some other crops. The leaf characteristic deficiency symptoms are distinctive green veins color and yellow interveinal areas.

Stripping of entire leaves is noted in sorghum and maize, while the complete leaf area becomes chlorotic in rice. Interveinal symptoms are also seen in citrus and complete leaf chlorosis is observed in peach trees. In the field, Fe deficiency does not always occur in a regular fashion. In some spots, the plants may be chlorotic, while in adjoing areas these may be green. Even chlorotic and green plant can be seen growing side by side.

The normal contents of Mn in plants ranges from 50 to 200 ppm, on a dry weight basis. Values less than 25 ppm in plant leaves are usually deficient and those over 400 ppm are considered excessive.

Mn deficiency symptoms are first seen on the new leaves. Chlorosis between the veins of young leaves, characterized by the appearence of chlorotic and necrotic spots in the interveinal areas.

Mn deficiency is soybean is recognised by intervienal chlorosis in young and middle leaves.

In sugarcane, Mn deficiency appears as alternating light green strips between dark green veins. The abnormalities associated with Mn deficiency are often referred to as "streak disease".

Symptoms of Mn deficiency in citrus are dark green bands along with midrib and main veins with lighter green areas between bands. In severe cases the light green areas often become grey or even whitish, the dark green turn pale green, the foliage becomes thin and the twigs bearing such foliage tend to die back.

Mn deficient sugarbeet leaves have an upright habit, are ttiangular in outline and have margins that curl forward. In the chlorotic interveinal areas lesions develop which perforate. In acute cases the entire leaf becomes chlorotic. Mn deficiency in sugarbeet is called "speackled disease".

In oats, the Mn deficiency symptoms appear on the basal part of the leaves first as greyish lesion, which then enlarges and becomes bright yellow or orange along the edges of the leaf. The tissue within the lession dies and becomes grey, giving rise to the name "grey speck" disease. The leaf top remains green, the base dies and this is followed by chlorosis of all green tissue. Penicles may become empty.

The optimum range of B in leaf tissue of most crops is from 20 to 100 ppm. Critical level for corn is about 4 ppm while apple, cotton and soybeans have a critical level of 20 ppm.

In maize, typical boron deficient cobs show dry tips, with empty sites, displacement of seed rows and asymmetrical arrangement of seed of varying size. yellow or white spots develop between the vein on young leaves, the spot often coalesce forming streaks.

In wheat, barley, oats and rye, boron deficiency causes similar symptoms. Small chlorotic spots from between the veins of the youngest unfolded leaves, the spots enlarge and coalesce to form the characteristic white strip. Sterility of ears occurs probably as a result of impairment of pollen germination and growth.

B deficiency in tobacco is characterized by short internodes and die back of the apical meristem. The first sign is the development of a basal chlorosis on the young leaves. Likewise, the stem near the top of the plant is often twisted. The flowering buds will be shed and very few seed pods are set.

In case of cotton, B deficiency is characterized by excessive shedding of square and young bolls, ruptures at the base of square and young balls, dark internal discoloration at the base of boll, half opened bolls, and retaining green leaves until frost.

Boron deficiency in sugarbeet is indicated by typical heart rot and in grapes "hen-and chick" symptoms appear.

B deficiency in citrus is indicated by thick rind and internal gum spots/pocket near axis. A gummy exudate may appear on the twig and fruit pedicels. The fruits, which are small, shrivel and go hard while on the tree.

In apple, B deficiency commonly causes cracking and external cork symptoms on the fruit.

In appricot, fruit shows severe cracking, internal cracking round the stone, and a tendency to premature ripening in the centre.

In tomato, carky patches and uneven ripening and in trunip terminal buds break down and leaves are curled, rolled and purplish-yellow. The root becomes hollow and cracked.

CONCLUSIONS AND RECOMMENDATIONS

It is gathered from the literature review that there are widespread deficiencies of Zn and B throughout the country. In some areas Fe is usually within the normal range. However, Mo and B are in excess in some areas. Owing to high alkalinity of the soil, the availabilities of Zn, Mn, Fe and Cu are low. Rice, maize, wheat, sorghum, cotton, sunflower, citrus and potatoes have shown response to various micronutrients. For proper dose recommendation, soil plant analysis and field trials should be conducted.

Keeping in view these facts, the following general recommendations of micronutrients are made tentatively for various crops:

Rice	10 kg Zn/ha	(as soil application)
Wheat	2–4 kg of Zn/ha	"
Maize	2–5 kg of Zn + 1 kg of B/ha	"
Soybean	5 kg of Zn + 2 kg B/ha	"
Cotton	5 kg Zn + 1.5 kg B/ha	"
Sunflower	5 kg Zn + 1.5 kg B/ha	"
Sorghum	5 kg Zn + 1.5 kg B/ha	"
Citrus	0.5–1.0 kg Zn + 0.25–0.50 kg Fe+ 0.25 kg Mn + 0.25 kg B+ 0.10 kg Cu/ha	(as a foliar spray in 1–2% solution)
Potatoes	0.25–0.50 kg Fe + 0.25 kg Mn/ha	"

Most of these nutrients will generally be applied by broadcast method and will be incorporated in soil before sowing crops. These micronutrients would be sufficient for at least three to five years. The sources of recommended nutrients are sulphates for all nutrients except B which is borax or boric acid. These doses are suggested as elemental form of the nutrients. It is assumed that these micronutrients will be applied to various crops in the presence of recommended doses of amjor nutrients. Zinc application to rice for transplanting could be done as seedling root dip for 5 minutes in 0.25% zinc solution. Similar treatment of various micronutrients could also be applied to wheat seed. Borates may damage seed and should never be applied with seed of any crop. It is preferable to apply zinc sulphate to various crops after 3-4 weeks of phosphorus fertilizers.

The above recommendations can be modified as more and more research is carried out.

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NITROGEN USE AND EFFICIENCY

NAZIR AHMAD*

INTRODUCTION

There is no disputing the fact that fertilization is paramount among the measures taken to enable crops to realize their full genetic potential. Fertilizers have occupied the leading position in the intensification of agriculture and they will retain this for years to come. Amongst these nitrogen is one nutrient that figures prominantly in plant nutrition and is most widely used nutrient on majority of soils and for most crops except legumes. Very often it has been termed as yield increasing nutrient.

Although plants and other living organisms live in an ocean of air that is 79% nitrogen, yet their food is limited more by the availability of nitrogen (N) than that of any other plant foods.

Nitrogen being the most used plant nutrient, world consumption increased from 13 million tons 1964 to 61 million tons in 1982-83. The upward trend is expected to continue. Greatest potential for increase is in developing countries where many farmers apply far less than half of the dose recommended by extension services.

Nitrogen use rates are much higher in some countries e.g. Great Britain fertilizes nearly all its agricultural land. Her average use rate is 224 Kg/ha while Brazil uses about 9, Turkey 310, Pakistan 47 and Japan 122 kg/ha.

Significant changes have occured in recent years in the forms of 'N' used with a definite trend towards the higher analysis materials with reduced transportation, handling and application costs. Table 1 illustrates the latest trend regarding fertilizer use in USA.

Table 1. Nitrogen Fertilizer Use in the United States in 1976-77

Material	Thousand Metric Tons of Nitrogen	% of Total Nitrogen
Anhydrous Ammonia	3 664	38.0
Aqua Ammonia	120	1.2
Nitrogen Solutions	1 528	15.8
Ammonium nitrate	853	8.8
Urea	775	8.0
Ammonium Sulfate	200	2.1
Ammonium Phosphates	92	1.0
Other Nitrogen Materials	107	1.1
Compound Fertilizers	2 312	24.0
Total	9 651	100.0

*National Fertilizer Marketing Limited, Lahore.

Since 'N' accounts for a significant portion of crop production costs, it is important that 'N' fertilizers be used as effectively for crops as possible.

NITROGEN USE EFFICIENCY

Some of the findings of agronomic interest as related to fertilizer 'N' use efficiency are presented in Table 2. As is clear from these findings that the recovery of applied fertilizer N rarely exceeds 50%.

Table 2. Recovery of Fertilizer Nitrogen By Crop

Crops	N Source	Rate kg/ha	Recovery %	Location	References
Field Experiments	—	63	23 – 39	Rothamsted	Widdowson et al (1964)
Wheat	—	126	27 – 35	(U. K)	
Wheat	Ammonium Sulfate	60 – 140	34 – 39	New Delhi (India) (India)	Dutta (1967)
Corn	—	80 – 240	35 – 75	New Delhi	Roome Gowda (1968)
Sorghum	—	50 – 100	25 – 32	New Delhi	Srivastava (1966)
Sorghum	Urea	120	58.50	New Delhi	Roy (1969)
Rice (Transplanted)	Urea	180	10 – 30	Lambayeque (Peru)	Sanchez and de Calderon (1971)
Rice (Transplanted)	Urea	150	34.30	New Delhi	Lakhdive (1968)
	Ammonium Nitrate	40 – 120	19 – 40	—	—
	Ammonium Sulfate	40 – 120	39 – 60	—	—
Rice (Transplanted)	Urea	50 – 150	28 – 34	New Delhi	Rajale (1970)
Pangola Grass (Digitaria decumbens)	Urea	114	53 – 68	Trinidad (W/Indies)	Weir (1969)

Ref: Nitrification retarders and slow release nitrogen fertilizers. Advences in Agronomy 23 : 339

FACTORS INFLUENCING FERTILIZER EFFICIENCY

Leaching, surface run off, denitrification and volatilization are the major sources of this nutrient loss. In addition, fertilizer efficiency can also be reduced by following agronomic factors. Poor seedbed preparation, improper seeding, delay in sowing, unsuitable crop variety, inadequate plant density, improper fertilizer placement, insufficient irrigation or drainage, weed infestation, insect attack and last but not the least imbalanced fertilizer application. Only "a whole package of agronomic skills" will result in the highest effectiveness of fertilizers.

MEASURE TO IMPROVE EFFICIENCY

In order to help improve the efficiency of applied 'N' fertilizer, a two-pronged approach be taken:

Agronomic:

Maximum care should be exercised in keeping all variables previously mentioned under check. In addition, application of 'K' will also increase the efficiency of applied N. Similarly split application of Nitrogenous fertilizers will also reduce various 'N' losses.

Manufacturing:

There are a number of ways, in which nitrogen recovery and efficiency can be improved. The idea being to minimize leaching and volatilization losses, lessen damage to plants, and permit closer matching of the plant's nitrogen needs with the rate and amount of N release from the fertilizer.

One approach is to develop compounds that release nitrogen slowly because of their limited water solubility or slow rate of degradation. In such compounds, the amount of surface area exposed determines the rate of dissolution.Varying the particle size thus can vary the rate of release. Magnesium ammonium phosphate, crotonylidenediurea (Floranid), isobutyridenediurea (I.B.D.U.), glycoluril, and oxamide all exhibit this property and the first three are produced commercially. The slow release of the urea forms (produced commercially) and the triazines depend also upon their resistance to microbial decomposition. All are costly to produce, which has limited their use largely to turfs, gardens and special crops.

Another approach is by coating nitrogen compounds with some material that will delay release or slow the rate of release. Waxes, paraffins, acrylic resins, polyethylene, vinyl acetate, latex, gums, oils, and sulfur have been used experimentally. Slow or delayed release is achieved through one or more of the following mechanisms: (i) Water vapour entering through the coating until the internal salt solution pressure is sufficient to break the coating; (ii) controlled or inhibited movement of dissolved salt out through tiny pores in the coating; and (iii) degradation of the coatings through microbial and abrasive action. Although coatings can be effective, yet they are costly to apply and also lower the nutrient content of the product. Moreover, it is extremely difficult to coat fertilizer particles uniformly in large-scale plant operations and, unless this is achieved, coatings are of little value. Sulfur being a low-cost non-crystalline material and also has value as a secondary nutrient can form a good coating material.

Natural organic materials which are resistant to rapid microbial decomposition also exhibit slow-release properties. Use of natural organics as sources of nitrogen in mixed fertilizer has decreased considerably. Still, a number of organic products are on the market, such as processed sewage and garbage and ammoniated brown coal and lignite. The 'N' content of such products is low and costs per kg of N are high, especially when the products are transported long distances. However, the growing problem faced by municipalities in disposing of these materials undoubtedly will lead to an increase in their processing for soil application.

Probably more effort is being placed on developing slow-release nitrogen products than is justified in view of the general lack of information as to their potential agronomic value. For example, little is known of the extent to which small quantities of nitrogen releases are tied up in the cellular structure of micro-organisms and must await mineralization before becoming available for plant uptake. If cellur tieup is appreciable, the rate of release to the plant may be too slow to cater its needs

under most situations. Studies focussing on basic plant physiology would be of prime importance not only in understanding how to use the slow-release materials at hand, but also in guiding their logical development.

A more sophisticated approach to the problem of increasing nitrogen fertilizer efficiency is through the development of nitrification inhibitors. Dow Chemical Co. is marketing 2-chloro-6-(trichloromethyl)-pyridine, "N-serve," which is highly toxic to soil organisms that convert NH_4^+ to NO_2^-. The product has been shown to be effective in sandy soils under severe leaching conditions, in clay loams subject to denitrification, under cool soil conditions when applied prior to planting. Thiourea, biuret, dicyandiamide, and other compounds also have been investigated.

Continued search for specific inhibitors in regard to blocking ammonium oxidation should prove of agricultural benefit. Such an inhibitor should be specific in blocking conversion of NH_4^+ to NO_2^-, be able to move with the fertilizer through the soil, and not being toxic to the growing plant or subject to rapid degradation by soil chemical or microbiological action. A effective urease inhibitor that would block NH_3 formation until urea is washed into the soil would greatly increase the versatility of urea.

Theoretically, the available N supply to the crop should coincide with its rate and pattern of seasonal uptake, with none left over in the soil for subsequent loss. The problem is complicated as the nitrogen needs of crops differ both in quantity and timing. For example, corn has a low nitrogen requirement during the first 4 to 6 weeks of its growth, as much as 4.5 kg per hectare per day are needed during its most rapid growth period. After tasseling and silking, the uptake rate falls of sharply, because during the fruiting period the plant largely maintains itself on the nitrogen reserves in the leaves and stem. This contrasts sharply with grass forages in which nitrogen uptake parallels the rate of dry matter elaboration, or cotton where a high N uptake rate continues until harvest. Obviously the patterns of N uptake for various crops dictate quite different nitrogen regimes. In addition, uptake patterns for the same crop in successive years may differ because of seasonal and fertility variations.

In practice, a farmer may make a single large nitrogen application aimed at having nitrogen available in sufficient quantities to meet the plant's needs throughout the season and then bear with the luxury consumption and nitrogen losses inherent in the system. Or, he may attempt to match the actual requirements more closely by split applications and hope that irrigation water will move the nitrogen into the root zone. While both systems are wasteful, the low cost of nitrogen in relation to the high returns makes both feasible from the economic standpoint. One hope is that a nitrogen fertilizer can be devised in which the release pattern can be made to coincide with the crop demand pattern. The development of slow-release N compounds in which the rate of release is related to the surface area of the particles offers some encouragement. It might be possible to formulate a fertilizer in which different particle sizes or coated materials were combined in such a way as to approximate the desired release pattern. A practical fertilizer of this type is not now on the horizon. However, experimental slow-release fertilizers with the desired characteristics can be made from existing compounds to determine the potential of this approach.

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THE NEED TO REVIEW RECOMMENDATIONS FOR EFFICIENT USE OF FERTILIZER IN PAKISTAN

M. TAHIR SALEEM*

INTRODUCTION

Fertilizer is a costly input in the package of crop production technology and, therefore, merits consideration for its efficient use by the farmer. In fact, improving fertilizer efficiency at the farm level is the highest priority in the Government's Sixth Five-Year Plan 1983-88. The question how much fertilizer to apply on a particular field, when, how, and in what combination of products, is important both from the farmer's as well as from the policy points of view. Apparently, one needs to determine the amount of nutrient required by the crop and the amount of nutrient present in the soil. What the soil lacks should be applied from fertilizer. In actual practice, however, this is rather complicated because of the dynamic nature of crop growth and the various factors affecting the behaviour of nutrients in soil and the uptake of nutrients by plants. Further, the fertilizer requirements necessitate review due to soil 'mining' of the nutrients, changes in crop varieties, fluctuations in crop/input prices ratios, revised yield targets and improvements in soil testing philosophies. Attempt in this paper has been made to review the rationale for formulating fertilizer recommendations in the context of present level of fertilizer use in Pakistan.

FERTILIZER USE IN PAKISTAN

Fertilizer use was introduced in Pakistan in 1952-53. The pace of fertilizer growth since then had been phenomenal upto the end of the 70's. However, the rate of growth has been lower than expected since 1980-81: 3.8% (for the 4-year period 1980-81 to 1984-85) against 8.0% target rate for the Sixth Plan (Table 1).

Table 1. Rate of annual fertilizer growth in Pakistan.

Period		Fertilizer off take (000 n/t)	Annual growth rate
1952–53	to 1960–61	1 – 31	53.9 %
1960–61	to 1965–66	31 – 71	17.7 %
1965–66	to 1970–71	71 – 283	31.2 %
1960–61	to 1970–71		24.6%
1970–71	to 1975–76	283 – 548	14.3%
1975–76	to 1980–81	548 – 1 079	14.5 %
1970–71	to 1980–81		14.2 %
1980–81	to 1984–85	1 079 – 1 253	3.8 %

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Five crops i.e. wheat, cotton, rice, sugarcane and maize account for about 90% of all fertilizer offtake: wheat 50%, cotton 15%, rice 10% sugarcane 8% and maize 7%. The overall use per cropped hectare is 60.6 kg. The actual rates, when applied by farmers, are about half of the recommended levels, the phosphate application being only about 1/4th. The use of phosphate in barani agriculture is particularly very low. It, therefore, seems that while 'barani' farmers need assured minimal rate depending on the rainfall in a particular area, the 'irrigated' farmers, especially those applying near-optimal rates of nutrients, require more specific advice tailored to their target yields and farm situations. Such a strategy may help accelerate the pace of fertilizer development in the country and improve efficiency.

BASIS OF FERTILIZER RECOMMENDATIONS

Greenhouse studies, soil and foliar analysis, and field trials are the approaches generally employed for determining fertilizer needs of crops. However, the plant in its natural environment being the final judge of nutrient availability, fertilizer field trials involving recording of yield response to the applied rates of different nutrients, is the surest way to determine the fertilizer requirements. The results obtained are evaluated to determine what fertilizer rates should be applied to produce an economic yield.

In Pakistan, the basis of fertilizer recommendations are the thousands of trials having been done in farmers' fields, since 1985 under the Soil Fertility Organizations, with the following objectives:

- To conduct fertilizer trials in the farmers' field and evaluate the data to find crop responses to major nutrients to formulate fertilizer recommendations to farmers under different soil conditions,
- To analyse soils to establish correlation between crop response and the soil analytical data,
- To advise and educate the farmers in the efficient use of fertilizers.

The mean crop responses, of several single-replicate simple trials laid out in an area, to graded dressings of fertilizers over a number of years provide the basis for formulating fertilizer recommendations. However, the recommendations thus formulated are generalized in nature. Besides this, the marginal or problem lands are hardly selected for such trials.

TAILORING RECOMMENDATIONS TO SPECIFIC REQUIREMENTS

The simple trials approach initiated during the Introductory Phase of fertilizer use in Pakistan proved excellent in sampling the areas for major nutrient deficiéncies and for fertilizer promotion. However, the year after year repetition of such trials have proved of little further guidance. This is borne out by the fact that today's fertilizer recommendations are basically the same as fifteen years ago. This state of affairs calls for a critical review of the approach in order to properly utilize the scarce resources. The following measures are suggested.

Interpreting the available data

Main conclusions on the N, P and K nutrient deficiencies have been drawn from the existing data and provided basis for developing generalized recommendations. This data can further be screen-

ed, consolidated and stratified on the basis of previous cropping, source of irrigation/rainfall, soil type etc, and re-interpretted in order to improve the present recommendations. This is being studied in the National Fertilizer Development Centre (NFDC). Wheat response data of 851 trials, from 1975-76 to 1984-85, in the Punjab have been selected as a test case. The data have been stratified into three agro-ecological zones covering 13 tehsils and response curves for N, P and K developed (Appendix-1) through multiple regression analysis. The differences among the control yields and the responses in these three zones are, however, non-significant. The data were further stratified on the basis of sources of irrigation (canal, canal + tubewell, and tubewell), previous cropping (cotton, fallow, Jowar, Bajra, maize, rice and sugarcane) and tehsils (Sheikhupura, Gujranwala, Phalia, Mianwali, Sargodha, Faisalabad, T.T. Sing, Sahiwal, Chishtian, Bahawalpur, Multan, D.G.Khan and R.Y. Khan). The preliminary investigations do reveal that sub-grouping data may lead to more meaningful interpretation.

The direction of future experiments

Discussions at various forums and their recommendations, as well as the published reviews on the existing status of soil fertility research in Pakistan (the latest being two NFDC's Consultancies Reports by Wahhab and Soper, 1985) point to the future directions. Implementing fewer trials—well—planned and conducted on carefully selected soil sites, based on soil survey reports, and representing typical cropping sequences—supported by greenhouse and soil dynamics laboratory research studies, would be a better course than a large number of simple un-replicated trials in farmers' fields carrying a dual objective of research information generation and demonstration value. The dual-purpose approach was relevant during the Introductory Stage of fertilizer use but does not seem valid for the present advanced Development Stage of fertilizer Take-Off in Pakistan: both objectives of research and promotion should be pursued separately. This shift should, however, be made gradual and some simple trials testing the validity of recommendations and identifying constraints—would be needed to be carried out, depending upon the crops and the areas.

Soil classification as basis of recommendations

The basic information on soil series/familes having been generated by Soil Survey of Pakistan should be used for interpreting results of all agronomic experiments. The results from SCAN project would already have been discussed at this forum. It may, however, be added that field observations of soil fertility trials in Lahore in mid-seventies clearly indicated the differential response of calcareous versus non-calcareous soils (Saleem and Ahmed 1974). Results have also been reported by Atomic Energy Agricultural Research Centre, Tandojam (Annual Report, 1982-83). Some doubts are sometimes expressed which should not dampen the effort in this direction. That soluble P and percentage yield response to phosphate were closely related in Nebraska was established as far back as 1954 (Olson et al, 1954) and further supported in 1958 that soil classification was useful in predicting crop needs for P, K and lime supplements (Olson et al, 1958).

The use of soil test values in refining recommendations

Needless to say that "a measurement qualifies to be termed a soil test for a particular naturient, if, and only if, it provides information on the fertilizer requirements of a crop for that nutrient". However, in the absence of proper soil test-crop response calibration studies, a committee of soil

fertility scientists can be constituted to agree on adhoc soil test values critical limits especially for phosphate. In the meantime, calibration studies should be strengthened/improved in order to refine the limits. Studies are underway at Nuclear Institute for Agriculture and Biology, Faisalabad (Hussain and Malik, 1983 and 1985) for developing soil nitrogen availability test. Regarding potassium, Dyer's remarks of 1894 that "the economy of potash is probably more complicated – and needs a good deal of further investigation" still hold good for Pakistan.

Recommendations for yield targets

Crop yield targets being a function of complex relationship of factors including soil types, irrigation water, cultural practices and managerial capacity of the farmer are not the same everywhere. The lower yield targets will require lower rates of fertilizers than the higher yield targest. The recommendations have, therefore, to be more realistic than those based on the research data. The recommendations based on research studies have to be adjusted in keeping with economic conditions of individual farmers. Various economic parameters such as optimal economic returns, marginal rates of returns (MRR), grain-nutrient ratios, value-cost ratios (VCR), net return per acre/hectrare etc have to be considered carefully for various yield categories in order to advise farmers on their individual farming situations.

STANDING COMMITTEE TO REVIEW RECOMMENDATIONS

The foregoing are some of the important measures which may help in developing 'site-specific' fertilizer recommendations. Some other related factors have not been discussed here. NFDC had, sometime back, proposed setting up Fertilizer Committees at the Provincial level. It would be useful to have at the Federal level a Fertilizer Recommendations Committee which will effect improvements in generalized recommendations, review the new information and monitor, through periodic meetings, the progress of research studies.

ACKNOWLEDGEMENT

Thanks are due to Dr. H. Nabhan, FAO Project Manager NFDC, for his valuable suggestions, especially pertaining to the stratification of crop response data according to different parameters, in the preparation of this paper. The data reported in Appendix-I is derived from an NFDC study in progress and is Mr. de Bie's contribution which is gratefully acknowledged.

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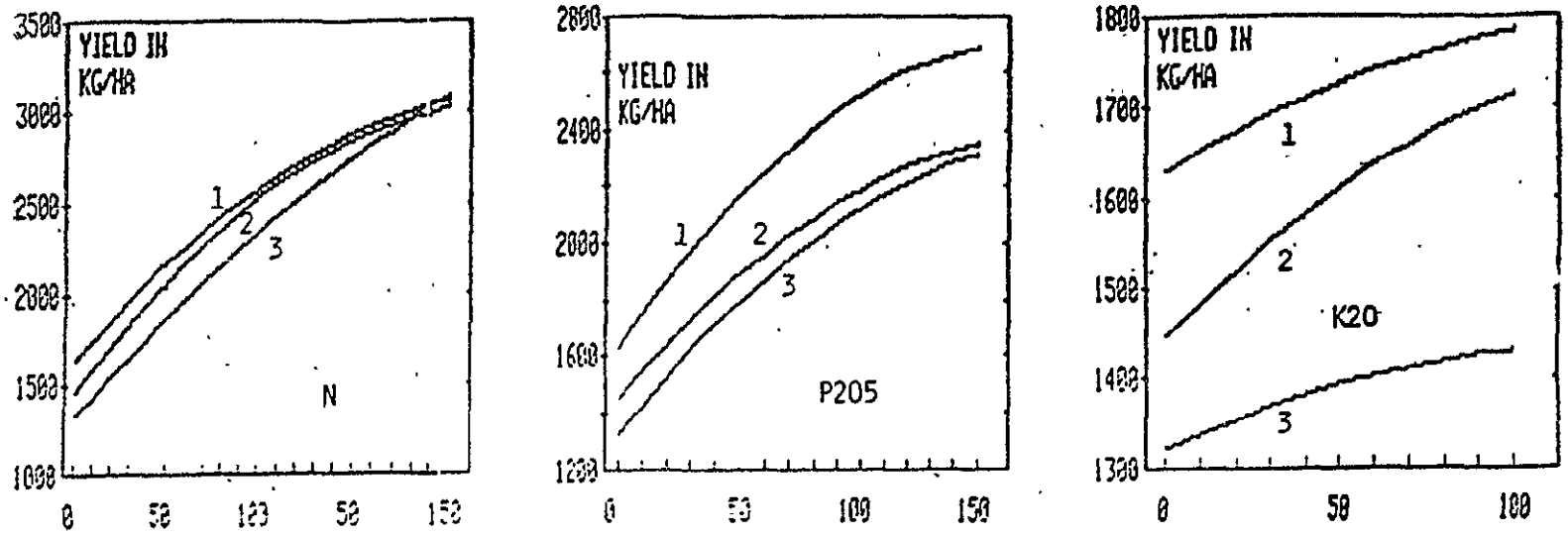

YIELD RESPONSE CURVES FOR N, P205 AND K20 FOR THE THREE AGRO-ECOLOGICAL ZONES (USING THE 13 TEHSILS)

ZONE 1 = GUJRANWALA ZONE
ZONE 2 = LYALLPUR ZONE
ZONE 3 = MULTAN ZONE

CNR PER ZONE & NUTRIENT AT 150-96-45 KG/HA

		CONTROL	N	P2O5	K2O
ZONE:	1	1631	8.35	9.11	1.96
	2	1446	9.33	8.58	3.35
	3	1321	9.50	8.20	1.50
AVERAGE:		1441	9.17	8.20	2.20

CONTROL YIELDS AND RESPONSES TO N, P AND K WERE NOT SIGNIFICANTLY DIFFERENT BETWEEN THE THREE AGRO-ECOLOGICAL ZONES UNDER STUDY & USING THE 13 TEHSILS.

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PART V
AGRONOMY OF IMPORTANT CROPS

• Wheat Agronomy in Pakistan	M.A. Bajwa
• Agronomy of Rice	Abdul Majid Chaudhry
• Maize Agronomy	Muhammad Qasim Chatha
• Agronomy of Sugarcane	Talib Hussain Chaudhry
• Some Agrotechnological Aspects of Cotton Production in the Punjab	W.S. Khan, M.S. Khan M.D. Khan and M.G. Khan,
• Agronomic Practices of Cotton Cultivation in the Punjab	Muhammad Islam Gill
• Citrus Agronomy	Daud Ahmed Khan
• Prospects of Agroforestry in Pakistan	M.I. Sheikh

WHEAT AGRONOMY IN PAKISTAN

M. A. BAJWA*

SUMMARY

Amongst various crops grown in Pakistan, wheat occupies the most prominent position with regard to area and production. It is the major source of food for the people. In order to achieve maximum wheat production a two-pronged strategy is required; namely (i) development and transfer of modern production technology constituted of improved varieties of the crop and suitable agronomic practices conducive to higher production, and (ii) improvement of salt-affected and waterlogged soils, conservation of moisture in rainfed areas and efficient resources management in which agricultural credit occupies a pivotal position. Wheat varieties with different planting times have been evolved to suit the rotation and other agro-eco-systems of wheat culture. To get maximum wheat yields, it is necessary that the crop should be planted within the optimum period. The new varieties possess inherent capabilities to fit in different environmental conditions. It is advocated that the farmers should plant only those wheat varieties which are recommended for their locality.

The crop should be grown by using 85—125 kg/ha of healthy seed and it is recommended that the seed must be treated with a suitable fungicide to control seed-borne diseases. A fine seed-bed preparation is most desirable for good germination. In rainfed areas, primary deep cultivation is emphasised for the efficient use of rain water and to avoid loss of moisture through evaporation and run-off. To ensure good germination/emergence, it is essential that planting should be done in moist soil, at the proper depth with the best available implement.

The use of balanced fertilizers, in right amount and kind, at the proper time and with the most suitable application method is the basic essential for high production and proper exploitation of the varietal potential. Addition of phosphatic fertilizer at planting time or with first irrigation and use of gypsum in the salt-affected soils should be kept in mind to ensure good yield of the crop.

The availability of water is extremely important for the development of plants. It is advisable to apply irrigations at least at the critical stages of the crop, i.e. 12-18 days after germination and at flowering and grain-filling stages.

Weeds reduce crop yields by 7-50% and must be controlled through appropriate cultural and /or weedicidal methods.

Mechanized harvesting and threshing operations greatly help in early and efficient gathering of the crop. This technology should be adopted, where feasible to save yield and quality losses accruing due to late harvesting.

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INTRODUCTION

In Pakistan wheat, the most important of cereals, is the staple food of people and is presently grown over an area of around 7.5 million hectares, yielding an annual production of about 12.5 million tons; the yield per ha being about 1 700 kg. When these figures are compared with the corresponding figures of 1947-48, it becomes clear that the country has taken great strides in improvement of the crop. The area, production and yield of wheat during 1947-48 were 3.9 million hectares, 3.35 million tons and 848 kg/ha of grain respectively. The Punjab leads the rest of the provinces in wheat production. More than 70% area and almost the same proportion of production comes from the Punjab alone, while the rest is shared by other three provinces i.e. Sind, NWFP and Baluchistan ranking in the given order.

The above statistics clearly indicate that the yield per unit area played the major role in increased wheat production in the country. Introduction of short-statured, stiff-stemmed, fertilizer-responsive varieties gave the greatest fillip in enhancing the yield and production of the grain. The trends in area, production and yield of wheat since 1947 are presented in Fig. 1.

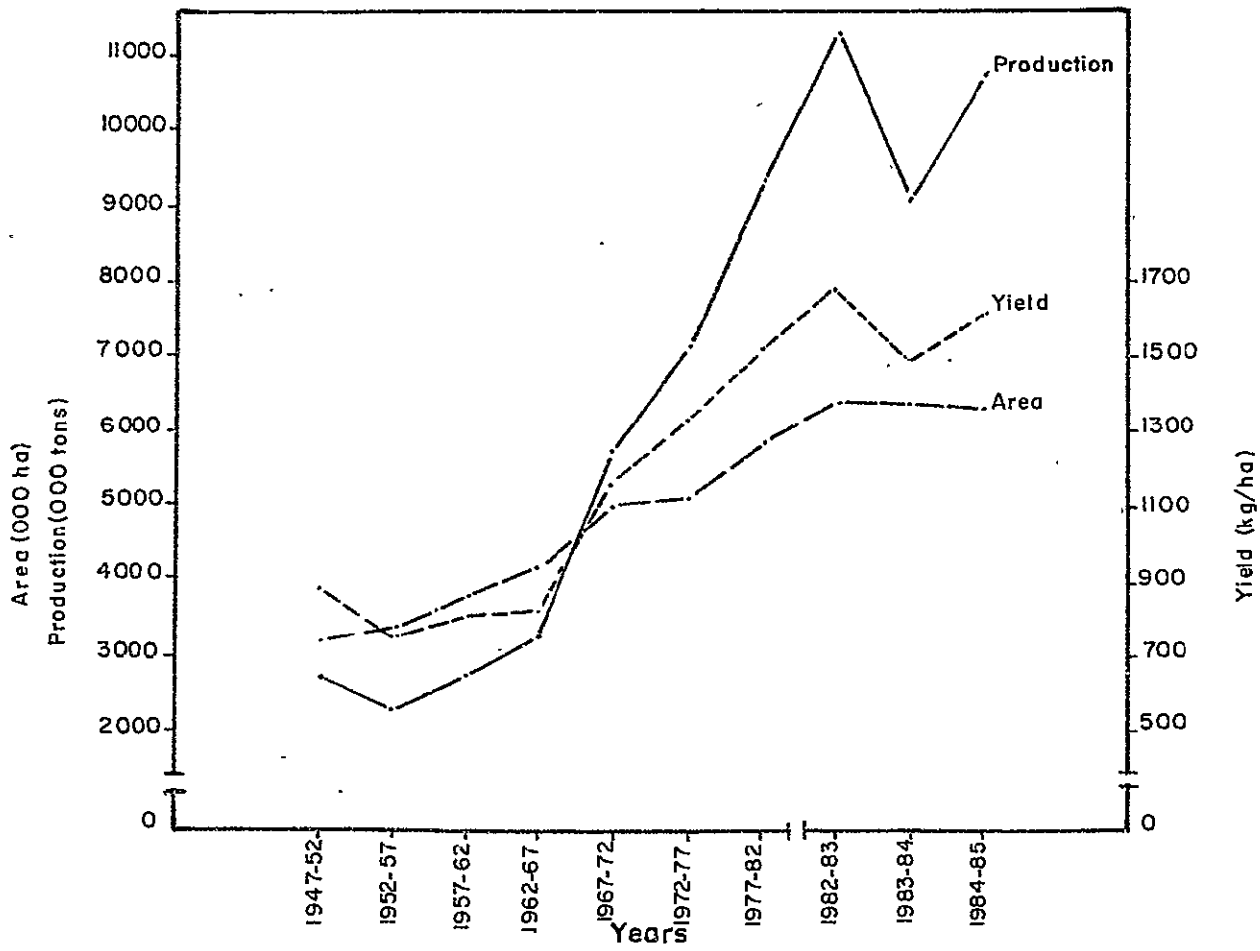

Fig. 1 Trend in area, production and yield (kg/ha) in Pakistan

Despite these impressive achievements, the yield of the crop is still much lower than that in many other countries of the world. The main underlying reasons are differences in agro-climatic conditions, types of wheat grown, availability and efficient utilization of inputs like seeds, water and fertilizers, and the harvest as well as post-harvest care.

Information provided in table 1 shows that wheat types grown under different agroclimatic conditions differ greatly in their production potentials. Winter types of wheat which remain in the field for a much longer time, usually yield higher than the spring types. Similarly, the countries with relatively moist climates and a better distributed precipitation during the crop season have higher average yields than those with drier climates.

Table 1. Yield of wheat under different agro-climatic conditions

Country	Wheat type	Av. growing period (days)	Growing environment	Area (million ha)	Yield (kg/ha)
Tunisia	Spring	160	Rainfed	1.00	500
Queensland (Australia)	"	160	"	0.90	1 000 – 2 000
United Kingdom	Winter	285	Rainfed (adequate rainfall)	1.10	5 000
Yaqui Valley (Mexico)	Spring	160	Irrigated	0.12	5 100

Source : Wheat in the third world by Hanson, H., Norman E. Borlaug and R. Glann Anderson, 1982.

Besides the use of high yielding varieties, appropriate agronomy plays very important role in wheat production. Wheat production technology is constituted of many factors including improved varieties, proper cultivation involving primary tillage and preparation of seed-bed, normal time of sowing, appropriate quantity of healthy seed, adequate and balanced input of plant nutrients, judicious use of irrigation water and suitable moisture conservation measures in rainfed areas, control of pests and diseases, weed control, proper harvesting and post-harvest care. To reap a good wheat crop, all these factors need to be appropriately combined and put into practice.

AGRO-ECOLOGICAL ENVIRONMENTS FOR WHEAT IN PAKISTAN

Pakistan grows spring types of wheat all over the country. The climate of the country well suits the crop which is planted in early winter and ripens in late spring. The near freezing night temperatures prevailing during mid winter season in most of the area are conducive to good tillering of the crop, while the warmer springs at the time of ripening aid in maturity of the crop. The abnormal high temperatures during late February, March and early April in some years (once in 5 to 6 years period) however, adversely affect the crop, causing shrivelling of the grain and lowering of grain weight. The precipitation occurring during wheat growing season is low and erratic in most area and the crop is, therefore grown mainly under irrigated conditions. In some northern parts where precipitation is rela-

tively high, rainfed cultivation of wheat is also practised. A normal winter precipitation generally proves highly beneficial for production of the crop, especially in rainfed areas.

The soil conditions, by and large, are favourable to the crop except in some localized areas where problems like salinity and/or waterlogging are faced. On the whole, the agro-climatic conditions of the country are fairly suitable for producing spring types of wheat. If wheat production technology recommended by the Department of Agriculture is employed, fairly high and sustained yields can be obtained.

CROP ROTATIONS FOLLOWED

In the Punjab, N.W.F.P. and some parts of the Sind, wheat is sown after vacation of land by a kharif (summer) crop such as rice, cotton, sugarcane, maize, grain legumes, summer fodders etc. in irrigated areas. Some area of wheat is also sown after fallow. Major rotation systems in vogue in the Punjab are:

– Irrigated areas:	Rice – Wheat
	Cotton – Wheat
	Maize – Wheat
	Summer fodder – Wheat
	Sugarcane – Sugarcane – Wheat
– Rainfed areas:	Fallow – Wheat

APPROVED WHEAT VARIETIES

One of the major components of wheat production technology is the suitable crop varieties. Research has led to the evolution of high-yielding, lodging-resistant, disease-tolerant, fertilizer-responsive and high-quality bread wheat varieties suitable for early medium and late sowings in different agro-ecological zones of the country. Some of the wheat varieties approved in the recent past for commercial cultivation in the Punjab are given below:

For early planting:	Pak-81, Barani-83
For mid season planting:	Pb-81, Kohinoor-83, Punjab-85
For late season planting:	BWP-79, Pb-81, Faisalabad-83, Faisalabad-85

SEED RATE

A seed rate of 85-125 kg/ha, depending upon the seed size and time of planting is recommended for obtaining maximum wheat yields. Higher seed rate is required in cases of large-seeded varieties and/or late planting. To control the seed-borne diseases, like loose smut, wheat seed must be treated with Vitavax/Benlate etc, at least a week before sowing.

TIME AND METHOD OF SOWING

It has been noted that the cultivators, by and large, pay little attention to the optium time of sowing. The fact that the time of sowing has significant effect on yields is illustrated in Fig. 2. As can be seen, no significant reduction in yield occurs if wheat is grown upto November 20. After that,

there is a sharp decline, if the sowing is delayed by even as little as ten days. This trend is much accentuated as the sowing is further delayed (Bajwa et al 1982).

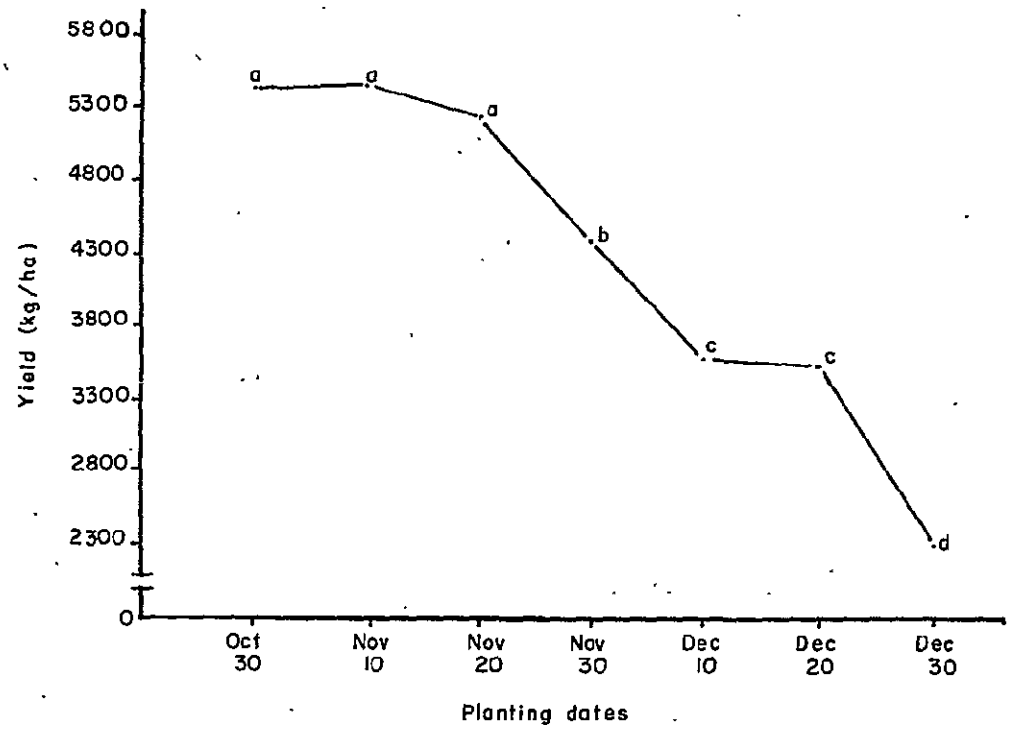

Fig. 2 Effect of sowing dates on yield of Punjab 85 during 1984-85

Under normal weather conditions, the short-duration varieties give higher yields than the long-duration and mid-duration ones when planted late. If, however, the temperatures remain mild during March and April, the reverse occurs, i.e. the long and mid-duration varieties yield better than the short-duration ones planted late (in December). This trend has been seen during 1979 to 1982. It may also happen that, when there is no frost at boot stage, the short-duration varieties yield higher in early plantings.

To ensure good germination of seed, it is essential that planting should be done in a moist soil at proper depth. This is more important in the rainfed areas because sowing at shallow depths in these areas may cause irregular germination due to rapid drying of topsoil. Too deep seeding is not also desirable as it will delay emergence or will effect no emergence at all due to insect pests, diseases or even due to inadequate food reserves in the seeds. The optimum depth of sowing is 5-6 cm which can be maintained by using a seed drill or 'pore' (a long funnel tied behind the local plough). In case these are not available, seeding may be done by the 'Kera' method (dropping of seed in furrows by hand).

FERTILIZER APPLICATION

Wheat varieties vary widely in their response to fertilizer application. The old tall varieties are less responsive while the improved, semi-dwarf ones are highly responsive to higher doses of fertilizers and are capable to convert the inputs into a better harvest.

It must be borne in mind that the fertilizers should be used in optimum recommended doses failing which the yield may not be as remunerative as desired. The imbalanced use of fertilizers, especially the high doses of nitrogen, may enhance disease susceptibility, cause lodging and late maturity of crop. Moreover, proper timing of fertilizer application is also essential in order to get the maximum benefit out of this input (Table 2).

Table 2. Effect of timings of phosphorus application on grain yield of wheat variety Faisalabad-83 (1984-85)

Phosphorus applied at	Grain yield (kg/ha)
Rauni (presowing irrigation)	5 048 a
Seeding	4 909 a
Ist Irrigation	5 187 a
2nd Irrigation	4 675 b
3rd Irrigation	3 964 c

Source: Director, Agronomy, Faisalabad.

Experimental evidences exist to prove that, from amongst various factors, fertilizer use has been the most important one in wheat production both in the irrigated and the rainfed areas. The contribution of fertilizers towards enhancement of yield in rainfed areas is about 50%, while in irrigated areas it ranges between about 50 and 75% which establishes the immense importance of fertilizer application in recommended doses. In addition, the soil type has also a bearing on the fertilizer use efficiency (Fig. 3)

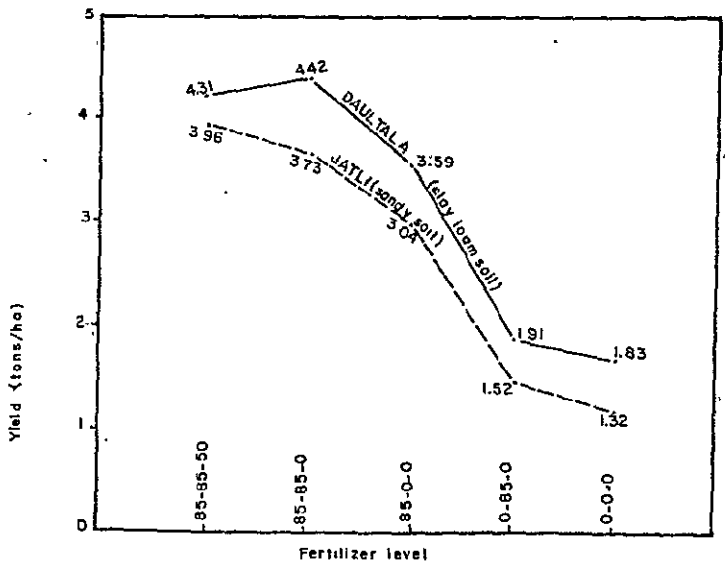

Fig. 3 Yield of wheat (Lyp-73) in two soil types of different fertilizer levels in high rainfall area.

Source: Agron, results for wheat in a rainfed area of northern Punjab. (D. Byerlee, 1985)

IRRIGATION AND WATER CONSERVATION

The moisture requirements of wheat plant are different at different stages of growth; these are low in early stages and rise progressively as the plants grow, the maximum being at the time of flowering and grain formation. The total consumptive use of the crop has been estimated to be 350-400 mm in most of the Punjab but varies according to the agro-climatic conditions within the Punjab and other parts of Pakistan.

In view of findings from various experiments, it is recommended that the first irrigation should be applied about 15 days after germination, 2nd at boot-anthesis, 3rd during grain development, 4th after the grain development and 5th, if necessary because of warm weather just before the maturity stage. Experiments relating critical stages of irrigation have revealed that there are two critical periods; the first occurs at 12–18 days after germination and the second during boot/grain formation. A yield reduction between 15 and 20 per cent was evidenced when plants were subjected to drought at tillering, while drought at later stages (boot-anthesis/grain formation), caused yield reduction between 30 and 45 per cent.

In rainfed areas, a lot of rain water is lost through run off. All-out effort should be made to conserve this precious resource by improving its infilteration and storage into soils through deep tillage. Studies by Byrlee (1985) have shown that, out of different primary tillage treatments the use of mouldboard plough proved the best for moisture conservation when compared with sub-soiler, chisel, cultivator and ordinary plough. A proper moisture conservation in these areas, no doubt implies a good harvest of wheat crop.

WEED CONTROL

The weed infestation in wheat fields is increasing year after year. The losses in yield due to weeds depend upon the intensity of infestation and vary from 7 to 50 per cent in Pakistan. The important weeds found are *Avena fatua, Phalaris minor, Chenepodium album, Medicago denticulata, Asphodelus tenuifolus, Convolvulus arvensis* and *Carthamus oxyacantha.* These weeds can be controlled through cultural operations such as 'Daab' and bar-harrowing and manual destruction or with the use of herbicides. Use of weedicides in the infested fields is found to be the most effective way to get rid of this problem. Several weedicides have been tested amongst which Stomp 330 E, Dicuran M.A., Buctril-M, Arelon 75 WP and Dosanex have been found to be most effective and are recommended for controlling weeds in wheat. The relative effectiveness of various weedicides was studied and the results of one of such experiments are presented in fig. 4.

HARVESTING

The optimum wheat harvesting season is very short and is very often followed by abnormal wheather conditions (rains or windstorms) which may result in reduced grain yield and deterioration of the grain quality. To avoid shattering losses in wheat varieties viz. Pb 81, Pari 73 and Blue Silver, and to minimise risk of unfavourable weather conditions, it is of utmost importance that harvesting and threshing operations should be completed as early as possible. Use of harvesting and threshing machines is now becoming very popular which clearly indicates the benefits of such machines over the traditional methods.

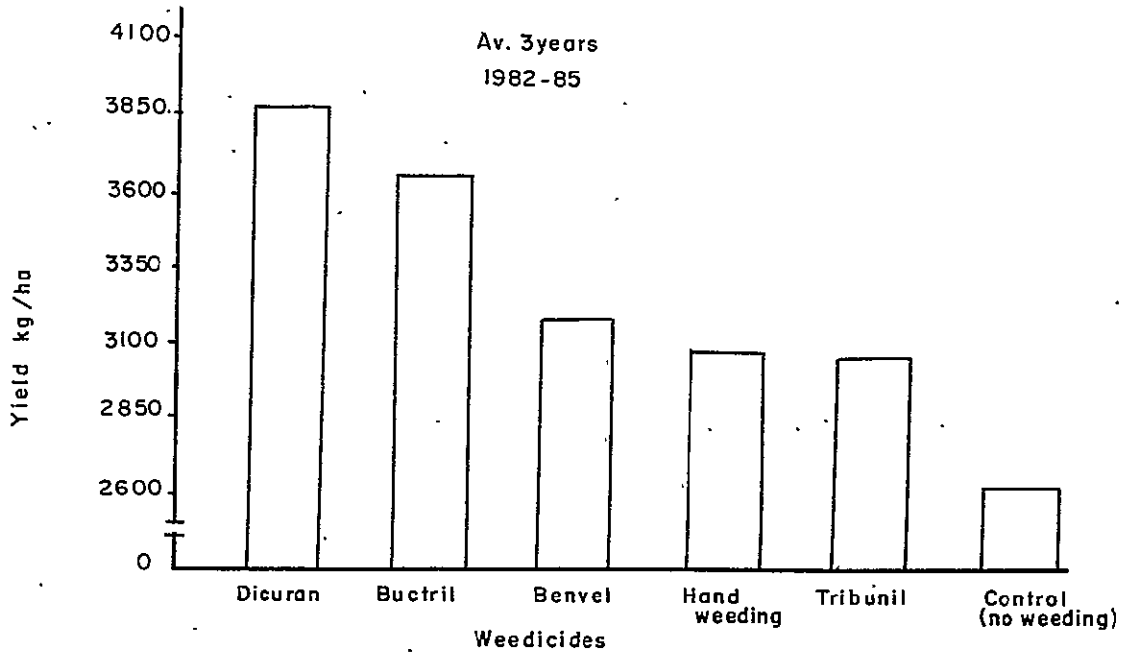

Fig. 4 Yield of wheat as influenced by different weedicides at WRI, Faisalabad

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AGRONOMY OF RICE

ABDUL MAJID CHAUDHRY*

INTRODUCTION

Out of the total annually cropped area of 19.3 million hectares in Pakistan, food-grain crops occupy about 12.3 million hectares. Among the food-grain crops, rice occupies about 2 million hectares (17%) and is next only to wheat (58%) in area. Punjab is the leading rice growing province, claiming 55% of the rice area; followed by Sind which has 40% of the area and the remaining 5% area lies in NWFP and Baluchistan.

Many rice varieties are grown in various parts of Pakistan. Main characteristics of the important ones are described in table 1.

Table 1. Approved varieties and their characteristics

Variety	Characteristics				
	Height (cm)	Stem Strength	Grain type	Growth period (days)	Av. Paddy yield (t/ha)
PUNJAB					
IR 6	105	Strong	Medium	105 – 110	5.0
KS 282	115	Strong	Medium	95 – 100	6.0
Basmati 370	170	Weak	Fine	115 – 120	2.5
Basmati Pak	170	Weak	Fine	115 – 120	2.5
Basmati 198	135	Strong	Fine	125 – 130	4.0
SIND					
IR 6 (Mehran 69)	105	Strong	Medium	105 – 110	6.0
DR 82	104	Strong	Medium	105 – 110	7.0
DR 83	107	Weak	Medium	90 – 95	5.0
Jaijai	176	Weak	Fine	110 – 113	2.1
Lateefy	109	Strong	Fine	90 – 95	5.0
Sugdasi	170	Weak	Fine	110 – 115	2.5
NWFP					
JP 5	160	Weak	Coarse	95 – 100	4.0
BALUCHISTAN					
IR 6	105	Strong	Medium	105 – 100	5.0

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Since 1969, IR6 has been the most common medium-grain variety in Sind as well as in Punjab. In 1982, a new early maturing line-KS 282 was approved for general cultivation in Punjab. This variety, in addition to being early-maturing, has relatively more translucent and attractive grains. In the fine group, Basmati 370 is the most common variety grown in the Punjab. In Sahiwal (southern side) where the temperature remains high for a little longer period, Basmati 198 performs well, but it is grown on a limited area. In Sind, some area is under local fine varieties and the popular ones are Jaijai and Sugdasi. Lately, a short-statured fine-grain type has been released as Lateefy to replace the tall fine-grain type Jaijai. Two medium grain types—one medium maturing DR 82 (IET 4094) and one early maturing DR83 (IR2053) have also been released recently. In NWFP, a Japonica type JP5 is grown. This variety performs well at low temperatures and is therefore, very popular in Swat.

The distribution of area under different varieties is given in table 2.

Table 2. Percent area under different rice varieties in Pakistan (1975-80)

Variety	Punjab	Sind	NWFP	Baluchistan	Pakistan
Basmati	61	–	13	–	34
IRRI	22	76	17	54	44
Others	17	24	70	46	22

Source: Agri. Statistics of Pakistan, 1982.

As evident from the above table, Punjab grows mostly the Basmati rice which sells at a very high premium in the international markets. The Basmati rice fetches a price which is almost 3 times that of IRRI. Of the total rice production in the country, about 1/3 is exported and the remaining 2/3 consumed locally. Pakistan is the third (after Thailand and USA) biggest rice exporting country in the world. During the last 3 decades, Pakistan made an impressive achievement in improving rice yield which at present stands at 2.6 ton/ha.

SEED RATE AND TIME OF SOWING/TRANSPLANTING

The recommended seed rate for medium and fine grain varieties are as follow:

Punjab:	Madium grain varieties (IR6 types)	= 15 to 17 kg/ha
	Fine grain varieties (Basmati types)	= 10 to 12 kg/ha
Sind:	Medium grain varieties (IR6 types)	= 30 to 35 kg/ha
	Fine grain varieties (Jaijai, Lateefy)	= 25 to 30 kg/ha

NWFP and Baluchistan: Same as for Punjab.

Sowing of seed and transplanting of seedlings at the optimum time is very important for obtaining good yields. Moths of rice stem borer emerge from the last year's rice stubbles in the end of March and remain active till the beginning of May. Sowing of nursery before 20th May is, therefore, prohibited to allow starvation of the emerging moth. The earlier transplanted crop also suffers from sterility on account of high temperatures at flowering time. On the other hand, the late transplanted crop would

suffer from heavy attack of the stem borer. The late transplanted IRRI varieties often fail to flower. The optimum time of sowing/transplanting of approved varieties is given in table 3.

Table 3. Optimum sowing/transplanting time of approved varieties

Variety	Time of sowing nursery	Time of transplanting
PUNJAB		
IR 6 & KS 282	May 20 to June 7	June 20 to July 7
Basamti 370 & Basmati Pak	June 1 to June 20	July 1 to July 20
Basmati 198	June 1 to June 15	July 1 to July 15
SIND		
Northern part	May 1 to June 10	June 1 to July 20
Southern part	April 20 to June 10	May 20 to July 15
NWFP		
Plains (Dera Ismail Khan)	May 15 to May 31	June 15 to July 10
Mountainous (Swat)	May 10 to June 10	June 10 to July 10
BALUCHISTAN	May 20 to June 30	June 20 to July 30

NOTE: Under unavoidable circumstances, the nursery of Basmati 370 can be sown upto 30th June, but in such situations, the transplanting will be late and the expected attack of insect-pests and disease will be severe.

METHODS OF RAISING NURSERY

Transplanting is the common method of rice cultivation in Pakistan. There are following three methods of sowing nursery which depend upon local customs, soil types and water availability.

- Wet bed method
- Dry bed method
- 'Rab' method

In the wet method, the plot is puddled and sown with soaked and pre-germinated seed. In the dry bed method, the plot is prepared under dry conditions, sown with dry, unsoaked seed and then irrigated at short intervals. In the 'Rab' method, wheat or rice straw (or any other plant residue) is first spread uniformly over the plot and burnt and then, next day, dry seed is broadcast over it which is followed by irrigation, In the dry and "Rab" methods of sowing 10 to 20% more seed is used. The nursery grown by wet method is ready for transplanting in about 25–30 days whereas it takes about 35–40 days in case of other two methods.

LAND PREPARATION

The method of land preparation depends upon availability of water, soil type and local customs. The following 3 methods are in vogue:

- Wet cultivation
- Semi-wet cultivation
- Dry cultivation.

The wet cultivation is practised on clayey and slowly permeable soils or where water is abundantly available. This method is the most popular in traditional rice growing areas of the Punjab.

The semi-wet cultivation is followed on clayey soils of some traditional rice growing areas of the Punjab whenever shortage of water is faced at the time of land preparation.

The dry cultivation is a practice followed in Sind and in non-traditional rice growing areas of the Punjab, generally on soils which are loamy and relatively permeable.

All methods of land preparation result in almost similar yields, provided weeds are effectively controlled. The wet and semi-wet methods favour economy of water whereas in the dry method substantial water losses occur due to high permeability of soils.

TRANSPLANTING

The optimum seedling age for transplanting in case of all varieties is 25-35 days. Two seedlings/hill are recommended. If however the nursery gets older than 40 days, 4 seedlings/hill should be transplanted to compensate for lower tillering capacity of over-aged nursery. If over 50-days, the nursery is too old to give a satisfactory yield. Fig. 1 shows the effect of age and number of seedlings/hill on the yield of KS282. The recommended distance between the plants and rows is 23 cm.

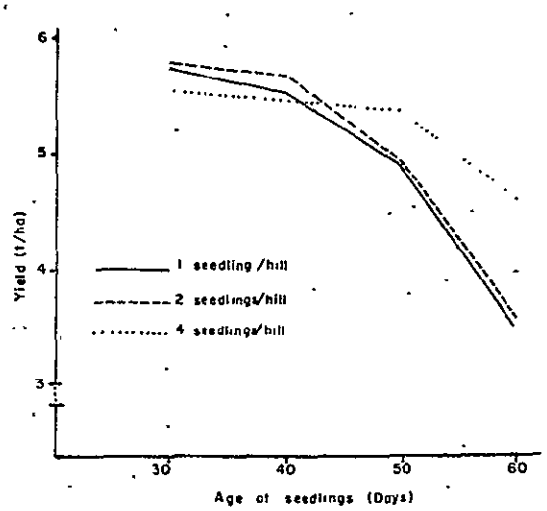

Fig. 1 Effect of age and number of seedlings on the yield of KS 282

FERTILIZER APPLICATION

The fertilizer doses recommended for different rice varieties are given in table 4.

Table 4. Recommended fertilizer doses for different rice varieties

Variety	Fertilizer dose (kg/ha)			Remarks
	N	P_2O_5	K_2O	
Basmati 370	100	67	67	When sown after wheat
"	67	67	67	When sown after fallow/berseem fodder
IR 6, KS 282 and Basmati 198	170	67	67	When sown after wheat
"	133	67	67	When sown after fallow/berseem fodder.

Note: For saline and saline-alkali soils, ammonium sulfate and SSP give better results.

The full doses P_2O_5 and K_2O and half dose of N are to be applied with the last ploughing in a way that it is properly incorporated in the soil. Thorough incorporation of basal N fertilizer is especially important to minimize N losses: through ammonia volatilization. The remaining 1/2 portion of N is top-dressed about 30-35 DAT in cases of Basmati 370, Basmati Pak and Basmati 198. Fig. 2 shows the effect of different doses of fertilizer on the yield of rice.

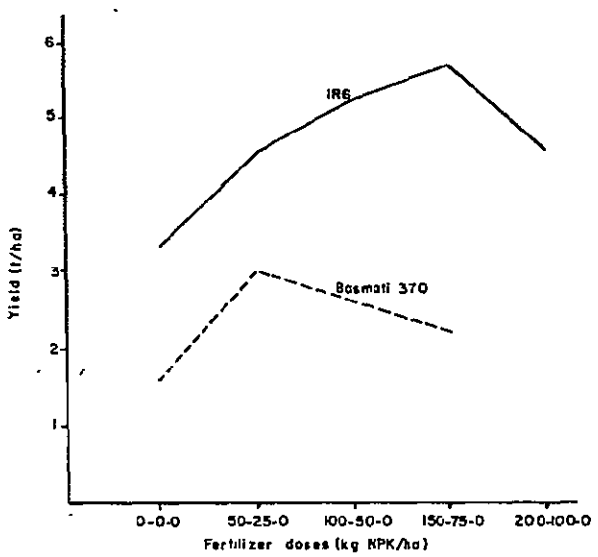

Fig. 2 Effect of different doses of fertilizer on the yield of rice

Deficiency of zinc has been noticed as a wide-spread phenomenon in rice soils, especially in the saline and saline-sodic ones. Therefore, application of zinc sulphate (35% Zn) at 12.5 kg/ha at 7-10 DAT is recommended. Fig. 3 shows the response of zinc application on rice on a nonsaline clayey soil. Zinc sulfate is now a regular part of recommended fertilizer package.

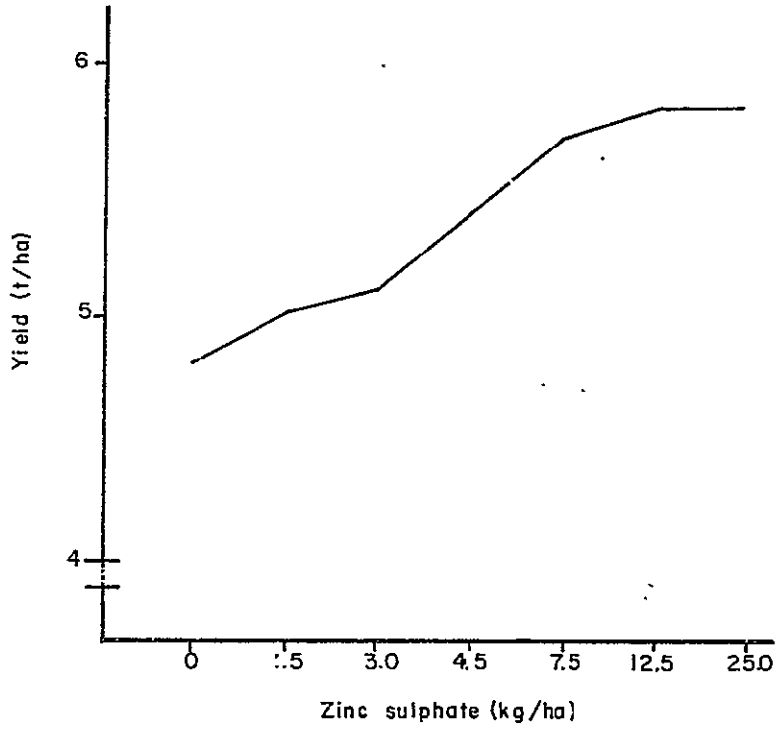

Fig. 3 Effect of different doses of zinc sulphate (35%) on the yield of KS 282

WEED CONTROL

Weeds grow profusely in rice fields as the presence of water and high temperature favour their growth. Weeds reduce yields generally upto about 20% but, in some cases, reductions may be as high as 50%. For good weed control, thorough land preparation, judicious water use and application of herbicides are essential measures. The first 30 days after transplanting are crucial for weed control. The weeds must be eliminated before the top-dressing of nitrogen fertilizer. Since the period (30 days) available for weed control is short and it is not possible to hand-weed all the rice crop within that period, an alternative to hand-weeding is the use of herbicides. The recommended herbicides, their doses and stage of application are presented in table 5.

Table 5. Recommended herbicides, their doses and stage of application

Herbicide	Dose (kg/ha)	Time of application	Method of application
Satum 10 G	17.5	3 – 5 DAT*	Broadcast in 6-8 cm deep standing water
Tok 8 G	30.5	3 – 5 DAT*	–do–
Machete 60 EC	2.0	3 – 5 DAT*	Broadcast in 6-8 cm deep standing water after thorough mixing in about 40 kg sand.

*DAT : days after transplanting

These herbicides are of pre-emergence type in action. An effective weed control is, therefore, achieved when the weeds have not yet emerged or have just emerged. Hence, the application of the herbicide at right time is essential.

WATER MANAGEMENT

Judicious use of water is essential for obtaining good yields. Water should remain standing in the field upto 25–30 DAT to supress the growth of weeds. The water depth at the time of transplanting and one week later should be kept low (3-4 cm) and, thereafter, it should be gradually increased to about 8 cm. Water depth higher than 10 cm affect tillering. About 25–30 days after transplanting, the field should be allowed to dry for 5-7 days and then reflooded. Watering should be stopped after the grain formation has completed, to allow the crop and field sufficiently dried up for harvesting. Fig. 4 shows the effect of different weekly water depths on the yield and water requirements of Basmati 370.

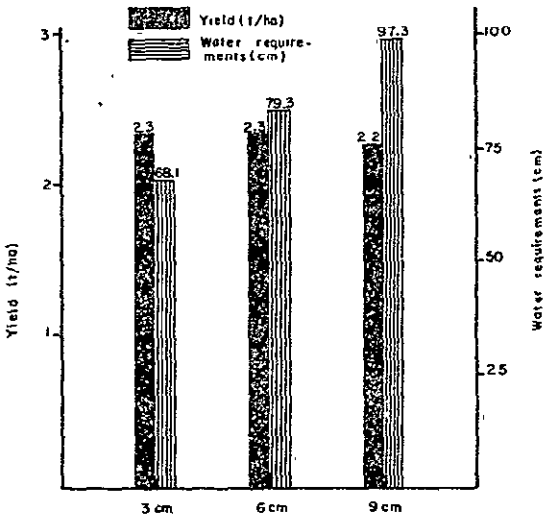

Fig. 4 Effect of different weekly depths of water on yield and water requirements of basmati 370

PEST CONTROL

There are many insects which cause damage to rice crop every year. Amongst them are the rice stem borers, white back hopper, rice leaf folder and rice hispa. The stem borers pose major threat to Basmati varieties. The stubbles of previous rice crop provide shelter to their hibernating larvae during winter season and moths appear from these stubbles in March which start multiplying on sprouts of last year's seed and early sown nurseries. So, it is recommended that rice stubbles must be uprooted latest by the end of February. The rice nurseries should be treated twice with the following insecticides in order to protect them from borer attack:

Insecticide	Dose (kg/ha)	Method and time of application
BHC 10 dust	3.5	Dusting, 8-10 days after sowing
+	+	
DDT 10 dust	8.5	
Basudin 10G	22	Applied in standing water, 15-17 days after sowing.
or Furadan 3G	37	
or Padan 4G	25	

The crop should also be treated twice about 30 and 55 days after transplanting.

The same insecticides are also effective against the hopper. In case of serious hopper attack, however, Sevin dust 10% at 25kg/ha should be used. For control of hispa and leaf roller also, dusting by Sevin 10 is recommended. The hispa appears on the IRRI varieties of rice in early season but is not wide-spread.

HARVESTING

Optimum time of harvesting is very important for rice crop. A deviation of 5 to 10 days from this time seriously affects the paddy yield as well as milling recovery. The optimum time for harvesting the crop is about 35 days after flowering and at a moisture content of about 20%. This range of moisture content is indicated when all the ears of paddy have turned yellow, except for a few lower one which are still green but are filled up with grains. The effect of harvesting time on paddy yield and milling recovery is demonstrated by table 6 below.

Table 6. Effect of harvesting time on paddy yield and milling recovery

Harvesting Time (DAF)*	Moisture content (%)		Paddy yield (t/ha)		Head rice recovery (%)	
	Basmati 370	IR 6	Basmati 370	IR 6	Basmati 370	IR 6
25	29.9	29.0	1.95	4.15	38.0	41.2
30	26.6	26.1	2.17	4.20	46.5	48.9
35	21.6	20.5	2.29	4.58	52.6	55.0
40	17.2	16.6	2.21	4.46	49.1	51.5
45	14.0	14.2	2.06	4.19	40.4	43.8

*DAF denotes days after flowering.

MAIZE AGRONOMY

DR. MUHAMMAD QASIM CHATHA*

INTRODUCTION

Maize is one of the important cereal crops of the world. In respect of its area and production, it is the third important cereal after wheat and rice, while in yield it ranks second among all cereals grown in the world. The world average yield of maize in 1983 was 2 798 kg/ha as against 2 166 and 3 114 kg/ha of wheat and rice, respectively (Table 1).

Table 1. Area, production and yield of major cereals in the world (1983)

Crop	Area (mil. ha)	Production (mil. tons)	Average Yield (kg/ha)
Wheat	230.03	498.18	2 166
Rice	144.47	449.83	3 114
Maize	123.00	344.10	2 798
Barely	79.10	167.18	2 113
Sorghum	46.50	62.48	1 344
Millet	41.50	29.56	712

Source: FAO Production Year Book, 1983.

At present, it is grown in about 81 countries of which USA, Mexico, India, Indonesia and Yugoslavia are the major maize producing countries. In Pakistan, maize is cultivated over an area of about 800 000 hectares which gives an estimated production of 1 014 million tons with an average yield of about 1 268 kg/ha. The available statistics (Table 2) reveal that there has been a substantial increase in area and production of maize in Pakistan. The area increased from 633 000 ha to 798 000 ha and the production from 729 000 tons to 1 014 000 tons from 1970-75 to 1983-84 which represented about 26% and 39% increase in area and production respectively during the last 14 Years. This increase in maize production is attributed mainly to the expansion in area but partly to the yield improvement effected by use of high-yielding varieties and better crop management. There has been only 10 per cent increase in yields during that period. The pace of vertical improvement has indeed been very slow.

*National Agricultural Research Centre, Islamabad.

Table 2. Area, production and yield of maize in Pakistan from 1970-75 to 1983-84

Year	Area (000 ha)	Production (000 tons)	Yield (kg/ha)	% increase over 1970-75 Area	Production	Yield
1970 – 75	633.00	729.00	1 153	–	–	–
1975 – 80	650.28	812.04	1 249	+ 2.73	+ 11.39	+ 8.33
1980 – 81	744.70	946.60	1 271	+ 17.65	+ 29.85	+ 10.23
1981 – 82	739.40	930.40	1 259	+ 16.76	+ 27.63	+ 9.19
1982 – 83	783.30	1 005.40	1 272	+ 23.82	+ 37.91	+ 10.32
1983 – 84	798.00	1 014.00	1 270	+ 26.07	+ 39.09	+ 10.14

Source: Agricultural Statistics of Pakistan – 1983.

Table 3. Area, production and yield of main maize growing countries (1983)

Country	Area (000 ha)	Production (000 tons)	Yield (kg/ha)
U.S.A.	29 604	213 302	7 205
Mexico	6 272	12 215	1 948
India	5 800	6 500	1 121
Indonesia	2 700	3 800	1 407
Yugoslavia	2 220	11 137	5 017
Canada	1 112	6 383	5 743
Itly	1 009	6 820	6 758
Pakistan	790	1 005	1 273
Turkey	590	1 400	2 373

Table 4. Yield potential of maize crop

		Yield (tons/ha)
(a)	Maximum grain yield obtained in USA	20.00
(b)	Grain yields obtained in Pakistan	
i)	on an experimental plot in Swat	10.78
ii)	on an experimental plot in A.J.K	10.31
iii)	on an experimental plot at Islamabad	7.00
iv)	on an experimental plot on farmers field in I.C.T	5.00
v)	at various progressive farms	5.00 to 6.00

The data given in Tables 3 & 4 is well illustrative of the comparative yields obtainable in various advanced countries and at progressive farms in Pakistan. This clearly indicates that there is a

high maize production potential in Pakistan and that we have yet to intensify research and development endeavours to enhance yields at farmer's field. The main reasons for the present low production level are identified as under:

- Partial adoption of improved varieties and production technology at farm level
- Inadequate supply of quality seed
- Small land holdings
- Cultivation of maize as grain-cum-fodder crop
- Poor agricultural extension service
- Lack of credit facility, particularly to the small farmers
- Lack of proper procurement and marketing system

ECOLOGICAL REQUIREMENTS

Maize species has a wide range of tolerance to environmental conditions. It is well adapted to warm and moist conditions. Neither semi-arid climates nor ever-wet conditions are favourable for its growth. It is mainly cultivated between 50°N and 40°S, and at altitudes from near sea level to about 3 300 m. At higher elevations, it is generally grown for green fodder. The optimum temperature for germination varies from 18 to 21°C; below 13°C, its germination is greatly reduced so that it fails to germinate below 10°C. At tasseling stage, temperatures of 21–30°C are most suitable. Annual precipitation of less than 200 mm is too low while that between 450 and 600 mm is optimum for its growth. In the tropical regions, it grows best with 600-900 mm of rain falling during the growing season.

Maize crop can be grown on a variety of soils ranging from sandy to clayey. However, the most suitable soils for maize are deep, nonsaline, well drained, medium textured ones which are high in organic matter content and are rich in nutrients available to plants. It does not grow well on alkaline and waterlogged conditions. The optimum soil pH ranges between 6.5 and 7.5 but the crop can be grown quite successfully upto a pH of 8.0

PREPARATORY TILLAGE AND SEEDBED PREPARATION

Normal practice of soil preparation includes 3 to 4 ploughings with cultivator and 2 to 3 plankings. The best soil tilth could, however, be obtained by cultivation with a mouldboard plough just after the harvest of previous crop and then one or two operations with a normal cultivator followed by planking.

Maize seed requires a bed that is warm, moist, well aerated and fine enough to give good contact between seed and soil particles. To obtain this kind of ideal seedbed, different operations are required for different types of soil. For a loam soil, two ploughings with a normal cultivator and one planking are sufficient for a good seedbed. Only one ploughing and one planking are sufficient for relatively sandy soils while three to four ploughings and two to three plankings are necessary for clayey soils.

Experiments conducted at MMRI, Yousafwala have shown that comparable good yields can be obtained without any seedbed preparation. The advantages in no/minimum tillage over conventional

tillage include saving in costs of land preparation and minimal soil compaction effected by tractor machinery. However, it works well only for loamy or sandy soils while some practical problems of poor seed germination may arise in case of clayey soils. Poor weed control is another problem associated with the minimum tillage which can be well solved with the use of herbicides.

SEED QUALITY AND RATE

Among all the environmental and genetic factors affecting crop stand, quality of seed is the most important one. The crop harvested before full maturity produces seed with a low viability. Similarly, improperly stored seed is likely to have low germination and weak seedlings. The seed should be thoroughly dried (with less than 12% moisture) after crop harvest and stored under cool conditions. Fungicide treatment is effective to protect seed against diseases. Insecticides can also be used to protect against damage by insects.

A plant population of 55 to 66 thousand per ha is recommended for optimum grain production. This population can be achieved with 30 to 35 kg/ha of good quality seed. The maize crop survey data has generally shown that high seed rates of 75 to 100 kg/ha are used by the farmers which consequently give initial population of 150 to 300 thousand plants per ha. Later on, plants are selectively removed by hand for green fodder, beginning at about 50 days after germination to obtain final plant densities of around 85 to 95 thousand/ha. This thinning process removes the weaker, damaged and barren plants. The higher seed rates, in fact, are maintained to suppress weeds, maintain enough plants after "seeling" (which is carried out to control weeds), cover risks of low germination rate and plant damages caused by borer, and fulfil fodder requirements at various stages of crop growth.

The higher seed rate and consequently higher plant densities, however, result in considerable reduction of grain yields. An utmost care should, therefore, be taken to keep the plant population near optimum to have high yields and better quality grain.

PLANTING

Maize planting begins in about the middle of May at higher elevations (in NWFP and AJK) and continues to middle of August in the plains. The experiments conducted in Bannu Distt. of NWFP have shown that beginning of July is the optimum period of planting maize. Likewise, early planting (mid-July) in central Punjab results in higher yield but farmers usually delay planting due to higher temperatures prevailing in this month.

The general practice of planting maize in Pakistan is by broadcast. However, line-sowing by 'Pora' (dropping seed through a long funnel tied behind the plough) and 'kera' (dropping seed directly by hand in furrows) methods and with tractor drill is becoming popular in important maize growing districts of Punjab and NWFP. In certain parts of NWFP and in Attock District of Punjab, a method known as "Choppa" is also used where 4 to 5 seeds are put together about 45 to 60 cm apart after digging with a small hand implement "Khurpa".

To obtain optimum grain yield, line-sowing at 75 cm distances between lines and 20 to 25 cm distances from plant to plant are recommended. The line-sowing reduces the amount of radiation available to the crop at early stages of growth and, therefore, reduces total dry matter production of

the crop. It would, however, improve grain yield, particularly where early thinning is practised. The other merits of line-sowing are:

- lower seed rates which become increasingly important with the use of improved quality seed
- seed placing at uniform soil depth and uniform emergence and maturity of the crop
- easy intercultural operations for weed eradication
- increased dry matter production and minimum plant to plant competition
- more effective use of fertilizers (top dressed) and insecticides

FERTILIZER APPLICATION

A maize crop with 5 to 6 tons/ha of grain yield removes approximately 100-150 kg of N, 40–60 kg of P_2O_5 and 100-150 kg of K_2O per ha from the soil. So, to obtain this quantity of grain, this nutrition must be afforded by the soil either from its inherent fertility or through application of fertilizers. The experimental results have shown that most of soils grown to maize in Pakistan have sufficient K_2O to support the optimum growth of the crop and, therefore, its application is not critical. The recommended dose for other major nutrients, i.e. N and P_2O_5 is 120 to 140 kg and 60 kg per ha respectively for improved varieties, while it is 80 to 100 kg and 40 to 50 kg per ha respectively for local varieties. The maximum uptake of nutrients by the crop is during the period from 10 days before to 20-30 days after tasseling. The demand for nitrogen is high and this is often the limiting nutrient in maize production. Nitrogen absorption is relatively slow during the first month after planting but it increases to a maximum of 4.5 kg/ha per day during tasseling. Thus, to ensure adequate availability of nitrogen throughout the plant life, one-third of the total N fertilizer dose should be applied at sowing time and the remaining two-third as a side-dressing when the plants are knee-high, a stage of greatest demand. All the quantity of P_2O_5 and K_2O fertilizer is applied at sowing time. The effective use of P fertilizer is obtained by band application or placement near the seed.

The quantity of fertilizer applied to maize in Pakistan is still very low compared to the recommended dose. The improved varieties can only reach their yield potential when they are supplied with adequate nutrients and have appropriate plant populations. The normal deficiency symptoms of important nutrient elements are as follows

Nitrogen	Reduced vigour and a pale green or yellowish colour; yellowing and drying along the midribs in widening bands towards the tip; symptoms appear first on the lower leaves
Phosphrous	Stunted growth, delayed ripening and purple coloration, particularly near the tips of leaves
Potassium	Small, whitish yellow spots on leaves, followed by scorching or browning of leaf edges
Magnesium	Whitish or yellowish stripping between the veins of leaves

Zinc	Chlorotic fading of leaves with broad whitish areas, especially toward the centre and base of leaves

WATER REQUIREMENT/IRRIGATION

Maize crop is very sensitive to its water requirements. Both the excess and deficiency of moisture have adverse effects on its yield. One cannot visually observe the effect of poor drainage/excess watering on growth of the crop but the crop yields are certainly reduced by these conditions. The number and intervals of irrigation required by the crop vary with the climatic and soil conditions and the stage of growth. Four to six irrigations are sufficient under semiarid climatic conditions on deep loamy soils with a medium waterholding capacity.

Pollination and dough stage is the critical crop growth period when even a slight water stress results in a great loss to the crop yield (Table 5). The experimental results show that water stress at the critical stage may decrease the yield by over 25%.

Table 5. Effect of number and intervals of irrigation on maize yield

Irrigations	Yield (kg/ha)	Precent increase in Treatment No. 1 & 2 over Treatment No. 3
6 irrigations; critical period covered	4 586	41
4 irrigations; critical period covered	4 159	28
4 irrigations; critical period not covered	3 250	—

Source: Annual Report, Maize & Millets Research Institute, Yousafwala, 1978.

WEED CONTROL

Crop yield losses due to weeds are proportional to the amount of water and nutrients used by them at the expense of the crop. The losses are relatively high when weed infestation occurs at early growth stage of the crop. The experiments conducted in various countries have shown that 15% to 20% losses in yield generally occur due to weeds. However, the author has estimated yield losses upto about 90%.

The results of weeding treatments indicate that ear length is the only character which is significantly affected. However, if weeding is delayed, the grain yield and number of ears also decrease. The growth stage of 3 weeks after emergence appears to be the threshold stage for weed control. A delay in weeding from this period would cause reduction in the grain yeild.

Experiments on 'chemical versus mechanical weed control of maize' carried out at farmer's fields in Islamabad area have shown very encouraging results. Primextra herbicide application resulted

in much higher return than even mechanical weed control (Table 6). This was probably due to the fact that frequent rainfall does not usually allow timely mechanical removal of weeds while chemical control is not much affected by such conditions. Primextra is a very effective herbicide, both for broad-leaf weeds and grasses. It is well tolerated by maize at recommended doses.

Table 6. Weed control trials on maize at I.C.T. (1983-84)

Treatment	Mean grain yield (tons/ha; Av. of 5 LOC)	Variable cost (Rs/ha)	Net Benefit (Rs/ha)	MRR %	No. of locations better than F.P.*
No weeding	2.49 a	–	2 835	–	–
a) Hand weeding (F.P)	4.03 b	600	4 021	–	–
b) Seeling	–	200**	4 496	830	–
Primextra at 1.5 lt. FM/ha	4.44 a	217	4 879	225	4/5
Primextra at 3.0 lt. FM/ha	5.18 a	460	5 601	297	5/5

L.S.D. 0.73

* Seeling (F.P) depends on rainfall distribution

**Assumes that tractor cultivation gives the same yield as manual weeding

CONTROL OF INSECT PESTS

Maize crop is often attacked by stem borer *(Chilo partellus)*. According to a rough estimate about 10-15% of the crop is damaged by this pest. To overcome theselosses, following practices are recommended

- Remove and destroy all affected plants in order to kill the larvae
- Remove all grasses, particularly sorghum which serves as a host for the borer
- Plough up and destroy the stubbles after harvest of the crop so as to eliminate hibernating places for the borer
- Adopt chemical control, if feasible, by using Furadan, Sevin and Diazinon at the rate of 12 – 15 kg/ha. These granules give quicker and most beneficial results. In case of severe attack of stem borer, two applications (12-15 kg/ha each), first at sowing and second one month after emergence, are recommended.

HARVESTING AND STORAGE

Maize crop is usually harvested when the moisture level of grain is about 30 to 40%. Although the physiological growth ceases when the moisture content of the grain is around 30%, it would be advisable if the crop is harvested about 6 to 7 days after the physiological maturity which is indicated by a

black layer formed at the bottom of grains. To determine the ideal maturity stage, one could crush the grain under teeth. If the grain cracks, the crop is mature and ready to harvest. After harvesting, the cobs should be removed and dired on a clean floor for a week or so and then grain should be separated from cob. The separated grain should be further dried to the mositure level of 10 to 12% for safe storage. A higher moisture level would increase the chances of insect attack and fungal diseases during storage.

MAIZE PRODUCTS AND CONSUMPTION

Maize is utilized in a multitude of ways. It is usually ground and meal is made by boiling, baking or frying. Sometime the whole grain is boiled or roasted and it may be fermented. The commonest maize dish in Africa is prepared by cooking the maize meal with water to provide a thick mush or dough. It is also cooked to a thinner consistency to gruel, porridge or soup. In Northern and Latin America, tortilla is made from maize flour. In Indo-Pak sub-continent, major utilization is in the form of bread. Immature cobs after boiling or roasting are also commonly used.

Maize grain is also an outstanding feed for livestock as it contains high energy, is low in fiber content and is easily digestible. For feed purpose, it is used mainly in advanced countries. It is also an important fodder crop, used in the form of green fodder, dried stalk and silage.

The important industrial products and their uses are explained in Table 7.

Table 7. Maize products and their uses

Products	Uses
Liquid glucose	Confectionery baking, jams, jellies, infant foods, food freezing, ice cream
Dextrose monohydrate (Glucose powder)	Bakery products, dry mixes and frozen foods, squashes and fruit juices, confectionery, ice cream, tomato ketchup, pickles, processed meat.
Maize Dextrin (white)	Used in sizing formulations to give extra binding and strengthening effects, superior finishing of white fabrics as well as dyed goods to obtain fuller mellow handle
Maize Dextrin (yellow)	A better binder than gum used in foundry for making steel and high duty alloys from Pig-iron
Maize Starch - 3401	Used in textile and paper: in textile indusry for yarn sizing and for finishing; for paper as the bonding agent in the manufacture of corrugated board
Maize Starch PF-3402	Used in compounding and processing of drug and pharmaceutical preparations
Corn oil	Used for cooking foods etc
Maize gluten meal/feed	Used in livestock production
Corn flakes	Used as human food

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AGRONOMY OF SUGARCANE

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INTRODUCTION

Sugarcane is grown in more than 60 countries and is one of the most important agricultural crops. The crop is grown under widely variable ecological conditions, i.e. in humid temperate climates without irrigation and in arid tropical climates with irrigation, on very sandy to clayey soils to volcanic ash and muck soils with pH ranging from 4 to 8.5.

Sugarcane yields vary tremendously due to many factors. Variable soil characteristics, cultural practices, use of fertilizers, irrigation methods, control of weeds, pests and diseases and many other factors explain low returns from some areas and high ones from others. There are also wide variations in the manner in which the production factors are applied to growing of the cane crop. There is a considerable contrast between the methods used in advanced sugar centres and those adopted in Pakistan. Description of the techniques and methods used in other countries are beyond the scope of this paper. The techniques used by the Pakistani growers are described and improvements suggested wherever necessary and which are feasible under the existing socio-economic conditions. The improvements suggested have come mainly from the author's own experience in growing sugarcane in Pakistan for over a decade.

The fundamental key to attaining higher efficiency and output is paying attention to the following aspects of cane agriculture:

- Preparation of land
- Planting and initial care of the crop
- Nutrition
- Irrigation water management
- Eradication of weeds
- Pests and disease control
- Harvesting and mill supply

These aspects are discussed one by one in the following text.

PREPARATION OF LAND

It is on the preparation of land that much of the success of sugarcane crop depends. In recognition of this fact, the cane grower must prepare his land in the best way he can. Disc ploughing and

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harrowing are the vital requirements toward this end. The disc plough will leave the old stools on the soil surface, partly burying them. Subsequent cultivation with disc harrow will cut the stools into small pieces which, for this particular purpose, is a valuable farm implement. The cultivation with disc harrow is generally not to the full depth, the prime objective of the operation is to destroy the stools and break the clods turned over by the plough.

The growth of weeds is so prolific during the preparatory period that frequent working of land is essential. Each field should be worked three to four times from April through June. Working the soil during this period is a prime requisite if the weeds have to be effectively controlled. The scorching heat and hot winds during these months would dry the exposed weeds. The process should be completed before the onset of the monsoon. The ridges left by the plough must be filled in during the pre-monsoon operations; otherwise the ponded water in the ridges will delay the post-monsoon operations. The abundant supply of moisture available in the soil during monsoon period supports luxurious weed growth. After the monsoon period, when the soils are again in working condition, preparation of seedbed is begun for the fall planting. The clayey soils would require a ploughing which may be skipped for loamy soils; in the latter case the surface crust is broken by harrowing only. Levelling and surface smoothing of the field is done at this last stage for uniform application of irrigation water. The levelled field is worked with a 2-way harrowing operation which prepares the land for making furrows.

The above procedure is quite intensive in contrast to that followed by a large number of cane growers. Most of tillage operations are performed by a common farmer with bullock plough which merely scratches at the surface of the soil. Mechanization of land preparation can certainly help him prepare a better seedbed.

PLANTING AND INITIAL CARE OF THE CROP

For planting of the crop, the first step is to open furrows. Majority of cane growers perform this operation with bullock plough and draw the furrows 45 to 60 cm apart. A wider inter-row spacing of 90 to 100 cm is recommended and furrows should be drawn deep with a tractor–mounted ridger. This recommendation is valid because of the following reasons.-

- Narrow spacing necessitates interculture either with hand-hoeing or with bullock plough. The scarcity and high cost of labour have made hand-weeding impractical while ploughing with bullocks falls short of the requirement and the weeds are most often allowed to get out of hands for the young cane.
- Wider row spacing of 90 to 100 cm suits the standard wheel base of most of the tractors. Inter-row cultivation with solid/spring tined cultivators or rotary hoes permits timely and effective control of weeds in the young cane.

Before planting, the seed should be carefully selected. The seed must not be taken from fields excessively flooded or badly lodged. The seed selection must be made with all possible considerations of quality as the attainment of good germination/stand is not possible with poor quality seed. Seed pieces (sets) are prepared by cleaning and cutting with hands in such a way that each piece has 3 to 4

buds. The convention of planting 2-budded sets is to be discouraged. The number of buds on the seed pieces has a great effect on germination of the crop as shown in table 1.

Table 1. Effect of number of buds on seed piece on the germination of sugarcane (Chaudhary, 1981)

No. of Buds	Germination% after 5 weeks
One	45
Two	56
Three	61
Four	63
Five	57
Six	49
Seven	41
Whole stalk	27

The extremely poor rate of germination with whole stalk is due to apical dominance, a process which supresses the growth of buds on the stem. Unless the top is removed, buds on the stem would remain dormant; only a few ones on the top will germinate which would result in poor crop stand. The suppressive effect of top is due to the presence of a class of harmones known as auxins in the apical part on the stalk. Topping the cane and removing the inhibiting effect of auxins is an essential requirement in the preparation of seeding material.

The seed pieces should be placed in the furrow end to end keeping buds on the sides and covered with 3 to 5 cm of soil material. Hand-covering of seed is cumbersome and results in low planting effeciencies. Moreover, the coverage is not uniform. Mechanization of this step becomes necessary in large-scale planting operations. An implement consisting of adjustable solid tines with specially designed toes can be used to cover the seed. This implement, mounted on tractor, can cover 6 to 7 ha in an 8-hour day. Besides a high efficiency in covering seed and planting work, the thickness of soil cover can also be adjusted as desired.

Irrigation must follow immediately after completion of the planting. A delay of 24 to 30 hours in irrigation results in a 10—12 per cent drop in germination over that obtained with immediately irrigated cane.

Mechanization of planting with the Australian horizontal-type planters was attempted at several places in the country, but did not gain favour. The major problem, most often quoted, was non-uniform distribution of seed due to slippage of gears. Also, the mechanical planting, though more efficient and labour-saving, gives poor strikes. This is due to the eyes being damaged by the feeding rollers and cutting knives. The requirement of high seed rate (in some cases as high as 10-12 tons/ha) also be come deterrant to adopting mechanical planting.

Hot water treatment (HWT) of seed at 52°C for 20 minutes is a regular feature of advanced sugar centres. It has been tried in Pakistan by Sind Sugar Corporation. Poor strikes following HWT did not let the process become popular. Poor germinations may have been due to poor temperature regulation and resultant heat injury to the tender buds.

A method of improving the quality of seed cane is through the application of NPK at 20-10-20 kg/ha to the land from where the seed is to be taken, about six weeks prior to cutting. This stimulates budding and improves the seed quality. This is an easy method of improving the potential of seed cane to get good germination but is not followed by our growers. Other methods are either expensive or cumbersome.

NUTRITION

The kinds and amounts of fertilizer needed vary with the fertility of the soil and the tonnage of sugar desired. The nutrient deficiencies are experienced mainly with respect to the three major nutrients, i.e. nitrogen, phosphorous and potassium; the micronutrient disorders are rare in most of the sugarcane growing areas. The importance, deficiency symptoms and application methods of the major nutrients are discussed separately in the following sections.

Nitrogen

Nitrogen fertilization is especially a very senstive problem. Too little of N results in lower cane yields while too much of it would impair the quality of juice. Nitrogen is actively absorbed by the young plants and must, therefore, be added during the first 3 to 6 months of the crop growth. Nitrogen application increases the total green and dry weight of cane as well as yield in terms of sugar. Delayed applications of nitrogen have little effect on the performance of the crop.

As nitrogen becomes deficient, the leaves exhibit a yellow color and growth retardation. The stalks are small in diameter and a premature drying and dying of the old leaves takes place. The roots attain a greater length but remain smaller in diameter. The cane hastens to enter the maturation stage. Of all the major elements, nitrogen has the greatest effect on cane ripening and juice quality.

Sugarcane crop removes about 450 to 650 g of N per ton of millable cane. However, the efficiency of nitrogen fertilizers is always low since a substential part of it becomes fixed in the microbiological complex in the soil or is lost by leaching and ammonia volatilization. These losses mean that N has to be applied in considerably higher amounts than actually removed by the cane. The planted crop appears to be more efficient users of nitrogen fertilizer than the ratoon crops.

There is a tendency of absorbing excess nitrogen for future needs in the young cane plants which stresses the desirability of luxury feeding in the first few weeks of its life. This fact plus the cheeper and easier applications at planting or ratooning time form basis for the recommendation that most of the nitrogen should be applied at the start of the crop for short-duration cropping and that one half to two-thirds of it for the long-duration crop. Since the time of nitrogen application is a deciding factor for the stage of maturity at harvest, caution must be taken in timing of its late applications.

Phosphorus

Phorphorous has a striking effect on root and shoot development of the crop. It helps in building up of proteins. The deficiency of P is indicated by reduction in length, diameter and strength of stalks. The P-deficient stools consist of only a few primary stalks with small internodes indicating a

very slow rate of growth and often no secondaries or suckers. The root systems of P-deficient cane are very poorly developed. The color of leaves becomes greenish blue in contrast to the dark green leaves of normal plants. The older leaves show drying and dying at the tips and margins. Tillering is markedly reduced and shoot to root ratio is considerably decreased.

Soils contains widely varying quantities of total P and show even a wider variation with respect to available P. The lack of response to application of the nutrient is related to the ability of soils fix large quantities of applied P in unavailable form. The total amount of phosphate fertilizer required should be applied prior to planting or ratooning. This eliminates the possibility of reduced early growth due to shortages of this nutrient. Various experiments conducted on sugarcane crop show that there were no effects of P application on maturity of the crop.

Placement studies conducted with radioactive phosphorous during the early 1950's showed that optimum placement was beneath the seed piece, where the maximum number of roots have access to the fertilizer. Under irrigated conditions when the soils are alternately wet and dry, the roots do not grow to the surface and hence are unable to use surface applied phosphorus as effectively as when it is placed in subsurface position. The phosphate broadcast on the soil surface or applied in irrgiation water is mostly fixed by the soil. Olsen and Watanabe (1963) reported that the rate of uptake of phosphorous will be approximately 1/3 as much from a sandy soil as from a clayey soil at equal concentrations of P in the soil solution. It stresses the need of placement of phosphate fertilizer within the root zone, particularly for sandy and loamy soils, under irrigated conditions.

Potassium

Potassium is required by sugarcane in amounts greater than any other nutrient. The functions of potassium are many. It is known to be required for cell structure, carbon assimilation, photosynthesis, protein synthesis, starch formation, translocation of proteins and sugars, the entry of water into the plant, root development and many other life processes. To perform all these functions and, finally, to produce 1 ton of millable cane, 1 to 1.5 kg of K_2O from the soils is removed.

Plants suffering from K deficiency show depressed growth, yellowing and spotting of older leaves and development of slender stalks. The older leaves develop an orange yellow color with numerous chlorotic spots which later become brown with necrotic centres. As the spots coalesce, general browing of leaves results. A reddish discoloration which is confined to the epidermal cells develops on the upper surface of the midribs. Later, the leaves begin to die back from margins and tips. This condition of the leaves is sometimes referred to as 'firing'. The young leaves of K-deficient plants become dark green in comparision with the older yellowish leaves. Both young and old leaves appear to have developed from a common point—a characteristics of a cane plant which is no more growing. The pattern of yellowing and drying associated with the K deficiency is different from that occurring in normal aging leaves. With an old age, abscission of the leaf margin from the stalk results in a breakage of the vascular bundles, causing margins to wither and die. In case of K deficiency, yellowing starts at the base of the blade and yellowing marginal bands taper off towards the tip.

Locsin et al (1956) in Phillippines found that increases in sugar yields from potash fertilization are small or non-significant where the level of exchangeable K in the soil is more than 120 ppm. As

the level of exchangeable K in the soils falls below 100 ppm, yield increases from potash fertilization are usually obtained. Their observations were supported by a similar trend on a sandy loam soil at Nukerji, Tando Muhammad Khan, Pakistan. According to Chaudhary (1985), no response to applied potassium was obtained on soils with levels of available K from 120 to 192 ppm.

There is a controversy about the use of potassium in the sugar sector. The processor does not want high–K cane as it inhibits crystalization of sugar in the manufacturing process and results in greater losses of sucrose going to molasses. Agricultural sector seriously feels concerned about the high rate of K depletion from the soil. Even if the soil analyses show high levels of exchangeable K and no crop response is obtained from the applied K, at least equivalent to that which is removed by the cane crop must be added.

IRRIGATION WATER MANAGEMENT

Water is the principal limiting factor of growth in Pakistan. Therefore, every precaution should be taken to preserve this life blood of cane industry. Due to dependence on canal supplies the water demands during the crop cycle are not properly met, so that the cane is subjected to severe moisture stress. Irrigation intervals of over 15 days are also allowed which are specially hazardous for the cane growing on sandy soils. Loamy soils show a lower degree of stress while heavier soils can carry the crop through longer irrigation intervals, although the irrigation stress would bring a definite reduction in yield. The cane grower must, therefore, do whatever in his power to bring improvement in water management by modifying field layouts, field levelling, reducing watercourse lengths and lining of water courses where practical.

The frequency of irrigation depends on the stage of development of cane. Light frequent irrigations are preferred when seed is germinating and the young seedlings are getting established. As the root system extends deeper in the soils, the irrigation intervals and depths should be extended. During the early growth period and at the boom stage of growth, it is especially avisable to apply the next round of irrigation as soon as 50% of the available water in the soils has been depleted. As the crop approaches maturity, extended irrigation intervals are scheduled to reduce the rate of vegetative growth, dehydrate the cane and allow conversion of reducing sugars to recoverable sucrose.

Varieties of sugarcane differ markedly in their tolerance to water stress. PR1000 variety grown in Lower Sind has a remarkable ability to reduce transpiration losses when atmospheric demands of water are high during mid-day and early afternoon. The plants roll up their leaves to expose minimum leaf surface area from where transpiration can take place.

Cowan and Innes (1956) related evapotranspiration in sugarcane, at the stage of full canopy, to pan evaporation by a coefficient of 0.58. Campbell and coworkers (1959) showed that average water-use rate for sugarcane was 5.6 mm per day. During the boom stage of growth in the summer months, the maximum water used was about 7.6 mm per day, while in the cloudy winter months water usage declined to approximately 2.5 mm per day. It must be borne in mind that the growth of sugarcane crop is stimulated by moderate quantities of soil moisture, and retarded by either excessive or deficient amounts.

ERADICATION OF WEEDS

The important weeds found in sugarcane crop are:

Puspalus paniculum	(Swank grass)
Cynodon dactylon	(Khabbal grass)
Cyperus rotundus	(Dela)
Digitaria timorensis	(Madhana)
Convolvulus arvensis	(Lehli)
Tribulus terrestris	(Bhakra)
Amorantus blitum	(Chulai)

The control of weeds in Pakistan is still largely affected by primitive methods employing hand-hoeing or cultivation with bullock plough. These methods are out-moded and must be replaced by mechanical cultivation and chemical sprays of weed killers technically known as herbicides. These chemicals are a new, effective and easily applied remedy. However, the adoption of weed killers as a standard practice at farmers fields requires extensive demonstrations because improper application would damage the crop which will deter the cane grower from accepting this package of technology.

Two herbicides, viz. Karmex (Diuron) and Gesapax Combi, are registered against both broad-leaf weeds and grasses. Karmex is used in pre-emergence applications whereas Gesapax Combi may be used in both pre-emergence and post-emergence applications by spraying on the cane row. Post-emergence application of Gesapax Combi when the weeds are at 2-4 leaf stage gives most effective control. The dose of Karmex is 5 kg/ha and that for Gesapax Combi is 4 kg/ha. In general, both the herbicides give equal weed control; the cost advantage with Karmex, however, makes it more attractive.

A point that calls for special attention in the use of herbicides is that application of herbicides needs to be made at high surface moisture levels. Application made at low moisture levels will not control weeds. The eradication of *Cyperus rotundus* is not affected by these chemicals. In such situations inter-row cultivation of young cane is necessary.

PESTS AND DISEASE CONTROL

The common pests and diseases of sugarcane include wild boar, rats, root borer, stem borer, top borer, Gurdaspur borer, pyrilla, termite, whip smut and red rot. The wild boar and rats offer problems for the sugarcane crop. No suitable measures are in practice for their control. The insect pests are relatively easy to control by chemicals as well as biological measures. The root borers, stem borers and top borers attack the crop when it is young. At this stage, EC spray or granular applications can be easily made. The Guradaspur borer and pyrilla emerge at a stage when the crop is tall and dense so that EC sprays and granular applications become out of question. Overhead boom sprayers with long swaths are not available in the country and aerial application cannot be effectively applied because the crop is scattered in small patches over large areas. The control of Gurdaspur borer is still an unsolved problem. The control of pyrilla has been effectively done by an actoparasite *Melanoleuca epipyrop*. Release/maintenance of populations of the parasite in the field, however, pose serious difficulties.

Cane fields affected by Gurdaspur borer appear as if they have dried. Very high percentage of affected stalks is found in severely attacked areas. A survey conducted in 1977 in Punjab revealed an intensity of damage shown in table 2.

Table 2. Extent of damage by Gurdaspur borer in Pattoki area of Punjab (Chaudhary, 1977)

No. of stalks (in 1/150th ha)	Affected stalks	Percent affected
495	209	42
516	206	40
447	178	40

Substantial losses in sugar recovery may occur in cane which has suffered serious borer attack. Secondary infections through bored holes and resultant borer-rot complex cause even more serious losses.

HARVESTING AND MILL SUPPLY

Harvesting of cane includes its cutting, cleaning, loading and transporting to the sugar factory. The factory is vitally interested in clean, fresh cane with a steady and regulated flow. This is more easily possible when the field and factory are under unified control. But there are inherent difficulties in bringing it about because there are a large number of small growers and the parties concerned do not act in as much coordination as is required. The processor is more to be blamed for not putting in the effort required for developing a close co-ordination with his counterpart, the grower.

The ideal would be to confine cane harvesting to the periods of peak cane quality; but this is not possible because:

- The factory is obligated to crush all the cane grown in its zone. In the absence of pre-planting contracts on acreage or quantity allocations, much longer season is required to finish the cane produced by the cane growers of the zone.
- Economics of sugar production demands long harvesting seasons. Crushing all cane in the peak quality period implies a short harvesting season and requires higher mill capacities which would cause long off seasons and unproductive overheads for the mills.

The harvesting is done manually which is less easy to regulate cane supply to the mill. Use of cane cutters, on the other hand, gives a tendency to cut the cane in excess of the quantities accepted from the growers. The cane cut in excess has to remain in the field for a longer time before it is lifted for factory processing. The situation is further aggravated by the mills staff who generally do over-indenting to win favours. The backlogs and long cut to crush period affects the quality of the cane. This needs stringent controls from both sides to avoid stale cane reaching the factory.

The necessity of replacing manual cutting of cane by mechanical harvesting is realized for various reasons, including steeply rising costs and shortage of labour and efficiently meet the cane requirements of large factories. Through a continued process of improvement in harvesting machines, cane

harvesters have been developed which are capable of cutting over 60 tons/hour. Both whole-stick (Soldier-type) and chopper harvesters are being used; the former type is used only in Louisiana, USA, while the latter are the most common machines. These harvesters cut, clean and load cane in one operation.

Mechanical harvesting has also been introduced in Pakistan since 1982. The first experiment was conducted at Fauji Foundation Sugarcane Experimental and Seed Multiplication Farm, Nukerji, Sind, with a versatile Toft 6 000 series III harvester. The harvester and in field transporters were donated by the Government of Australia to Fauji Foundation. The road transporters and unloading stations were designed and built locally. The machine has since then completed three harvesting seasons quite successfully. For more details on the subject, the paper on 'Mechanical Harvesting—And Appraisal of Our Experience with it' by Chaudhary (1983) may be referred.

Small acreages scattered in large areas of the Punjab and NWFP offer unsurmountable difficulties in the application of mechanical harvesting. Large growers in Sind are ready for adoption of this technology. Their cane acreages and field layouts are compatible to mechanical harvesting, but owning and operating a harvester with the complementary hardware is beyond their capacity. A harvester, infield transporters, road transporters and tractors will cost about 6.0 million rupees. The mills will have to construct an unloading station the cost of which will be in addition to the above figure. A mechanization programme, centrally owned and operated by the sugar factories can, however, work in Sind. In other cane growing provinces, even this arrangement seems difficult.

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SOME AGRO-TECHNOLOGICAL ASPECTS OF COTTON PRODUCTION IN THE PUNJAB

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INTRODUCTION

Cotton is one of the main farm crops of Pakistan. It gives employment to millions of people in field and industry and earns a sizeable foreign exchange to the country. Although the cotton production technology has fairly improved and many new varieties have been evolved for the last few years, the yields per unit area still remain at a lower level as compared to other developed cotton growing countries. The total area grown to cotton and its production during 1984-85 are shown in table 1.

Table 1. Area and Production (1984-85)

Province	Area (000 ha)	Production (000 bales)	Yield (Kg/ha lint)
Punjab	1 568.0	4 450.93	482
Sind	662.0	1 445.07	401
N.W.F.P.	3.0	3.00	180
Baluchistan	0.4	1.00	420
Pakistan	2 233.4	5 900.00	447

The development of cotton varieties and realization of their yield potential have been subjected to many limitations imposed by weather, strong pest attacks, water availability, marketing and some multifarious factors.

In order to overcome the cotton production problems, the Directorate of Cotton Research Institute, Rahimyar Khan (Punjab) alongwith its 15 Research Centres/Sub-Stations, is working on various aspects of cotton crop, including especially the varietal evolution, evaluation of the role of varying environmental conditions and development of production technology packages for the farmers of different eco-zones.

ECOLOGICAL REQUIREMENTS AND EXISTING CONDITIONS

Cotton is a fair-weather plant. It requires 180 to 200 frost-free days and 120 to 150 sunny days with more or less but moderate temperature during the growing season. For optimum growth, an average temperature of 21°C to 27°C and low relative humidity are necessary. The crop does best on

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deep, friable, medium textured soils rich in humus, with a good moisture holding capacity. A soil pH range of 6.8 to 7.7 provides its optimum growing conditions.

In the Punjab, cotton is grown on a variety of soils which range from somewhat sandy to clayey in texture, have a low humus content and possess a pH of 8.0 to 8.5. The growing period of the crop falls in the hottest months of the year with the average maximum temperatures ranging from 38°C to 46.7°C. In addition, a high relative humidity prevails during a significant part of the growing period which favours a high attack of pests and diseases. It is apparent that the ecological conditions of the Punjab are not very suitable for cotton production.

RECOMMENDED VARIETIES

Realizing the fact that the climatic and soil conditions of the Punjab are not ideal for cotton production and that the varieties evolved in different ecological regions of the world should not be directly released to the growers, research on cotton was taken up on ecological basis and the varieties evolved under different ecozones of Pakistan and other countries of the world are tested for their adaptability in different parts of the Punjab. The characteristics of important varieties evolved since 1914 are listed in table 2. According to the behaviour and response of different varieties, cotton zoning has been done. The schedule of zoning for the year 1985-86 is given in Table 3. The cotton varieties evolved before 1970 possessed yield potentials of 3200 to 3700 Kg/ha. Since then, the yield potential has been improved to about 5 000 Kg/ha provided that the crop is grown according to the recommended technology in the respective ecological zone.

MAIN FINDINGS ON AGRONOMIC ASPECTS

Besides developing better varieties of cotton for various tracts, agronomic experiments have been carried out in various disciplines. The main findings from these experiments are as under:—

Sowing date experiments

- The best sowing period for the variety B 557 in Mianwali District is from mid March to early April.
- The variety B 557 gives optimum yield when grown during mid April to end of May in the district of Sargodha, Jhang, Faisalabad and Sahiwal.
- The best planting period of varieties B557, MNH93 and MS84 for areas of Multan, Vehari, Bahawalpur, Bahawalnagar, Muzaffargarh and D.G.Khan districts is the last week of May to end of June; for Rahimyar Khan district, it is the 3rd week of May to 3rd week of June.
- The suitable planting period of the new variety 'Ravi' for districts of Lahore, Kasur, Gujranwala and Sialkot is second fortnight of April, and for Rawalpidni and Jhelum districts from mid March to mid April.

Table 2. Characteristics of Commerical Varieties Released in the Punjab since 1914

Name of variety	Year of release	Ginning Outturn (%)	Lint length (mm)	Fineness (Micronaire)	Fibre Strength (000 lb. PSI)	Counts	Genetic yield potential (Kg/ha)
Upland Hirsutum Types							
4F (Selection from stray plant of American cotton)	1914	32.0	23.00	4.5 – 5.5	80 – 90	20's	2 305
LSS (Selection from 4F)	1933	32.0	23.00	4.5 – 5.5	80 – 90	40's	3 225
289/F43 (Selection of 289F)	1934	30.0	20.00	–	–	40's	3 320
124F (Early strain 289F/43)	1945	31.8	22.12	4.5 – 5.5	90–100	40's	3 320
199F (4F selection)	1946	32.0	23.00	–	–	40's	3 320
268F (Selection of LSS)	1948	34.1	23.37	–	–	40's	3 410
238F (Reselection of 289F/43)	1948	31.3	24.13	–	–	40's	3 410
362F (Selection from LSS)	1959	33.0	22.61	–	–	40's	3 690
387F (Selection of LSS)	–	34.3	26.42	–	–	60's	–
AC134 (148F x 199F)	1959	35.0	26.42	4.6	94	60's	3 960
L11 (181F selection)	1959	33.7	27.69	4.0 – 5.0	–	70's	2 305
BSI (13/26) (M4 Selection)	1962	33.0	23.80	4.0 – 5.0	88 – 95	60's	3 690
MS–39 (Natural hybrid)	1970	33.0	31.60	3.5 – 4.2	85 – 90	70's	3 225
MS–40 (124F x 181F)	1970	34.0	31.60	3.5 – 4.2	89 – 94	70's	3 225
B557 (268 X LS)	1976	35.9	28.50	4.0 – 4.3	93 – 95	74's	5 070
MNH93 (149F) x (C–518 = MS39 x Mex–12)	1980	37.5	28.50	4.3	94	60's	5 070
MS84 (MS40 x DPL16)	1982	34.0	33.00	3.9	91.3	80's	4 150
NIAB78 (DPL16 x AC134) (radiated)	1983	35.5	27.00	4.4	92	50's	–
SLH41 (L–11 x 124F) x (149F x Mex 68)	1984	36.0	28.00	4.4	95	60's	5 070
Local (Arboreum) Types							
39M	1934	35.0	18.00	6.8	–	10's	2 770
119S	1945	35.4	17.50	7.8	–	10's	2 770
231R	1959	38.0	16.00	7.8	–	8 – 10's	2 950
D–9	1971	39.5	15.00	8.0	–	8's	3 225
RAVI	1982	41.0	14.50	8.1	–	6 – 8's	3 690

–At present, B557, MNH-93, NIAB78, SLH-41, among Upland types and D-9 and RAVI of the Local types of cotton are being cultivated on large areas of the Punjab.

Table 3. Schedule of Cotton Zoning* (1985-86)

District		Area	Varieties approved for cultivation during, 1985-86.
Lahore & Kasur		Whole District	Ravi, B 557 & D9
Sheikhupura	i)	Sheikhupura & Ferozwala Tehsil	Ravi, D 9 & B 557
	ii)	Sangla Hill & Nankana Sahib Tehsil	B 557
Gujranwala & Sialkot		Whole Districts	Ravi & D 9
Sargodha, Faisalabad & T.T. Singh		Whole District	B 557/NIAB 78 with the permission of Agri. Department.
Mianwali & Bhakkar	i)	Isa Khel Tehsil	Ravi, B 557
	ii)	Rest of the District	B 557
Gujrat	i)	Area falling to the South West of Upper Jhelum Canal, right from Head Works to River Chenab	B 557
	ii)	Rest of the District.	Ravi & D 9
Attock, Rawalpindi and Jhelum		Whole Districts	Ravi & D 9
Multan & Vehari		Whole Districts	B 557/MNH 93
Sahiwal & Okara		Whole Districts	B 557/SLH 41/NIAB 78 with the permission of Agri. Department.
Bahawalpur		Whole District	B 557/MNH 93/NIAB 78
Bahawalnagar	i)	North of Railway line from Bakhshan Khan to Amroka including strip North of Ber Distributory	B 557
	ii)	Rest of the District	Ravi/D 9/B 557
Rahimyar Khan		Whole District	B 557/MNH 93/NIAB 78
Muzaffargarh		Whole District	B 557/MNH 93/NIAB 78
Leiah		Whole District	B 557
Dera Ghazi Khan and Rajinpur		Whole Districts	B 557/MNH 93

Note – The cotton variety MS 84 is recommended for cultivation in dry areas of Multan and Dera Ghazi Khan.

Fertilizer experiments

- In poor soils, one bag of DAP (25–40–0) at sowing and one bag of Urea (50–0–0) at flowering should be applied.
- In rich soils, only one bag of Urea (50–0–0) should be applied at flowering.
- The fertilizer with 50/75–40–0 composition gave the best results.
- Response of cotton crop to the application of phosphorus varies from place to place.

*Cotton Zonal Notification by Government of the Punjab, No. SO(R&E)1(9)/84, dated Lahore, the 27th March, 1985.

Irrigation experiments

- Cotton crop does not need water at early stages of growth.
- The first irrigation may be delayed by 35–45 days after planting.
- The total water requirement of the cotton crop are 635 mm.
- In case there are no rains, 6–7 Irrigations are needed to mature the crop.
- The last irrigation should be applied by the Ist week of October, depending upon weather conditions.
- In case of very hot weather conditions and on alkaline soils, one additional irrigation in the month of October gives good results.
- Irrigation during the months of August and September is essential to get high production.

Cultural experiments

- Seed rate of 20 to 25 Kg/ha for the Upland cotton and 15–20 Kg/ha for local cotton gives optimum yield.
- The best germination percentage be obtained if the seed is placed at depths ranging from 5 cm to 8 cm.
- Normal flat sowing in rows gives high yield of cotton than sowing by the Egyptian technique (ridge sowing).
- For eradication of weeds, 1–2 dry hoeings and 2–3 normal hoeings after each irrigation are must to get high crop yields.
- Deep ploughing effect better yields than the normal cultivation.

Plant protection studies

- The varieties Express, LH62, 3227/75, 129/77, SLH41 and BRS61 are relatively resistant to sucking pests.
- Various new groups of pesticides were studied to test their efficacy against various cotton pests. Synthetic pyrethroides proved to be the best over organo–phosphorus pesticides in controlling all types of bollworms and lepidepterous larvae:
- Spetember is the most critical period for pest management.

Multi-crop system

In Multan region, cotton fields are usually kept fallow and unproductive from February to May. To utilize land during this specific period and to make it more productive, the efforts were directed to study planting soyabean or sunflower during this period. The results favoured planting of soyabean and brought about Rs. 2 170 per ha as an additional income to the farmers. The next cotton crop can be easily planted in the rotation 'Cotton-Soyabean-Cotton'.

This rotation will also improve the soil fertility and may be helpful to decrease the expenses on manure or fertilizer.

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AGRONOMIC PRACTICES OF COTTON CULTIVATION IN PUNJAB

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ABSTRACT

The soils suitable for cotton cultivation in Pakistan extend over about 7 million hectares of which about 3.3 million hectares are classified as well suited. While preparing the land, residues of previous crop are completely destroyed and soil is put in good tilth to have trouble-free planting. On soils that are poor in physical conditions, sub-soiling or chiseling is done to improve the conditions. Uniform, heavy pre-soaking irrigation is applied to charge the soil profile to a depth of 1.5–2 meter. Good-quality seed at rate of 12.5–15 kg/ha (acid delinted) is planted from mid March to end of June, in rows 75 cm apart, and covered to a depth of 5-6 cm with moist soil. After the emergence of seedlings when the crop is 20 cm in height, plants are spaced within the rows so as to maintain 43 000–52 000 plants/ha. Fields are kept free of weeds by inter-row cultivation till the crop makes complete canopy. The first post-planting irrigation is applied 35-45 and 20-30 days after planting on soils with high and low water holding capacity, respectively. Mid-season irrigations are managed to ensure that there should be no dearth of water when the crop is at peak flowering (September). The last irrigation is cut-off by the end of September, particularly in the area where wheat is to be planted after cotton. Soils deficient in phosphorus are fertilized at the rate of 45-65 kg P_2O_5/ha at planting and nitrogen application varies from 56-112 kg/ha in accordance to the nitrogen status of the soil. The crop is protected against sucking insects and bollworms which play havoc if not properly taken care of. Well opened and fluffy cotton is picked by hand to ensure good quality and profitability.

GENERAL

The cotton plays a vital role in the economy of Pakistan. Besides supporting the local textile industry and earning a substantial amount of foreign exchange, it provides livelihood to millions of people at the farms and factories, and thus possesses unique position among the cash crops. Pakistan ranks among the few topmost cotton producing and exporting countries of the world. The yield per hectare, however, is quite low compared with other advanced cotton growing countries (Salam, 1983). Therefore, the need for emphasizing the good harvest is utmost essential. There are several agronomic aspects such as crop rotations, choice of soils, seedbed preparation, method and time of planting, quality and rate of seed, thinning, weeding, fertilizer application, irrigation and plant pro-

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tection etc. A proper crop management in view of the climatic conditions will certainly ensure to harvest high yields. These aspects are briefly touched below.

CLIMATE

The cotton crop performs best under a dry, hot (not very hot) climate with long sunny days. Heavy precipitation in abnormal years has been experienced to have adverse effects on cotton, by either causing its destruction through washouts or germination failures or resulting in too lush and rank growth. The unusual rains received at the critical time of planting result in failure of germination due to capping of the soil. The second aspect of climate is the temperature regime. The peak daily maximum of 40 to 45°C with the concurrent minimum of about 30°C is reached in May/June. This period coincides with the planting time of cotton. Early plantings in Punjab (in April/May) result in flowering at the peak high temperature periods; the flowers, therefore, mostly shed without being fertilized and consequently, there is poor boll formation (Saunders and Anwar, 1978).

SOILS

The soils suitable for cotton cultivation in Pakistan cover about 7 million hectares, of which about 3.3 million hectares are graded as very suitable. A small proportion of the area used for cotton is affected by high water-table (0.1%) and salinity (1.7%) (Ashraf & Alim, 1979). The other important limitations of less suitable cotton soils are somewhat sandy or too clayey textures and unfavourable surface topography. The good cotton soils are deep, well drained, homogeneous, medium textured and calcareous (3-15% lime). They generally have high silt content and an alkaline reaction (pH 8.0-8.5), and are low in organic matter (0.3-0.6%). Because of the low organic matter and high silt content in the surface layers, the soils have a tendency to develop surface crust which restricts seedling emergence and reduces soil aeration (Taha, 1982).

LAND PREPARATION

About seventy percent of the cotton is grown following a wheat crop, so that at a time when land is to be prepared for cotton, the farmers are busy in harvesting and threshing of wheat. The majority of farmers pay greater attention to their wheat crop and, consequently, land preparation for cotton is neglected. The implements available are generally the indigenous plough and tractor cultivator tines. Four to five ploughings and one to two plankings are sufficient to prepare the land Levelling of land is also taken care of when needed to have uniform pre-soaking and post-planting applications of water. If the previous wheat crop is harvested mechanically, the excessive amount of wheat straw stubbles in the field by the harvestor needs to be disposed-off for proper land preparation. In such cases, the wheat straw is either burried deep into the ground by a mouldboard plough or chopped by disc harrow or rotavator, or burnt away.

The soils having poor physical conditions are ripped to a depth of at least 30 cm while preparing the land. This operation accelerates intake of water by the soil to a greater depth during pre-soaking irrigation (Gill and Saunders, 1983b).

Where cotton is planted after wheat or on fallow land, two heavy pre-soaking irrigations are essential for deep moistening of soils. The second irrigation should be given when the soil comes into workable condition and has once been ploughed after the first irrigation. This practice results in a deeper penetration of water than applying the second irrigation immediately after the first (Gill. 1984) and reduces the number of subsequent irrigations after planting.

After pre-soaking irrigation, when the field comes in workable condition again, the land is broken to depths of 15-20 centimeters to provide a suitable condition for cotton seedlings. On an average, 3-4 cross cultivations are sufficient. After each cultivation, planking is done to break up the big clods. On large mechanized farms, disc harrow or spring tine harrow with crumbler is also in use (Gill and Saunders, 1983a).

SEED RATE AND PLANTING

The quantity of seed used per hectare varies according to the quality and characteristics of the seed, efficiency of the planter and the plant population to be established. The quality of the seed is improved by treating the fuzzy cotton seed with sulphuric acid to remove the fuzz, to make it free from disease organisms and to permit its free flow from the seed box through furrow opener tubes into the soil. A good recommended stand varies from 42 500 to 50 000 plants per hectare; thus varies the seed rate. In general, 12.5-15.0 kg of acid-delinted or 20-25 kg of fuzzy seed is sufficient to plant one hectare. When fuzzy seed is used, it is soaked in water for 4-6 hours prior to planting. The soaked seed is rubbed with soil or ash to separate seeds from each other and facilitate their free flow in a drill.

The optimum time for planting of cotton varies for different places on account of climatic differences. Excessive temperatures, desiccating winds, storms and early rains all have an affect on determining the planting date. In the Punjab planting is generally carried out from mid-March to the end of June. Cotton plants are spaced so as to enable them to take best advantage of the conditions at planting time. At the optimum time of planting, the row-to-row and plant-to-plant distances are kept as 75 cm and 25-30 cm respectively; In late planting when adequate growth is not expected, the distances are reduced to 60 cm and 15-22 cm respectively. The distance from plant-to-plant is adjusted by taking out the extra plants after emergence when these are 20 cm in height.

Planting is done in rows or lines, by tractor-driven drill or bullock-driven single-row cotton drill. Small farmers not having the drill generally use 'pore' a long funnel, tied with the local plough. The seed is placed at 5 cm depth and covered properly with moist soil. The major drawback to the use of common drill is that it promotes crust formation and thus restricts the emergence of seedlings,as well as reduces soil aeration. Planking of the seedbed after planting is very important operation for seed germination, even though the soil has been well pulvarized already. The planking is done because of high temperature (40-45°C) and hot winds that may affect seed after planting. Moreover, drills commonly used by the grower lack press wheel which firm up the soil around the planted seed.

In saline and clayey soils, cotton is planted on ridges. In saline soils, the cotton seed is dibbled safely 7.5 cm down on one side of the ridge. This provides good drainage conditions and least salinity for the germinating seed (Anonymous, 1983; Gill and Saunders, 1983a).

IRRIGATIONS

The first irrigation after planting can be delayed for 40-50 and 20-30 days on well pre-soaked clayey and sandy soils respectively (Gill, 1984). It is in fact the depth to which pre-soaking irrigation water had penetrated that determines the first irrigation interval after planting (Gill and Saunders, 1983b). Under normal conditions, a good pre-soaking irrigation provides enough moisture for the first 40-60 days after planting. It is important that early stage irrigation should not be heavy in view of the danger that small plants may be damaged by long standing water which in fact implies temporary waterlogged conditions or restricted oxygen supply to the roots. These conditions depress plant growth and development, thereby making it prone to diseases and insects attack. Judicious irrigation during juvenile stage is essential also to avoid rank growth and late fruiting (Malik, 1982).

The crop generally reaches the fruiting stage (developing squares and blooms) with only 1 to 2 irrigations on soils with good water holding capacity and with 2 to 3 irrigations on relatively sandy soils. The plant growth is accelerated during the fruiting phase (August and September) and water consumption is maximum during this period. The timing of irrigation during this period is most crucial. To harvest good cotton yeild, the crop is not permitted to suffer from water shortage at this stage. Inadequate water supply during the fruiting phase not only causes heavy shedding of fruit but also restricts the boll growth. The optimum irrigation interval required during this period varies from 12 to 20 days, depending on soil and climatic conditions. In areas of high water table, however, an interval of 30 days or longer may be allowed.

The last irrigation cut-off after the boll opening starts, has also an important bearing on water economy and crop yield. The need for water is not so pronounced at this stage and only that much moisture is essential which can keep the plants in healthy conditions and enable late-formed bolls to mature properly. Scarcity of water at this stage also affects the quality of lint adversely. In the Punjab, the last irrigation is completed by the end of September till the middle of October. Irrigations given after this period would undoubtedly delay the opening of crop. Delay in maturity also encourages boll rot as well as bollworm attack on the young bolls. There is seldom any benefit from irrigation after the end of September, particularly in the area where wheat is to be planted after cotton.

FERTILIZER APPLICATION

Cotton is relatively less exhaustive crop. Its nutrient requirements are slightly less than those of maize, sugarcane and wheat, and considerably less than those of vegetables. The amount of nutrients removed from the soil, however, depends on the level of yield atttained and whether the crop residues are removed or incorporated in the soil (Taha, 1982).

The application of P fertilizer to cotton remains a controversial subject between different institutions engaged in phosphorus experimentation. The results of the trials conducted by various organizations revealed that there was erratic response to the addition of P fertilizer to cotton crop. The requirement of the crop for phosphorus is nevertheless very low so that, to produce 100 kg of lint, only 8 kg of P are required (Malavolta et al 1962). Cotton can meet its P needs even on soils which are low in available phosphate. Soils having received little or no P application to the previous

crop, however, require P fertilization at planting time or with the first irrigation at a rate of 45 to 65 kg P_2O_5 per hectare (Gill and Saunders, 1983a-1984b).

The cotton soils are generally very low in organic matter as well as nitrogen content. The crop generally requires and removes nitrogen in greater quantities than phosphorus. To produce the first 2 bales of lint per hectare on irrigated land, the crop needs approximately 30 kg N/ha, and a further 70 kg N/ha will be needed for the next two bales (Hern, 1981). Thus, N application is the most important nutrient factor in cotton production. High crop yields are possible only by adequate and judicious use of N fertilizer. It is well known that the nitrogen contribution of the soil is usually far short of the total needs of a cotton crop. In case of soils previously planted with legumes, however, the rate of nitrogen application will be reduced.

The N up-take by cotton plant can be divided into three periods. In the early growing period (seedling stage), the plant growth is restricted because of high temperatures and inherent characteristics of the plant. Nitrogen is not a limiting factor at this stage. About 20% of the total nitrogen is absorbed from planting to the appearance of first flower. From then onward the demand drastically increases because of increased growth, flowering and boll setting. During this period, approximately two-third of the total N dose is required to meet the plant demand. The remainder is taken up at decreasing rates until the maturity. It is very important to supply an ample quantity of nitrogen, well in advance of the period of high demand (Larson, 1964).

As a general recommendation, the quantity of nitrogen to be added is 56, 84 and 112 kg N/ha for soils with high, medium and low fertility, respectively.

In relatively sandy soils, N fertilizer is applied at least in three split doses;one-third at planting time, one-third at Ist irrigation and one-third at peak flowering stage. Split applications are preferred because of possible nitrogen losses through leaching. These applications may be continued through mid-August to the end of September without any detrimental effects. On medium textured soils, two split doses, i.e. 1/3 at first irrigation and 2/3 at peak flowering stage, give better results. On heavy textured soils, the nitrogen application at peak flowering in a single dose is satisfactory for a good harvest, provided that the soil is not poor in nitrogen at planting time(Malik et al 1980).

WEED CONTROL

Weeds emerge alongwith the cotton seedlings. These weeds cause yield reductions to the extent of 50% or even more. The most common weeds are listed in the following table.

Common Weeds of Cotton Crop

Botanical Name	Local Name
Cyperus rotundus	Deela
Trianthema monogyna	Itsit
Cynodon dactylon	Khabbal ghas

Digitaria tomoorensis	Madhana ghas
Convolvulus arvensis	Lehli
Amaranthus virdis	Chulai
Digera Arvensis	Tandla
Euphorbia hypericifolia	Dodhak
Portulaca spp	Lunak
Tribulus terrestris	Bhakra

The usual practice to eradicate weeds is interculture with 'triphali' or cultivator tines. It sufficiently reduces the weed problem in a normal dry year but it is not generally possible to enter the field in rainy years. Additionally, the growth rate of weeds during rainy season is accelerated and the method becomes ineffective. The number of interculturing operations varies with the intensity of weeds in the field as well as the type. Three or four cultivations are usually sufficient.

Under wet conditions, the control of Itsit *(Trianthema monogyna)*, Deela (*Cyperus rotundus)* and Khabbal grass *Cynodon dactylon)* is one of the major problems in cotton production. Under such circumstances, a chemical control measure is the best solution to supplement the intercultural measure. The concept of using herbicide in cotton is new and is still in its infancy stage. Herbicides are likely to have a real value in Pakistan in the very near future, especially under wet weather conditions. The agronomic research at Central Cotton Research Institute, Multan revealed that the chemical pendimethalin, commonly marketed as Stomp—33OE, is the best to supplement the cultivation to control the weeds. This herbicide selectively eradicates the annual broad-leaved weeds and grasses (Gill and Saunders, 1984a). It is sprayed, at the rate of 2.5—3.75 litres/ha, on the surface of a prepared seedbed before planting and incorporated in the upper 5 cm of soil by a disc-harrow. The chemical is also used just before pre-soaking irrigation when not possible at seedbed-preparation stage. It may also be sprayed on the dry land surface before seedbed preparation, immediately followed by pre-soaking irrigation.

PEST CONTROL

A number of insect pests attack the cotton crop at different stages of plant development. The major cotton pests include cotton jassid, whitefly, thrips, spotted bollworm, pink bollworm, American bollworm and spiny bollworm.

In addition, there are minor and sporadic pests such as leafworms and Spider mites. The thrips usually attack the plant at seedling stage from May to June but, in certain areas, its infestation continues upto August/September. The jassid and whitefly are dominant during July and August. The bollworms increase their population when the temperatures fall; this is particularly true of the pink bollworm. The period from mid August to mid October is the critical time when fruit setting occurs. This is the period when crop protection is most critically needed (Salam, 1983).

HARVESTING AND STORAGE

Cotton is in strong competition with man-made fibres in the world market. Therefore, the need for emphasizing quality is essential. Cotton quality is determined by a number of pre-harvesting

cotton production factors (seedbed preparation, planting, seed rate, thinning, spacing, time of planting, weeding, fertilizer and irrigation etc), but is largely dependent on the time of picking, handling in the field and storage. Even though the quality cannot be improved when the crop is already in harvesting stage, there is still room to avoid deterioration of quality while picking and storing.

The time to begin cotton picking is determined by the maturity of the crop. The maturity is judged by the amount of open cotton bolls, the quantity of dry leaves and moisture contest of the seed cotton. If picking is started before the cotton is mature, the gin turn out will be lower because of soft seed and there will be more spindle twist in the textile industry. The cotton quality is preserved best when picking is delayed until seed cotton moisture on the plants is eight percent or less (Gill and Saunders, 1983c).

Hand picking is the common harvesting practice in Pakistan. In this way, only the seed cotton is picked from the bur. This mekthod is in fact the standard by which all other methods of harvesting are measured. It produces the highest grade of cotton as compared with any other method in vogue. It also gets more cotton out of field than any other method. The following points must be taken into consideration while picking, to ensure good quality of cotton (Gill and Saunders,1984c).

- The mature and well fluffed cotton is picked carefully
- The leaf trash is not mixed with the cotton while picking
- Picking is started when the plant leaves are free from dew and rain drops
- In case of rain, cotton is not picked till it is dry to about 8 percent moisture level
- Cotton is picked only from locks of open cotton
- Picked cotton is placed on a dry, clean surface

The amount of cotton that any one picker can collect per day by hand picking depends on the yield and percentage of open bolls, efficiency of the picker, size and kind of bolls and weather condition. Under ideal conditions, an average woman can pick about 30-40 kg of seed cotton per day. Hand picking can usually recover about 95% of the cotton available in the field.

SEED COTTON STORAGE

Moisture, temperature and humidity are three important factors which affect the quality of seed cotton in the storage. Efforts are made so that the seed cotton is kept in a ventilated store which is free from dampness. Cotton having more than 12 percent moisture is never stored till the excess moisture is removed by drying in the sun to check deterioration of quality.

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CITRUS AGRONOMY

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INTRODUCTION

Citrus fruits are not native to Pakistan but the environmental conditions of certain parts, especially of the Punjab, are very hospitable to them. Presently, about 136 000 hectares are under these fruits in Pakistan, which account for about 38% of the total area under all fruits. About 94.6% of the area under citrus occurs in Punjab.

Kinnow is the most important citrus fruit which is grown over about 63 100 hectares and leads export list. During 1983-84, more than 37 000 tons of citrus fruits worth about Rs. 100 million were exported. Kinnow alone contributed 98.6% to this value.

Production of citrus fruits is concentrated mostly in the divisions of Sargodha, Bahawalpur, Faisalabad and Multan but the fruits are also grown on a limited scale in Sukkur, Malakand and Peshawar Divsions.

ECOLOGICAL REQUIREMENTS

Citrus trees grow well in tropical and sub-tropical areas with well defined summer and winter seasons but regions of heavy rainfall and high atmospheric humidity are not favourable. Citrus species tolerate low temperatures in the following ascending order :

Citron, lime, lemon, grape-fruit, sweet orange, sour oranges, mandarin. Kumquat and trifoliate orange can tolerate still lower temperatures. The trees need protection against cold injuries in relatively cold climates and against sunburn and wind storms in hot and dry climates.

Climate has a profound effect on the vegetative vigour, production potential and quality of the fruit. Anthocyanins which are responsible for red colouration in sweet oranges occur in places with colder climates. The fruits ripening in warmer weather are less acidic and the flavour is better developed in tropical areas with longer dry periods (Chandler, 1958).

Citrus fruits can be grown over a wide range of soils but deep, fertile, well drained, sandy loam soils give the heaviest production. The waterlogged, saline, sodic, too clayey, sandy and gravelly soils are not suitable. In reaction, the soils with pH values around 6.5 are considered to be the best but the fruits can be successfully grown within a pH range of 5.5 to 8.5. Calcareous soils are suitable if they are free of active (powdery) lime. Nonetheless, some soil adjustments are possible by using proper rootstocks and addition of farmyard manure.

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ESTABLISHMENT OF THE ORCHARD

Planting systems and tree spacing

In Pakistan, citrus orchards are usually planted on flat lands. Contour and terrace planting are also practised, depending upon topography of the land. In poorly drained soils, bed and ridge planting is more advisable. Surface and sub-surface drainage is of paramount importance in citriculture.

The rectangular or square system of planting is the one most commonly used throughout the world. The quincunx system is also practised to a great advantage, especially for high-density plantations. The hexagonal or triangular system has an advantage; of accomodating 15% more trees but, according to Platt (1973), it is seldom used because of being confusing and more difficult to manage.

Distancing of trees in an orchard is important for obtaining good yields as well as for cultural operations. Tree distances depend upon the cultivar, rootstock, soil type and the climate. In Pakistan, the planting distances vary between 5.5 and 8 metres.

For high-density orchards, dwarfing rootstocks and less vigorous stock-scion combinations are important. The promising rootstocks for close plantings as listed by Castle (1981) include 'Rubidoux' and certain hybrids of 'Rangpur' lime and trifoliate orange. Cole and McCarty (1982) reported 'Flying Dragon' as a markedly dwarfing rootstock for 'Valencia late' orange. Duncan et al (1978) stated that orange trees, on trifoliate orange and citrange rootstocks, could be dwarfed by inoculation with a bud transmissible factor.

In view of inadequacy of sunshine in the closely planted orchards, hedgerow planting is recommended. In this system the distances between the trees are half of those between the rows. A north-south direction of the rows is desirable for maximum advantage of the sunshine. A spacing of 7m x 3.5 m is practised for hedgerow system in California. The best arrangement would be, first planting at half the normal distances and pruning back for few years, and then uprooting of the alternate trees (Platt, 1973).

Layout of the orchard

For layout of the orchard, land should first by properly prepared by removing the natural vegetation, levelling, thorough ploughing and planking. The orchard boundaries should then be clearly marked by embankments. The positions of rows and of trees in each row are determined by proper spacing according to the system followed and marked by lime, gypsum or wooden pegs, keeping in view that a 5-6 m wide space is left between the last tree of each row and the orchard boundary in order to facilitate end turnings by cultural equipments.

Planting

At each tree site, a circular pit with about 1 m depth and 1 m diameter is generally dug and left open for a few days for weathering. The pit is then filled up with a good loamy soil material prepared by mixing the topsoil, sand (if the toposil is somwehat clayey) and well rotten farmyard manure, keeping it slightly higher than the original field level, so that it attains normal level after settling down with irrigation. Water is then applied to the pits copiously so that the growing media settles down properly.

There are two proper seasons to plant citrus in Pakistan i.e. the spring and the fall. Healthy, vigorous and true-to-type plants of proper age (2 to 2-1/2 yrs), should be purchased from reliable nurseries. It is desirable to head back and prune the plants just before or after digging them from the nursery. This operation is necessary in order to balance the root and top systems of the trees as the roots are cut and damaged to a considerable extent while digging them out.

For planting a balled tree, a hole, slightly bigger than the length and the diameter of the ball, is dug in the centre of the pit already prepared for this purpose. The tree is then placed in this hole, so that the plant is pushed in the ground to the same level as it was in the nursery. Planting boards are helpful for exact positioning of the trees. The soil around the tree should then be tamped properly and irrigated immediately after the planting operation.

Addition of fertilizers to the holes at planting time is generally harmful than useful. Use of incompletely cured organic manures should be avoided as it would invite root diseases.

Training and after care

Training of citrus trees is very important in order to privide a strong, durable and properly balanced framework which is capable of bearing the load of foliage and fruit.

Young trees are headed back in the nursery to about 60 cm size. Four or five branches, well spaced around the top are selected for forming the structure, and cut back to 15-20 cm size while the remaining branches are thinned out. During next 2-3 years, only the bud sprouts etc are removed. Then, upto an age of 5-6 years, the weak, criss-crossing and other unwanted branches are regularly removed.

Due to ease and conveniecne in protecting the trees from frost, the prostrate training method has been considered suitable. Lavriichuck (1980) successfully trained the plants of various citrus species as prostrate trees with 15-20 cm long main trunk and wiresupported horizontal cordon branches.

For attaining success with the new plantation one should always guard against situations of drought and water shortage. Frequent irrigations, in small amounts should be applied at initial stages of establishment. The plants should be protected against inclement weather as well as pests, diseases and weeds. Their trunks may be painted with lime, or preferably with Bordeaux paste, against sun-burn as well as gummosis, and wrapped with news-paper mats or light card-boards for protection against cold in cooler climates.

WEED CONTROL

Summer growing perennials like 'Baru' (*Sorghum halipense*) and 'Deela' (*Cyperus rotundus*) are the problem weeds in citrus orchards. Some annual weeds also grow but are of minor importance. Tillage at proper time intervals is quite helpful to eradicate these weeds. For economical reasons and technological lag, the use of herbicides has not so far gained ground in Pakistan.

From their long studies on grape-fruit orchard, Leyden and Duke (1982) found that trees under chemical weed control (Non-tillage) out-yielded those under clean cultivation and sod culture. In Punjab (India), according to Bajwa et al (1976), pre-emergence application of diuron at the rate of

4.0 kg/ha gave the best results. A mixed weed infestation was controlled by Prates et al (1980) using diuron at 4 kg/ha, pendemethalin at 3 litres/ha and oryzalin at 2.5 kg/ha.

SOIL MANAGEMENT SYSTEMS

Following different soil management systems are practised, depending upon the economic conditions as well as the soil and climatic aspects of different orchards.

Clean cultivation

The orchard is kept adequately clean of any weeds by occasional tillage operations and no inter-crops are sown. This is the usual practice in the premier citrus growing district of Pakistan i.e. Sargodha. Daito et al (1981) recorded lowest yields of Satsuma trees under clean cultivation but fruit colour and quality parameters had increased. Oliveira et al (1981) found that clean cultivation by tillage increased disease incidence and this was attributed to mechanical damage of roots and stem.

Inter-cropped cultivation

Selected crops are grown in between the tree rows. The crops to be grown are to be selected on the basis of several factos, e.g. amount of organic matter produced, competition with weeds and water availability. It is advisable to grow certain vegetables and quickmaturing, non-exhaustive (leguminous) crops only during the first 3-4 years of establishment of the citrus orchards, as it is of great help to cover the initial costs of planting and irrigation etc. These crops should neither interfere with the nutrition or moisture availability to the citrus plants, nor be antagonistic in pest diseases and weed control.

No tillage

In this system, orchards are planted with permanent sod and weeding is carried out by hand hoes or herbicides. This system of soil management is non-existant in Pakistan. Cant (1980) reported that non-tillage in the citrus orchards resulted in yield increases of more than 50% within two years of conversion to non-cultivation and irrigation with low-level sprinklers. Comparative studies by Nel (1980) revealed that tree growth was much greater in the orchards under grass as compared to clean cultivation.

NUTRITION

The aim of nutrition to citrus orchards by manuring or fertilizer application is to ensure a high production level, superior fruit quality and longer productive life of the trees. Deficiency of nitrogen is a common phenomenon in citrus orchards. It is said to be most critical at the time of or just before blossoming, fruit setting and June drop. The deficiencies of phosphorus and potassium are seldom noticed but their application has been found to increase yields and improve the fruit quality.

In the Punjab province, the recommended doses of manures and fertilizers in terms of nutrients per tree per year are:

N	=	1.5 – 2 kg
P_2O_5	=	1 kg
K_2O	=	1 kg

Deficiency of zinc and manganese have also been noted in several orchards and are corrected by the application of Zn and Mn fertilizers, usually by foliar sprays.

As a matter of general practice, in citrus growing areas of Pakistan, farmyard manure is added in December-January, while N fertilizers are applied in two split doses, one a fortnight before the onset of flowering and the other about a fortnight after fruit setting. The month of June was found to be the most effective time for application of Zn, while both June and September were found suitable for addition of Fe and Mn in the experiments carried out by Taha et al (1979).

As far as method of application is concerned all the space under the tree, upto the drips of peripheral branches, except 60 to 90 cm space around the trunk in case of full bearing trees, should be hoed with spade and then the manure/fertilizer be mixed evenly in the loosened topsoil. Irrigation should follow immediately after the application of manures/fertilizers.

PRUNING

Pruning is carried out as a regular cultural operation throughout the life of the plant for maintenance of a good framework, keeping the plant in healthy condition, facilitating cultural operations and improvement of fruit quality.

Certain branches are thinned out from the top of the mature tree in order to stimulate growth of fruit wood on the sides. Little pruning is done on the sides. The branches reaching other trees and thus shading the skirts are also pruned back. Watersprouts and all branches which are weak, dried, cris-crossing or interfering with the cultural operations are also removed.

Lewis and McCarty (1973) recommended that, for rejuvenation of old trees, all branches less than 2.5 cm diameter are removed. This practice is known as 'skeletonization. Merle and Nador (1978) reported that rejuvenation pruning in Morrocco led to a marked increase in yield and regular bearing in 'clementine' tangerin.

In advanced countries, mechanical toppers and hedgers etc have been invented to facilitate pruning operations, especially in the older orchards where trees have grown together and skirts lost from excessive shading.

Regarding the time of pruning, it has been found that the best results are obtained if it is done early in Spring, i.e. after the danger of frost has passed and before the trees start new growth.

IRRIGATION

It goes without saying that water itself is a nutrient as well as a solvent and carrier of the nutrients. The root growth, top growth, productivity, as well as fruit quality, are all under the strong influence of irrigation.

Surface irrigation methods are generally practised in Pakistan for citrus orchards. The basin and modified basin systems are the most common. The 'Furrow' and 'Alternate Middles' irrigation methods are also used in other countries for saving irrigation water. The sprinkle, drip or sub-surface irrigation methods have aroused a great interest in the foreign countries and are being introduced in Baluchistan province, where there is great shortage of irrigation water.

Marsh (1973) has pointed out that the micro-climate of the orchard is greatly influenced by irrigation. In this context, it is advisable that irrigations should be more frequent but lighter during summer and less frequent but slightly heavier during winter.

It has been amply proven that citrus roots do not grow satisfactorily in poorly aerated soils, therefore, saturation of the root zone should be avoided at all costs, at least during the main growing season.

QUALITY IMPROVEMENT

Good quality always earns premiums and, for citrus, the good quality means a balanced and pleasant combination of its physical and organoleptic characteristics. The external characters such as shape, size and colour of the fruit are very important from marketing point of view. The internal characteristics like juice content and its taste and quality in terms of the contents of sugars, acids and flavouring substances etc. are of great value for processing and fresh consumption.

Citrus species as well as their cultivars vary in their bearing habit; some are shy bearers and the others bear heavily. The shy bearers produce scanty crops of larger and heavier fruit and are considered uneconomical. The heavy bearers produce so abundantly that quality is adversely affected. Several practices are in vogue in different parts of the world for correcting these situations.

Girdling and ringing has been practised for forcing the shy bearing trees into normal fruiting. As noted by Lewis and McCarty (1973), their productivity in the succeeding years is reduced; however, it is useful where an orchard is to be uprooted within a few years. This operation is carried out by giving a single knife cut to severe through the phloem. It is performed soon after the full bloom. In the experiments performed by Merle and Nador (1978), arching proved superior to ringing and better than double ringing in case of 'Clementine' tangerin.

In case of heavy producers, there is a need of decreasing their load, primarily for two reasons. Firstly, to save the tree from exhaustion and subsequently falling in irregular, erratic or alternate bearing, and secondly, to improve the quality of the remaining produce. Fruit thinning, therefore, is carried out to achieve these objectives. In advanced countries, growth regulators are employed to cause the droppage of some fruit, taking care that there are no adverse effects on the remaining crop and the trees, and that there is no excessive shedding of the fruit.

Experimenting with 'Valencia' orange trees, Gallasch et al (1980) found that sprays of 250 ppm ethephon reduced crop loads from 14 to 29% in different localities; and this was sufficient to avoid alternate bearing by these trees.

CONCLUSIONS

Notwithstanding an ever-increasing acreage under citrus fruits in Pakistan, favourable changes in the productivity level of these fruit crops are yet to be seen. In order to raise the level of production, orchard management practices ensuring better nutrition, agronomical practices and plant protection measures, based on production technology packages for different agro-ecological zones, should be adopted.

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PROSPECTS OF AGRO-FORESTRY IN PAKISTAN

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INTRODUCTION

Pakistan is virtually facing a wood famine. Prices of constructional timber and fuelwood have registered an alarming increase during the last few years. Country's 84 million people are going to be more than doubled by the year 2 000 and their current annual demand of timber of 2.0 million m^3 for wood products would increase with the same ratio if not faster. Against that the state forests are producing only 0.4 million m^3. The story of fuelwood is even worse. Out of total requirements of 18.9 million m^3, state forests produce only 1.9 million m^3. The rest of the demand for timber as well as fuelwood is being met from imports and farmlands.

One possibility to bridge this yawning gap between supply and demand could be to put more area under state forests. For the time being it seems rather difficult because of paramount claim of agriculture on land. Even if in view of the promised self-sufficiency in food, more land is made available to expand the almost static forest base and twenty thousand hectares are planted annually, it would take about 100 years to increase the forest area by another 2.5%.

Almost everywhere in the world, the trees on farm lands and marginal lands are an important source of fuelwood and timber to supplement the production from state forests. In Pakistan, trees on farm lands have since long been making a very handsome contribution towards this end. However, as the removal of the trees has not been accompanied by consistent planting of new ones, the inevitable result is that erstwhile resource is dwindling at a very fast pace. Inspite of that, 55% of timber and 90% of fuelwood requirements of the country are still being met from the farm and waste lands.

THE SYSTEMS AND THEIR PRACTICE

Agro-forestry implies integration of farming with tree planting on agricultural land to the benefit of the farmer. This concept of trees on farm lands originated from the realization that trees play a very important productive and protective role in safeguarding the vital interests of agricultural lands and their produce. Forest and agriculture crops can either be grown simultaneously or in rotation.

The necessity to focus on private lands for tree planting has been realized since long in many countries of the world. The practice of forestry on private land was actually initiated in Europe and the farming community in that continent is considered to be the pioneer in this regard. For example in

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Norway 65% of the productive forest area is maintained on agro-forestry system of management. Small private forest holdings differ from one European country to another and similar is the case in U.S.A. Some of these forests are of commercial nature, cover large areas and are owned and developed by the industrial concerns. The other category comprises relatively small private forests which are known as farm forests and form an integral part of the farm and are a useful source of extra income.

The concept of agro-forestry is not entirely new. A widely practised form is known as "Taungya" and was introduced in Burma more than one hundred years ago from where it spread to India, Bangladesh and many other countries in the Far East. Teak and *Gmelina arborea* are the main tree species planted in combination with agriculture for timber and fuelwood. Cashew, *Anacardium occidentale,* has been successfully grown together with maize, sometimes with grain in Guinea. In China intercropping is applied in forestry as a rule. Agricultural crops are commonly planted between rows of poplars and pines. In some cases both pines and tung oil trees are spaced out in the agricultural crops. This system has a positive impact on both the landscape and productivity in the rural areas. In the north-western China for example, 0.7 million farmers established a shelterbelt, 1 500 km long and 12 m wide in two seasons. In FU Kou county 74 million trees, about 140 trees per person were planted and some 10 000 hectares of windbreaks established between 1958-75. In Chou Chou county extensive forestry programmes have been closely associated with doubling of agricultural yields over 10 years. It will not be out of place to mention that mass participation in forestry by people has been the key to such spectacular success stories.

Another example of mixed cropping comes from Southern Pacific Coast of Columbia where trees such as *Cordia alliodora* and *Cedrela odorata* are planted on small land holdings together with traditional crops of *banana, maize* and *coco.* In Malaysia, Senegal, Assam and Kerala tree growth gets accelerated as a result of rice cultivation in between the lines because the weeds are eliminated due to soil working. In the Republic of Korea, Government introduced a number of measures in 1975 to protect existing forest lands and create village fuelwood plantation. The Village Forestry Assoication is responsible for carrying out afforestation. By 1978, the annual planting rate had reached over 40 000 hectares.

Not only trees are grown alongwith agricultural crops but also controlled grazing can be practised in well established plantations as a major land use. In Papua New Guinea some 2 000 heads of cattle are grazed in about 4 000 hectares of *Araucaria* plantations. Similarly in Sahel, *Acacia* trees are being used to help enrich poor Savanna grazing. In the Cap Vet region of Senegal, *Acacia albida* is being planted at 10 meter intervals. In Indonesia, pines are being planted together with Eucalypts and Elephant grass is grown under the trees. This is being done in uphills to protect the land from erosion while providing fodder for domestic animals. In Sudan, cattle are allowed to graze in *Acacia senegal* plantations. Apart from yielding gum, the trees are used for many other pruposes: fencing, building timber, fuelwood and rope-making. They also provide fodder and shade for livestock and markedly increase soil fertility during the fallow period.

In Phillipines, *Albizzia falcataria* is being planted by farm families on a 8-year rotation yielding 240 m^3 of wood per hectare. In Nigeria, Agro-forestry was started about 50 years ago. The main food crops grown during the 2 year period when teak and Gmelina plantations are being established

are maize, yams and vegetables. Sufficient experience has been gained to confirm that small farmers will rapidly respond to incentives for tree planting, such as credit, assured market outlets and extension services. In the case of the Philippines Phase I Tree Farming Project, for example, 1 000 small farmers took advantage of the loans available in the first pilot phase of two years and established 8 3000 hectares of fast growing *Albizzia falcataria* and Iple Iple pulp wood plantations. This scheme is now being greatly expanded in a second phase project.

Studies of the economic impact of such tree farming projects provide encouraging evidence that acceptable rates of return can be expected from short rotation fuelwood or pulpwood crops. Tree crops offer the farmer the prospect of diversifying his cropping pattern, making more effective use of marginal farm land significantly improving farm family income. There is obvious scope for rapid bank lending when conditions are favourable.

Many species of trees can be successfully planted in homesteads, farms and forest estates, schools, hospitals, government buildings for multiple uses-timber, poles, pulpwood, fuelwood/charcoal, leaf fodder, organic green manure, phyto-chemicals, oilseeds, floss, fiber, edible products, tannin and other valuable forest products. They can also be planted for purposes such as live fencing, soil improvement and rehabilitation (through nitrogen fixing and nutrient cycling), soil reclamation, ersoion control, flood control, protection of irrigation works, regulation of stream flow, consolidation of river banks, improvement of local environment, landscaping, shade trees, windbreaks, host trees for silk or lac cultivation. Easy propagation, coppicing power, natural resistance to conditions of stress, etc. adds to the value of multi-purpose trees.

Some example of multipurpose trees are –*Acacia albida. A. modesta, A. nilotica, A. Seval. Azadirachta indica, Emblica officianalis Eucalyptus* spp., *Leucaena leucocaephala, Mangifera indica, Morus alba, Pinus roxburghii, Pithocolobium dulce,* Poplars, *Salmalia malabarica, Sesbania* spp., *Tamarindus indica, Zizyphus mauritiana.*

Some of these trees need renewed attention due to their multiple use.

ATTITUDE OF THE FARMERS IN PAKISTAN

Unfortunately bulk of the farming community in Pakistan is illiterate and ignorant. The farmer is so grossly entangled in his low yield and consequential financial worries, his feuds and litigation that he seldom gets time to think of other avenues of prosperity. Fully knowing that he needs fuel, wood for implements and construction, fodder trees to feed his cattle in the time of fodder scarcity and trees in the form of belts to save his crops from wind damage, he does not show much enthusiasm to plant trees on his land and continues to use large quantities of cow dung which ought to have gone to his fields to boost up agricultural yields. Efforts made in the past to increase tree growth in the farm lands have not achieved the desired results partly due to the indifference of the farmers but mostly because the follow up operations were lacking. Although when travelling in the country-side one finds trees of almost all ages which have been planted by some progressive farmers, yet these are only a few spots in the vast treeless tract.

The notion that the trees have a deletereious effect on the land has to be erased from the mind of the farmer. He has to be told that the trees have a longer root system as compared to the agricultural

crops and that they do not compete with it for nutrients and water; the shade does have some effect but it is only within a small radius (most of the trees in the country are leafless during winter when the sunlight matters the most). Also quite a few varieties of trees do not form a crown at all and grow straight, viz. *Cupressus* variety of kikar (*Acacia nilotica*) and black poplar *Populus nigra;* that birds do use trees as resting places for eating grain but they also pick up a large number of harmful insects. For instance, there is a ban on shooting of starlings for this very reason. And why we cannot emulate the Chinese way of finishing the sparrows.

The villager has to be explained that planting of trees on his land is a highly renumerative proposition. Farmers of Change Manga have grown turmeric in between poplar trees and have earned an annual profit of Rs. 40 000 per hectare. Farmers of NWFP are selling 5-year old poplar trees grown on the boundaries of their fields for Rs. 100 each and a eucalyptus tree of 3 years growth without irrigation fetching Rs. 30. The Sind farmers have since long practised the system of 'Hurries" involving planting of babul (*Acacia nilotica*) for reclamation of salt infested land and selling the wood as fuel and pitprops. Planting of mulberry has an added advantage as the leaves provide food material for the silk worm. With leaves botained from 25 mature trees it is possible to rear one ounce of the silk seed giving a net income of about Rs. 1 000 over a span of just 60 days. Grafted ber (*Zizyphus mauritiana*) and shahtoot (*Morus alba*) can bring him handsome revenue. So is the case with mango, myrobalan, walnut and persimon. Even if the trees do have some shade effect on the agriculture crop, the return from fruit and wood compensate him handsomely.

RESULTS OF STUDIES CONDUCTED

It would be worthwhile to review the effect of trees on the yield of agricultural crops. Several studies have been conducted.

Sheikh and Haque (1978) conducted a study to find out how far the shade of individual trees growing in the agricultural fields effect the yield of crops. Trees of *Acacia nilotica* (Babul) and *Dalbergia sissoo* (shisham) were selected for this purpose in two localities. It was found that the trees did have a deleterious effect on the crop yield, the maximum loss being within 2 metre radius of the tree and also that the yields were poorer from the portions of the crop falling on the northern side of the tree.

Kermani (1980) published the results of large scale experiments laid out to determine the best combination of agro-forestry crops in the irrigated areas in the province of Sind. The tree species, 3 year old were *Acacia nilotica* and *Eucalyptus camaldulensis* while the crops under test were cotton, wheat, sesamum and sorghum. It was found that yield of agricultural crops was higher when grown with *Eucalyptus camaldulensis* than yield under *Acacia nilotica*. The author indicated that Eucalyptus-cotton combination was the best for higher yields of wood as well as monetary returns from agricultural crops.

Sheikh and Khattak (1980) reported the effect of forest trees on the yield of agricultural crops grown as interculture. *Populus deltoides. Eucalyptus citriodora, Dalbergia sissoo* and *Salmalia malabarica* were planted at 4.3 x 4.3 metres. The area was sown to wheat. It was found that yield under *Dalbergia sissoo* was significantly higher (1 996 kg per hectare) as compared to other species. The yield from control plots was 2 000 kg per hectare on the average.

The latest studies have been conducted by Sheikh (1984) in the shelterbelts laid out in the provinces of Sind and the Punjab. The site in Sind is a private land near Mirpurkhas where 650 m long shelterbelts of Eucalyptus have been planted 200 metres apart to assess its effect on different crops such as cotton and wheat. It is indicated that trees had depressed the yields on either side of the belt, the more adverse effect being on the northern side of the trees. The positive effect of the shelterbelt started appearing about 2.5 times of the tree height and gradually increased attaining peak increase over control at 6 to 9 times distance. The average grain yield of all sample plots came to 1 660 kg per hectare which was 30 kg more than the crop under control plots. A similar effect was shown on the yield of cotton. In the first thinning the farmer was able to get lot of wood for fuel and poles from the trees belts.

In the agricultural farm near Mianwali where 25 year old shisham trees with 20 metres average height are growing in rows 68 metres apart, it was found that the wheat crop at 3 metre distance from tree row was poorer as compared to the rest of the crop. The average yield was 3 191 kg per hectare, about 417 kg per hectare more than the control. At Sandanwala farm, Harnoli effect of *Populus euramericana cv-I-214,* 20 metre tall trees, was measured on wheat when the sheltered area gave 267 kg per hectare more than the control. In addition, the farmer was able to sell 100 poplar trees at Rs. 135 each fetching him handsome amount.

Sheikh et al., (1983) conducted a study in Changa Manga irrigated plantation to find out the effect of poplars on the yield of wheat. In the study area hybrid poplars had been planted in 1978 at a spacing of 5.5 x 5.5 metres. The data indicated that poplars did not depress grain or straw yields within the rows and that the farmers could safely adopt this practice in the country.

RESEARCH PROGRAMME

A vigorous research programme covering the silvo-agro-pastoral and socio-economic aspects of planting for energy production needs to be launched. This would include the following.

- Effect of various spacing, thinning and pruning regimes on tree form, growth rate and on the yield of agricultural crops and vice versa.
- Effect of fertilizers on the growth of trees and agricultural crops and the pattern of nutrient cycling.
- Assessment of the effect of reduced light on the quantity, quality and composition of agricultural crops.
- The extent of crown and root competition with agricultural crops.
- Effect of different tree species on agricultural yields.
- Evaluation of shade tolerant pasture species.
- Behaviour of fast growing multipurpose trees on the farm lands.
- How far the trees deplete the agricultural lands if at all.
- Comparison of the agro-forestry system with other forms of land use.
- How far the agri-silvi-pastoral system could be successfully introduced in the same unit area to get the maximum benefits out of it.

And above all, study of the human behaviour and reaction to the introduction of community forestry programme. Experiments started by the Pakistan Forest Institute would provide answers to at least some of the questions.

TREE PLANTING MUST GO TO PRIVATE LANDS

No substantial increase in the tree wealth of the country can be expected if planting remains confined to government owned lands only. Unless the farmer joins the forester in this crusade, it would never be possible to achieve the desired targets. The farming community will have to appreciate that the trees are in no way a hurdle in the practice of agriculture but as a matter of fact are essential for the preservation and protection of not only the crops but also the land itself. Tree planting campaigns have, to some extent, succeeded in educating about the value of trees; the people have now to be motivated to take up the integrated use of land. A corps of dedicated foresters, social workers, agronomists etc. is needed who have the energy and patience to reach every nook and corner of the land, win over the confidence of the farmer and make him believe that growing of trees will bring him prosperity. It will take years of sustained labour but the task in spite of its magnitude is well within the grasp of a determined nation.

Fortunately a change is visible in the attitude of the farming community and they are coming forward in large numbers not only with a demand for conventional trees but also for improved varieties of local and exotic tree species. With, sufficient monetary benefits in view, with a little more persuation, guidance and motivation, there is every hope that the people would make the expected contribution to make Pakistan greener.

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PART VI
SOIL TAXONOMY AND AGROTECHNOLOGY TRANSFER

- Agrotechnology Transfer Based on Soil Taxonomy — F.H. Beinroth
- A System- Based Approach to Agrotechnology Transfer — F.H. Beinroth
- Soil Capability Assessment Network (SCAN)-History and Concepts — Aurangzeb Khan
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AGROTECHNOLOGY TRANSFER BASED ON SOIL TAXONOMY THE BENCHMARK SOILS PROJECT EXPERIENCE

F. H. BEINROTH*

GENERAL

Uehara (1981) defined agrotechnology transfer as the taking of an agricultural innovation from its site of origin to a new location where it is likely to succeed. Transfers of both the mechanical and biological components of agricultural technology can occur through (i) material transfer and (ii) knowledge transfer. While material transfer, such as seed or machinery, are rather straightforward, knowledge transfers are much more complex and difficult as they involve the conveyance of scientific information about how to employ inputs, such as germplasm, fertilizer, tillage implements, or irrigation water, to produce optimal yields (Beinroth et al., 1980). For agrotechnology transfer to succeed, the transferred technology must be compatible with the characteristics of the farmer's land and with the labor, capital and management resources of the farmer. Agrotechnology appropriate for transfer should thus be (1) technically sound, (2) environmentally safe, (3) economically feasible, (4) socially desirable, and (5) culturally acceptable.

One way of transferring agricultural knowledge and experience is by analogy. In this approach soil and climate classifications are used to identify analogous areas. The assumptions are (i) that the taxa of the classifications stratify the environment with sufficient precision to allow successful transfers, and (ii) that all occurrences of a defined class have similar production potentials and responses to management. While general, multi-attribute schemes of agroclimatic classification are of limited value in the analogue transfer of technology (Burgos, 1968), soil classifications have been more successful. The U.S. system, Soil Taxonomy (Soil Survey Staff, 1975), is particularly suited for this purpose as it incorporates both soil and climate and thus stratifies the agro-environment into distinct niches of agroproduction (Beinroth, 1984).

Transfer by analogy is also implied in the concept of benchmark soils advanced by C.E. Kellogg (1961). As currently defined, a benchmark soil is an important soil selected for intensive study and complete characterization because it occupies a key interpretative position in the classification and/or covers large areas (Miller and Nichols, 1980). A benchmark soil represents a reference site from which research results can be extrapolated to other areas with similar characteristics.

Soil scientists have long assumed that soil classification, in conjunction with soil surveys, provides an adequate basis for the transfer of pedologic knowledge and agronomic experience. Many

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authoritative statements can be found in the literature which allude to this conjecture. In the foreword to the FAO-UNESCO Soil Map of the World (FAO, 1974), for example, it is stated that one of the objectives of the map is "to supply a scientific basis for the transfer of experience between areas with similar environments ..... (because) ..... with the tremendous amount of knowledge and experience gained in the management and development of different soils throughout the world, the hardship perpetuated in some areas by methods of trial and error is no longer justified". G.D. Smith (1965) pointed out that "we make the basic assumption that experience with a particular kind of soil in one place can be applied to that particular kind of soil wherever it exists if consideration is taken of any climatic differences".

The stated assumptions and the transfer hypothesis implied therein were subjected to a thorough scientific test in the Benchmark Soils Project of the Universities of Hawaii and Puerto Rico whose primary objective was to test the transferability of agroproduction technology on the basis of soil families as defined in Soil Taxonomy.

THE BENCHMARK SOILS PROJECT

The Benchmark Soils Project (BSP) was established in 1974 to demonstrate the viability of a soil classification based approach to the transfer of agroproduction technology in the tropics as a means to increase the efficiency of agronomic research through its wide geographical diffusion and thus to accelerate the pace of agricultural development in the developing countries.

In the first comprehensive study of its kind, the Benchmark Soils Project ventured to scientifically establish the transferability of agrotechnology, particularly soil and crop management experience. Central to this effort is the bacnhmark soils concept and the soil family as defined in the US system of soil classification, Soil Taxonomy. The intent of the soil family is to group together soils that are relatively homogenous in properties important to plant growth. Consequently, comparable phases of all soils of a family should have a common and predictable response to management practices, correlative input-output characteristics, and similar crop production potential. The transfer hypothesis underlying the BSP is derived from these principles and is that empirical agroproduction experience gained with a soil of a particular family can be transferred and extrapolated to all other comparable members of that family, irrespective of their geographic occurrence.

The general aim of the project was to experimentally and statistically validate this hypothesis. The primary research objectives were:

- To demonstate that soil management and crop production knowledge can be transferred among tropical countries on the basis of soil families as defined in Soil Taxonomy, and
- To establish that the behaviour of tropical soils and their potential for food production under various levels of management inputs can be predicted from soil taxonomic units.

The basic research strategy of the project was to conduct a series of identical experiments in a network of soils belonging to the same family, monitor crop performance and weather conditions, and statistically compare response to management and yields. The experiments were highly controlled, drip-irrigated fertility trials with phosphorus and nitrogen as variables and maize as the test crop. They

were specifically designed to generate the data based for the statistical analyses. A total of 157 of these so-called transfer experiments were conducted alongwith 60 pragmatic soil and crop management experiments and variety trials.

Three contrastingly different soil families representing three distinct agroclimatic zones of the tropics were chosen for experimentation: the clayey, kaolinitic, isohyperthermic Tropeptic Eutrustox; the thixotropic, isothermic Hydric Dystrandepts; and the clayey, kaolinitic, isohyperthermic Typic Paleudults.

The Project established a research network that comprised 23 experiment sites in Brazil, Cameroon, Hawaii, Indonesia, the Philippines, and Puerto Rico. Collaborating with the project were the Empresa de Pesquisa Agropecuaria de Minas Gerais (EPAMIG) in Brazil, the General Delegation of Scientific and Technical Research (DGRST) in Cameroon, the Philippine Council for Agriculture and Resources Research and Development (PCARRD) in the Philippines, and the Soil Research Institute (SRI) in Indonesia.

The field data of the transfer experiments were statistically evaluated with three different techniques developed under the auspices of the BSP. They were the P-statistic, the confidence interval procedure, and a graphical method (Benchmark Soils Project, 1982a, Cady et al., 1982). The results with the confidence interval procedure and the graphical method provided strong positive evidence for transferability. The results with the P-statistic were less conclusive but not negative. The graphical method was particularly illustrative as it allowed an instant visual appraisal of the transferability of management practices. The comparison of predicted and observed response surfaces showed that, if certain site variables are considered, fertilizer response at a new site can be predicted on the basis of experiment conducted at other sites with the same soil family essentially as well as by an experiment conducted at the new site.

On balance, the statistical studies yielded a qualified validation of the postulated transfer hypothesis and, by implication, of the concepts of benchmark soils and the soil family. In view of the complexity of the conjecture under study and considering the difficulties encountered in its experimental and mathematical corroboration, these results are very reassuring.

Moreover, the agronomic results of the project demonstrate that soil families as defined in Soil Taxonomy indeed provide groupings of soils that have relative homogeneity in properties important to plant growth, common and predictable responses to management practices, and similar crop production potential, and thus startify the agroenvironment into distinct niches of agroproduction. This is evidenced for example, by the very similar maximum yields obtained in Puerto Rico and Brazil with comparable inputs, the absence of response to potassium at both locations, and the fact that one specific variety of maize performed best in the two countries. Even a casual inter-family comparison of data obtained shows that the three soil families are characterized by distinctly different patterns of soil behavior. The P-isotherms for instance, which are in large measure conditioned by soil family characteristics, are markedly different for the three soil families but very similar for all soils of the same family.

The highest mean maize yields were about 9 000 kg/ha for the Eutrustox in Puerto Rico and Brazil, 7 000 kg/ha for the Hydrandepts and 6 700 kg/ha for the Paleudults. Although these yields are not vastly different, the fertilizer inputs necessary to achieve them difinitely are. Whereas the Eutrustox required only about 40 kg P/ha to obtain these yields, the Dystrandepts needed 150 kg/ha and the Paleudults 100 kg/ha. Furthermore, the Dystrandepts and Paleudults required substantial applications of potassium and lime which were not needed for the Eutrustox. The soil management technology developed for Eutrustox is therefore, clearly not applicable to either Dystrandepts or Paleudults, reflecting the soil-specificity of agrotechnology transfer as implied in the transfer hypothesis.

The results of the Benchmark Soils Project (1982a, 1982b) show that transfer of soil management practices can be successfully achieved and yields can be predicted with considerable accuracy on the basis of Soil Taxonomy families, if additional site factors are taken into account. By implication, this validates the concept of the soil family as postulated in Soil Taxonomy and the principle of benchmark soils. A comparison of the results obtained in soil fertility and management experiments at the various sites of the project network also shows that Soil Taxonomy stratifies the agroenvironment into distinct niches of agroproduction and allows qualitative predictions of soil potential and management requirements. In conjunction with soil surveys, Soil Taxonomy thus defines the geographic and pedologic applicability of agronomic experience.

At the same time, the project results allude to the limitations of analogue transfer of agrotechnology based only on Soil Taxonomy taxa. Soil Taxonomy constitutes an effective vehicle for agrotechnology transfer in cases where a high degree of specificity is not needed, such as in large-scale land use planning. Transfer of agrotechnology to specific farm situations, however, requires a more holistic approach that sould be based on systems analysis and employ computer simulation techniques to model the soil-weather-crop-management continuum.

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A SYSTEMS-BASED APPROACH TO AGROTECHNOLOGY TRANSFER

F. H. BEINROTH*

Transfer of agrotechnology has evolved along an evolutionary path that led from trial and error and statistical methods to transfer by analogy and, more recently, systems analysis and simulation. The disadvantage of transfer by trial and error is that it is attained slowly and at high social cost. Statistical techniques, mainly analysis of variance and multiple regression, lend themselves more to interpolations than extrapolations. Transfer by analogy has traditionally been advocated by pedologists on the rationale that soil classification stratifies the agroenvironment in sufficient detail to facilitate transference. This assumption has been shown to be valid for instance where the emphasis is on broad assessments rather than specific predictions and prescriptions. Information, however, can only be transferred from the locations where it has been generated, leading to the need for ever more research sites. Simulation models have long been recognized as the conceptually best approach to agrotechnology transfer, but various constraints have prevented their use in the past. Advances in crop modeling, coupled with advances in computer technology, now make that approach entirely feasible.

As crop performance results from the interaction of a multitude of soil, plant, climate and management factors, the development and evaluation of crop simulation models requires data that monitor the whole genotype-environment management system. Cultivar-specific "minimum data sets" have, therefore, been devised which identify the soil, atmosphere, plant, and management parameters needed for modeling. Such data sets should be collected at sites that cover the complete spectrum of environmental conditions where the crop will grow, including sites with severe stress. The effective utilization of these data sets require a functional data base management system whose output is compatible with the input requirements of the models.

The biophysical processes of agricultural systems can be described mathematically and hence simulated, but the socio-economic and other judgemental aspects of the system defy such mechanistical treatment and mathematical expression. However, the techniques of knowledge engineering known as expert systems now allow to address these aspects, either in combination with simulation models or independently. In additon, stochastic methodologies are needed to deal effectively with the systematic and random variability, both spatial and temporal, that characterizes the soil landscape.

Systems-based agrotechnology transfer thus integrates three main elements: data bases, simulation model and expert systems. The International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT) exemplifies this approach. Central to this project is a relational data base manage-

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ment system and a generic crop simulation model that is user-oriented, of universal applicability, and can be executed on microcomputers with a minimum of input data.

IBSNAT is an outgrowth of the Benchmark Soil Project of the Universities of Hawaii and Puerto Rico. It was implemented in 1982 and is funded, in part, by the U.S. Agency for International Development under a contract with the University of Hawaii. IBSNAT is a collaborative endeavor that consolidates a group of developing, validating and utilizing a scientific methodology for the effective transfer of agrotechnology among and within countries of the lower latitudes.

IBSNAT's goal is to devise ways and means that will enable countries in the tropics and subtropics lacking resources and institutional capacity to meet their agricultural development needs through technology transfer. Accordingly, the project's objectives are to:

- accelerate the diffusion of agricultural innovations from their sites of origin to new locations;
- increase the success rate of technology transfer to farmers' fields; and
- assess the long-term effect of agricultural practices on the environment.

IBSNAT aims to achieve its objectives by:

- establishing a network of collaborating national, regional, and international agricultural research centres to serve as sources and recipients of agrotechnology;
- identifying the soil, crop, weather and management data needed to successfully transfer agrotechnology;
- testing soil, crop, weather and management simulation models in a network of experimental sites;
- using systems analyses, simulation models and expert systems to predict the performance of crops and management systems; and
- training collaborators in the use of systems analysis and simulation and management models for agrotechnology transfer.

The realization that in successful transfer the characteristics and requirements of cultivars must be compatible with the environmental conditions at the transfer site implies that quantitative knowledge of the genotype-environment-management interactions must be generated and incorporated into the crop performance simulation models. In the course of field experimentation it is thus essential to collect balance sets of soil-crop-weather-management data that monitor the whole system and facilitate the identification of "minimum data sets" which are a pre-requisite for transfers via simulation techniques.

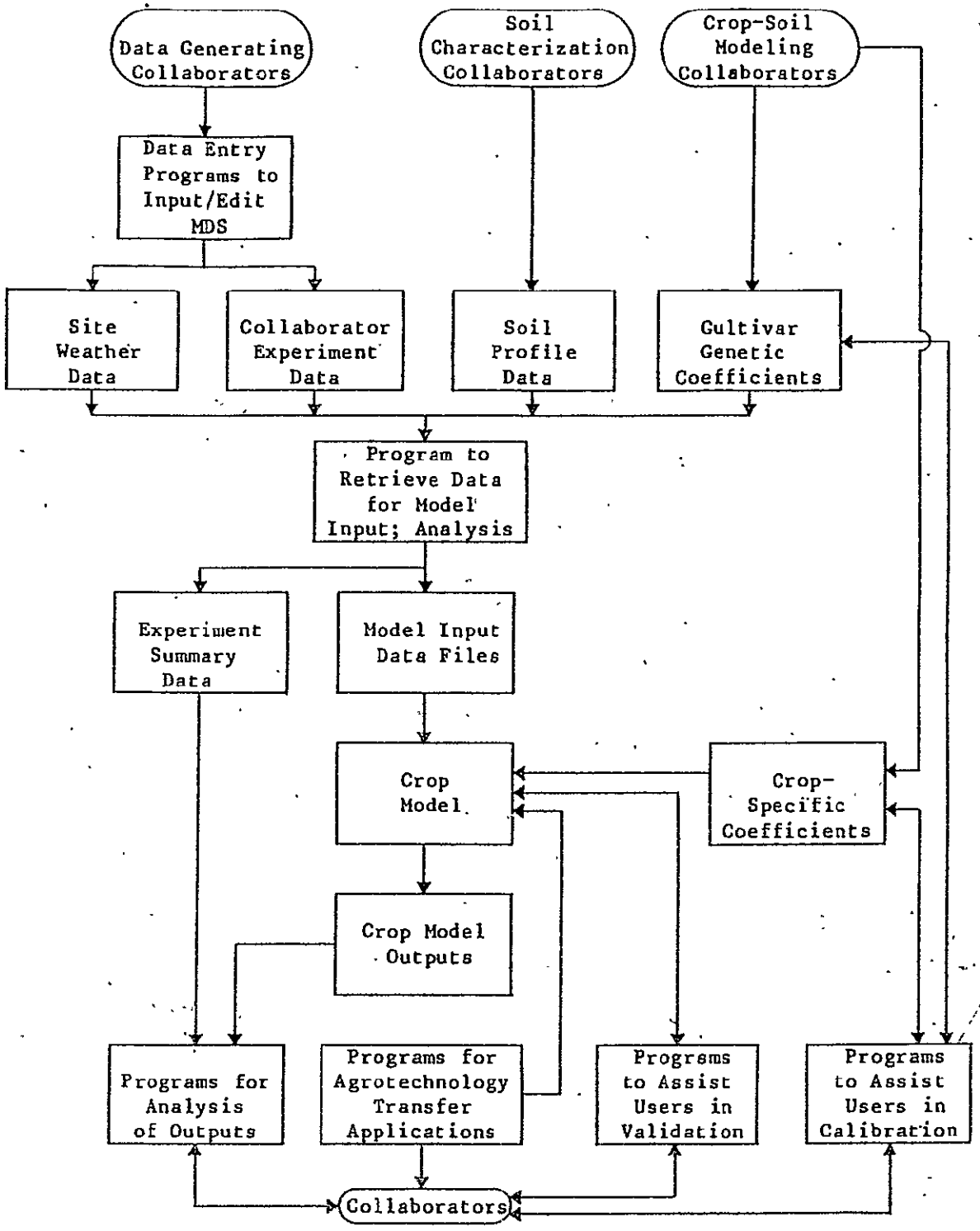
The crops for which simulation models are being developed by IBSNAT include four cereals (maize, rice, sorghum, wheat), three grain legumes (beans, groundnuts, soybeans) and three root crops (aroids, cassava, potatoe). Guidelines for the experiment designs and detailed procedures for data collection have been completed and circulated to IBSNAT collaborators. Field research is currently in progress at 30 benchmark sites in 16 developing countries including Pakistan.

The maize and wheat models have been subjected to global testing and were found to predict crop performance with reasonable accuracy. The soybean model is operational and ready for worldwide validation; the seven other models are in various stages of development.

The project has further designed a Data Base Management System for storing and analysing the data sets collected in the network. The system employs commercially available software (dBase III by Ashton-Tate) and is characterized by ease of use, flexibility, precision, relatability, and data independence. Moreover, the system's outputs are identical to the model inputs, enabling all IBSNAT crop models to have access to the data from a single data base management system.

IBSNAT is currently developing a computerized Decision Support System for Agrotechnology Transfer (DSSAT) that attempts to provide users with convenient and easy to use procedures for a systematic evaluation of the performance of agrotechnology at new locations. In order to be able to generate the desired outputs, the DSSAT incorporates and links the crop models, data files, the data base management system, utility programs, and, eventually, expert systems. The DSSAT will consist of data files, programs for entering and retrieving data for analysis and model inputs, programe to assist users in validation and calibration of the crop models, and programs for evaluation agrotechnological practices for various sites. The programs for entering and editing data sets are now available. Other components of the DSSAT are currently in various stages of design and development. A flow chart of the DSSAT is presented in the following Figure.

Finally, IBSNAT fosters the establishment of regional networks that employ systems-based methods for the transfer of agrotechnology. IBSNAT staff assisted scientists from the ASEAN countries in developing a proposal which is now under consideration for funding. Similarly, the project plans to collaborate with scientists from other group of countries in an effort to stimulate the creation of networks in various regions of the tropical and subtropical world.



IBSNAT Decision Support System for Agrotechnology Transfer (DSSAT)

SOIL CAPABILITY ASSESSMENT NETWORK: HISTORY AND CONCEPTS

AURANGZEB KHAN*

INTRODUCTION

Soil variation has not been properly taken into account in agronomic research, except a few soil parameters like soil texture, pH and organic matter. The research findings had limited applications in local areas and often failed to produce the desired results when applied in other areas having different soils. This problem was especially noticed in countries like U.S.A., Canada, USSR, Australia, etc. in which great variations in soils occurred. Emphasis was placed on improving the knowledge of soils, and then soil science was developed as a separate science, with a new concept of soil as a three dimensional natural body having specific chemical, physical and hydrological properties. The soil variations within a given area were shown on soil maps through soil surveys.

During the last three decades great advances have been made in both agronomy and soil science. The stage has been reached when the developments in these two sciences need to be integrated to make further progress in crop production technology, especially to make it sitespecific and to transfer it from one area to others and one country to other countries.

Some groups of U.S. scientists have developed and are testing a hypothesis that crop production technology developed on a soil family can be transferred to areas of the same soil whether occurring in one country or other countries. Of special interest is the Benchmark Soils Project (BSP) of the Hawaii University, which is aimed at developing soil fertility management practices for selected soil families with respect to certain crops. A scientist, Dr. Saleem Ahmed of the Hawaii University came to Pakistan under the National Talent Pool Scheme, Government of Pakistan, at the request of Pakistan Agricultural Research Council. Upon his recommendation, the Soil Capability Assessment Network (SCAN) Project was formulated by the Pakistan Agricultural Research Council in collaboration with the Department of Soil Survey of Pakistan with the main aim of improving the quality of soil fertility and agronomic research through the use of soil survey information.

The basic information on soils is available in the Department of Soil Survey of Pakistan who have carried out a systematic reconnaissance soil survey of more than 625 000 sq. km., covering whole of the agriculturally important area of the country, and established 500 soil series, the basic units of soil classification.

The SCAN Project was started in February 1982 at two locations, in Sheikhupura and Attock districts of the Punjab Province. Considering the encoursaging results of two years experiments, the

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Pakistan Agricultural Research Council made provision of funds to start the SCAN research programme in Peshawar vale in 1984. It will be progressively extended to some sites in Sind and Baluchistan Provinces.

THE PROJECT

The Soil Capability Assessment Network (SCAN) Project is aimed at testing the hypothesis that all soils belonging to one soil family have the same management requirements for agricultural production. Initially, it is planned to investigate and compare the fertilizer response of the main crops in selected soil familes. Other factors of soil management would be included later to develop appropriate package of soil management technology for the important soil families of the country.

Field experiments are conducted on farmer's fields, using appropriate experimental design to produce data needed to correlate soil, climate and other site characteristics with crop performance under various levels of fertilizers and other soil management practices. The experiments are replicated and the site is also duplicated. Very few agronomic trials are conducted in this manner. This is similar to the Benchmark Soils Project which repeated the same experiment on the same family but in different parts of the world; in SCAN the same experiment is performed on the same family but in different locations.

The crops included in the studies are: wheat, rice, maize, cotton and sugarcane under irrigation; and wheat, maize, millets, and groundnut under rainfed cultivation.

At present, experiments on wheat and maize crops are being conducted on five soil families, three in the irrigated and two in the rainfed area. The locations both of existing and proposed research sites are shown on the attached map.

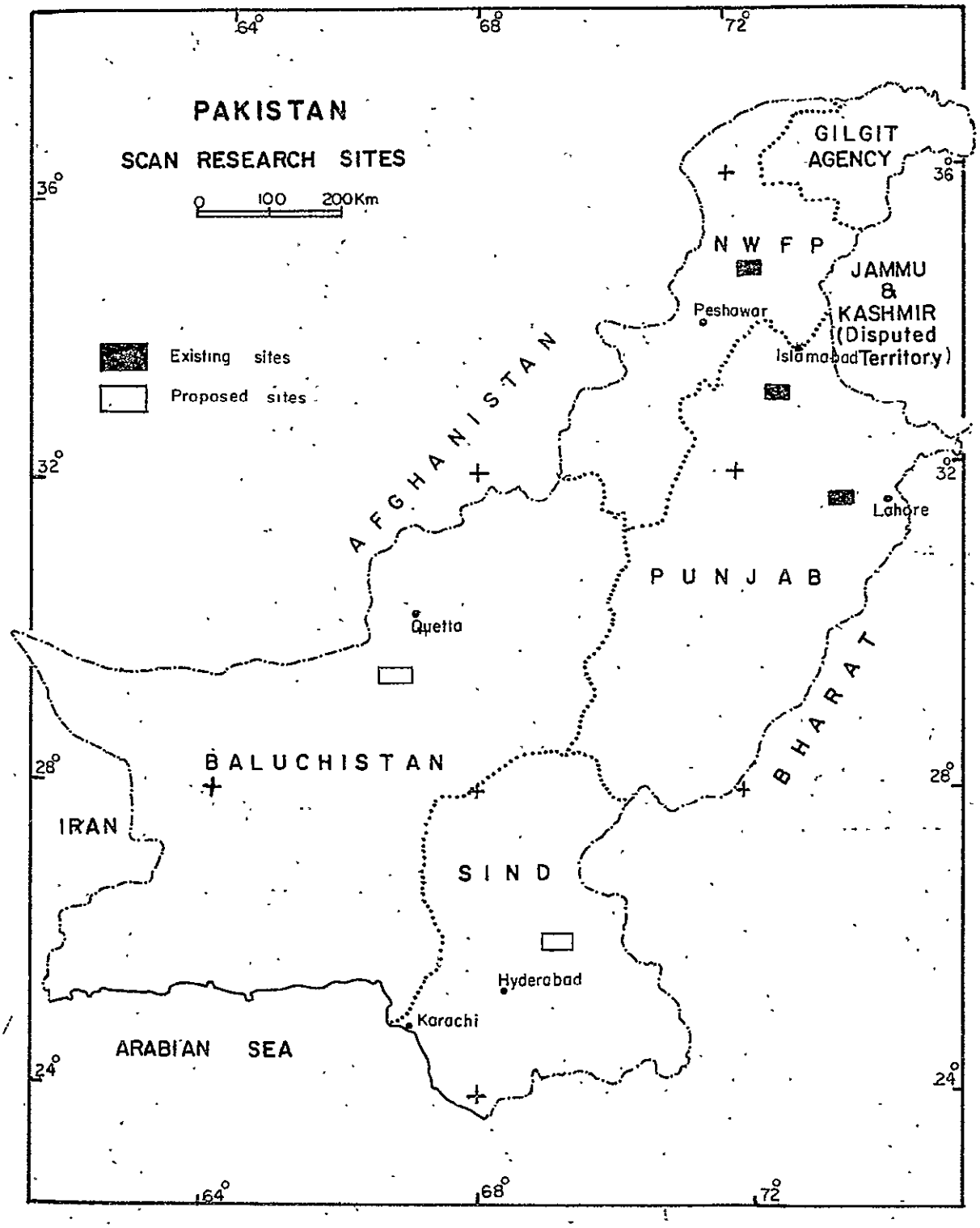
PROJECT RATIONALE

It is assumed that the soil management requirements of all soils within a soil family are the same. So it is enough to concentrate our research activities on a few sites representing the important soil families and then apply the findings to other areas of these soils, using soil maps to demarcate the extent of the given soils. This approach helps to find out the crop production potential of various soils under different levels of management defined in terms of soil management practices and inputs. Using the experimental data and soil survey information including soil maps, it would be possible to develop—agro-production models in order to optimize the utilization of our land resource and the costly and limited inputs.

PROJECT OBJECTIVES

The main objectives of the project are:

- To group soil series into soil families and select the important ones for research on soil management for crop production.
- To undertake analysis of soil samples to provide additional data required for the classification of soils into soil families. Of special importance is the determination of mineralogical composition of sand and clay fractions of important soil series.


PAKISTAN
SCAN RESEARCH SITES
0 100 200Km
Existing sites
Proposed sites
64°
68°
72°
36°
32°
28°
24°
GILGIT AGENCY
N W F P
JAMMU & KASHMIR (Disputed Territory)
Peshawar
Islamabad
AFGHANISTAN
Lahore
PUNJAB
Quetta
BHARAT
BALUCHISTAN
IRAN
SIND
Hyderabad
Karachi
ARABIAN SEA

- To develop fertilizer (NPK) yield response curves for major crops in selected soil families in different agroecological zones of the country.
- To develop a package of soil management practices for crop production for the main soil families of the country.
- To establish coordination in research amongst various agencies engaged in soil survey, soil fertility and crop production research.
- Dissemination of research findings amongst agricultural research workers and farmers.

COLLABORATION WITH FOREIGN INSTITUTIONS

Work similar to SCAN is in progress in other parts of the world, particularly under the Benchmark Soils Project (BSP) of the Universities of Hawaii and Puerto Rico and the new Project of USAID called the International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT). The IBSNAT coordinates site-specific soil management research activities in the tropics and sub-tropics. The main premise of IBSNAT is that agrotechnology transfer can be achieved by correlating the performance of crop cultivars and crop production management practices with site characteristics defined in terms of soil and climatic perameters.

To share the experience and research findings the SCAN Project has developed contacts with the scientists working on the above projects. This arrangement has led to a highly beneficial exchange programme. Dr. Hari Eswaran Coordinator of the IBSNAT and SMSS projects visited Pakistan in January 1984. On his suggestion the SCAN Project was linked with the IBSNAT through an agreement signed by IBSNAT, Pakistan Agricultural Research Council and Soil Survey of Pakistan. Dr. Eswaran's visit also helped materialize this forum.

PROGRESS OF WORK

The progress of work and achievemnts in 1982-83 and 1983-84 are as under:

Classification of soils into soil families

The soil classification category that forms the basis of the SCAN research work is the soil family, as defined in the Soil Taxonomy (USDA, 1975).

The Soil Survery of Pakistan has identified about 500 soil series, based mainly on reconnaissance soil surveys. This number will more than triple when we will undertake detailed surveys. These 500 soil series were tentatively grouped into about 100 soil families.

Soil families selected for experimentation

After considering the area occupied by each soil family, it was found that twenty three soil families are very extensive, covering about 80 per cent of the agriculturally important land. A systematic study of these twenty three soil families is essential to find the fertilizer requirements of individual crops and crop rotations and to investigate special soil management problems. Research work has been initiated on five soil families, three in the irrigated and two in the rainfed area. The main features of the soil families selected for conducting experiments are presented in the annexure 1.

Field Experiments

Field experiments on maize and wheat crops were conducted on five soil families (Annexure 1), three in irrigated and two in rainfed area. Herein, for simplicity, only the fertilizer trial on wheat 1982-83 and 1983-84 on the three irrigated soil families are discussed.

Soil families: Three soil families namely Rasulpur, Hafizabad and Miranpur in Sheikhupura district have been selected for the experiments.

Cultivar: Wheat variety Punjab 81, with the yield potential about 7 000 kg/ha and sowing time Ist November to 10th December.

Seed rate: 40 Kg per ha for all plots

Fertilizer treatments: Sixteen treatments with varied levels of N and P.

Fertilizer application rates (kg/ha)

P_2O_5				N			
P_1	P_2	P_3	P_4	N_1	N_2	N_3	N_4
0	50	100	150	0	75	150	225

Experimental design: Serial Randomized Complete Block design with three replicates on each site, and the site is duplicated

Plot size: 8 x 6 meters

Harvest area: 1 m^2 from three random locations per plot

Parameters kept constant:
- Basal dose of K at 50 kg/ha
- Quantity and quality of irrigation water
- Fallow field i.e. no crop was grown in the previous season
- Time of sowing
- Crop variety
- Climatic conditions
- Tillage operations for seed bed preparation
- Insecticides and pesticides

Processing of yield data

The yield data was processed by statistical methods to infer:

- difference between the soil families
- the soil family giving the highest crop yield
- the best fertilizer treatment for each soil family

MAIN FINDINGS

Based on statistical analysis of wheat yield data, the main findings are given below.

Difference between the soil families

Difference between three soil families is highly significant as shown by a summary of yield data given below:

Soil family	Average wheat yield Kg/ha (1982-83)	(1983-84)
Rasulpur	3 797	3 256
Hafizabad	4 472	5 043
Miranpur	3 462	–

Yield potential of soil families

The maximum yield of wheat was obtained with the treatment N225 P150 in all the three soils. The difference between soils was however, highly significant, as shown by the summary data given below:

Soil family	Wheat yield Kg/ha (1982-83, wet year) Control Plots	Maximum Yield	(1983-84, dry year) Control Plots	Maximum Yield
Rasulpur	1 773	5 465	1 900	4 905
Hafizabad	3 455	5 068	3 856	6 700
Miranpur	2 482	4 041	–	–

The control plots give the capacity of the soil which is the performance at zero amelioration. The maximum is an estimate of the potential of the soil which is the performance with best management.

Optimum fertilizer dose for each soil family

The optimum fertilizer dose for dry and wet years are different. The wet season (1982-83) optimum fertilizer treatments for the three soil families are given below:

Rasulpur	N 225 P50	5 225 Kg/ha
Hafizabad	N 75 P50	4 598 "
Miranpur	N 75 P50	3 605 "

The statistical analysis of the experimental data of dry year (1983-84) shows that optimum fertilizer treatment for the Rasulpur and Hafizabad soil families is the same. The yield data are as under:

Soil family	Yield Kg/ha (N225 P150)
Rasulpur	4 905
Hafizabad	6 700

Statistically, it is evident that three soil families have different capacities, potentials and target yields (function of economics of operation). This implies that the basic thesis of SCAN holds, and soil survey information has a rational basis for the discriminatory use of soils. If data on soil capacities, potential and target yields are available for other soil families it becomes possible to relate the agro-production recommendation to the soil instead of having a blanket application all over Pakistan.

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Annexure 1. Soil families selected for SCAN experiments

S. No.	Soil family	Grid location	Benchmark soil series	Main characteristics of soil series
A –	**IRRIGATED**			
1.	Coarse loamy, mixed hyperthermic Ustochreptic Camborthids	31° 45′ N 73° 45′ E	Rasulpur	Nearly level, somewhat excessively drained *sandy loams* with very weak coarse subangular blocky structure; moderately calcareous; average pH 8.2; EC less than 2 mmhos. The series is developed in Late Pleistocene mixed alluvium under semiarid climate.

2.	Coarse loamy, mixed hyperthermic, Ustalfic Haplargids	31°	48′	N	Hafizabad	Level, well drained *loams* with weak coarse subangular blocky structure; moderately calcareous; average pH 8.2; EC less than 2 mmhos. The series is developed in Late Pleistocene mixed alluvium under semiarid climate.
		73°	49′	E		
3.	Fine, mixed, hyperthermic, Ustertic Camborthids	31°	53′	N	Miranpur	Nearly level, seasonally imperfectly drained clays and *silty clays* with weak coars subangular blocky structure; noncalcareous; average pH 8.0; EC less than 2 mmhos. The soil is developed in Late Pleistocene and Early Holocene mixed alluvium under semiarid climate.
		73°	47′	E		
B –	RAINFED					
4.	Fine silty, mixed hyperthermic, Udic Haplustalfs	33°	34′	N	Guliana	Nearly level, well drained *silty clay loams* with moderate medium angular and subangular blocky structure; noncalcareous; average pH 8.0; EC less than 2 mmhos. The series is developed in Late Pleistocene loess under subhumid climate.
		72°	40′	E		
5.	Coarse silty, mixed hyperthermic, Typic Ustochrepts	33°	36′	N	Missa	Sloping, excessively drained *silt loams* with weak structure; moderately calcareous; average pH 8.0; EC less than 2 mmhos. The series is developed in Late Pleistocene loess on Subrecent erosional surfaces under subhumid climate.
		72°	40′	E		

SOIL CAPABILITY ASSESSMENT NETWORK (SCAN) RESULTS AND ACHIEVEMENTS

M. I. NIZAMI*

SUMMARY

The main objective of the project is to test the concept that package of soil technology developed on a soil family can be applied to the soils belonging to the same soil family elsewhere; in the country. To test the concept five soil families were tested three in the irrigated tract and two in the rainfed area. The main package for each soil family is given below:

Rasulpur series: Coarse loamy, mixed, hyperthermic, Ustochreptic Camborthids

- *Optimum fertilizer dose for wheat N225 P50*
- *Optimum fertilizer dose for maize N270 P0*
- *No hoeing is needed*
- *Deep ploughing may be avoided*

Hafizabad series: Coarse loamy, mixed, hyperthermic, Ustalfic Haplargids

- *Optimum fertilizer doze for wheat N75 P50*
- *No heoing is needed*
- *Deep ploughing be avoided*

Miranpur series: Fine, mixed, hyperthermic, Ustertic Camborthids

- *Optimum fertilizer doze for wheat N75 P50*
- *Maize crop is not recommended*
- *Crust formation is serious problem, hoeing be done to avoid reduction in yield.*

Guliana series: Fine silty, mixed, hyperthermic, Udic Haplustalfs

- *Optimum fertilizer doze for wheat is N150 P50*
- *Optimum fertilizer doze for maize N150 P0*
- *Chiseling upto 45 cm after some interval be adopted. No significance increase by chiselling upto 30 cm*
- *For moisture conservation deep ploughing be adopted.*

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- *Sowing of maize crop on ridges be adopted*
- *Crust formation is a serious problem. Hoeing must be done to break crust*
- *Weeds being serious problem, weeding be done by manual labour*

Missa series: Coarse silty, mixed, hyperthermic, Typic Ustochrepts

- *Optimum fertilizer doze for wheat N150 P100*
- *Optimum fertilizer doze for maize N150 P50*
- *There is need to do deep chiselling after some interval for greater yield*
- *For moisture conservation deep ploughing be adopted*
- *Weeding by manual labour be done. Weeds reduce yield about 1/4th.*
- *Sowing of maize crop on broad bed be adopted*
- *Crust formation is not problematic, therefore, hoeing may not be done*

The fertilizer packages developed for the above mentioned soil families were also tested at other places. The results show that optimum fertilizer dozes of the respective soil families are the same.

It can be concluded that soil family should be taken as a base for soil fertility, soil management research and agrotechnology transfer.

INTRODUCTION

Agrotechnology transfer may be envisaged as a two component system; a horizontal component deals with exchange of information between scientists either in a country or between countries and a vertical component is concerned with the transfer of technology generated by experimental stations to farmers. Agro-technology transfer is also defined as the taking of technology from a site to where it is likely to succeed. The basic tenet of this approach is that on-site research is reduced to adaptive testing thus reducing duplication and cost of research.

Some groups of U.S. Scientists have developed and are testing a concept that crop production technology developed on a soil family can be transferred to areas of the same soil whether occurring in one country or other countries. Of special interest is the work done by Benchmark Soils Project (BSP) of the Hawaii University, International Benchmark Site Network for Agrotechnology Transfer (IBSNAT) and Soil Management Support Services (SMSS) of USDA.

The SCAN Project was started in February, 1982, on similar pattern in two locations, Sheikhupura district and Attock district through a collaboration between the Department of Soil Survey of Pakistan and Pakistan Agricultural Research Council. It has been extended in 1984 to N.W.F.P and will be progressively extended to some sites in Sind. and Baluchistan with the collaboration of concerned research institutions. Because of the limitations of space, it is not possible to present and discuss here data generated and results achieved during three years, therefore, only a few examples are cited in the text.

OBJECTIVES

To test the concept that package of soil technology developed on a soil family can be applied to soils belonging to the same soil family elsewhere in the country.

THRUSTS

- Provide analytical data especially pertaining to clay mineralogy for refining the existing soil classification undertaken by Soil Survey of Pakistan upto sub-group level and to further classify the soils at soil family level
- Refine the land capability classification
- Refine the crop suitability classification
- Develop a package of soil management technology for soil family level to increase the production of important crops
- Establish project related coordination in research work amongst various agencies engaged in doing relevant research

In order to achieve the objective, experiments were conducted to develop package of technology i.e. optimum fertilizer doze, effect of different tillage practices on the yeild and moisture conservation, effect of hoeing, weeds and methods of sowing on the yield of wheat and maize crops.

FIELD EXPERIMENTS

Field experiments were conducted on wheat and maize crops on five soil families three in irrigated and two in rainfed areas (Table 1).* Fallow farmer fields having the same fertilizer history were selected at Mangial (Missa series), Fatehjang (Guliana series) and around Chuharkana (Rasulpur, Hafizabad and Miranpur series). Seed bed preparation was done at proper moisture level. Four ploughing and planking operations were done in order to get rid of weeds and ensure proper seedbed for germination. Serial randomized block design with three replicates in irrigated areas and randomized complete block design with four replicates in rainfed areas were adopted. Nitrogen as urea and phosphorus as single super phosphate were applied at the following rates by broadcost method while potash was applied at the rate of 50 kg/ha as a basal doze. In all, there were sixteen fertilizer treatments per replicate including control.

* Table 1. Soil families and representative benchmark soil series (See Annexure 1 of the preceding article)

Fertilizer application rates (kg/ha)

Crop		N				P_2O_5			
		N_1	N_2	N_3	N_4	P_1	P_2	P_3	P_4
Wheat	i. Irrigated	0	75	150	225	0	50	100	150
	ii. Rainfed	0	50	100	150	0	50	100	150
Maize	i. Irrigated	0	90	180	270	0	75	150	225
	ii. Rainfed	0	50	100	150	0	50	100	150

In rainfed area all the fertilizer was applied at the time of sowing while in irrigated area all single super phosphate and½ urea was applied at the time of sowing. The rest of urea was applied at tillering and tasselling stage of wheat and maize respectively.

Wheat variety L-73 in rainfed area and Punjab-81 in irrigated area while corresponding maize varieties Gohar and Akbar were put to trial. The seed rates for wheat and maize were 100 kg/ha and 40 kg/ha respectively. Seed was sown by manually drawn cultivator. Hoeing and weeding was done by manual labour. 'Furadon' was applied at the rate of 20 kg/ha to control stem borer of maize.

Details of Field Experiments

A series of experiments were conducted to see the performance of wheat and maize on aforementioned series under different agronomic practices. The details of experiments are discussed below.

Optimum fertilizer dose for wheat with respect to different soils

The experimental results regarding yield of wheat under various treatments are given in table 2 to 6. Based on the statistical analysis of the yield data and field observations made during crop growth period, main findings are:

Soils series	Yield (kg/ha)			Optimal fertilizer doze (kg/ha)	
	Control	Average	Maximum	N	P_2O_5
Rasulpur	1 773	3 798	5 465	225	50
Hafizabad	3 455	4 472	5 068	75	50
Miranpur	2 482	3 462	4 041	75	50
Guliana	1 990	3 730	5 405	150	100
Missa	1 608	2 493	3 084	150	100

The performance of wheat crop has been found to be different on different soil series and difference amongst them is highly significant. Experiments conducted on same soils at other places indicate the same fertilizer doze conforming thereby that the package of technology developed for a soil family at one place can be applied to same soil family elsewhere in the country.

Table 2. Rasulpur series. Wheat yield (kg/ha) under various fertilizer tretments.

N225	N225	N225	N150	N150	N225	N150	N75	N75	N75	N150	N75	N0	N0	N0	N0
P150	P50	P100	P100	P150	P0	P50	P100	P50	P150	P0	P0	P100	P150	P0	P50
T16	T8	T12	T11	T15	T4	T7	T10	T6	T14	T3	T2	T9	T13	T1	T5
5465	5225	5161	4865	4830	4681	4573	4156	3797	3760	3679	3389	2072	1793	1773	1541

Cd1 at 5% level 541.0 & Cd2 at 1% level: 711.0
Optimum Fertilizer Doze: T8 = N225 P50

Table 3. Hafizabad series. Wheat yield (kg/ha) under various fertilizer treatments

N225	N150	N225	N75	N150	N225	N150	N75	N75.	N225	N150	N75	N0	N0	N0	N0
P150	P100	P50	P100	P50	P100	P150	P150	P50	P0	P0	P0	P100	P150	P50	P0
T16	T11	T8	T10	T7	T12	T15	T14	T6	T4	T3	T2	T9	T13	T5	T1
5068	5049	4910	4888	4841	4785	4775	4623	4598	4349	4330	4261	4068	3776	3775	3455

Cd1 at 5% level : 568.5 & Cd2 at 1% level: 747.1
Optimum Fertilizer Doze : T6 = N75 P50

Table 4. Miranpur series. Wheat yield (kg/ha) under various fertilizer treatments

N225	N225	N225	N150	N150	N75	N225	N150	N150	N75	N75	N75	N0	N0	N0	N0
P150	P100	P0	P100	P150	P150	P50	P0	P50	P50	P100	P0	P50	P150	P0	P100
T16	T12	T4	T11	T15	T14	T8	T3	T7	T6	T10	T2	T5	T13	T1	T9
4041	4015	3892	3876	3842	3789	3763	3668	3661	3605	3385	3382	2982	2853	2482	2158

Table 5. Guliana series —Wheat yield (kg/ha) under various fertilizer treatments

N100	N150	N150	N150	N50	N100	N50	N100	N150	N50	N0	N0	N0	N100	N50	N0
P150	P150	P100	P50	P150	P100	P100	P50	P0	P50	P150	P50	P100	P0	P0	P0
T15	T16	T12	T8	T14	T11	T10	T7	T4	T6	T13	T5	T9	T3	T2	T1
5405	5035	4984	4786	4163	4143	4118	4012	3388	3376	3143	2920	2884	2767	2519	1990

LSD2 : 1075.0 Optimum Fertilizer Doze : T8 = N150 P50

Table 6. Missa series — Wheat yield (kg/ha) under various fertilizer treatments

N150	N150	N100	N150	N100	N50	N50	N100	N50	N150	N100	N50	N0	N0	N0	N0
P150	P100	P150	P50	P100	P150	P100	P50	P50	P0	P0	P0	P100	P150	P50	P0
T16	T12	T15	T8	T11	T14	T10	T7	T6	T4	T3	T2	T9	T13	T5	T1

3 084	3 013	2 902	2 850	2 799	2 788	2 633	2 577	2 540	2 425	2 373	2 333	2 004	2 001	1 952	1 608

LSD 2. 168-7 Optimum Fertilizer Doze: T12 = N150 P100

Table 7. Rasulpur series. Maize yield (kg/ha) under various fertilizer treatments

N270	N270	N270	N270	N180	N180	N180	N180	N90	N90	N90	N90	N0	N0	N0	N0
P225	P150	P75	P0	P75	P0	P225	P150	P75	P225	P150	P0	P75	P0	P225	P150
T16	T12	T8	T4	T7	T3	T15	T11	T6	T14	T10	T2	T5	T1	T13	T9
4 568	4 563	4 502	4 491	4 042	3 990	3 974	3 924	2 960	2 530	2 472	2 382	806	801	734	733

Cd 1 at 5% level: 244.97 & Cd 2 at 1% level : 321.95
Optimum Fertilizer Doze : T4 = N270 P0

Table 8. Guliana series. Maize yield (kg/ha) under various fertilizer treatments

N150	N100	N150	N150	N150	N100	N50	N50	N100	N100	N50	N50	N0	N0	N0	N0
P100	P150	P150	P50	P0	P100	P150	P100	P0	P50	P0	P50	P150	P100	P50	P0
T12	T15	T16	T8	T4	T11	T14	T10	T3	T7	T2	T6	T13	T9	T5	T1
7 023	6 477	6 438	6 153	5 619	4 922	4 488	4 119	3 716	3 693	3 659	3 606	3 593	3 420	3 228	2 856

LSD2 : 1 441.09 Optimum Fertilizer Doze: T4 = N150 P0

Table 9. Missa series. Maize yield (kg/ha) under various fertilizer treatments

N150	N150	N100	N150	N100	N100	N50	N50	N150	N100	N0	N50	N50	N0	N0	N0
P150	P100	P150	P50	P100	P50	P150	P100	P0	P0	P100	P50	P0	P0	P150	P50
T16	T12	T15	T8	T11	T7	T14	T10	T4	T3	T9	T6	T2	T1	T13	T5
4 278	3 879	3 755	3 675	3 109	2 913	2 722	2 423	2 397	2 255	1 963	1 836	1 616	1 513	1 420	1 389

LSD2 : 1 046.27 Optimum Fertilizer Dose: T8 = N150 P50

Optimum fertilizer doze for maize

The data of maize yield under various fertilizer treatments are given in tables 7, 8 and 9. Based on the statistical analysis of yield data, main findings are :

Soil series	Yield (kg/ha)			Optimum fertilizer doze (kg/ha)	
	Control	Average	Maximum	N	P_2O_5
Rasulpur	801	2 967	4 568	270	0
Guliana	2 856	4 562	7 023	150	0
Missa	1 513	2 571	4 278	150	50

Experiments conducted at other places also show the same optimum fertilizer dozes. However, yields vary because of environmental factors.

Effect of different tillage practices on the yield of wheat crop

Out of six replicates in each soil, three were chiselled upto 20 cm depth to break the plough pan in Rasulpur and Hafizabad soils in order to see the chiselling effect on crop yield. The experimental results are given in table 10.

It is evident from table 10 that in Hafizabad soil, there is 20 and 15.5 per cent decease in yield when we compare average yield and maximum yield with both tillage practices. This is because chiselling distrubed the porosity and hence available moisture decreased in profile.

In Resulpur series, there is 8.8 per cent decrease in yield when we compare average yield obtained with cultivator and average yield obtained with chiselled plough. There is also decrease in yield of 11.7 when we compare maximum yield with both tillage practices. This is because soil has more voids and less pores. When the soil is chiselled porosity and structure are destroyed and the water retention power of the soil decreases and the internal drainage increases due to which nutrients especially nitrogen are lost.

Table 10. Wheat yield (kg/ha) under various fertilizer treatments with respect to difference tillage practices

Hafizabad series				Rasulpur series			
Treatment No.	Cultivator	Chiselling upto 20 cm	Percent decrease w.r.t. cultivator	Treatment No.	Cultivator	Chiselling upto 20 cm	Percent decrease in yield
1.	3 856	3 217	16.6	1.	1 900	1 691	11.0
2.	4 132	3 403	17.6	2.	2 230	1 934	13.3
3.	4 259	3 615	15.1	3.	2 957	2 595	12.5
4.	4 705	3 869	17.8	4.	3 316	3 133	5.5
5.	4 114	3 321	19.3	5.	1 791	1 870	+4.4
6.	5 181	3 995	22.9	6.	3 174	2 996	5.6
7.	5 683	4 335	23.7	7.	3 493	3 162	9.5
8.	5 924	4 457	24.8	8.	4 236	3 600	15.0
9.	4 046	3 449	14.8	9.	1 967	1 678	14.7
10.	5 427	4 266	21.4	10.	3 521	3 310	6.0
11.	6 013	4 515	24.9	11.	4 245	3 809	10.0
12.	5 967	5 044	15.5	12.	4 545	4 140	8.9
13.	3 715	3 097	16.6	13.	1 850	1 802	2.5
14.	5 030	3 986	20.8	14.	3 773	3 404	3.7
15.	5 943	4 310	27.5	15.	4 198	4 036	3.8
16.	6 700	5 659	15.5	16.	4 905	4 331	11.7
Average	5 043	4 034	20.0	Average	3 256	2 968	8.8

Effect of different tillage practices on the yield of maize crop

These experiments were conducted on Guliana and Missa soils. Out of nine replicates in each soil, three were chiselled upto 30 cm, three upto 45 cm and on remaining three replicates only cultivator was used before fertilizer application. The results are given in tables 11, 12, 13, and 14.

Table 11. Guliana series. Maize yield (kg/ha) average of three replicates

T.No.	Cultivator	Chiselling upto 30 cm	Percent increase	Chiselling upto 45 cm	Per cent increase
1.	2 855.7	3 386.7	18.6	4 836.7	69.4
2.	3 659.3	4 908.5	34.1	5 477.3	49.6
3.	3 716.0	5 454.0	46.7	5 763.7	55.1
4.	5 619.0	5 904.3	5.1	6 483.7	15.4
5.	3 228.0	4 169.7	29.2	7 697.7	138.4
6.	3 606.3	4 524.0	25.5	6 820.0	89.1
7.	3 693.0	4 986.3	35.0	7 180.0	94.4
8.	6 153.3	6 936.3	12.7	7 171.7	16.6
9.	3 420.0	3 700.7	8.2	6 574.3	92.2
10.	4 119.0	5 480.3	33.0	6 043.7	46.7
11.	4 922.0	6 525.7	32.6	7 340.0	49.1
12.	7 023.0	7 735.0	10.1	8 024.3	14.3
13.	3 595.0	3 527.7	18.9	5 888.7	63.8
14.	4 488.0	5 341.0	19.2	6 953.0	54.9
15.	6 476.7	6 709.7	3.5	6 876.7	6.2
16.	6 438.0	7 453.0	15.8	7 821.3	21.5
Average	4 562.2	5 421.4	18.8	6 747.7	47.9

Table 12. Missa series. Maize yield (kg/ha), average of three replicates

T. No.	Cultivator	Chiselling upto 30 cm	Per cent increase	Chiselling upto 45 cm	Per cent increase
1.	1 513.0	2 104.3	39.1	2 323.6	53.6
2.	1 616.0	3 205.7	98.4	3 740.3	131.4
3.	2 255.0	3 662.0	62.3	4 098.7	81.7
4.	2 597.3	4 083.3	57.2	4 468.0	83.6
5.	1 389.0	2 745.0	97.6	3 006.0	116.4
6.	1 836.0	3 955.0	115.4	4 168.7	127.0
7.	2 913.3	4 216.7	44.8	4 917.3	68.8
8.	3 675.3	4 824.3	31.3	5 681.0	54.6
9.	1 963.0	2 937.0	49.6	3 392.3	72.8
10.	2 423.3	4 137.3	70.3	4 595.7	89.7
11.	3 109.3	4 379.0	40.8	4 629.3	48.9
12.	3 879.0	5 059.7	30.4	6 218.0	60.3
13.	1 420.0	3 124.3	120.0	4 054.7	185.6
14.	2 722.0	4 396.7	61.5	5 057.0	85.8

15.	3 755.0	3 027.0	–19.4	5 185.7	38.1
16.	4 278.0	5 823.7	36.1	6 243.3	46.2
Average	2 584.0	3 983.8	54.2	4 486.2	73.6

Table 13. Yield potential of soils

Soil family	Tillage practice	Maximum yield (kg/ha)	Percentage increase w.r.t. cultivator
Missa	Cultivator	4 278	
	Chiselling upto 30 cm	5 824	36.1
	Chiselling upto 45 cm	6 243	45.9
Guliana	Cultivator	7 023	
	Chiselling upto 30 cm	7 735	10.1
	Chiselling upto 45 cm	8 024	14.3

Table 14. Difference in average yield between two soils

Soil series	Tillage practices	Average yield (kg/ha)	Percentage increase over cultivator
Missa	Cultivator	2 584	
	Chiselling upto 30 cm	3 984	54.2
	Chiselling upto 45 cm	4 486	73.6
Guliana	Cultivator	4 562	
	Chiselling upto 30 cm	5 421	18.8
	Chiselling upto 45 cm	6 748	47.9

Tables 11 and 12 in the text give total weight of grain (kg/ha) as average of three replicates of: cultivator, chiselling upto 30 cm and 45 cm.

Table 14 shows that in Guliana soil there is only 18.8 per cent increase in yield when we compare average yield (kg/ha) obtained with cultivator and average yield obtained when chiselled upto 30 cm. Table 13 show that increase in yield of the maximum with chisel plough over maximum of the cultivator is only 10 per cent.

There is significant (47.9%) increase in yield when we compare average yield obtained with cultivator and average yield obtained when chiselled upto 45 cm.

Table 11 shows increasing trend in yield when cultivated with cultivator, chiselled upto 30 cm and chiselled upto 45 cm. This is because of weak thin plough pan in this soil at about 20 cm depth which is broken when the soil is chiselled upto 30 cm. However, because the texture up to this depth is silt loam which usually is friable and easily workable, the increase in yield over cultivator is not much. When soil is chiselled upto 45 cm depth, the underlyingsilty clay loam layer is broken which provides more moisture and, therefore, increase in yield over cultivator when chiselled upto 45 cm is significant.

Table 14 shows that in Missa soil there is 54 and 74% increase in yield when we compare average yield obtained with cultivator and average yield obtained when chiselled upto 30 cm and 45 cm respectively. Table 13 shows, that increase in yield of the maximum with chisel plough at 30 cm depth and 45 cm depth over maximum of the cultivator is 36 and 46 per cent respectively.

Table 12 shows increasing trend in yield when cultivated with cultivator, chiselled upto 30 cm and chiselled upto 45 cm. This is because (a) The soil has lime concretion zone after 11 cm depth which is hard and not easily penetrable by roots (b) It has been proved through another experiment done on this soil that better soil moisture is conserved with chiselling than with cultivator. The conserved moisture, increased the efficiency of fertilizer specially phosphorous (c) Fertilizer specially P_2O_5 is better incroporated in soil than with ordinary cultivator.

Effect of hoeing on the yield of maize

Table 15 represents the average yield (kg/ha) obtained with and without hoeing on Guliana and Missa soils.

Table 15. Average yield (kg/ha) obtained with and without hoeing on Guliana and Missa soil series.

Treatment No.	Guliana series			Missa series		
	Guliana series		Percentage of decrease in yield w.r.t. hoeing	Missa series		Percentage of decrease in yield w.r.t. hoeing
	With hoeing	Without hoeing		With hoeing	Without hoeing	
1.	2 855.7	1 642.3	42.5	1 513.0	1 294.7	14.4
2.	3 659.3	2 784.3	23.9	1 616.0	1 702.7	– 5.3
3.	3 716.0	2 931.7	21.1	2 255.0	2 178.0	3.4
4.	5 619.0	3 584.3	36.2	2 597.3	2 751.6	– 5.9
5.	3 228.0	2 150.7	33.4	1 389.0	1 494.3	– 7.5
6.	3 606.0	2 826.7	21.6	1 836.0	2 586.0	– 40.8
7.	3 693.0	3 413.3	7.6	2 913.3	2 691.0	7.6
8.	6 153.3	4 911.7	20.1	3 675.3	2 729.7	25.7
9.	3 420.0	2 271.0	33.6	1 963.0	1 504.3	23.4
10.	4 119.0	2 468.3	40.1	2 423.3	2 443.7	– 0.1

11.	4 922.0	5 645.0	14.7	3 109.3	2 932.0	5.6
12.	7 023.0	5 317.7.	24.3	3 879.0	3 122.7	19.5
13.	3 595.0	2 366.3	34.2	1 420.0	2 131.7	– 50.0
14.	4 488.0	3 020.6	32.7	2 722.0	2 372.7	14.6
15.	6 476.7	5 132.0	20.7	3 755.0	3 749.3	0.2
16.	6 438.0	4 944.0	23.2	4 278.0	3 830.7	10.5
Average	4 562.2	3 338.1	26.8	2 584.0	2 472.8	4.3

The following are the main findings:

Soils	Management practices	Yield (kg/ha)			
		Average	% decrease w.r.t. hoeing	Maximum	% decrease w.r.t. hoeing
Guliana	Hoeing	4 562		7 023	
	Without hoeing	3 338	26.8	5 318	24.3
Missa	Hoeing	2 584		4 278	
	Without hoeing	2 473	4.3	3 831	10.5

It is evident that there is significant decrease in yield (7 to 42.5%) in Guliana soil. The average decrease in yield is 26.8%. In case of Missa soil the average decrease is 4.3%. This is because the percentage of sand and clay in the plough layer of Missa soil is 12.6 and 11.6 respectively while in Guliana soil it is 6.5 and 19.3 respectively. The percentage of silt is almost the same. The results indicate that crust formation is more pronounced in case of Guliana soil because of compartively lesser percentage of sand.

Effect of "Flat, parts, Ridge and Broad bed" sowing on maize yield

Tables 16 and 17 show comparison of average yield kg/ha by sowing maize crop on; flat parts, ridges and broad bed. The results show that broad bed always gave better yield than ridges which in turn have better yield than sowing on flat parts. Secondly the response is better on Missa soil than on Guliana soil. This is because, maize crop is very sensitive to stagnent water. Missa being on terraced slopes, runoff collects which damages crop and results in deteriorated yield. Guliana soil occurs on level plains where runoff does not accumulate. There is an increase in yield of 13% in respect of Guliana soil and 16% in respect of Missa soil of broad bed over ridges. The increase in yield is not significant because of more labour cost involved in preparation of broad beds than ridges.

Cultivation of maize on broad bed in respect of Missa soil and on ridges in respect of Gulaina soil is useful. The optimum fertilizer dozes with all the three methods taken into consideration is the same.

Table 16. Guliana series. Average yield (kg/ha) by sowing maize crop on: flat parts, ridges and broad bed

Treatment No.	Flate parts	Ridges	Percentage of increase in yield w.r. to flat parts	Broad bed	Percentage of increase in yield w.r. to flat part
1.	2 855.7	4 242.0	48.5	4 263.0	49.3
2.	3 659.3	4 391.7	20.0	5 526.7	51.0
3.	3 716.0	4 242.3	14.2	5 681.3	52.8
4.	5 619.0	5 342.3	– 4.9	5 711.3	1.6
5.	3 228.0	4 327.6	34.0	5 030.0	55.8
6.	3 606.3	4 394.0	21.9	5 825.0	22.3
7.	3 693.0	4 137.0	12.0	4.347.0	17.7
8.	6 153.3	6 539.3	6.3	6 660.0	8.3
9.	3 420.0	4 781.3	39.8	5 146.3	50.5
10.	4 119.0	5 121.7	25.7	5 695.0	38.3
11.	4 922.0	5 391.3	9.5	6 482.0	31.7
12.	7 023.0	7 257.6	3.3	7 538.5	7.3
13.	3 595.0	5 154.0	43.4	5 251.3	46.1
14.	4 488.0	5 877.0	30.9	6 171.0	37.5
15.	6 476.0	6 542.0	1.0	7 020.6	8.4
16.	6 438.0	7 406.0	15.0	8 283.7	28.7
Average.	4 562.2	5 320.5	16.6	5 914.5	29.6

Table 17. Missa series. Average yield (kg/ha) by sowing maize crop on: flat parts, ridges and broad bed.

Treatment No.	Flat parts	Ridges	Percentage of increase in yield w.r. to flat parts	Broad bed	Percentage of increase in yield w.r.t. flat parts
1.	1 513.0	1 867.3	23.4	2 211.0	46.1
2.	1 616.0	2 205.0	36.6	2 471.0	52.9
3.	2 255.0	3 774.0	49.6	3 633.0	61.1
4.	2 597.3	3 583.3	37.9	3 923.3	52.6
5.	1 369.0	2 112.3	54.3	2 372.3	73.3
6.	1 836.0	2 488.3	35.5	3 430.0	86.2
7.	2 913.3	2 923.3	0.4	3 773.7	29.5
8.	3 675.3	4 150.0	12.9	4 711.0	28.2
9.	1 936.0	2 145.3	9.3	2 456.7	25.1
10.	2 423.3	3 298.7	36.2	3 451.3	42.4
11.	3 109.3	3 550.7	14.2	4 025.0	29.5
12.	3 879.3	4 512.3	16.3	4 990.3	28.7
13.	1 420.0	2 556.7	80.0	2 787.3	96.3

14.	2 722.0	3 131.7	15.0	3 290.0	20.9
15.	3 755.0	4 474.7	19.2	4 960.3	32.1
16.	4 278.0	5 538.3	29.5	5 950.0	39.1
Average.	2 584.0	3 243.9	25.5	3 652.3	41.3

Effect of weeds on maize yield

Using nine replicates and sixteen treatments; experiments were conducted to know the ffect of weeds on the yield of maize crop in respect of Guliana and Missa soils. The results are tabulated in table 18.

Table 18. Average yield (kg/ha) of maize under various treatments

Treat-ment No.	Guliana series			Missa series		
	Weeding by her-bicide	Weeding by manu-al labour	With weeds	Weeding by her-bicide	Weeding by manu-al labour	With weeds
1.	3 809.3	3 338.3	1 724.7	2 179.3	1 781.3	1 391.3
2.	5 393.3	4 836.3	1 964.3	2 299.7	1 899.7	1 677.7
3.	5 643.0	5 257.7	3 235.3	3 071.7	2 990.0	1 991.0
4.	6 318.3	6 053.0	3 953.7	3 428.3	3 196.7	2 289.7
5.	4 861.0	4 476.3	2 097.0	1 404.3	1 657.7	1 463.0
6.	5 613.7	5 146.7	2 272.0	2 524.0	2 509.7	2 161.7
7.	5 683.7	5 432.7	2 943.0	3 465.0	3 440.3	2 421.7
8.	6 712.7	6 236.3	4 977.0	4 521.7	3 761.3	2 674.0
9.	4 376.0	3 420.7	2 124.0	2 114.0	1 713.0	1 446.0
10.	5 892.7	4 964.7	2 696.3	2 531.3	2 696.3	2 335.0
11.	6 198.3	5 259.7	3 382.3	3 900.3	3 065.0	2 752.7
12.	7 384.0	7 806.0	5 886.0	4 148.7	3 977.3	3 092.7
13.	4 643.0	3 514.3	2 241.0	2 149.3	1 930.3	1 969.0
14.	5 911.0	5 731.3	3 974.0	3 226.0	3 009.0	2 206.3
15.	7 080.0	6 374.3	5 220.4	3 881.3	4 080.7	2 384.3
16.	7 725.0	6 944.3	5 523.0	5 262.7	4 646.7	3 500.7
Average.	5 827.9	5 300.1	3 384.1	3 132.4	2 897.2	2 234.8

The following are the main findings :

Soil series		Yield (kg/ha)	%Decrease in yield w.r.t. Manual labour	w.r.t. Herbicide
Missa	Weeds	2 235	22.9	28.7
	Weeding by manual labour	2 897		
	Weeding by herebicide	3 132		
Guliana	Weeds	3 384	36.1	41.9
	Weeding by manual labour	5 300		
	Weeding by herebicide (Primextra)	5 828		

The grain yield data show that highest grain yield is obtained by application of herebicide (Primextra). The yield obtained by weeding through manual labour is only 7.5 to 9.8% less than obtained by the application of herbicide. The reduction in yield may by attributed to more time required for weeding by manual labour than by application of herbicide. Guliana being a more fertile soil than Missa, has greater amount of weeds and, therefore, yield is more effected by weeds than in Missa soil.

TRANSFER OF SOIL TECHNOLOGY TO AGRICULTURAL EXTENSION SERVICE IN PAKISTAN-A PRAGMATIC APPROACH

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ABSTRACT

The Soil Survey of Pakistan initiated the process of Agro-technology Transer in late sixties by disseminating soil resources information to the users including policy makers, landuse planners, resource surveyors, agricultural extensionists, researchers etc. by employing various strategies including field excursions, distribution of soil survey reports and information brochures and by interpreting soils data for user agencies. Refresher courses were organized for agricultural extensionists, university students and administrations. But the response to all these ventures was not very encouraging. Recently a short-term project has been started under the name of "Transfer of Soil Technology to Agricultural Departments". Through this Project, the Department of Soil Survey of Pakistan is collaborating with the Provincial Agricultural Extension Service in their ongoing training programme to in-service staff under their extension and agricultural development projects (T & V System). The training course includes information on nature and use of the land resources and is imparted in national and regional languages. The course includes 12 lectures, 6 practicals and three field trips. A soil pit near each centre serves as a field laboratory. Field trips are arranged near the training centres to cover maximum landscape and soil variations. All the visits are arranged along these preselected traverses to study (i) land-scapes, (ii) soil profiles and (iii) rating soils for various crops of the area and for overall production. Emphasis is placed on proper characterization of landscapes and surface soil conditions including effects of past agricultural practices. Few and easy field tests are also included for estimation of profile characteristics. In all 27 training centres in seven selected districts have been chosen for the initial phase of training. Besides, three more districts will be covered in due course of time. After the completion of the project, the performance will be evaluated for further expansion.

INTRODUCTION

At the moment, the Agricultural Extension Service of the selected districts of the country is being re-organised under Training and Visits System (Benor and Harrison, 1977). With specified duties, more facilities and additional staff, the service is required to bring about a change in rural economy. An important component of this system is a regular fortnightly training of the entire staff at Tehsil (sub-division of districts) level. Training includes regular advice for the farmers about aspects of agrotechnology.

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It was realized that the training courses imparted under T & V system included almost all components of agrotechnology except soil management. Therefore, to fill this gap, Soil Survey of Pakistan started a project called Transfer of Soil Technology to Agricultural Departments. A wide range of trainees from Field Assistants (village level workers) to Assistant Directors of Agriculture (Tehsil level workers) are included in the scheduled fortnightly training.

Transfer of Soil Technology is a multi-facet, short term pilot project basically aimed at disseminating the soil resources information to the farmers, largely through the existing net work of Provincial Agricultural Extension Services. Initially, ten districts will have to be covered in a period of three years. Of these, work has been started since September, 1984, in five full districts and in parts in two districts. The following is the framework of the training programme which is continuously being elaborated during the course of implementation of the project. On the basis of this programme, training activities have been started uniformly and efficiently in all the centres taken up so far.

AGRICULTURAL EXTENSION REQUIREMENTS, A REVIEW

Agricultural Extension takes education to the rural people, in a form best suited to their needs. It is a service or a system which assists farm people, through educational procedures, in improving farming methods and techniques, increasing production efficiency and income, bettering their level of living and lifting the social and educational standards of rural life (maunder, A.H. 1973). According to a more practical approach (Savile, 1965), peoples own efforts and use of their own resources of manpower and materials with minimum assistance from the Governments, is very crucial. The effectiveness of extension is measured by its ability to change the static situation which prevails in the rural areas into a dynamic one. It varies from place to place, from community to community and from country to country. The efforts of education should always be focused on solving peoples *immediate problems.* The farmers are required to be told what to do where and why. For agricultural development the knowledge and skill of the farmers must keep increasing and changing.

Economic and social growth among village people in any nation depends on the ability of building an adequate staff of properly trained professionals who are to manage the rural development enterprise. In reality, shortage of experienced staff limits the effectiveness of extension work, this is true at all levels (Leagans, 1964). Thus, an extension worker has to be a technical leader in the rural areas. But very often the strong administrative control hampers leadership. Ideally the leadership and administration should go together, but that is not the case (Joseph and Franco, 1966). In order to inculcate leadership, the Extension Worker has to be in a much better position of technical awareness than most of the farming community.

The Project of Transfer of Soil Technology to Agriculture Extension Service is aimed at developing leadership qualities in the workers through enhancement of their technical skill. After their training in soils and soil management they would be able to tell the farmers confidently what to do where and why.

TRANSFER OF SOIL TECHNOLOGY IN PAKISTAN

Research

In Pakistan, there are several provincial and federal agencies conducting research on various aspects of agrotechnology. There are two main handicaps in these research activities:

- the research is not being conducted on identified principal soils, occurring extensively in the country and
- the research is not exclusively designed to transfer to the ultimate users i.e. the farmers. It largely serves academic interests.

Whatever research is going on, its results cannot be very accurately applied as blanket recommendations on all kinds of soils. This situation is prevailing despite the fact that the soils of all the main Research and Experimental Stations have been described and mapped in detail.

Soil Taxonomy (Soil Survey Staff, 1975), which is being used by the Soil Survey of Pakistan since the date of its issue provides a framework for transfer of agrotechnology through systematic classification of soils based on both chemical and physical properties. It treats soils as natural bodies having properties inherited from the combined effect of soil forming factors. Wherever these factors have been the same, the soil is the same. This assumption persists throughout the Soil Taxonomy (SSSA, 1984) and serves as practical means of transfer of research findings.

Field studies

The other endeavour of Soil Survey of Pakistan is the mapping of soils using uniform criteria in all the agriculturally important areas of the country. The regional maps and reports provide a framework for transfer of agrotechnology evolved at the Research Stations. With the exception of a few Research Organisations (University of Agriculture, Faisalabad, 1984), hardly any other organisation has started testing known soils in the field conditions. An effective mechanism is needed to use the field studies for agrotechnology transfer.

Agricultural extension

Whereas it had always been so difficult to disseminate soils information to the Agricultural Research Scientists, transfer of this information has been relatively easier on the extension side. Being field workers, the extension people are in a better position to appreciate soils and their conditions under natural environments. For the process of successful transfer, "Field workers had to learn from their own observations which properties of soils they mapped were important to plant growth and how to identify the important properties in the field" (Smith, 1983). This is the key principle which makes the basis of the Transfer of Soil Technology to Agricultural Extension Service in Pakistan.

Unfortunately, even at this stage the Agricultural Extension Service has not recognized the significance of resource information. The Project Document (Revised 1984) entirely relies on the research information being generated at the Adaptive Research Stations. However, efforts are being made to motivate Adaptive Research Scientists to recast their research by known soils.

SUB-PROFESSIONAL TRANSFER STRATEGY

PREPARATION OF TRAINING MATERIAL

Lecture notes

Keeping in view the diversity of the staff requiring training and the foreseeable duration of the ongoing training opportunities available at various levels in Agricultural Extension Service, the lecture notes were tailored according to their specified needs. The course is prepared in the national language although versions are being developed in regional languages also.

Basically this course is aimed at training of the front line extension workers such as Agricultural Officers (A.O's) and Field Assistants (F.A's) actively engaged in the selected districts. This course is adequately supported by practical work, field trips and audio-visual aids. The contents of this course include 12 lecture units, 6 practical units and 3 field trip units. Table 1, 2 and 3 show the details of this course.

Table 1. Details of lectures (Core component)

Lecture No.	Title	Contents
1.	Collaboration for training	General activities of the Department and detailed outline of this Project
2.	Soils and soil forming factors	Modern concept of soils and effects of soil forming factors as revealed by the soil profiles
3.	Environmental characteristics of soils — Part I.	Concept of landscapes, relief, landforms and landform units.
4.	Environmental characteristics of soils — Part II.	Natural vegetation and present land use
5.	Profile characteristics of soils (differentiating criteria) and their importance in agriculture	Palpable soil characteristics as observable and measurable in the filed and how they influence agricultural practices and production
6.	Estimation of profile characteristics	Generalized methods of estimation, mainly qualitative
7.	Land qualities	Evaluation of land quality through determination of combined effect of sets of soil characteristics
8.	Soil requirements of principal crops	Characteristics of soils which are suited to various crops: optimally, moderately and poorly
9.	Land evaluation	Outline of the land capability system used and brief introduction of land evaluation concepts and procedures
10.	Soil degradation, conservation and reclamation	Causes of degradation, conservation and reclamation on the basis of kinds of soils

11.	Soil fertility	Definition, chemical, physical and biological aspects of soils with due importance in relation to their role in soil fertility evaluation and importance, fertilisation by kinds of soils
12.	Water management	Judicious use of water according to soil and crop requirements, statistics of water resources, its losses and measures to minimize.

Table 2. Details of the soil identification practicals to be arranged at each training centre (Analytical component)

Practical No.	Subject	Details
1.	Texture by feel method	Typical soil samples of the main soils of the region are collected to practise method of texture determination
2.	Profile examination	In the vicinity of the Training Centre, a pit is exposed for repeated study. During the first practical, visual and palpable properties are demonstrated briefly
3.	Simulation of soil textures	Soil samples dominant in primary particles sand, silt and clay are arranged and the participants are asked to mix them with required percentages to prepare main soil textures i.e. sandy loam, loam, clay loam, silt loam etc
4.	Measurement of the main soil characteristics	Undisturbed soil samples are arranged to illustrate principal characteristics of the typical soils of the regions, i.e. texture, porosity, pH, calcareousness and consistence
5.	Description of soil profile	The pit already excavated near the training centre is described at sub-professional level using criteria as explained during the lectures
6.	Rating of the soils (Land Capability, Crop Suitability)	On the basis of presence or absence of soil limitations (s) and severity of limitation (s), if present, the soil profiles near the Training Centre are rated and suitable crops are named accordingly

Table 3. Details of field trips (Demonstrative component)

Field trip No.	Subject	Details
(a)	**General trips**	
	i. Description of landscapes	A field trip is arranged to study a preselected traverse representing typical landscapes of the region. The description of each landscape unit is recorded on a specially designed proforma which is supplied to all the participants before the field trip. Method of filling up the proforma is explained on-the-spot
	ii. Description of typical profiles	Along the above mentioned traverse, pits are excavated. The trainees are taken to these sites and method of easy description of these profiles is explained according to the subject matter already transferred to them

iii. Land Capability and Crop Suitability ratings	The main soils, occurring along the traverse already selected, are classified according to the outline of the Land Capability Classification. These soils are also rated for the main crops of the area on the basis of soil characteristics and soil requirements of the crops
(b) Special trips	
i. Contact farmers farms	With the administratively controlled areas of each Agricultural Officer, three types of contact farmers. – owners of big farm one – owners of medium farm one – owners of small farm one along with the concerned Agricultural Officer (AO) and Field Assistant (FA) are visited. The main soils of the farmers' land are examined and on-the-spot advice given to the farmer for improved land use practices
ii. Adaptive research farms/ experimental areas	Special visits are paid to the Adaptive Research Farms. The soils of the farms are examined and efforts made to recast the research by major soils of the area, in consultation with the researchers.

Audio-visual aids

In order to maintain uniformity in the subject matter to be taught to the trainees in various regions, the text of the basic structures of the courses is being put on audio-cassettes. These cassettes may be duplicated for future needs of the Training Institutes and other areas of interest.

PROFORMAS

The Agricultural Extension Workers are not supposed to be soil surveyors or land evluation or classification experts. They are, however, supposed to identify soil problems, to assess soil potential and to prescribe some measures in the right directions for reclamation, conservation or improved management. This requirement has been achieved through preparation and practising of some special proformas. As an aid to use these proformas all the possible land characteristics are listed in standard categories as key to be used for describing the site or soil conditions.

STUDY OF SITE CONDITIONS

The Soil Taxonomy uses the landscapes as exclusive components of soils. But less emphasis is given to surface soil conditions, apparent without digging it. It has been experienced that a combination of landscape characteristics and surface soil conditions represent a set of characteristics which reveal lot of information about the kinds of soils and their management requirements. The landscape includes landforms, relief, vegetation and land use. It may be realized that type of plants, their proportion, population and health, signifies several soil conditions. These conditions are repeated on various parent materials with similar site conditions. In the same way surface soil hardness, type of clods, nature of seedbeds, size and shape of parcels, nature of embankments and water courses are good indicators of soil conditions.

AN EYE ON THE PROFILE

After recording site conditions, the Extension Workers only need an eye on the profile to perform certain quick field tests which have been explained to them during lecture series. A proforma has been developed for ready description of profiles as well. The idea is to identify the problem and its severity.

QUESTION HOUR

The trainees learn through several ways; some by listening, some by seeing, some by doing and still others through discussions. Apart from these means, it has been observed that people learn most by getting appropriate answers to their questions. From this it can be understood that our extension workers have problems but very often they don't get proper answer from the trainers. The question hour is usually very much interesting and extends over long time. People try to participate in discussions. This gives us chance to seek our message conveniently. Some questions are asked repeatedly and all over the country. So, specific answers to such questions have been prepared and widely circulated among the participants.

TEHSIL-WISE SOIL BULLETINS

Generalized Tehsil soil maps will be prepared with national language symbols, titles and legends. These maps will be accompanied by small booklets containing soils information recast on the outline of the training course. This material will represent the end product of the training. These bulletins will be supplied to the AO's, EADA's and DDA's for general use.

MASS COMMUNICATION

It has been experienced in all the provinces that the occasional mass communication activities of the Soil Survey of Pakistan gain spectacular attention of the people relating to the agricultural sector. Agricultural Fairs (Zari Mēlas), Farmer Rallies and Cultural Exhibitions are frequently held all over the country. In order to make the best use of these platform, efforts are being made to continuously participate in at least really important communication forums.

TRAINING PROCEDURE

- For evaluation of pre-training general knowledge of the participants, basic tests are given about soils, their conditions and behaviour towards cultural practices.
- Copies of the lecture notes are supplied to all the trainees.
- Each lecture is started with a brief revision of the previous lecture.
- The contents of each lecture are presented in articulated models for quick understanding of the trainees.
- At the end of the lecture there is a question hour. Sufficient time is devoted for answering the questions of the trainees in detail.
- Slides are shown to enhance apprehension of the trainees about the aspects of the training material.

- After completion of each stage of the training, a list of typical questions about the text are supplied to the trainees. The trainees are required to answer these questions as home work.
- At the end of the training course subject, an objective type class test is given to evaluate the progress of trainiug.
- During the visits to the contact farmers, the AO's and FA's are guided to underline the problems and to evaluate the potentials of the farmer's land. They are taught the technique of formulating qualitative suggestions for reclamation or for the improved use of the famer's land.
- At the end of the course, the participant are given the final test. 50 per cent marks are reserved for objective test and 50 per cent for description of environments for two contrasting soils of any selected agricultural farms falling in the jurisdiction of the agricultural trainee concerned. The successful trainees are awarded diplomas/certificates.

COLLABORATION IN ADAPTIVE RESEARCH

A significant component of T and V activities of the Agricultural Departments is Adaptive Research being carried out on regional basis. Senior Subject Matter Specialists (SSMS) in Agronomy are conducting such research in all the T and V districts. It has been observed that this research does not include experiments on known soils, especially about their problems and potentials. Our staff is collaborating with the SSMS's of Agronomy to start mutually agreed experiments on known and defined soils. This exercise will help the Extension Service to disseminate their research results on similar soils in the respective regions. Updated Tehsil maps will be supplied to all the SSMS's and AO's. After this training course, all of these officers will be able to apply the research results on known soils at the experimental stations as well as on the similar soils elsewhere in the Tehsil.

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PART VII
GENERAL

- Agricultural Research Priorities and Constraints in Pakistan — M, Anwar Khan
- Barani Agricultural Research and Development in Pakistan — A. Rehman Khan and Abdul Qayyum
- Use of Gypsum for Reclamation of Salt Affected Soils — Muhammad Rashid, Muhammad Yasin and Hayat M. Bhatti
- Need for International Cross Checking and Correlation in Soil Analysis for International Classification System — G. Saeed Khan

AGRICULTURAL RESERACH PRIORITIES AND CONSTRAINTS IN PAKISTAN

M. ANWAR KHAN*

INTRODUCTION

Agriculture is the largest single sector of Pakistan's economy, accounting for 29 percent of the Gross Domestic Product (GDP). It employs 55% of the total labour force and supports directly or indirectly 70% of the country's population.. The share of agriculture in export earnings amounts to about 70%, including both raw as well as processed agricultural commodities.. Although contribution of agriculture to GDP has shrunk over the years due to structural changes and relatively faster growth in industrial sector, agriculture itself has maintained a steady pace of expansion at the rate of 4% per annum throughout the period since early sixties.

There is a vast potential for increased agricultural production. The country has large areas of deep soils, favourable topography, suitable climatic conditions and water resources capable of producing a variety of food, feed and fibre crops. The cultivable land is 32 million hectares, of which 20 million hectares are actually being cultivated. A considerable part of the remaining 12 million hectares can be brought under cultivation by harnessing the available resources. There is a wide gap of 50 to 80% in yield levels obtained by progressive farmers and the farmers using outdated farming methods. There are vast tracts of rangelands (about 70% of the total land mass in the country), which if properly developed and judiciously exploited can support a livestock industry of substantial size. There is also considerable scope to improve the productivity of livestock sub-sector through intensive selec -tion and cross-breeding as well as development of economical and nutritious balanced feed for livestock. Area under forests is also grossly inadequate.

It is evident from the above that prosperity of the country and welfare of the vast majority of the people, to a very great extent, are intimately linked with efficient harnessisng of the agricultural resources on a progressively sustained basis. Any significant economic development in the country would,therefore, essentially depend on radical improvement in agricultural productivity. This necessitates realization of the production and research constraints and setting up of priorities for achieving the goals. In the following pages, effort has been made to enlist agricultural production and research constraints in Pakistan and concepts of priorities and the priorities as foreseen in the near future.

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AGRICULTURAL PRODUCTION CONSTRAINTS

Agriculture in Pakistan remained a simple and easy profession as long as its activities remained confined to sowing and harvesting of crops. Visits to the field during the intervening period depended on the availability of time and the mood of the peasant. During the last two decades, agriculture has become a commercial and multi-dimensional scientific profession.Multi-national companies regulate the flow of agricultural inputs in the developing countries.Internationally, food can be used as a political weapon to achieve vested interests. Pakistan is blessed with plenty of sunshine, fertile soils, sufficient water resources and ample manpower to fully exploit the agricultural base, but potential has always remained a cherished hope and got never realized. Many commissions/missions/enquiry committees have attempted to diagnose the weakness of our agriculture production system.

Below are listed some of the constraints that have overshadowed actual performance of the agriculture sector.

- High population growth rate, about 3% per annum, wipes out the benefits that should have been forthcoming from sustained investment in agricultural research and development. Pakistan's population which is 94.7 million in 1985, is projected at 136 million by the year 2000.
- Man to land ratio for cultivated land comes to about 0.94 ha per capita, which is quite low.
- Periodic occurrence of floods and droughts.
- Wide spread prevalance of insect-pests and diseases of plants.
- Continued deterioration of the vast rangelands in arid/semi arid tracts.
- Highly variable genetic potential of various classes of livestock which in majority of the cases is below economic level.
- Inability of the common man to pay prices of milk and meat commensurate with the cost of production at commercial scale, resulting in economically non-viable dairy and meat industry.
- Insufficient information about potential production of fisheries from the relevant parts of the sea.
- Lack of scientific data on basic organic formation under given conditions of sunshine, temperature, nutrients and oxygen supply to ensure optimum output of fisheries.
- Low forest area being insufficient to meet the normal requirements of timber, fuel wood and other forest products, its inadequacy further accentuated by traditional mismanagement and outdated forestry concepts.
- Insensitivity of agricultural research and production technologies to diverse ecological parameters and varied socio-economic constraints.

- Overemphasis on the so called "PACKAGE OF TECHNOLOGY" which for most of the crops is not only incomplete but also too complex for farmers to adopt.
- Apparent weaknessess in 'MANAGEMENT' of research, technology transfer, education, production inputs, services, marketing, etc. as a real life integrated system.
- Inadequate awareness about scientific management of natural resources base for agricultural production, resulting in its continued deterioration due to overcultivation, overgrazing, overexploitation and mismanagement of resources.

AGRICULTURAL RESEARCH CONSTRAINTS

The constraints to agricultural research are often complex and not easily perceived or defined. As per perceptions of the author the agricultural research in Pakistan still has some of the constraints given below.

- Inadequate conceptual clarity in determining agricultural research priorities, e.g: perception of ideological policy, strategic dimension and dynamism of time, space, science, technology, resources, culture, economics, socio-politics, etc.
- Inadequate number, quality, discipline-wise balance of professional scientific manpower across the country and inter-regional and inter-institutional imbalances, e.g. availability of 3 431 (1983-84) vs estimated requirement of about 12 000 scientists at Pakistan level, or clustering of Ph.D scientists in fewer institutions like University of Agriculture Faisalabad (UAF) and Pakistan Agricultural Research Council (PARC) etc., and accentuated shortage in Baluchistan, Sind, NWFP, AJK, Northern Areas, etc.
- Inadequate motivation, incentives, recognition of quality research and/researchers, e.g. seniority rather than research output still general criteria for career advancement, or lack of economic incentives especially in prevalent salary structure generating financial pressures.
- Research environment marred by socio-political weaknesses or immaturities.
- Inadequate allocation or availability of resources for research scientists, e.g. Funds for agricultural research in Pakistan for (1983-84).

  Recommended 0.5% of GNP
  Allocated 0.21% of GNP
  Released 0.14% of GNP

- Critical inadequacy of lab. equipment maintenance/repair facilities within National Agricultural Research System (NARS), NARC, Lab. Equipment Maintenance and Repair Unit initiated in November, 1984.
- Inadequate opportunities for national and international professional interactions amongst research scientists, e.g. difficulties in participation in international scientific forums, or fewer collaborative agricultural research programmes with international agencies.

- Historically weakened or lack of "Research-Education-Extension" traingle "reedex" linkage and interactions, resulting in weak or no feed-back and interaction with "reedex" pivot - the farmer or end user.
- Lack or inadequate coordination and positive interaction amongst reserch related institutions.
- Slow development of scientific research culture-a synonym of developing state of LDCs (less developed countries) with consequential mistrust amongst research scientists discouraging sharing of knowledge/expertise, and discouraging team work and integration of research across disciplines or sub-sectors of agriculture.
- Lack of recognition of ecology as an important discipline for agricultural research/productivity, resulting in imbalance in physical, biological and farming system dimensions with ill-defined agro-ecozones as well as integrated land use research (ILU).
- Imbalance amongst longterm basic or fundamental research, short-term applied and or adaptive research and operational research, e.g. most scientists or most institutions attempting to do just all kinds of research, or absence of complex system oriented researches like watershed, farming systems, integrated land use, etc.
- Inadequate planning, coordination, programme definition, programme implementation, research monitoring, research evaluation within institutions or inter institutions.
- Almost lack of research on impact of research in objective, scientific and economic terms.
- Research priorities as determinant of research is an extremely complex model based on tangible as well as intangibles. We still do not have acceptable quantitative model to determine intersectoral or intrasectoral agricultural research priorities.
- The agricultural research as well as research system in Pakistan continue to suffer from "Personality Cult" individual subjectivities, projecting scientists leaders rather than science or working scientists — an antithesis of science, research or institutionalization of research system.

CONCEPT OF AGRICULTURAL RESEARCH PRIORITIES

The agricultural research priorities are conceptually determined by many tangibles and non-tangibles. The collective wisdom is still the rule rather than exception. We still do not have a universally accepted scientific, quantitative and mathematical model for determining priorities. Some of the perceived factors which provide a conceptual basis for determining the priority, inter alia, should include :

Ideology of a country/state/nation

A food surplus country pays for no-production (USA), and a state controlled economy achieves state targetted food grain production at lavishly state provided inputs (DPRK). Pakistan, on the other hand, is committed to upgrade quality of life of its people including 72% rural populace with literacy

lower than 27%. It has to formulate its own policy to realize the national objectives in the best possible manner.

Agricultural policy of the country

The policy generates real forces and determines factors resulting into research priorities, e.g. (a) self-sufficiency in all commodities in Pakistan would attach crisis priority to oilseed crops, (b) greater emphasis on small farmers in Pakistan would necessitate research on technology generation for resource poor, small farms, illiterate farming community and transformation of subsistence agriculture to modern agriculture.

Agriculture defined

Whether defined as a crop culture or as encompassing all components of agricultural system like crops, forestry, range management, livestock, watershed, land resources, water resources, energy, machinery, socio-economics and other related disciplines (agrometeorology, ecology) and institutions (marketing etc.). According to the Government of Pakistan, (1981), "Agriculture" means crops, livestock including poultry, fisheries, forestry, range management, soil science, socio-economic institutional and engineering aspects connected therewith and such other activities and subjects as the Federal Government may by notification in the official gazette, declare to be Agriculture within the meaning of this clause.

National state of science and technology

Relatively primitive status of science and technology would not warrant agricultural research priorities appropriate to a country highly advanced in science and technology.

Cultural traditions of agriculture

These include pastoral, crop culture, shifting cultivation, subsistence agriculture, intensive agriculture, industrial agriculture, mixed farming of wheat-sheep belt as in West Australia, mono-crop culture, integrated land use based agriculture, etc.

Levels of literacy, education, natural resources and agricultural education, general awareness from farmer to the policy makers.

Felt needs and aspirations related to agricultural production acorss its all sub-sectors, e.g. Basmati rice vs non-aromatic rice, or fast growing trees for pulp or fuel or multi-purpose "FFF" (Fuel, Feed, Fiber).

National agricultural objectives, thrusts, and targets set over finite time frame, e.g. 6th five-year plan, or year 2000 or beyond.

Perceived or recognised constraints to production or achievement of targets.

Accuracy in diagnosis of researchable problems, issues, and their relative urgency for solution to eliminate constraints for overall performance of agriculture sector.

The intrinsic or inbuilt capability of NARS (National Agricultural Research System) to successfully launch or undertake the type of research.

Research priority dynamic over time, space, science, technology, resources, culture, economics and socio-economics.

Recognition and definition of the agricultural research system.

Agriculture in Pakistan has historically developed as a provincial enterprise. The provincial research net-work may or may not comprehend national priorities. The currently evolving national agricultural research system of Pakistan provides a logical dimension for determining national, regional as well as local research priorities.

NATIONAL AGRICULTURAL RESEARCH PRIORITIES

The concept of prioritization of research was first done in 1974 and the then Agricultural Research Council approved research priorities for range management and forestry sector. The subsequent major effort was made when the same author (Dr. Ch. M. Anwar Khan) led Pakistan team of scientists and established national research priorities in all sectors of agriculture and these were equally acceptable to USDA for PL-480 funding. The counterpart mission from USDA was led by Dr. Perry Smith. This book was presented as first comprehensive national priority for agricultural research in 1981. It was subsequently revised through participation of various subsector committees and published in 1983. The latest effort (PARC-FAO, 1985), reflects the consensus of PARC scientists. The salients of the priorities are presented below.

NATURAL RESOURCES

Land and water

- Study physical and chemical properties of soils in relation to maximum productivity.
- Study the mineralogical composition of clay fraction and provide detailed analytical data for refining soil and land classification.
- Study the concept that soil family can serve as a base for agrotechnology transfer.
- Study macro and micro nutrients of Pakistan soils in relation to requirement for different crops.
- Study low cost method for development of gullied land.
- Study soil water movement and retention of soil moisture in soil.
- Study the feasibility of adaption of high efficiency irrigation system i.e. sprinkler and trickle irrigation systems.
- Make intensive techno-economical evaluation in several rainfed regions with different climates, soils and crops to identify the potential of rain water harvest.
- Monitor changes in soil chemical and physical properties induced by irrigation with saline water.

- Estimate critical water-table depths under different climate and soil conditions.
- Develop a climatic data base for developing weather models.

Watershed and rangelands

- Review the institutional constraints on better management of watershed and range areas.
- Study the classification of rangelands in terms of their ecological development or regressions.
- Study the potential for enhancing range productivity through natural or artificial reseeding and replanting with and without water and fertilizer.
- Study instability of populations traditionally using the watershed and rangelands.
- Collect air and space remote sensing data for monitoring and analysing crops and natural resources to help in planning, management and development of those resources.
- Study alternatively energy resources to establish comparative efficiencies with a view to relieving the pressure on the forests and rangelands.

Forestry

- Introduce, select and manage fast-growing tree species with emphasis on their industrial importance.
- Develop planting techniques for areas affected by waterlogging, salinity, aridity, infertility and compaction.
- Study the influence of wind breaks, shelter belts and trees on crops.
- Screen germplasm collection of economically important forest crops for resistance to insect, nematodes, fungus and virus attack.
- Study Life-cycle etiology and host-parasite relations of potentially serious insects and diseases to devise control measures.

CROPS

Crop production

- Collection, evaluation and selection of germplasm of food crops, pulses, oilseeds and other important crops for breeding programmes to produce varieties resistant to diseases and other hazards.
- Introduction of high yielding and high quality varieties of conventional crops, particularly of pulses and oilseeds in the rainfed areas.

- To improve crop production technologies by agronomic studies for various agro-ecozones.
- Study of weeds and weed control measure for different crops.
- Research on seed production and testing.
- Research on the use of growth regulators particularly for fruit crops and vegetables.
- Asceptic culture of plant cell, tissue and other culture for improving plant health, propagation, breeding and preservation of plants particularly for potato, cittrus, datepalm etc.
- Research on farm mechanization to develop simple and precise tools and farm machinery.

Crop protection

- Prevention of post-harvest losses with focus on research on post-harvest technology.
- Research studies to evolve an integrated pest management control system for all the economically important crops.
- Use of modern techniques like remote sensing in crop production; plant protection and monitoring.

ANIMAL SCIENCES

Livestock

- To study and improve the genetic potential of various indigenous breeds through cross breeding and selection.
- To study the basic reproductive physiology of buffaloes and use of new embryo transfer technology.
- Improve disease diagnosis and monitoring of disease incidence and develop effective disease control methods/techniques.
- Evolve suitable strains of sheep and goats in selected areas for higher productivity.
- Diagnosis and control of economically important poultry diseases.
- Evolving new breeds/strains of poultry capable of higher production under scavenging conditions in villages.

Fishries

- Study biology and ecology of commercially important fresh water and inland fisheries from the point of view of food, feeding, reproduction, life cycle and stock assessment.

- Study marine flora and fauna including sea weeds, mangrove etc.

SOCIO-ECONOMICS

- Studies on the economics of developing food processing industry, marketing of various agricultural commodities, price-cost structure, efficiency of marketing channels.
- Evolution and evaluation of most intensive farming systems using early maturing varieties and monitoring their long term effects on fertility, ecology and economics; determining the influences of prices, credit and its availability, sub-sidies and other such factors on socio-economic conditions of farming community.
- Identification of socio-economic constraints to crop and livestock production and recommend appropriate technologies for the farming community.
- Studies on rural labour migration and wage structure, agricultural taxation, man-power availability and training in different agricultural disciplines.
- Study existing cropping patterns and crop rotation in different agro-ecological zones, evolve alternative cropping patterns, identify constraints to their adoption and suggest appropriate policy measures.
- Collection, compilation and processing of historical data obtained through primary as well as secondary sources pertaining to agriculture and related sub-sectors, computerization of such data for retrieval and developing programmes for updating of these statistics to serve as useful data bank for researchers, planners and policy makers.

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BARANI AGRICULTURAL RESEARCH AND DEVELOPMENT IN PAKISTAN

A. RAHMAN KHAN AND ABDUL QAYYUM*

INTRODUCTION

Agriculture is the predominant economic activity of the people of Pakistan. About 70 percent of its population lives in rural areas, the majority of which are subsistence farmers. Annual population growth rate for 'barani' regions is over 3.5 per cent as compared to 3 per cent observed in other areas of Pakistan. Per capita income has been calculated at Rs. 1 180 which is well below the national average of Rs. 4 919 (Pakistan Economic Survey, 1984-85).

In recent times, there has been an increased emphasis on the development of barani areas. In1975, Punjab Government constituted the Punjab Barani Commission. Basically, the Commission's task was to recommend measures for the barani tract. The Commission recommended various projects for the development of the tract.. Creation of the Agency for the Barani Areas Development(ABAD), envisages conservation of soil and water, improvement of livestock, introduction of packages of technology and setting up of site specific industry to raise the standard of living of the rural masses. Punjab Barani Agricultural Research Institute, Chakwal is another institution designed to develop agriculture of the barani tract. The research work under the Institute contemplates agronomic and varietal/yield trials and adaptive research. The plan of work of this Institute needs substantial financial and technical support for operation in full swing.

In order to develop the arid lands for agricultural production, scheme for the establishment of Arid Zone Research Institute (AZRI) was approved by the Government of Pakistan in 1971. However, the research work was initiated in 1974. The project aims at using the potential of desert areas and unproductive land with annual precipitation of less than 250mm, for raising crops/orchards and rangelands for livestock. The headquarter of the Institute is located at Quetta (Baluchistan) with substation at Umer Kot (Sind), Bahawalpur (Punjab) and D.I.Khan (NWFP).

In NWFP a 'Barani' Research and Extension Project is operative. The project is named as the Barani Agricultural Development Project.. The overall objective of the project is to verify and transfer practicable and economically sound production technology to barani farmers.

Recently, Government of Sind has created the Sind Arid Zone Development Authority (SAZDA) for the development of agriculture in the arid zone of Sind province.Liaison between Authority and BARD Project is being established for mutual benefits leading toward the improved agricultural production in the province of Sind.

*BARD Project, National Agricultural Research Centre, Islamabad.

The idea of a Barani Agriculture Research and Development (BARD) Project was firstly mooted by the Joint World Bank/CIDA/US-AID Mission. Later on, in March, 1980, Canadian International Development Agency (CIDA) fielded a project design mission.. The mission identified a definite need for the development of a coordinated and self-sustaining national research programme to properly address the requirements of agriculture development in the barani areas of Pakistan.

Barani Agriculture College and Livestock Research Institute, Kherimuret are other projects initiated for the development of barani areas.

BARD PROJECT

BARD is a Pakistan–Canada Project, jointly managed by the Pakistan Agricultural Research Council (PARC) and the Canadian International Development Agency (CIDA). It came into existence on October 10, 1982. The project goals focus on improving the quality of farmer's life, who dominate the agricultural sector in terms of numbers but not in terms of their contribution to national production in barani areas through increasing farm productivity and stablizing the income of farm families. The main objectives of the project is to increase agricultural productivity of the barani farmer and subsequently elevate and stabilize his income (Khan and Mc Ginnis, 1985).

RESEARCH RESULTS

AGRONOMIC

Conservation of moisture

Moisture conservation is fundamental to successful production under barani conditions. A technique used successfully in many parts of the world for moisture conservation consists of planting in a ridge and furrow configuration. Tests conducted at the National Agricultural Research Centre (NARC) have confirmed its value in Pakistan also. Table 1 shows that the moisture available in mid-October (rabi planting time) after a kharif crop planted in the ridge and furrow configuration is greater than that on the flat bed after khaiif fallow.

Table 1. Effect of ridge and furrow planting during kharif season on soil moisture available to subsequent rabi crop (at NARC, 1984)

Soil depth (cm)	Soil moisture (%)			
	Ridge/Furrow		Flat bed	
	Maize	Fallow	Maize	Fallow
0 – 12.5	8.99	8.99	5.34	7.38
12.5 – 25	11.85	11.92	7.61	9.70
25 – 50	15.61	16.11	12.72	14.38

Although these results are being reconfirmed experimentally but they are sufficiently impressive to deserve testing under actual farm conditions. Of course if the ridge and furrow system is to be practical, appropriate equipment must be available to the farmer.

A trial was carried out at Quetta and Dasht in which the strips were planted along the contour at right angles to the natural direction of the slope to interrupt the flow of water. The conservation practices involved were: construction of bench terraces, preparation of water catchment area, contour strips cropping, diversion of rain water etc. The local varieties of chickpeas and lentils were grown, the yield of which are given in table 2.

Table 2. Yield of chickpea and lentils as affeted by soil moisture (at Quetta and Dasht, 1983-84)

	Treated area	Untreated area
Chickpea yield (kg/ha)	500	365
Lentil yield (kg/ha)	1 200	410

Source: PARC, 1983-84 Annual Report.

To evaluate the relative effect of the moisture stress, row spacing and fertilization on grain yield and total dry matter (TDM) of millet, an experiment was laid out in a Split Plot Design. The soil type was sandy clay loam utilizing limited and residual moisture levels at two row spacings and two fertilizer levels (Table 3).

Table 3. Total grain and TDM yield (kg/ha) interactions of moisture x rowspacing x fertilizer treatments (AZRI, 1982-83)

	Limited moisture				Residual moisture			
Row Spacing	51 cm		102 cm		51 cm		102 cm	
Fertilizer	Applied	Nil	Applied	Nil	Applied	Nil	Applied	Nil
Grain Yield	1 100	851	1 138	988	739	493	859	593
TDM	38 366	21 252	29 094	19 099	32 035	19 825	21 888	17 783

Source: PARC, 1982-83 Annual Report.

The row spacing of 51 cm was found to be better for TDM production while 102 cm was better for grain yield under limited moisture conditions. However, the response of fertilizer application was better on TDM than on grain yield.

Intercropping and planting configuration

Intercropping is another agricultural practice used successfully in other countries to increase returns to the farmer. This technique consists of row planting but alternating crops from row-to-row. The crops and the ratio of rows of one crop relative to those of other crop are both important in attaining an acceptable intercropping pattern. If it is to be successful, intercropping must provide more rupees per ha (net) than when single crops are grown in solid blocks on the same land. One of the successful intercropping combinations identified todate consists of sunflower and groundnut (1:1). Table 4 shows that with "Banki", the bunch type of groundnut, the overall yield of biomass is greater when intercropped with sunflower than when grown alone.

Table 4. Yield (kg/ha) comparison for groundnut and sunflower intercropped under ridge-furrow conditions. (at NARC, 1984)

	Planting Configuration			
	Ridge-Furrow		Flat Planting	
	Sole	Intercrop	Sole	Intercrop
Sunflower	1 070	1 248	681	678
Groundnut	1 444	1 611	291	305

Similar results were also obtained when the spreading type of groundnut was intercropped with sunflower. Again the advantage of the ridge and furrow configuration over flat planting is also reconfirmed (Table 5).

Table 5. Effect of planting configuration, row spacing and cultivar on groundnut yield (kg/ha) at NARC, 1984.

	Variety			
	Banki		C-344	
Planting Configuration	60*	75*	60*	75*
Ridge	973	1 150	1 362	1 092
Furrow	1 030	1 064	1 174	905
Flat	757	732	1 080	788

* Space between rows (cm)

When new technology is being developed many factors have to be considered to assure that the system will perform. Table 5 compares the results obtained with groundnut when planted in two configurations at two spacings. Ridge planted groundnut generally outyielded either the furrow or flat-planted crop except for the 60 cm spacing with Banki. The effect of row spacing was not the same for the two cultivars, presumably because of growth habit.

Weed Control

It is well known that weed control is essential if the farmer is to obtain the best yields. It is not so well known that time of weed removal is also very important in maximizing crop yields. Table 6 shows the overall beneficial effect of weed control. If the farmer is to get the most out of his weed control activities, however, he must remove them not later than the 4th week after planting.

Table 6. Effect of time of weed removal after planting on soybean biomass (at NARC, 1984)

Weed Removal (Weeks after planting)	Soybean Biomass* (kg/ha)
2	2 729 a
3	2 825 a
4	2 645 a
5	2 066 b
6	2 145 b

2 and 4	2 912 a
3 and 5	2 854 a
2, 4 and 6	2 829 a
No weeding	1 412 c

*Values followed by the same letter are not different at 5% level.

Experimental results during kharif season in 1984, with maize (Table 7) show how seriously weeds can affect yield on the farmer's fields. The crop treated with herbicide produced almost double the yields of both grain and stalks compared with those blocks treated in the traditonal 'seal' fashion.

Table 7. Effect of weed control on maize 'Azam' yeild (at Haripur, NWFP, 1984)

Treatment	Yield (kg/ha)		
	Grain	Stalk	Total
Primextra*	4 809	14 633	19 442
"Seal"**	2 577	8 329	10 906

* applied with napsack sprayer at the rate of 2.5 litre/ha
** post-emergence cultivation that reduces populations of both maize and weeds

Yield tests

The 1982-83 and 1983-84 rabi seasons contrasted greatly in terms of rainfall pattern. In the former, rainfall was considerably above average while a four month drought: October to February-characterized the latter. It is interesting to note (Table 8) that with one exception, yields of the four rapeseed cultivars tested in the two years showed the same ranking; yields in 1984, however, were only about one half of those in 1983. These results also show that the high quality cultivar 'Westar' yields as high as or better than any of the others in the test.

Table 8. Yield of rapeseed cultivars (at NARC during 1982-83 and 1983-84)

Cultivar	Yield (kg/ha)	
	1982-83	1983-84
Westar	2 116	1 096
Tower	1 839	870
Tobin	1 794	713
PR. 7	1 656	851

During the dry, 1983-84 rabi season several mustard lines were also tested and the oil content of the seed was measured (Table 9). One line, Steff, was below the average in oil percentage yet because it yielded so well it rated at the top in terms of oil yield/ha. For general use any cultivar selected must be assessed on the basis of oil yield per unit area. Another feature of importance to the farmer is the capacity of cultivar to produce fresh fodder. Steff seems to excel in this attribute as well.

Table 9. Oil production of selected mustard lines (at NARC during 1983-84)

Mustard Line	Yield (kg/ha)	Oil Content %	Oil (kg/ha)
Steff	2 938	32.2	946
R 3251	1 685	40.0	674
R 2625	1 247	44.4	534
R 1900	1 286	41.1	529
Domo	1 294	39.0	505
R 2773	1 330	19.4	259

Land preparation in advance of seeding is always a very important factor in farming, but especially under barani conditions where moisture conservation is so important. Traditionally all tillage, primary as well as secondary, has been done with either the tractor mounted cultivator with chisel tynes or the bullock drawn pora plow. Frequent passes are made with the implement often resulting in significant moisture loss despire the planking that follows.

In our experiments with maize, deep tillage, especially with a moldboard plow has proven very beneficial. Hobbs (1984) has shown a similar beneficial effect in wheat production. With maize, yields were greater from land that had been deeply plowed two consecutive years, less when deep plowed in only the current year, and least when tilled with the traditional cultivator, (Table 10).

Table 10. Comparison of yields (kg/ha) maize 'Azam' from 1984 planting after moldboard plowing (30 cm) and traditional tillage with tractor mounted cultivator (at Haripur)

Pre-seeding Treatment-1984	Tillage Treatment-1983	
	Moldboard Plow	Cultivator
Moldboard Plow	5 695	4 566
Cultivator	5 286	3 217

In yield trial on wheat (Fig. 1) variety Pak-81 produced highest yield followed by S-19. These yields are much better than the existing variety Lyallpur-73.

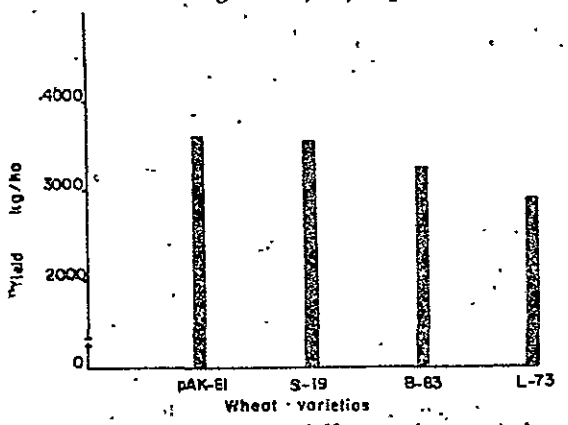

Fig. 1 Yield test on different wheat varieties

Source: Barani Agricultural Research Institute, Chakwal, 1984-85.

The results of the yield experiments on groundnut are depicted in Table 11. The variety NC-7 gave highest yield followed by NC-6 as compared to No. 334 and Banki.

Table 11. Yield of different varieties of groundnut in Barani areas during 1981-83

Variety	Yield (kg/ha)
NC-7 (spreading type)	3 538
NC-6 (semi-erect)	3 472
No. 334 (spreading type)	3 325
Banki (erect)	1 683

Source: Barani Agricultural Research Institute, Chakwal, 1985.

Effect of seedbed preparation on insect and disease incidence

Dry years are part of barani agriculture and the farmer must prepare as best as he can. The 1983-84 rabi season with about four months of drought offers an excellent example of how proper land management benefits the crop. It is well known that white ants and root rot are problems in the wheat crop in dry years. A small survey of fields that had been cultivated differently confirm that statement (Table 12). The Wheat Programme fields had been deep-tilled while the farmers' fields had been prepared with the traditional cultivator. Clearly the extra moisture allowed the plants to be more vigorous and thereby suffer less from insect and disease infestation. The BARD fields were intermediate so far as land preparation is concerned and accordingly, the damage was intermediate as well.

Table 12. Effect of seedbed preparation on insect and disease injury on wheat crop (at Sahng, District Rawalpindi, 1983-84)

Type of Primary Tillage	Plants Examined (No.)	Extent of Damage (%)		
		Rootrot	Insect	Total
Moldboard Plow (30 cm)	1 732	7.1	1.0	8.1
Cultivator (Seeps) (15 cm)	11 945	8.2	5.6	13.8
Cultivator (Traditional) (10 cm)	2 522	19.3	10.3	29.6

Testing of germplasm of winter cereals

An experiment was carried out to select improved varieties of bread wheat, durum wheat, barley and triticale for cultivation under dry-land farming conditions at high altitude in Baluchistan namely, Mehterzai and Quetta. The experiment included segregating population, observation lines and the yield trials.

The experiments planted at Khan Mehterzai were not havested since the crop did not produce grain due to exceptionally dry weather. At Quetta, the crop was saved by applying one irrigation to obtain some seed for the next year. Due to abnormally dry weather, selection on individual plant basis was not possible in the segregating populations. Entries were selected or rejected as a whole on the basis of disease attack and growth duration. Results are shown in table 13.

Table 13. Selected entries in winter cereal (at Quetta)

Experiment	No. of entries planted	No. of entries. selected
Segregating population		
Bread wheat – F2	155	32
Bread wheat – F3	374	335
Bread wheat – F4	14	–
Durum – F2	149	28
Durum – F3	87	7
Barley – F3	65	30
Observation lines		
Group–I		
Bread wheat	15	15
Durum	22	22
Barley	18	18
Tritical	9	9
Group–II		
Bread wheat	75	6
Durum	125	10
Tritical	143	101

All yield trials failed except the bread wheat which was harvested and brought to the laboratory to determine the yield potential, grain per spike and 100-grain weight of individual entries (Table 14).

Table 14. Yield and yield components of bread wheat yield trial (at Quetta)

Entry No.	Variety/pedigree	Yield (kg/ha)	Grain/ Spike	100-grain weight (g)
1	'Be 30stayal'	75.8	34.0	2.75
17	'Hys/No/LV/ /. Fi/3/F1, KVZ/Hys'	237.5	26.6	3.16
18	'69.153/YMH, F3/ /237.24'	140.3	32.0	3.26
23	ROM. TAST/BON. Fi/Dibo/ /Su 92/01 13845	148.6	39.5	2.83
24	J1/3/pj/NAR/HNF/CD/4/JAR/GNS/LP	104.6	36.1	2.63

25	SPN/ /AU/YMH	20.2	18.6	2.96
27	TOP/237-30/KVZ	146.3	29.9	3.36
32	KC/BEZ/3/1150. 18/P 101/ /1150. 18/VGDW	76.5	28.1	2.86
69	Hgn-Son.64 x 1150. 18 P101/KK ZYE 451-15-3-1. OE	55.8	26.0	2.90
81	Kanred-Funox 119933-3801 Y IB-IT TA 4302. 3A. 1A. 1A. 0A.	100.7	32.7	3.20
107	Cl 13447/Nebr. Rest 3899/NB 69457	154.0	31.7	2.96
110	NS 984-1 NE 7.01136	122.0	35.5	2.33
116	Atl 66/Cmn/3/Justin/Gav/ /wG 175	142.2	38.1	2.50
117	Nap Hal/Cl 13449/4/Sel 14. 53/3/Lancer/2/Atl 66/Cmn	194.0	40.8	2.55
118	Lovrin B/Sane Son	247.2	43.1	3.37
	'Local White'	108.8	30.5	3.54
	'Sarghoon'	213.2	44.3	2.64

Fertilizer trial

An experiment was conducted on wheat at different localities of barani tracts in Punjab during 1980-81. The results are depicted in Fig. 2, which indicate that higher yield was obtained with increased fertilizer application. It could be concluded that optimum fertilizer use would increase the yield from 1½ to 2 times. Another experiment was conducted on gram using variety CM-72. Results indicate that NPK 0-70-35 kg/ha gave double yield as compared to control (Fig. 3). The next highest yield was obtained using NPK 0-90-35 kg/ha.

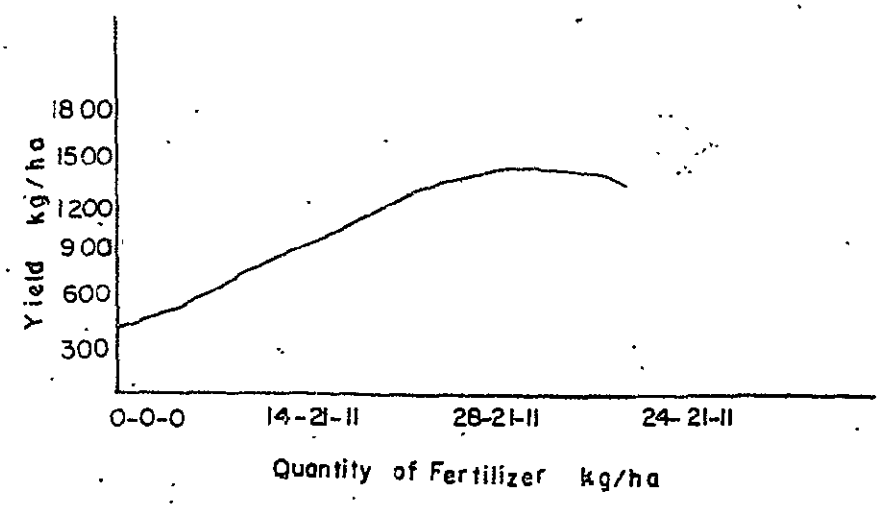

Fig. 2 The effect of fertilizer application on the yield of wheat under barani condition 1980-84

Source: Barani Agricultural Research Institute, Chakwal

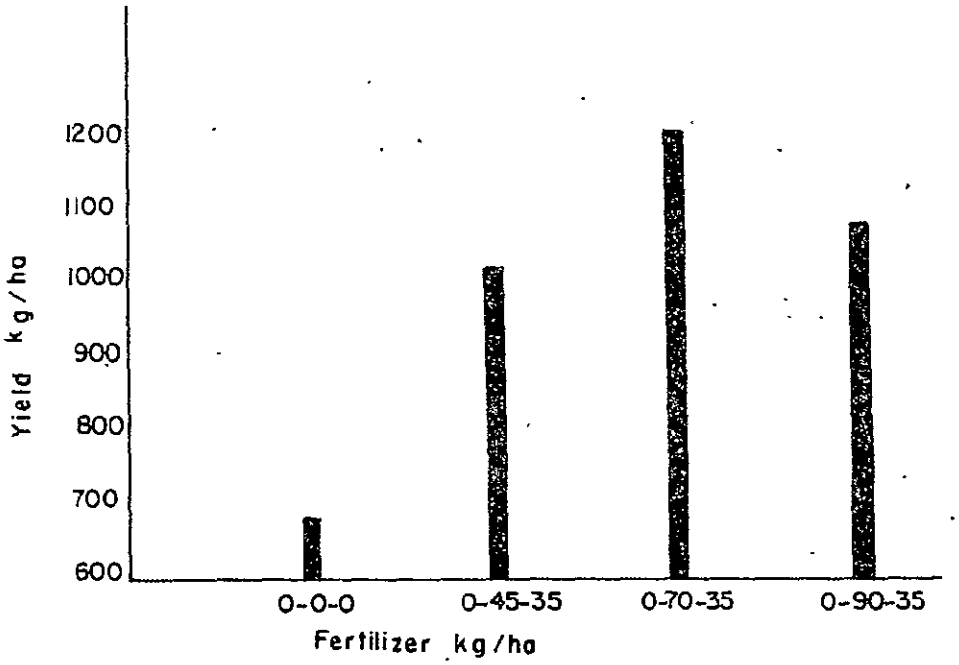

Fig. 3 The effect of fertilizer application on gram yield using variety CM-72

Source: Barani Agricultural Research Institute, Chakwal. 1982-83

Similarly another experiment was conducted on groundnut, variety Banki, during 1982-84. Highest yield was obtained using NPK 40-80-20 followed by 20-80-20 kg/ha. The doses higher than these decreased the yield substantially.

Agro-meteorology

Because of the extreme importance of weather to barani agriculture the BARD Project has contracted with an agro-meteorologist to analyse historical weather data and provide rainfall probability indices for the various areas in which we are working. Such values, of course, can serve many purposes and agro-meteorology is a discipline that needs to be strengthened further (Robertson, 1985a, b, c, d, e).

Approved varieties of different crops for the Punjab Barani Areas

These are presented in table 15.

Table 15. Approved varieties of different crops for Barani Areas of Punjab

Crop	Recommenced varieties	New varieties/lines
— Wheat	Lyallpur-73 and Pak-81 (Early sowing), ARZ (Mid Season) Blue Silver (late season)	K-342 (B-83) V-80001, V-81188, V-80099, V-8116, V-0067.
— Gram	C-44, CM-72, C-235	C-141, E-23, 6, E-2283, C-88, C-89, C-91.
— Masoor	6-9	ARRI 337, 355.
— Mung	66.1, 66.2, M-28	No. 41, No. 87, F-56, A-17.
— Mash	No. 48, No. 80	No. 59, No. 216.
— Groundnut	No. 45, No. 334, Banki	Ne-6, Ne-7.
— Toria, Raya	Toria solution 'A', Raya L-18	b-carinata, Probi-raya 80, Yellow Raya, '00'.
— Sunflower	—	Sankum 90, 110.

Source: Barani Agricultural Research Institute, Chakwal.

Other activities

Farm machinery suitable to the farm and farm activities is essential for improving production and stablizing farm income. The small average farm size complicates the problem because individual farmers generally cannot afford the more sophisticated equipment. Nevertheless, power equipment is being introduced to barani agriculture on rental basis. The BARD Project, therefore, in cooperation with the Farm Machinery Institute, (FMI) at NARC has played a role in evaluating available equipment and recommending modifications that would improve performance. Among the quipment items of concern to date have been a seed drill for general planting with fertilizer attachment, a groundnut planter, a local cultivator with sweeps, a ridger-seeder, a bullock drawn tool bar, a small reaper-windrower and a groundnut digger. Most of these implements are produced locally. A rabi drill has been manufactured by a local manufacturer. Its performance is rated as excellent. Similarly, groundnut drill has also been manufactured under the guidance of BARD and FMI. It needs a few modifications before it is available for commercial use next year. The use of sweeps as a replacement of conventional cultivation tyne has proved useful in removal of weeds and moisture conservation.

Productivity of any farm depends in part on the soil and its fertility. Many barani farmers are now applying fertilizer at the time of seeding. Unfortunately, at present we do not know the amount and type that should be applied for any crop or soil type for maximum economic benefit. Accordingly the BARD Project and Provincial Institutes have established laboratories capable of analysing soils for the major nutrients, N, P and K, alongwith some of the microelements. With this capability it will now be possible to determine what kind and how much fertilizer should be used and thereby improve efficiency of fertilizer use. Some analyses have already been done on soil samples from experimental blocks thus providing a solid basis for production trials and fertilizer use.

Sunflower is a crop grown in more temperate regions because of its oil producing capability. Experimental results with this crop to-date have been discouraging under barani conditions at NARC. Charcoal rot, a disease caused by the fungus organism *Macrophomina phaseolina,* has proven to be a very serious problem. In an effort to understand the factors that exacerbate the problem in this area the Project contracted with a sunflower pathologist to spend a month in Pakistan and identify means of overcoming the disease. The report (Hoes, 1985) indicates that conditions which stress the plant (high temperature and low soil moisture) must be avoided if the sunflower crop is to be successful. For much of the barani land, therefore, sunflower cultivars resistant to charcoal rot need to be developed. Work is continuing to screen out a charcoal resistant material from the available world stocks at NARC.

During kharif season, 1983, an improved cultivar of maize, was introduced to the farmers of the Haripur region of NWFP. Some 27 ha were planted and 35 individual farmers were involved. This cultivar, Azam, out yielded local material by 60 and 50 per cent, respectively, in grain and fodder. To preserve this high quality seed a procurement and distribution system was developed with the aid of funds provided by the Canadian Emabssy. Seed Centres have been developed at two sites and over the first year, October 1983 to June 1984, 11.8 tons of maize seed was purchased, stored and subsequently resold to farmers for seeding. These facilities have subsequently been used to store and resell quality wheat seed as well. Farmers from other areas are now exploring the possibility of establishing such centres in their regions as well.

The significance of 'Range Management' to barani agriculture and the potential for its improvement were detailed in a report prepared by Looman (1984). Again this report was the result of a short-term contract established with a range management specialist.

EDUCATIONAL MANPOWER DEVELOPMENT

Barani Agricultural College, Rawalpindi is the only institution in the country, where the theme of the study is completely barani oriented. The first batch in 1984 comprised of 45 graduates while 46 students graduated in the subsequent year.

INFRASTRUCTURAL DEVELOPMENT

In addition to the sampling of experimental results noted above certain other areas of involvement deserve mention. Each in its own way is designed to support the ongoing research and development activities and strengthen the overall BARD capabilities. These are:

Contractual research

In January 1984, a contract was established with the H.E.J. Institute of Chemistry, Karachi University, to provide an analytical service to the oilseed component of the Project. In addition to the measurements on quantity of oil, levels of erucic acid and glucosinolates were necessary to be determined for the oilseed scientists to evaluate the total worth of the various lines and cultivars under test. This service was also made available to the Provincial oilseed scientists. A second contract has just been established with the Agricultural Research Station at D.I. Khan. This one is designed to demonstrate that cotton can be grown successfully under the 'rod kohi' system of agriculture in the region.

Another contract was also approved to study biology and control of charcoal rot in sunflower at NARC.

Prototype machinery development

Arrangements are being made to develop a local prototype for a reaper-windrower. This activity will be finalized in a proposed contract: A second contract will be established with a local seed drill manufacturer to improve the design and produce a groundnut planter. Both contracts are anticipated to be in place during 1985.

Contracts to be acceptable to, and funded by BARD, must relate to the needs of barani agriculture and the BARD Project objectives. There is no restriction as to who can prepare a project for consideration as long as there is the basic competence and infrastructure to handle it. For any single contract, there is a funding limit of Rs. 300 000 and the term of the contract cannot exceed three years.

Training

This is a very important aspect of the BARD Project and is an ongoing activity. So far, three local scientists have been sponsored for training. A senior oilseed counterpart worked in the Candian rapeseed programme at the Saskatoon Research Station from May to September, 1984. During this period, he was exposed to all aspects of the research and development work as well as to commercial production facilities. With this experience, he can now provide greater leadership and service to the oilseed work.

During the months of December, 1984 and January, 1985, two young-men from PARC received training in agrometeorology at the Pakistan Meteorological Services Offices at Karachi. As noted earlier, this is a discipline very important to barani agriculture and this extra training will help in strengthening agrometeorolgy in Pakistan. Arrangements have also been finalized to sponsor another scientist for training. He is scheduled to receive about four months of training in Farming Systems research at ICARDA in Aleppo, Syria, commencing in February, 1986.

PROBLEMS AND CONSTRAINTS

There is a broad range of problems and constraints that the barani farmer must face. Two basic constraints are; uncertainity of rainfall during the growing season and the low natural soil fertility. Other major problem is the lack of approved production technologies such as improved cultivars, use of quality seed, optimum fertilizer rates, plant protection measures etc. All the existing barani projects have attempted to provide solutions to these, some by extending knowledge already available and others through innovative research

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USE OF GYPSUM FOR RECLAMATION OF SALT AFFECTED SOILS

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ABSTRACT

Efficiency of gypsum was studied with respect to its particle size, quantity used and methods of application for reclamation of salt affected soils. Gypsum was also compared with sulphuric acid when both applied with and without farmyard manure for reclamation.

Mixing of gypsum with soil columns improved the soils in much shorter time as compared to surface application. Finer gypsum particles (60-100 mesh) caused earlier reduction of EC and SAR of leachate than coarser ones (< 30 mesh) but after period of six months coarser particles also showed the effects similar to the finer particles. Addition of 100% gypsum on the basis of gypsum requirement reclaimed the soil by mixing with column in shorter time than 50% gypsum. Soil analysis and yields of maize and wheat crops showed that all the sizes of gypsum particles and all the doses of gypsum reclaimed the soil, but at the cost of time and water input. Coarser particles and low dose of gypsum involved more water and longer time.

Sulphuric acid yielded better results as compared with gypsum when leaching was allowed for only 20 days but with 40 days leaching yield was higher where gypsum application was made in one of the soils.

INTRODUCTION

The pressing need for more food coupled with scarcity of good arable land necessitates to expand to marginal lands that lie barren largely because of soil stresses. Soil stresses fall into three broad classes viz: chemical (mainly mineral), physical and hydrological. Mineral stresses that depress crop yields are soil toxicities, nutrient deficiencies or both, which also occur in saline-sodic and waterlogged soils.

It is needless to emphasize that the magnitude of salt affected soils in Pakistan is highly alarming. According to an estimate by Chaudhri et al (1978), 5.81 million ha are affected by salts in Indus plains. According to Muhammad (1978), 80% of the salt affected soils in Punjab and 60% in Pakistan are saline-sodic. The arid climatic conditions involving scanty rainfall and high evaporation in the country has led to unfavourable salts redistribution and accumulation in the root zone.

To combat the problems of salinity and waterlogging in the country besides the surface drainage, vertical drainage through large number of deep tubewells has been employed so as to lower the

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watertable and wash down the salts accumulated in the root zone of the soils with the pumped water. This measure, though effectively ameliorated the waterlogged conditions and to some extent saline situation, but it proved to be like out of frying pan into the fire. Unfortunately, our soils contain excess of sodium salts and most of the deep tubewells installed are pumping water with high sodium content and total soluble salts. This situation is leading towards progressive increase in the sodicity of soil resulting in deterioration of its physical conditions. This problem has been further accentuated with the installation of large number of tubewells by private farmers who have put in their tubewells indiscriminately without much considerations for the quality of water to be pumped up.

Reclamation of saline soils is done by simple leaching with suitable water while for the improvement of sodic and saline-sodic soils, replacement of exchangeable sodium with calcium is involved which is a complicated and multi-dimensional problem. At present, gypsum alone or in combination with organic manure is considered to be the most practicable, effective and efficient amendment for reclaiming sodic and saline-sodic soils. But the suitable size of gypsum particles, its quantity and method of application yet need to be standardized for efficient and economic reclamation of affected soils. An effort has been made in this direction and the study was carried out with the following objectives:

- To assess the efficiency of fineness of gypsum particles (mesh size) for reclamation
- To find out economic dose of gypsum in relation to gypsum requirement determined in the laboratory
- To compare mixing of gypsum with surface application
- To compare the efficiency of various amendments for reclamation

MATERIALS AND METHODS

This study was carried out in the green house of Ayub Agricultural Research Institute, Faisalabad. Two types of soils namely A and B were collected from Soil Salinity Research Institute Farm, Rakh Pindi Bhattian, Gujranwala district. Texture-wise both these soils were sandy loams but differed in EC, SAR and pH which are: EC 14.2, 12.6; SAR 73.9, 244.6 and pH 8.6, 10.3 respectively. Analytical data are shown in table 1.

Table 1. Analysis of the original soil

Soil	pH	EC x 10^3	Na	Ca + Mg me/l	SAR	O.M %	P mg/kg	K mg/kg	Texture	
A	8.65	14.2	263.7	25.60	73.9	0.30	6.6	218.5	Sandy	loam
B	10.30	12.6	280.5	2.64	244.6	0.33	9.5	235.0	"	"

The soils were prepared and packed in lysimeters of 60 cm height with a provision for collecting leachate at the bottom. Before packing the soil, wire guaze, glass wool and coarse sand were put on the base of lysimeters to obtain clear leachate. Following 3 experiments were conducted:

– Experiment No. I

Treatments

i. Mesh size
   a. Less than 10
   b. 10–30
   c. 30–60
   d. 60–100

ii. Methods of application
   a. Surface application
   b. Mixing

iii. Two types of soils

– Experiment No. II

Treatments

i. Percentage of gypsum requirements
   a. 0%
   b. 50%
   c. 75%
   d. 100%

ii. Methods of application
   a. Surface application
   b. Mixing

iii. Two types of soils

– Experiment No. III

Treatments

i. Amendments
   a. Control
   b. Gypsum
   c. H_2SO_4

ii. Time of leaching
   a. 20 days
   b. 40 days

iii. Organic mater
   a. No FYM
   b. 10 T/ha FYM

iv. Two types of soils

In experiment No. I and II, gypsum. was mixed in amount and size as mentioned in treatments in the column of soil and in the other set of treatments, it was just spread on the surface of the soil column. The lysimeters were dipped in water for proper packing of soil in the column. The soils in the lysimeters were leached with canal water and the leaching process was continued, till the leachate of

uniform composition was obtained. During leaching process, leachate was collected at 15 days intervals and analysed for EC, Ca+Mg, Na and SAR. After completion of leaching process, which took different time for different treatments, soil samples were collected and analysed for pH, EC, Ca+Mg Na and SAR. In the first two experiments, the reclaimed soil was shifted to glazed pots and maize crop (Akbar variety) was grown to which normal dose of NPK was applied. This was irrigated with canal water throughout the season. In one experiment comprising different mesh sizes, the maize crop was heavily damaged by insect attack and the data for this experiment has not been incorporated. The rest of the crop was harvested after about 60 days and the data of dry matter was recorded.

In the same reclaimed soil wheat crop (Pb-81) was sown and NPK fertilizers at recommended dose were applied. Canal water was used for irrigation throughout the growing season. Crop was harvested at maturity and straw and grain weights were recorded.

RESULTS AND DISCUSSION

EFFECT OF GYPSUM ON CHEMICAL COMPOSITION OF LEACHATE

Electrical conductivity

The data of EC of leachate are presented in tables 2, 3, 4 and 5. Where no gypsum was applied the EC of leachate was very high. Under the control treatment in case of soil A after a period of 3 months, no leachate was received, whereas in soil B, leaching process stopped in a period of even less than 2 months because this soil was highly sodic with SAR of 244.6 as compared to SAR 73.9 in soil A. Treatments with different doses of gypsum resulted in very conspicuous differences in EC of the soil. The EC of leachate became higher and higher where no gypsum was applied and it reached to the figure of 45 after a period of 3 months. Gypsum application in different doses resulted in drastic reduction of EC within a period of only two months. Surface application of 75% gypsum decreased the EC upto 8.8 in the period of 6 weeks whereas by mixing the same quantity of gypsum in soil column EC reached to the figure of 1.4.

In soil B, the trend was also similar. After period of one month, the EC was in the range of 30 with 50 and 75% treatments, but it decreased to EC 8 with 100% gypsum application in the same period by mixing method.

Gypsum application by mixing proved better than surface application in 100% treatment as the EC of leachate was decreased in far shorter a time as compared to surface application. However, by surface application also the EC of leachate did decrease, but after longer period of time.

No appreciable difference was observed in reduction of EC of leachate when gypsum of different particle sizes was applied by mixing with soil column in soil A, whereas in soil B the finer size reacted more quickly by mixing.

Table 2. Effect of applied gypsum on EC x 10^3 of leachate in soil A.

Date	No gypsum (Control)	G-50%		G-75%		G-100%	
		Suface application	Mixing	Surface application	Mixing	Surface application	Mixing
5-2-1984	10.0	14.7	9.6	7.5	15.5	11.8	11.6
21-2-1984	23.9	9.9	14.3	19.9	4.6	18.6	6.0
8-3-1984	34.4	5.4	6.8	13.3	1.5	11.2	3.6
24-3-1984	34.6	5.4	2.6	8.8	1.4	9.0	2.9
11-4-1984	36.3	4.1	3.4	5.9	0.9	8.3	1.6
28-4-1984	45.6	4.1	3.2	5.8	0.9	7.0	1.6
28-5-1984	–	4.3	3.2	5.5	1.0	6.3	0.9
17-6-1984	–	1.6	3.9	3.0	0.9	3.4	0.8
22-7-1984	–	0.4	0.6	0.6	0.4	0.6	0.4

Table 3. Effect of applied gypsum on the EC x 10^3 of leachate in soil B.

Date	No gypsum (contol)	G-50%		G-75%		G-100%	
		Surface application	Mixing	Surface application	Mixing	Surface application	Mixing
5-2-1984	6.4	7.1	12.4	6.7	12.2	10.4	10.8
21-2-1984	19.9	23.1	20.6	9.5	15.9	17.2	15.3
8-3-1984	47.9	31.4	45.1	28.2	29.9	23.1	8.2
24-3-1984	73.6	33.3	44.4	29.5	32.6	26.5	6.8
11-4-1984	–	22.3	40.4	24.8	15.9	14.9	3.2
28-4-1984	–	18.6	26.7	22.1	13.0	12.6	3.5
28-5-1984	–	14.3	20.9	20.0	3.7	11.7	3.6
17-6-1984	–	12.5	12.5	8.1	4.4	5.9	1.9
22-7-1984	–	2.9	3.7	2.7	1.4	1.6	0.6

Table 4. Effect of gypsum fineness on EC x 10^3 of leachate of soil A.

Date	Coarser than 10 mesh		10-30 mesh		30-60 mesh		60-100 mesh	
	Surface application	Mixing	Surface application	Mixing	Surface application	Mixing	Surface application	Mixing
5-2-1984	13.2	15.3	4.4	12.0	4.5	18.7	16.7	15.8
21-2-1984	30.0	2.6	29.7	3.2	29.8	2.5	14.3	2.8
8-3-1984	18.4	2.0	13.5	1.7	16.0	1.6	7.9	1.2
24-3-1984	11.2	1.3	7.9	1.3	8.3	1.2	8.2	1.0
11-4-1984	7.1	0.9	4.7	0.7	5.0	0.7	4.1	0.6
28-4-1984	8.7	0.9	4.2	0.7	9.7	0.7	4.2	0.7
28-5-1984	4.8	1.0	3.4	0.9	4.0	0.8	4.4	0.6
17-6-1984	2.7	1.1	2.2	0.8	2.5	0.9	2.9	1.1
22-7-1984	0.5	0.5	0.7	0.4	0.6	0.7	0.7	0.7

Table 5. Effect of gypsum fineness on EC x 10^3 of leachate of soil B.

Date	Coarser than 10 mesh		10-30 mesh		30-60 mesh		60-100 mesh	
	Surface application	Mixing	Surface application	Mixing	Surface application	Mixing	Surface application	Mixing
5-2-1984	9.7	12.3	9.3	10.5	9.3	12.2	7.8	10.7
21-2-1984	20.8	18.0	21.7	16.2	20.6	15.5	21.3	9.9
8-3-1984	22.0	25.0	22.1	17.3	21.6	13.3	28.2	4.5
24-3-1984	20.6	17.4	17.3	11.7	16.4	11.7	25.6	3.7
11-4-1984	12.4	10.9	9.6	10.1	9.1	7.4	15.4	4.5
28-4-1984	13.7	9.1	8.8	9.1	8.4	7.4	18.1	2.5
28-5-1984	9.6	8.4	8.2	7.6	7.1	6.7	20.2	2.5
17-6-1984	4.2	4.4	3.9	4.6	2.4	6.0	7.1	1.4
22-7-1984	0.9	1.0	0.8	1.2	0.8	0.9	0.8	0.6

All sizes of gypsum particles proved equally effective in both the soils when applied by surface application. Mixing of gypsum with soil column resulted into much earlier reduction of EC of drainage water in comparison to surface application.

Sodium adsorption ratio

The data regarding the effect of gypsum on SAR of leachate are given in tables 6, 7, 8 and 9. Gypsum when applied by mixing, reduced the SAR of leachate in much shorter time as compared to its application by spreading on the surface in all the doses as well as all the sizes in both the soils. In control, the SAR of leachate reached upto 300 in a period of 3 months whereas, it was in the range of 11 with 50% application by mixing, and SAR was not more than 2 when gypsum was applied at 75 and 100% of its requirement by mixing in soil A. In soil B, the SAR of leachate was 556, 416, 287, 61 in control, 50%, 75% and 100% gypsum application by mixing, respectively, after a period of one month. However, in the same soil after a period of about 6 months the SAR came down to 15 by only 50% gypsum application.

Table 6. Effect of applied gypsum on SAR of leachate in soil A.

Date	No gypsum (control)	G-50%		G-75%		G-100%	
		Surface application	Mixing	Surface application	Mixing	Surface application	Mixing
5-2-1984	27.1	38.3	18.4	17.6	39.1	52.7	49.1
21-2-1984	109.2	82.3	65.0	83.8	17.5	102.6	18.8
8-3-1984	151.1	59.9	35.9	98.0	1.2	93.4	4.4
24-3-1984	181.6	53.6	24.0	69.8	3.8	85.5	2.2
11-4-1984	281.0	36.7	13.5	65.8	3.4	68.5	2.1
28-4-1984	300.1	28.0	11.5	45.9	1.9	42.5	1.6
28-5-1984	–	17.6	19.8	15.4	5.4	35.6	5.1
17-6-1984	–	7.2	17.7	7.7	4.3	11.2	5.4
22-7-1984	–	3.9	8.4	4.4	5.7	2.6	2.4

Table 7. Effect of applied gypsum on SAR of leachate in soil B.

Date	No gypsum (contol)	G-50%		G-75%		G-100%	
		Surface application	Mixing	Surface application	Mixing	Surface application	Mixing
5-2-1984	57.5	48.1	66.0	91.1	64.8	132.7	40.4
21-2-1984	363.2	403.2	204.0	351.9	140.0	295.7	105.0
8-3-1984	556.4	662.8	415.9	503.9	286.7	442.4	61.1
24-3-1984	1098.6	446.4	447.7	427.0	306.3	372.4	59.1
11-4-1984	971.9	360.2	459.3	341.1	142.7	183.8	41.3
28-4-1984	–	193.7	200.0	226.0	132.2	155.4	39.4
28-5-1984	–	111.4	94.4	189.1	94.3	165.2	41.9
17-6-1984	–	112.1	32.4	71.3	57.3	45.4	21.0
22-7-1984	–	15.0	24.6	16.7	18.3	28.2	4.9

Table 8. Effect of gypsum fineness on SAR of leachate in soil A.

Date	Coarser than 10 mesh		10-30 mesh		30-60 mesh		60-100 mesh	
	Surface application	Mixing	Surface application	Mixing	Surface application	Mixing	Surface application	Mixing
5-2-1986	35.5	65.5	21.4	42.6	27.3	74.0	69.6	52.1
21-2-1984	106.6	10.0	114.2	9.1	106.0	5.7	94.4	7.6
8-3-1984	120.5	3.7	113.1	1.8	83.0	1.7	62.9	1.1
24-3-1984	63.4	2.0	52.3	2.2	70.3	2.0	31.7	2.2
11-4-1984	79.6	2.9	28.1	1.8	29.8	1.4	20.2	2.0
28-4-1984	71.7	3.8	19.4	1.6	32.2	2.2	4.4	1.4
28-5-1984	25.9	5.9	5.6	5.3	12.4	3.5	6.5	3.3
17-6-1984	11.3	5.4	5.1	4.2	5.9	4.5	6.4	3.6
22-7-1984	2.8	4.1	2.2	1.8	3.0	5.1	3.6	3.0

Table 9. Effect of gypsum fineness on SAR of leachate in soil B.

Date	Coarser than 10 mesh		10-30 mesh		30-60 mesh		60-100 mesh	
	Surface application	Mixing	Surface application	Mixing	Surface application	Mixing	Surface application	Mixing
5-2-1984	82.0	50.2	72.1	32.1	68.8	43.7	51.0	50.0
21-2-1984	357.4	217.0	319.5	59.5	330.3	125.3	327.6	70.5
8-3-1984	395.4	101.9	362.5	77.2	402.2	93.3	432.3	14.5
24-3-1984	316.0	99.2	234.9	65.1	255.4	79.6	337.3	16.0
11-4-1984	201.2	102.2	151.8	96.7	141.9	62.2	258.3	15.4
28-4-1984	176.9	138.4	73.2	88.8	75.6	70.1	221.4	25.4
28-5-1984	81.4	93.9	46.2	111.7	44.5	60.8	153.7	30.5
17-6-1984	22.2	38.4	13.9	45.6	6.5	53.9	39.2	5.8
22-7-1984	4.4	7.8	5.3	13.2	3.7	10.7	5.1	6.1

Finer particles of gypsum resulted in earlier reduction of SAR of leachate in soil A. After a period of one month, the SAR of leachate was 120, 113, 83, 63 with less than 10 mesh, 10-30 mesh, 30-60 mesh and 60-100 mesh respectively. Within a period of six months, the SAR reached to the value of 5 or less with all the particle sizes in soil A. In soil B, it took more than 4 months to bring down the SAR of leachate in the range of 30 to 40 with the particles size of 60 mesh or less. The finest gypsum particles under study (60-100 mesh) resulted into reduction of SAR to the value of 15 in the period of only one month. In period of 6 months, the SAR of leachate in this soil came down to the value of 13 or less with all the sizes of gypsum particles.

EFFECT OF GYPSUM ON SOIL PROPERTIES

Data regarding the effect of gypsum on the pH, EC_e and SAR of soil, after reclamation process are given in tables 10, 11, 12 and 13.

Table 10. Effect of quantity of gypsum on pH, EC_e and SAR of soil A after leaching

	Depth of column (cm)	No gypsum (Contol)	Surface application 50%	75%	100%	Mixing 50%	75%	100%
pH	0 – 15	8.3	8.3	8.1	8.0	8.2	8.2	8.0
	15 – 30	8.3	8.4	8.1	8.1	8.3	8.1	8.2
EC_e	0 – 15	2.0	1.3	1.5	1.3	1.4	0.9	1.0
	15 – 30	1.9	1.1	1.2	1.4	1.2	1.1	1.1
SAR	0 – 15	10.9	3.3	2.4	2.4	4.6	2.9	2.0
	15 – 30	14.5	3.6	2.8	2.9	5.5	3.4	3.2

Statistical analysis

Gypsum quantity	0	50%	75%	100%	Surface application	Mixing
pH	8.29 a	8.28 a	8.12 b	8.08 b	8.16	8.16 N.S.
EC_e	1.98 a	1.28 b	1.17 b	1.24 b	1.31	1.14 N.S.
SAR	12.70 a	4.20 b	2.90 b	2.60 b	2.89	3.61 N.S.

Table 11. Effect of quantity of gypsum on pH, EC_e and SAR of soil B after leaching

	Depth of column (cm)	No gypsum (Control)	Surface application 50%	75%	100%	Mixing 50%	75%	100%
pH	0 – 15	8.7	8.5	8.1	8.1	8.7	8.5	8.3
	15 – 30	8.9	8.5	8.2	8.4	8.7	8.5	8.2
EC_e	0 – 15	2.6	2.2	2.3	2.2	1.9	1.6	1.0
	15 – 30	2.8	1.6	1.6	1.9	1.8	1.5	1.0

SAR	0. – 15	24.1	16.4	5.0	5.3	21.9	11.7	3.9
	15 – 30	18.6	10.5	7.5	7.9	20.0	12.9	3.2

Statistical analysis

Gypsum quantity	0	50%	75%	100%	Surface application	Mixing
pH	8.77 a	8.62 a	8.33 b	8.25 b	8.29 b	8.51 a
EC_e	2.69 a	1.89 b	1.74 bc	1.51 e	1.95 a	1.47 b
SAR	21.30 a	17.20 a	9.20 b	5.00 b	8.80 b	12.20 a

Table 12. Effect of gypsum fineness on pH, EC_e and SAR of soil A.

Depth of column (cm)		< 10 mesh		10-30 mesh		30-60		60-100 mesh	
		Surface application	Mixing	Surface application	Mixing	Surface application	Mixing	Surface application	Mixing
pH	0 – 15	8.3	8.3	8.3	8.2	8.3	8.3	8.3	8.2
	15 – 30	8.4	8.3	8.4	8.2	8.3	8.3	8.4	8.2
EC_e	0 – 15	1.3	0.8	1.2	1.0	1.4	0.9	1.3	1.3
	15 – 30	1.0	0.9	1.1	1.1	1.5	0.7	1.2	0.9
SAR	0 – 15	3.2	3.2	3.1	2.7	3.5	3.0	2.6	3.2
	15 – 30	3.4	3.0	3.1	2.7	3.1	2.7	3.1	3.4

Statistical analysis

Size of gypsum	< 10	10 – 30	30 – 60	60 – 100	Surface application	Mixing
pH	8.30	8.28	8.28	8.28 N.S.	8.35 a	8.23 b
EC_e	1.00	1.12	1.13	1.11 N.S.	1.24 a	0.96 b
SAR	3.19	2.87	3.10	3.07 N.S.	3.12	2.99 N.S.

Table 13. Effect of gypsum fineness on pH, EC_e and SAR of soil B.

Depth of column (cm)		< 10 mesh		10-30 mesh		30-60 mesh		60-100 mesh	
		Surface application	Mixing	Surface application	Mixing	Surface application	Mixing	Surface application	Mixing
pH	0 – 15	8.4	8.6	8.3	8.6	8.2	8.5	8.3	8.4
	15 – 30	8.2	8.6	8.3	8.6	8.3	8.6	8.4	8.4
EC_e	0 – 15	1.8	1.4	1.7	1.4	1.5	1.5	1.7	1.0
	15 – 30	1.6	1.4	1.5	1.4	1.4	1.1	1.8	1.3

SAR	0 – 15	4.8	6.3	3.4	7.1	3.6	4.0	3.9	2.8
	15 – 30	3.5	5.3	2.9	7.2	3.1	4.0	6.0	3.2

Statistical analysis

Size of gypsum	< 10	10 – 30	30 – 60	60 – 100	Surface application	Mixing
pH	8.48	8.46	8.40	8.34 N.S.	8.30 b	8.54 a
EC_e	1.54	1.49	1.38	1.46 N.S.	1.62 a	1.32 b
SAR	4.97	5.15	3.74	4.00 N.S.	3.90	5.0 N.S.

pH of soil

pH of soil A decreased from 8.65 to 8.1 with 75 and 100% gypsum application respectively, whereas in soil B, such reduction was from 10.3 to 8.3. The effect of methods of gypsum application on pH, was non-significant in soil A, whereas in soil B, methods of application showed significant difference.

The effect of various particle sizes of gypsum was non-significant but the methods of application indicated significant effects on pH of both the soils. In the case of soil A, decrease in pH was more by mixing, whereas in soil B it was otherwise.

EC_e of soil

The EC_e of soil A decreased from 14 to 1.2 with gypsum application. Different doses of gypsum showed similar effects in reduction of EC_e in soil A. The effect of method of gypsum application was also not statistically different on EC_e of soil A. In case of soil B, the EC_e decreased from 12.6 to 1.9 by 50% gypsum application and this value reached to 1.5 with 100% gypsum. Methods of application showed statistically different effect on EC_e of soil. More reduction was caused by mixing of gypsum in soil. The effect of different sizes of gypsum particles was non-significant on EC_e of both the soils. Methods exhibited statistically different behaviour. Mixing of gypsum caused more reduction in EC_e in both the soils.

SAR of soil

The application of gypsum at 100% reduced the SAR from 74 to 2.6 in soil A and from 245 to 5 in soil B. The effect of gypsum at 100% was statistically similar to the rate of 75% in both the soils. The methods of application showed statistically similar effect in soil A, whereas, in soil B surface application resulted in more reduction of SAR as compared to mixing. The effect of various particle sizes of gypsum as well as the methods of application showed nonsignificant effect on SAR of both the soils.

It can be clearly seen from the effect of gypsum on composition of leachate as well as on soil properties that reclamation of both the soils was done with all the doses of gypsum and all the sizes of its particles but at variable costs of time and water inputs. Finer particles and more quantity of gypsum resulted into earlier recolamation with smaller quantities of water, whereas coarser particles and less quantity of gypsum achieved the same goal in longer period of time and with more water

input. Methods of gypsum application showed conspicuous difference. Mixing of gypsum with soil column caused very quick reclamation as compared to its surface application.

EFFECT OF GYPSUM ON MAIZE DRY MATTER YIELD

The data for maize yield (Table 14) indicate that in soil A, gypsum application did not increase the yield. It may be due to the fact that soil A was initially not highly sodic and with continuous leaching for 6 months alongwith gypsum, most of the nutrients might have leached out, therefore, the best yield was obtained in soil where no gypsum was applied.

On the other hand in soil B, the yield in control was 10.2 which increased 3 times with gypsum application. All the doses of gypsum resulted in statistically similar yields. It is because of the fact that 50% gypsum also reclaimed the sodic soil but in longer time. The methods of gypsum application did not show any effect on yield. Reason for this was also the same: that soil was reclaimed through both the methods but in different length of time.

Table 14. Efficiency of applied gypsum on the yield of maize fodder (g/pot).

Soil	No gypsum (Control)	50% gypsum		75% gypsum		100 % gypsum	
		Surface application	Mixing	Surface application	Mixing	Surface application	Mixing
A	22.9	19.1	17.7	12.5	18.2	22.8	20.6
B	10.2	25.2	34.1	30.6	26.3	27.8	39.5

Statistical analysis

Gypsum quantity	0	50%	75%	100%	Suface application	Mixing
Soil	22.9 a	18.4 a	15.3 b	21.7 a	20.0	19.2 N.S.
Soil B	10.2 b	29.7 a	28.4 a	33.6 a	24.6	26.4 N.S.

EFFECT OF GYPSUM ON WHEAT YIELD

The data for wheat grain and wheat straw as affected by gypsum application are presented in tables 15 and 16. Like maize, gypsum application did not cause any increase in the yield of wheat as well. The grain yield in soil A was statistically similar in all the treatments. In soil B, which was highly sodic before the start of reclamation, the grain yield was significantly better with 75% and 100% gypsum applications as compared to control. In soil A, surface application of gypsum gave more grain and straw yields than mixing, whereas in soil B, methods of gypsum application did not show any significant difference. The effect of particle size of gypsum on wheat grain and straw yields was nonsignificant in both the soils.

Table 15. Efficiency of applied gypsum on yield of wheat

Soil	No gypsum (Control)	Gypsum 50% Surface application	Gypsum 50% Mixing	Gypsum 75% Surface application	Gypsum 75% Mixing	Gypsum 100% Surface application	Gypsum 100% Mixing
			Grain yield (g/pot)				
A	33.1	41.1	33.9	38.5	33.4	35.6	30.5
B	25.9	26.9	28.8	32.5	29.9	33.3	28.9
			Straw yield (g/pot)				
A	48.7	56.0	48.1	41.7	43.8	45.8	44.6
B	39.8	37.7	41.8	41.2	40.9	46.8	42.6

Statistical analysis

	Grain yield				Straw yield			
% Gypsum	0	50	75	100	0	50	75	100
Soil A	33.1	37.5	36.1	33.0 N.S.	48.7 ab	52.1	42.7c	45.2 bc
Soil B	25.9 b	27.9 ab	31. 1 a	31.2 a	39.8	39.8	41.0	44.7 N.S.
		Surface application	Mixing			Surface application	Mixing	
Soil A		37.5 a	32.3 b			49.8 a	44.5 b	
Soil B		29.4	28.7 N.S.			41.8	40.9 N.S.	

Table 16. Effect of fineness of gypsum on the yield of wheat

Soil	< 10 mesh Surface application	< 10 mesh Mixing	10-30 mesh Surface application	10-30 mesh Mixing	30-60 mesh Surface application	30-60 mesh Mixing	60-100 mesh Surface application	60-100 mesh Mixing
				Grain yield (g/pot)				
A	27.6	27.2	25.0	25.8	26.0	28.3	29.1	24.6
B	31.5	26.3	28.1	25.6	29.3	28.7	28.3	26.9
				Straw yield (g/pot)				
A	41.0	42.6	45.3	40.8	39.7	40.1	39.1	45.7
B	43.0	39.9	41.5	41.1	40.9	39.7	39.4	48.4

Statistical analysis

	Grain yield				Straw yield			
Gypsum sized	<10	10 – 30	30 – 60	60 – 100	<10	10 – 30	30 – 60	60 – 100
Soil A	27.4	25.4	27.1	26.8 N.S.	41.8	43.1	39.9	42.4 N.S.
Soil B	28.9	26.9	29.0	27.6 N.S.	41.4	41.3	40.3	43.9 N.S.

	Surface Application	Mixing	Surface application	Mixing
Soil A	29.9	26.5 N.S.	41.2	42.3 N.S.
Soil B	29.3	26.9 N.S.	41.2	42.3 N.S.

EFFECT OF VARIOUS AMENDMENTS ON WHEAT

The efficiency of various amendments and their impact on wheat grain and straw are given in tables 17 and 18.

Table 17. Efficiency of various amendments with and without F.Y.M. on the grain yield of wheat in pots (g/pot)

Amendment	No F.Y.M.		10 t/ha F.Y.M.	
	20 days leaching	40 days leaching	20 days leaching	40 days leaching
		Soil A		
Control	3.52	0.7	8.7	1.0
H_2SO_4	15.70	8.7	14.3	14.0
Gypsum	13.30	12.6	12.7	11.8
		Soil B		
Control	–	–	3.28	–
H_2SO_4	7.3	12.4	11.60	8.1
Gypsum	5.8	7.8	8.50	6.5

Statistical analysis

	0	H_2SO_4	Gypsum	No. FYM	FYM	20 days	40 days
Soil A	3.5 c	13.2 a	12.6 b	9.1 b	10.4 a	11.4 a	8.1 b
Soil B	–	9.8 a	7.2 b	8.3	8.7 N.S	8.3	8.7 N.S.

Table 18. Efficiency of various amendments with and without F.Y.M. on the straw yield of wheat (g/pot)

Amendment	No F.Y.M. 20 days leaching	No F.Y.M. 40 days leaching	10 t/ha F.Y.M. 20 days leaching	10 t/ha F.Y.M. 40 days leaching
		Soil A		
Control	3.8	0.63	8.9	1.33
H_2SO_4	21.7	9.90	16.8	14.20
Gypsum	12.3	12.90	13.7	13.10
		Soil B		
Control	–	–	2.4	–
H_2SO_4	12.1	15.6	15.2	10.6
Gypsum	6.1	12.2	12.1	7.0

Statistical analysis

	0	H_2SO_4	Gypsum	No FYM	FYM	20 days	40 days
Soil A	3.7 c	15.6 a	13.0 b	10.2	11.3 N.S.	12.8 a	8.7 b
Soil B	–	13.4 a	9.5 b	11.6	11.2 N.S.	11.5	11.3 N.S.

In soil A, sulphuric acid resulted in higher yield with 20 days leaching but with 40 days leaching gypsum gave better results. With the addition of farmyard manure to the soil the yield did not decrease even after 40 days leaching in case of H_2SO_4. It is clear that when farmyard manure was not applied, 40 days leaching after sulphuric acid application caused leaching of the nutrients as well and hence resulted in decreased yield, but application of farmyard manure helped in improving the physical condition of soil in addition to holding of nutrients. In the soil B, use of sulphuric acid resulted in higher yield than gypsum in all cases. The wheat yield with 40 days leaching after H_2SO_4 application without farmyard manure was more as compared to farmyard manure application. It is, because the soil B was highly sodic and 40 days leaching period without farmyard manure caused fast reclamation as compared to farmyard manure application. It can be infered that H_2SO_4 is quick acting amendment but it may also result into loss of nutrients from the soil.

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NEED FOR INTERNATIONAL CROSS-CHECKING AND CORRELATION IN SOIL ANALYSIS FOR INTERNATIONAL CLASSIFICATION SYSTEMS

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INTRODUCTION

Soil analytical data provides basic information for use in soil classification and is also interpreted for multifarious soil-oriented uses. Reliability of this data depends upon many factors i.e. methodology, instruments, competence and acumen of the analyst. Due to these reasons, data generated by various laboratories is often quite variable.

In general various determinations made through anlysis are not absolute but method dependent. Mostly methods are chosen on the basis of convenience of the analysts and their theoretical soundness. For example soil texture, an important property of soils which has a simple method of direct determination in soil laboratories is determined indirectly through saturation percentage in some of our laboratories only for the sake of convenience. Almost the same principal of convenience is applied to few other properties as well.

Reliability of results is a function of precision (reproducibility) and of accuracy (nearness to true value). The precision of results can easily be determined by internal measures. The accuracy, however, in most cases requires more detailed procedures such as:

- Analysis to be carried out by as many different methods, analysts and instruments as possible. In cases where agreement is good, results are assumed to be accurate.
- Control analysis of so-called certified reference material, i.e. material of certified qualitative and quantitative composition which is as similar as possible to the material to be analysed. Agreement between certified and observed values is then a direct measure of accuracy for particular type of analysis.
- Participation in an interlaboratory comparison. Samples used in such an intercomparison should be, as far as possible, similar in composition and concentration to the samples to be analysed on routine basis. The agreement of results from a particular laboratory with the most probable values obtained from a statistical evaluation of all the results is a measure of the accuracy of the type of analysis under investigations.

For practical reasons, most analytical laboratories are not in a position to check accuracy internally, specially in less developed countries as:

*Soil Survey of Pakistan, Lahore.

- Generally resources are available for only one method.
- Certified reference material is not easily available.
- Intercomparisons are rarely organized and many important types of analysis are usually not covered.

All this strongly necessitates the need for cross-checking and standardization of the analytical procedures. Two approaches are commonly followed for cross-checking i.e. cooperative and collaborative approach.

Cooperative approach

The laboratories use their own analytical procedures developed and adopted through their experience and convenience. The appraisal of results from this approach may help in establishing correlation between different procedures.

Collaborative approach

The laboratories use exactly the same procedures for various determinations. This approach can be considered as most advanced since a standard procedure already introduced is put to test. However, both approaches can run parallel so that the local (regional) procedures can be compared with the standard procedures.

HISTORICAL DEVELOPMENT

Need for quality control in soil analysis for soil classification and correlation was already felt in early fiftees (Van Reeuwijk, 1983), but most of the work done in this context was of regional level. Most recently quality control exercise has also been taken up on international level but it is still in its infancy. Following is a brief account of earlier efforts of some organizations:

Canadian Soil Survey Committee (CSSC)

In Canada, a collection of reference soil samples was made available to some laboratories for comparing results but in 1973 the CSSC decided to set up a new reference collection of 28 samples for analysis by 24 laboratories.

This was a collaborative scheme since most laboratories were to use the CSSC procedures manual (Mckeague, 1976). The scheme basically aimed at quality control of laboratories. The analytical results of these laboratories showed considerable variation which led to the continuation of the exercise. But, despite of these variations, many results clustered around a certain mean value. Hence these values could serve as tentative yardstick. As a result, the Canadian laboratories were urged to include these reference samples in their routine analyses.

Northeast soil characterization study and north central states interlaboratory comparison of soil characterization data

Interlaboratory cross-checking was also organized in the USA in seventies when it was realized that soils cross state borders and data from two or more laboratories had to be compared. Two such

programmes i.e. the Northeast Soil Characterization Study and the North Central Region Interlaboratory Comparison of Soil Characterization Data (Rust and Feuton, 1983) were initiated. The former involved nine laboratories while the latter eight laboratories each analysing ten soil samples. National Soil Survey Laboratory, Lincoln, Nebraska served as a common member. The study followed collaborative approach of comparison as all the laboratories used the procedures of USDA Soil Conservation Services (USDA, 1984). Both the schemes found significant differences in some vital determinations and felt need and room for improvements and recommended for continuation of this task with emphasis, specially by the latter, on uniformity in procedures among laboratories.

New Zealand interlaboratory comparison

In New Zealand a group of five soil laboratories (Kennedy et al, 1983) analysed the Canadian Soil Survey Committee reference samples according to local procedures. The comparison was found to be unsatisfactory.

Arab Centre for the Studies of Arid Zones and Dry Land (ACSAD)

The regional programme of analysis for Middle East and North Africa was initiated in 1977 by the Arab Centre for the Studies of Arid Zones and Dry Lands (Job, 1979). Since no statement about method was made, this could probably be assumed as cooperative approach. The results showed large variations. The recommendations urged the initiation of cooperation between countries dealing with similar problems to improve some basic analytical methods for soil characterization.

Kenya Soil Survey comparison of data

A modest step in international cross-checking was taken in 1978 by Kenya Soil Survey. Soil samples from three profiles were sent to Brazil, Hawaii and Nigeria for independent analysis and comparing the analytical results with their own (Somebroek, 1977). The variations in the values of exchangeable cations, acidity, cation exchange capacity (CEC) and the base saturation percentage (BSP) between four laboratories illustrated the problems that arose if CEC and BSP are taken as important criteria in international soil correlation work. The study advocated the need for more comparative analyses of some characteristic soil profiles by international laboratories.

Round-Robin cross-check for soil fertility analysis of Pakistan benchmark soil

Realizing the basic necessity in improving soil testing procedures, a cross-checking of ten benchmark soil series was initiated by National Fertilizer Development Centre, Pakistan with the cooperation of F.A.O. in 1970. Almost all important laboratories in Pakistan as well as some from abroad were to be involved in this cross-checking. This was purely a cooperative approach with the objective of standardization of procedures within and among laboratories. Unfortunately the programme did not get serious push hence no results were achieved.

US-Pak interlaboratory comparison

In 1984 scientists from US Soil Conservation Service (USDA) took 183 soil samples from 23 soil series of Pakistan for analysis in connection with the XII International Forum on Soil Taxonomy and Agrotechnology Transfer to be held in Pakistan. Of these 144 samples from 19 Soil Series were

analysed at Soil Survey of Pakistan (Lahore) and National Laboratory at Lincoln (Nebraska) of U.S. Soil Conservation Service. The comparison scheme was cooperative one.

On comparison of data of four important parameters i.e. clay content, organic matter, CEC and pH, it was found that significant variation exist specially in CEC values. In other parameters the variations were non-significant on the whole (Table 1-4). The comparison, though looked satisfactory, but calls for standardization/correlation to get almost similar (within acceptable limits) results.

Table 1. Comparison of pH value

Name of soil series	Total No. of samples	pH (Sat. paste) U.S. Lab.	pH (Sat. paste) PAK Lab.	F value (ANOVA) Tabulated	F value (ANOVA) Calculated	Remarks (Variations)
Miranpur	8	7.9	8.00	4.60	0.4098	Non-significant
		8.0	8.00			
		8.0	8.10			
		8.0	7.90			
		8.0	7.85			
		7.9	7.70			
		7.7	7.40			
		7.5	7.20			
Gajiana	9	7.8	8.80	4.60	0.0176	"
		8.7	8.80			
		8.7	8.80			
		8.7	8.60			
		8.7	8.50			
		8.6	8.40			
		8.5	8.35			
		8.6	8.35			
		8.6	8.40			
Eminabad	6	9.2	10.00	4.96	0.015	"
		10.1	10.00			
		10.2	10.15			
		9.0	8.80			
		8.6	8.30			
		8.5	8.50			
Satghara	11	7.5	7.90	4.35	0.110	"
		7.9	8.50			
		8.9	9.00			
		9.1	9.30			
		9.1	9.15			
		9.0	9.30			

		8.7	9.30			
		8.6	8.70			
		8.5	8.60			
		8.5	8.40			
		8.2	8.10			
Consolidated	34			3.99	0.00376	"

Table 2. Comparison of organic matter value

Name of soil series	Total No. of samples	% Org. matter U.S. Lab.	% Org. matter PAK Lab.	F value (ANOVA) Tabulated	F value (ANOVA) Calculated	Remarks (Variation)
Miranpur	8	2.47	2.16	4.60	0.4180	Non-significant
		0.87	0.86			
		0.64	0.55			
		0.52	0.38			
		0.38	0.24			
		0.29	0.17			
		0.26	0.13			
		0.33	0.17			
Gajiana	9	0.64	0.51	4.49	2.99	"
		0.52	0.44			
		0.40	0.34			
		0.36	0.24			
		0.31	0.24			
		0.31	0.17			
		0.29	0.13			
		0.22	0.10			
		0.26	0.10			
Hafizabad	6	1.09	0.96	4.96	0.2026	"
		0.59	0.55			
		0.47	0.38			
		0.40	0.34			
		0.26	0.20			
		0.26	0.17			
Rasulpur	8	0.73	0.55	4.60	5.1	Significant
		0.40	0.24			
		0.40	0.24			
		0.36	0.20			
		0.34	0.17			

		0.33	0.17			
		0.33	0.17			
		0.22	0.03			
Lyallpur	8	1.06	0.86	4.60	12.58	"
		0.59	0.38			
		0.55	0.38			
		0.47	0.30			
		0.40	0.27			
		0.34	0.20			
		0.29	0.13			
		0.29	0.10			
Bhalwal	7	2.02	1.78	4.75	0.0321	Non-significant
		0.73	0.69			
		0.29	0.30			
		0.22	0.20			
		0.20	0.17			
		0.19	0.13			
		0.22	0.13			
Wazirabad	8	0.36	0.38	4.60	0.72	"
		0.27	0.17			
		0.15	0.13			
		0.17	0.13			
		0.12	0.10			
		0.13	0.10			
		0.10	0.10			
		0.08	0.03			
Gujranwala	7	1.30	1.20	4.75	0.1913	"
		0.64	0.58			
		0.52	0.44			
		0.47	0.38			
		0.38	0.30			
		0.34	0.24			
		0.26	0.20			
Pindorian	8	0.85	0.75	4.60	0.0345	"
		0.57	0.44			
		0.50	0.44			
		0.40	0.34			
		0.40	0.34			
		0.38	0.30			
		0.33	0.24			
		0.33	0.24			

Eminabad	8	0.97	0.69	4.60	1.93	"
		0.33	0.27			
		0.19	0.13			
		0.17	0.10			
		0.15	0.10			
		0.13	0.06			
		0.13	0.06			
		0.13	0.06			
Satghara	12	1.63	1.41	4.30	0.5876	"
		0.90	0.65			
		0.29	0.17			
		0.26	0.17			
		0.27	0.13			
		0.22	0.13			
		0.24	0.13			
		0.22	0.13			
		0.24	0.13			
		0.20	0.10			
		0.26	0.13			
		0.15	0.06			
Kotli	7	1.89	1.80	4.75	0.0965	"
		0.64	0.51			
		0.55	0.48			
		0.52	0.44			
		0.43	0.34			
		0.40	0.34			
		0.31	0.17			
Guliana	7	0.95	0.75	4.75	0.3209	"
		0.78	0.75			
		0.97	0.82			
		0.80	0.82			
		0.57	0.55			
		0.48	0.48			
		0.34	0.24			
Missa	6	0.83	0.72	4.96	0.353	"
		0.73	0.62			
		0.43	0.48			
		0.41	0.38			
		0.31	0.24			
		0.31	0.13			

Rajar	5	0.33	0.24	5.32	9.58	Significant
		0.34	0.27			
		0.31	0.20			
		0.27	0.17			
		0.24	0.13			
Peshawar	7	1.77	1.55	4.75	4.77	,,
		1.08	0.86			
		0.83	0.72			
		0.90	0.72			
		0.73	0.69			
		0.52	0.55			
		0.47	0.48			
Balkassar	7	0.67	0.58	4.75	0.69	Non-significant
		0.60	0.55			
		0.40	0.27			
		0.29	0.20			
		0.24	0.13			
		0.20	0.10			
		0.15	0.06			
Murree	8	9.47	4.94	4.60	0.3030	,,
		1.84	1.74			
		0.74	0.75			
		0.59	0.41			
		0.36	0.20			
		0.24	0.51			
		0.55	0.17			
		0.17	0.17			
Warsik	8	1.46	1.38	4.60	0.79	,,
		0.69	0.65			
		0.59	0.58			
		0.47	0.34			
		0.24	0.24			
		0.24	0.20			
		0.33	0.24			
		0.36	0.30			
Consolidated	144			3.88	2.31	,,

Table 3. Comparsic ı of Cation Exchange Capacity (CEC) value

Name of soil series	Total No. of samples	CEC, meq/100 gm of soil		F Value (ANOVA)		Remarks (Variation)
		U.S. Lab.	PAK Lab.	Tabulated	Calculated	
Miranpur	8	22.4	20.00	4.60	0.015	Non-significant
		24.8	24.80			
		24.5	26.40			
		21.7	20.80			
		16.9	19.20			
		10.3	10.40			
		15.2	16.00			
		17.6	18.40			
Gajiana	9	7.5	16.00	4.49	66.3	Significant
		9.9	22.00			
		11.0	20.80			
		10.4	19.20			
		6.7	16.80			
		6.0	24.00			
		6.1	18.80			
		4.0	16.80			
		2.8	14.00			
Hafizabad	6	6.4	15.20	4.96	66.1	"
		6.3	15.20			
		6.4	14.80			
		8.1	12.80			
		8.9	11.20			
		5.2	15.20			
Rasulpur	8	3.6	11.20	4.60	90.93	"
		4.4	11.20			
		5.2	12.00			
		5.7	12.80			
		5.5	8.80			
		4.6	12.80			
		2.5	10.00			
		1.5	10.00			
Lyallpur	8	6.9	12.80	4.60	22.5	"
		8.3	14.00			
		9.7	15.20			
		9.0	16.00			

		6.5	15.20			
		4.7	10.00			
		4.0	12.00			
		4.7	12.00			
Bhalwal	7	4.0	18.00	4.75	23.95	"
		6.3	14.00			
		10.4	11.20			
		8.9	18.00			
		10.2	15.20			
		10.8	16.80			
		8.6	12.80			
Wazirabad	8	5.7	10.00	4.60	28.07	"
		5.8	15.20			
		4.2	11.20			
		6.5	15.20			
		5.9	16.80			
		6.1	16.80			
		4.6	8.00			
		2.6	8.00			
Gujranwala	7	12.8	19.20	4.75	0.201	Non-significant
		15.2	20.80			
		17.4	24.80			
		18.8	24.00			
		16.4	19.20			
		15.3	20.80			
		11.2	10.40			
Pindorian	8	6.9	6.40	4.60	0.014	"
		6.4	4.80			
		10.5	8.00			
		11.6	10.40			
		12.4	12.80			
		12.2	13.60			
		10.6	9.60			
		8.0	14.40			
Eminabad	8	5.8	6.40	4.60	15.4	Significant
		7.7	19.20			
		9.1	21.60			
		11.8	16.80			
		8.7	15.20			
		6.5	13.60			

		3.8	8.80			
		2.5	8.80			
Satghara	12	9.4	11.20	4.30	.00206	Non-significant
		9.8	7.20			
		13.7	14.40			
		15.6	15.20			
		15.5	16.80			
		14.0	10.40			
		27.7	10.40			
		11.5	12.80			
		10.7	17.60			
		12.1	15.20			
		12.6	12.80			
		6.7	14.40			
Kotli	7	29.2	24.80	4.75	.028	"
		31.4	30.40			
		31.8	29.20			
		28.9	24.00			
		19.6	13.60			
		9.8	18.40			
		10.4	17.60			
Guliana	6	14.7	20.80	4.75	1.47	"
		15.7	25.60			
		20.6	18.40			
		20.4	20.80			
		18.7	21.60			
		16.5	13.60			
Missa	6	8.8	16.80	4.96	25.23	Significant
		9.9	14.40			
		9.7	21.60			
		10.7	19.20			
		11.3	16.00			
		11.9	23.20			
Rajar	4	10.8	16.00	5.93	19.0	"
		12.2	17.60			
		12.1	20.10			
		9.8	14.40			
Peshawar	7	13.6	17.60	4.75	67.44	"
		13.4	17.60			
		13.4	18.40			

		14.2	19.20			
		14.2	16.80			
		13.9	18.40			
		11.4	15.20			
Balkassar	6	19.9	22.40	4.96	1.074	Non-signifcant
		19.7	21.60			
		19.4	20.80			
		17.7	17.60			
		15.3	17.60			
		13.2	15.20			
Murree	8	36.5	36.80	4.60	2.914	"
		21.9	24.80			
		18.9	24.00			
		14.2	20.80			
		14.5	24.00			
		11.8	21.60			
		15.6	16.00			
		10.3	19.00			
Warsik	5	6.8	14.40	5.32	27.8	Significant
		5.3	12.00			
		5.2	12.80			
		2.0	8.00			
		2.6	11.00			
Consolidated	138			3.88	120.8	"

Table 4. Comparison of Clay Content

Name of soil series	Total No. of samples	% clay U.S. Lab.	% clay PAK Lab.	F value (ANOVA) Tabulated	F value (ANOVA) Calculated	Remarks (Variation)
Miranpur	8	46.0	44.0	4.60	0.770	Non-significant
		54.6	54.0			
		54.5	54.0			
		47.2	48.0			
		35.1	34.0			
		21.5	20.0			
		23.7	17.0			
		27.0	22.0			
Gajiana	9	15.9	16.0	4.49	0.0025	"
		20.2	20.0			

		22.8	24.0			
		23.1	23.0			
		21.4	24.0			
		24.4	24.0			
		24.3	23.0			
		11.6	10.0			
		6.1	6.0			
Hafizabad	6	12.3	13.0	4.96	0.91	"
		14.5	16.0			
		16.7	22.0			
		19.3	22.0			
		18.7	20.0			
		12.3	13.0			
Rasulpur	8	7.1	8.0	4.60	0.51	"
		9.3	10.0			
		11.0	9.0			
		11.4	12.0			
		11.0	12.0			
		9.9	12.0			
		7.2	10.0			
		3.9	5.0			
Lyallpur	8	13.6	13.0	4.60	0.628	"
		15.8	17.0			
		18.8	21.0			
		17.2	19.0			
		14.4	17.0			
		11.1	14.0			
		9.1	10.0			
		14.4	14.0			
Bhalwal	7	15.9	15.0	4.75	0.27	"
		16.5	19.0			
		20.9	21.0			
		21.1	19.0			
		18.5	18.0			
		16.6	15.0			
		22.7	19.0			
Wazirabad	8	7.5	7.0	4.60	0.118	"
		10.5	9.0			
		9.4	10.0			
		8.6	9.0			

		7.9	6.0			
		7.2	6.0			
		5.0	5.0			
		2.3	3.0			
Gujranwala	7	18.2	15.0	4.75	0.158	”
		22.9	27.0			
		29.9	31.0			
		32.1	34.0			
		26.9	29.0			
		23.3	27.0			
		18.4	18.0			
Pindorian	8	11.1	13.0	4.60	0.258	”
		10.7	12.0			
		16.9	15.0			
		17.8	19.0			
		18.7	20.0			
		18.1	18.0			
		16.6	18.0			
		13.9	15.0			
Eminabad	8	9.7	9.0	4.60	0.926	”
		13.8	12.0			
		17.0	15.0			
		18.2	14.0			
		14.1	9.0			
		12.9	12.0			
		7.5	8.0			
		4.6	5.0			
Satghara	12	18.9	22.0	4.30	0.0185	”
		23.2	27.0			
		37.6	31.0			
		42.3	40.0			
		44.7	40.0			
		44.6	39.0			
		35.2	35.0			
		20.9	22.0			
		16.5	19.0			
		17.2	18.0			
		19.2	20.0			
		9.3	9.0			
Kotli	7	49.3	47.0	4.75	0.123	”
		53.9	54.0			

		54.4	54.0			
		51.9	56.0			
		37.5	36.0			
		24.7	27.0			
		21.6	23.0			
Guliana	7	19.3	18.0	4.75	0.0704	"
		20.3	21.0			
		29.6	28.0			
		29.9	31.0			
		26.0	29.0			
		22.7	24.0			
		14.8	17.0			
Missa	6	11.6	15.0	4.96	4.62	"
		12.8	17.0			
		14.2	20.0			
		17.2	24.0			
		17.2	20.0			
		19.9	20.0			
Rajar	5	10.5	13.0	5.32	3.33	
		14.7	17.0			
		15.3	18.0			
		15.8	18.0			
		11.6	15.0			
Peshawar	7	28.4	28.0	4.75	1.338	
		27.6	28.0			
		25.7	28.0			
		28.8	30.0			
		30.6	33.0			
		29.6	33.0			
		21.0	25.0			
Balkassar	7	12.2	15.0	4.75	1.06	"
		14.9	18.0			
		13.3	14.0			
		9.3	10.0			
		5.6	8.0			
		2.6	5.0			
		0.2	2.0			
Murree	8	29.9	38.0	4.60	0.111	"
		39.2	39.0			

		37.5	38.0			
		23.3	23.0			
		26.9	30.0			
		19.7	26.0			
		27.5	19.0			
		17.1	19.0			
Warsik	8	16.6	17.0	4.60	2.21	"
		14.8	17.0			
		14.8	16.0			
		14.0	10.0			
		4.0	6.0			
		5.7	5.0			
		9.5	9.0			
		11.4	10.0			
Consolidated	114			3.88	0.00642	"

RECENT DEVELOPMENT

The need for international cross-checking, correlating and possibly standardizing laboratory methods in various parts of the world had long been felt and recommended (Bramao, 1963), and is being continuously voiced at various international forums (Eswaran, 1984). It was only in compliance with the recommendations of the 2nd International Soil Classification Workshop held in Malaysia and Thailand in 1978, sponsored by USAID, that the then International Soil Museum (ISM) the Netherlands and now International Soil Reference and Information Centre (ISRIC) initiated a programme of international cross-checking called as LABEX. The programme started with a pilot round, in which limited number of laboratories analysed a selection of different soils for some essential parameters. Following is a brief account of this pilot round.

Twenty two laboratories from twenty countries analysed ten reference samples, mainly for particle size distribution and cation exchange capacity. Some laboratories, however, analysed these soils for exchangeable bases and pH. This was a cooperative approach and a variety of methods were employed by the individual laboratories. Even if the same method was used, details often varied i.e. shaking time, leaching time etc. The results obtained in this pilot round of LABEX showed wide variations (Van Reeuwijk, 1982-84). This led the ISRIC to expand the programme by inclusion of more laboratories, more soil parameters and more reference samples to widen the scope of the programme. They intend to widen the participation to about 50 laboratories and also to organize a workshop where results can be evaluated and improvement/standardization agreed.

ENDEAVOURS OF SOIL SURVEY OF PAKISTAN

Till recently soil characterization in the Soil Survey of Pakistan was done mainly on field observations with some support of the laboratory. This definitely had some drawbacks. Need for enhancing the role of the laboratory and its improvement by standardization of the procedures and their correlation to bring it at par with international standards, is now felt.

Internally we are in constant touch with National Fertilizer Development Centre persuading them to activate the vital task they started in the late seventees. We are also trying to compare various methods for different determinations to suit our local conditions (Khan and Rafiq, 1982). At international level we are now participating in the LABEX programme. In addition we are also participating in the Analytical Quality Control Service of International Atomic Energy Agency (AQCS) which provides certified reference material for intercomparison as well as in Worldwide Plant Samples Exchange Programme (Houba, 1984) jointly sponsored by the Department of Soil Science and Plant Nutrition, Wageningen Agricultural University and the Government of the Netherlands. These two programmes, especially the last one, has no direct relation with the characterization/classification of soil in Taxonomic terms, but has sure bearings on the quality control; i.e. inter-comparison/standardizations of laboratory analysis.

CONCLUSIONS/RECOMMENDATIONS

Whereas the necessity for standardization of objective description of a pedon (Soil Taxonomy, 1975) is being felt, the necessity for standardization of laboratory analysis may be given almost equitable treatment for the refinement of the description. The LABEX programme needs support from other countries/agencies, as presently it is funded solely by the Dutch Government which probably is not enough for this task.

The results of the present efforts indicate a strong need for standardization of analytical procedures. Such a standardization though feasible will still have a certain level of variability to be reckoned with. Consequently, taxonomic criteria for which these analyses are mainly to be carried out will have to be implemented flexibly. The acceptable minimum level of variability for each parameter has to be established after thorough cross-checking and possible standardization.

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PART VIII

FORUM EVALUATION AND RECOMMENDATIONS

FORUM EVALUATION

At the end of the Forum, four participants representing a fair cross-section were invited to evaluate the Forum. Their comments are presented below.

1. Dr. Kazi Suleman Memon, Associate Professor (Soils), Department of Agricultural Chemistry, Sind Agriculture University, Tandojam, commented:

   - Forum being educative, provided a unique opportunity for all the participants. We came to know about our deficiencies and strength in the field of Agricultural Research and Production.
   - Deficiencies of Soil Taxonomy also came to light. Mineralogical aspect of soils of Pakistan became clearer through the analytical data of 23 soil series of Pakistan which were discussed in the Forum. All these soils have been classified as of mixed mineralogy. It would be useful if comparatively finer splits in mineralogy are prescribed at subgroup and family level classification to be more objective, for example for phosphorus management.
   - Agrotechnology transfer part of the forum was not as well covered as the soil taxonomy part.
   - IBSNAT work be taken up in Pakistan as well.
   - Soil Survey of Pakistan and SMSS are to be thanked for organizing such a successful and useful forum.

2. Dr. Tahir Hussain, Asstt. Professor, Department of Soil Science, Agriculture University, Faisalabad, evaluated the forum as under:

   - Material provided and lectures delivered covered a wide range and were educative and useful.
   - It would have been better to hold a pre-Forum one day workshop to acquaint the participants with the type of exercise they were going to have in the Forum.
   - The Forum provided an opportunity to exchange views and to get personalized attention of the experts group to answer many questions.
   - Discussions on each pedon site were very fruitful. Staff of Soil Survery of Pakistan proved helpful to other participants who had first time exposure to this type of exercise.
   - All agricultural research work should be based on Soil Taxonomy.
   - Agricultural Universities in the country should establish a close liaison with the Soil Survery of Pakistan for the preparation of their curricula. The students at postgraduate level should carry out research on different categories of the Soil Taxonomy.
   - Forum was well organized and facilities provided are appreciated.

3. Mr. Mushtaq Ahmed Khan, Deputy Director (R), Pakistan Agricultural Research Council, opined:

   - The Forum has provided deep insight to the participants for recognizing soil as a dynamic living body which in turn will open new areas of research for scientists, engineers, economists and ecologists.
   - The lectures delivered and material provided were excellent.
   - Technical papers presented were also good but most of them lacked a set format which should have been provided to the subject matter specialists while asking for contribution.

- The remaining soil series of Pakistan may also be characterized on the pattern of 23 pedons considered in the Forum.
- Determination of soil moisture regime, temperature regime and clay mineralogy on microlevels be carried out to standardize local findings with the rest of the world.
- SCAN project has provided a safe cushion through field demonstrations for agrotechnology transfer. Its activities may be further extended to other places to cover different agro-ecological zones of the country.
- There is a dire need to review the university curriculum relevant to soil classification for its improvement.
- Forum may also suggest, on adhoc basis, the follow up action by SSP for the benefit of related institutions.
- Collaboration of all relevant provincial/federal organizations is a must to bridge the communication gap between them.
- The Forum was sufficiently well organized; logistics and hospitalities were excellent. The schedule of the forum was, however, too heavy and lacked recreation. A day off for sight seeing or other recreational activities would have been welcome.

4. Malik Waqar Abbas, Agronomist, Fauji Fertilizer Company said :

- Forum was very educative and useful. It made me wiser for replying the querries of farmers who come in contact with me as a field officer.
- Field trips and examination of soils in pits were interesting. But, for better understanding the basic data about these pedons should have been distributed among the intending participants, a few days before the start of the forum.
- Time allotted for examination of each pedon was short which did not give each participant ample time to examine the pedon and take part in discussion. In fact, only 2 or 3 pedons should have been examined in a day.
- Efforts should be made to extend requisite technology to our farmers so that they may grow the crops and adopt the management practices according to the soils.

COMMENDATIONS AND RECOMMENDATIONS SUBMITTED BY THE FORUM RECOMMENDATIONS COMMITTEE

Members

Name		Affiliation
Mr. Mohammad Akram	Chairman	Soil Survey of Pakistan
Dr. Kazi Suleman Memon	Secretary	Sind Agriculture University
Mr. Aurangzeb Khan		SCAN Project, PARC
Dr. Talib Hussain Choudhry		Agriculture Consultant
Dr. John Witty		USDA SCS
Mr. Mushtaq Ahmad		Soil Survey of Pakistan

Commendations

Realising the value of soil resources inventories to agricultural development and appreciating the fact that quality inventories using the same technical language are the basis for agrotechnology transfer, the participants of the XII International Forum wish to record their gratitude and appreciation to the following organizations for initiating, organizing and conducting the Forum:

- Soil Survey of Pakistan
- Pakistan Agricultural Research Council
- Soil Management Support Services
- International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT)

Funding and other operational support was also provided by the following organizations which assured the success of the Forum:

- U.S. Agency for International Development
- Soil Conservation Service, USDA
- National Fertilizer Development Centre, Pakistan
- National Fertilizer Corporation of Pakistan
- Millat Tractors Limited
- Punjab Agricultural Development and Supplies Corporation
- Fauji Fertilizer Company

The participants express their gratitude to these organizations for their financial support of the Forum.

Recommendation I

Recognizing the growing need for reliable land resource inventories as an indispensable prerequisite for land use planning and agrotechnology transfer, the participants recommend that the Soil Survey of Pakistan continue to expand its mapping program with emphasis on high intensity surveys in agriculturally important areas.

In addition and in view of the commendable accomplishments of the SCAN project to date, the participants recommend that the project be expanded to include additional key soil families so that the sphere of applicability of

the information generated at the SCAN sites covers the majority of the arable land of Pakistan.

Recommendation II

Realizing the rapidly growing importance of the use of computer hardware and software in agriculture, the participants recommend that PARC increase its efforts to make Pakistan an active member of the International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT). In particular, it is recommended that initially four strategically located SCAN sites be upgraded to IBSNAT sites and that the so-called minimum data sets, be collected from experiments conducted there.

Recommendation III

Realizing the need for soil survey interpretation and recognizing the fact that an adequate system designed for the intertropical countries does not exist, the participants strongly recommend that the Soil Management Support Services (SMSS) and the International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT) in collaboration with the Soil Survey of Pakistan and other national and international organizations work towards developing a framework of soil survey interpretations which could be used by all countries.

To operationalize this project, it is recommended that:

- SMSS develop an international working group for this purpose
- SMSS and IBSNAT consider using expert systems and artificial intelligence techniques for computerised soil survery
- at a suitable time a workshop is organized to discuss the mandate and strategy of the working group
- SMSS already consider special training courses on soil survey interpretations

The participants further recommend that a first training course on soil survey interpretations be held in Pakistan, if possible, in 1987.

Recommendation IV

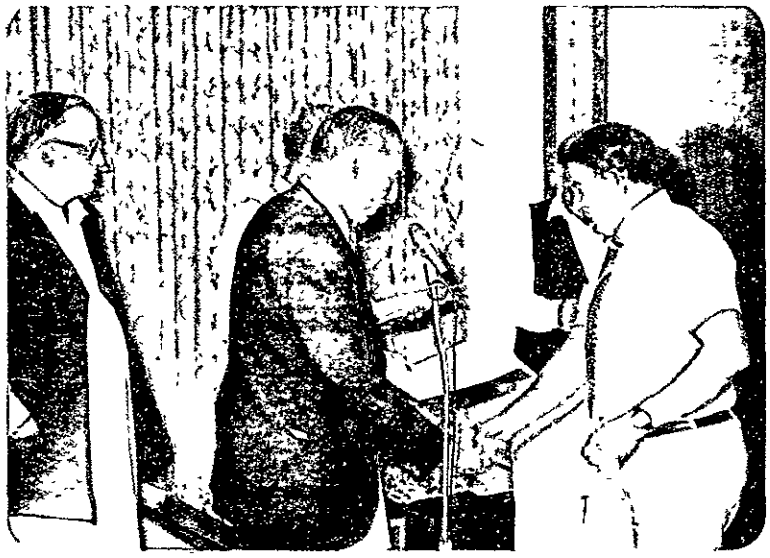
As Pakistan is using Soil Taxonomy as the national system of soil classification and to benefit from international research and experience of other countries with similar agro-ecological conditions, the participants recommend the following follow-up activities:

- that the Soil Survey of Pakistan organize in-service training courses for the staff of universities and research organizations in Pakistan
- that the Soil Survey of Pakistan assist the universities in a review of their curriculum so as to include the subject of soil survey at an appropriate level
- that linkage with SMSS and IBSNAT be continued and strengthened
- that soil survey support services at the Soil Survey of Pakistan be strengthened and improved and that SSP request the US Agency for International Development or other donors for this component
- that the Soil Survey of Pakistan consider the development of national resource inventories at two levels
  - 1 : 1 000 000
  - 1 : 20 000

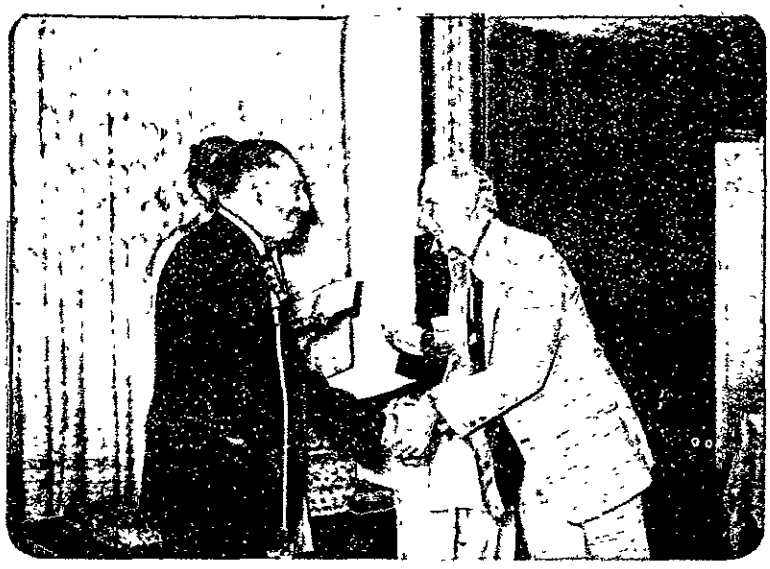
  and in order to be able to do this, SSP approach USAID or other organizations to fund such a project
- that a computerized data base on the soil resources of the nation be developed by SSP and that training courses be conducted for the utilization of such data bases
- that all reports of field experiments and agronomic research identify the soil using the Soil Series name and/or Soil Taxonomy classification and that the Soil Science Society of Pakistan require this as mandatory in its official Journal
- that the Soil Survey of Pakistan approach the Government for enacting zoning regulation prohibiting the use of prime-quality agricultural land (a non-renewable resource) for non-agricultural purposes

CLOSING CEREMONY

Islamabad Hotel, Islamabad



Dr. Tahir Hussain of University of Agriculture, Faisalabad, receiving certificate from the Chief Guest



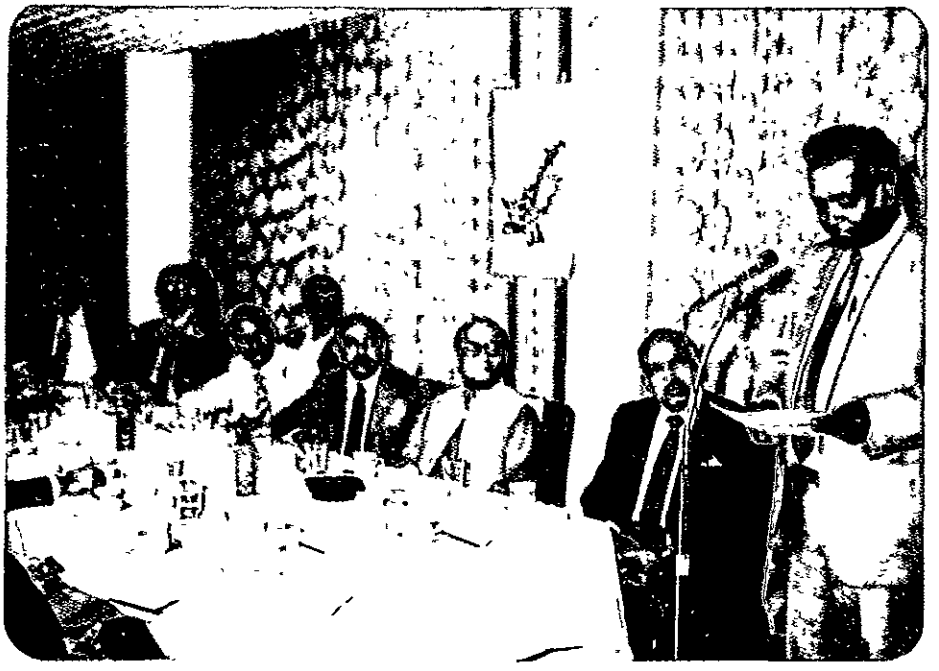
Award of certificate to Mr. Terry D. Cook of the S.M.S.S., Washington

29800

CLOSING CEREMONY

Islamabad Hotel, Islamabad

A memento from the Soil Survey of Pakistan to the Soil Management Support Services, being received by Dr. H Eswaran



Dr. H. Eswaran presenting his closing observations

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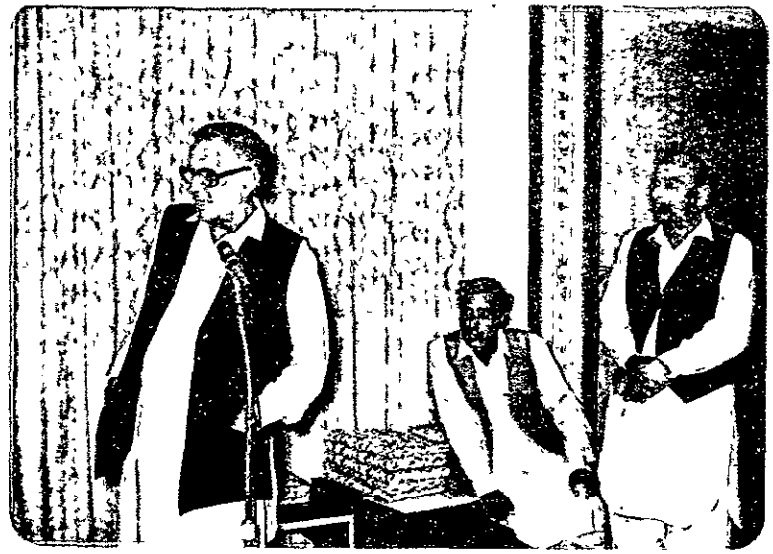
CLOSING CEREMONY

Islamabad Hotel, Islamabad



Dr. M. Bashir Choudhri, Director General, Soil Survey of Pakistan, presenting his concluding remarks

FORUM ORGANIZING COMMITTEE

Seated (L to R) Mushtaq Ahmad, Muhammad Akram, H. Eswaran, F. H. Beinroth, M. Alim Mian

Standing (L to R) : J. E. Witty, T. D. Cook, Shamsul Haque, D. J. Lytle, Riazul Amin, G. Saeed Khan, M. Nawaz Syal, Aurangzeb Khan, M. Yasin Javed

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PARTICIPANTS AND GUESTS

at the National Agricultural Research Centre, Islamabad

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CLOSING ADDRESS

OF

DR. HARI ESWARAN
Programme Leader, Soil Management Support Services

Mr. Manzoor Ahmad Consultant (Coordination), PARC,

Distinguished guests, ladies and gentlemen !

Attaining self-sufficiency in food and fiber production was the goal of many of the countries in this part of the world. In Pakistan, this goal of self-sufficiency has been attained or is being attained in several agricultural sectors. The goal now is slowly changing to sustaining this production and more importantly, keeping pace with population growth. We have been told that the population of the country is currently at about 90 million but has the capacity to increase to more than 120 million by the beginning of the next century. The land area available for agriculture is fixed and so the challenge of the next few decades is to increase the productivity of the land.

The creation of the National Agriculture Research Centre (NARC) is consequently timely and with its dynamic Director General we can anticipate great progress. However, in Pakistan as in many countries of the world, one aspect of agriculture, the soil, which can also be considered as the roots of agriculture, has received less attention. This is partly due to historical reasons. The rapid advances in plant breeding in the sixties and seventies resulted in the short-lived green revolution. Many international donors thought that this was the answer to the problems of developing countries and this idea led to the development of a number of commodity based International Agriculture Research Centres such as IRRI, ICRISAT and IITA. These Manhattan projects of agriculture research with an annual budget of 20-30 million dollars each have not had the impact on developing country agriculture because the crucial element in the system—the soil—has been systematically ignored by all the centres. FAO's world-wide network on fertilizer evaluation program which was conducted over two decades has not really contributed to our knowledge of the fertility of soils in these countries. Billions of soil fertility tests and hundreds of thousands of NPK trials are conducted annually world-wide and hundreds of thousands will continue to be conducted. This of course keeps many agronomists employed but the question remains, cannot we do better? This is one of the question we have tried to address during this 12th International Forum on Soil Taxonomy and Agrotechnology Transfer.

I would also address another question which was put to me by one of the participants on what the role of soil surveys should be in Pakistan. I have been very impressed with the staff of the Soil Survey of Pakistan and I believe they are doing a commendable job. But they are doing this job with one hand tied behind their back.

Soil survey is not merely drawing lines on a map. The soil resource inventory and the data base which the soil survey is making is the basis for all other decisions that will be made. If this data base is

of poor quality, everything else that follows will be unreliable and agriculture research and development will suffer. Unfortunately, the national planners do not appreciate this. A good soil survey program must be backed up by a good soil research program. The soil research will not only serve the soil survey activities but later, when the soil survey is completed, it will provide the interpretations necessary to translate the soils information for the end users.

On October 5th, at the First Congress of the Soil Science Society of Pakistan, a recommendation was made to create a Soil Research Institute. I fully endorse this recommendation and I will go one step further to suggest that the Soil Survey of Pakistan be upgraded to the Pakistan Soil Research Institute. This Institute will play a tremendous role to guarantee the judicious use of the soil to increase agricultural production while conserving this scarce resource for generations to come.

Mr. Ahmad! at this 12th International Forum, we had the opportunity to study many soils all the way from Lahore to Peshawar. We saw examples of soil degradation through salinization and also some classic examples of erosion. We also saw some excellent examples of land use. We discussed problems of classification and interpretation and we evaluated aspects of agrotechnology transfer. I believe we had a productive two weeks.

This Forum would not have been possible if not for the excellent support and collaboration of a number of organizations. We would like to thank the Soil Survey of Pakistan and the Pakistan Agriculture Research Council for holding this meeting. I would like to thank Dr. Amir Mohammad, Chairman of PARC and Dr. Anwar Khan, Director General of NARC for their interest and enthusiastic support of this Forum. I would also like to thank Dr. Bashir Choudhri, Director General of the Soil Survey of Pakistan for his valuable suggestions and guidance. The Forum also received financial support from various organizations which I would like to mention.

- National Fertilizer Development Centre in the person of its Project Manager and former classmate of mine Dr. Hassan Nabhan
- National Fertilizer Corporation of Pakistan, in the person of its member Mr. Anees
- The Punjab Agricultural Development and Supplies Corporation and its managing Director, Dr. Ghulam Rasul Chaudhri
- Millat Tractors Ltd
- Fauji Fertilizer Company

Mr. Ahmad, ladies and gentlemen, on behalf of the U.S. Agency for International Development and the U.S. Department of Agriculture, I would like to thank the Government of Pakistan in inviting us to participate in this Forum. My colleagues and I will take back many pleasant memories of our short stay in this beautiful country and some of my colleagues will also take back a bit more painful memories of indulging too much on the hot curries and samosas.

Thank you.

CONCLUDING REMARKS

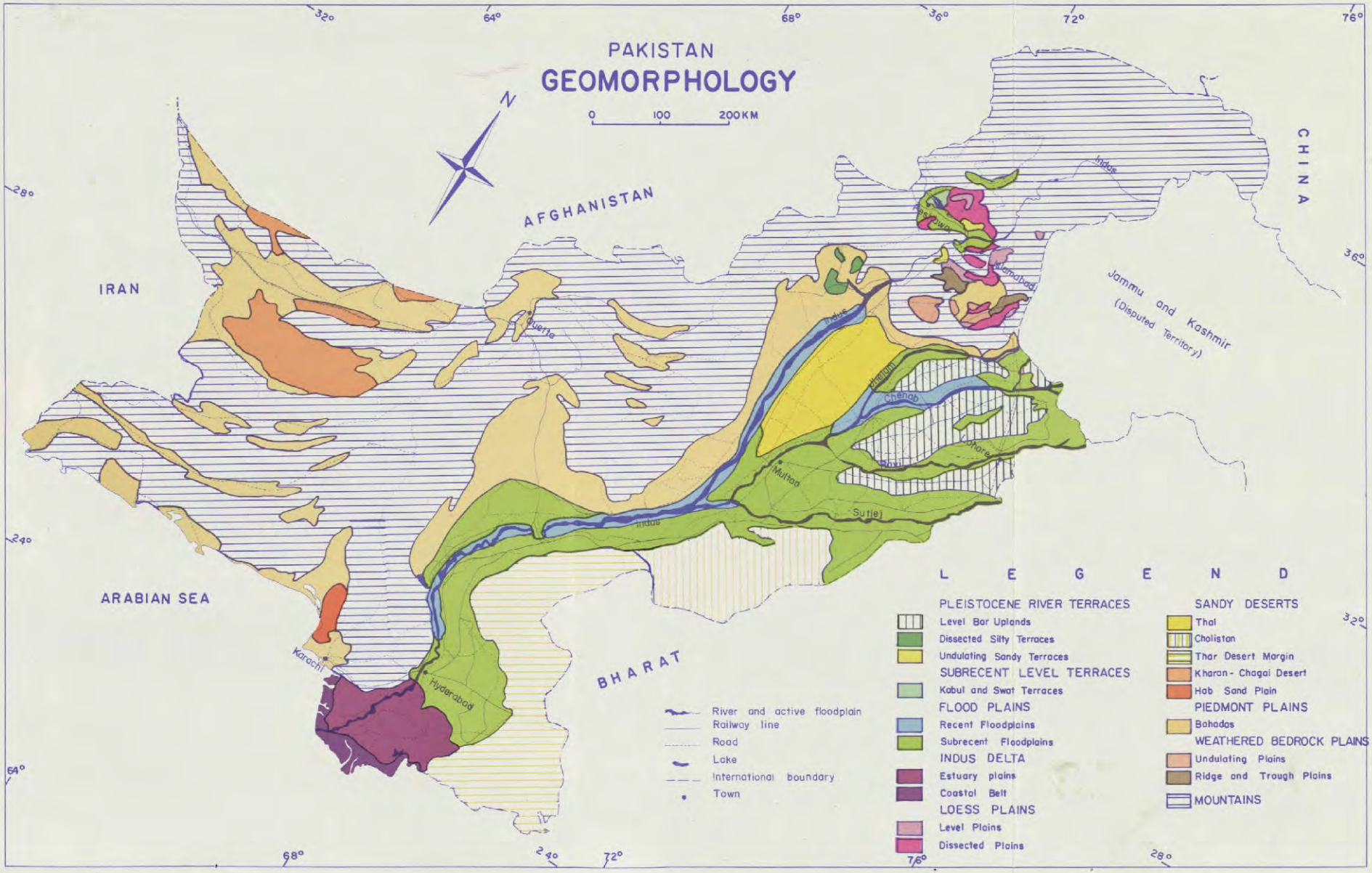
BY

DR. M. BASHIR CHOUDHRI
Director General, Soil Survey of Pakistan

I am grateful to Mr. Manzoor Ahmed, Consultant (Coordination) of Pakistan Agricultural Research Council, for sparing time to chair this concluding session on behalf of Dr. Amir Muhammad, Chairman of the Council, who unexpectedly had to go to Lahore last night for urgent official work.

The Forum has been an unqualified success. This is evident from the interest shown by the participants in the lecutres and also in the physically exchaustive field trips. For many agronomists and soil scientists, the study of soils in their natural environments was a new and refreshing experience. I hope that the Forum has sensitised them to the importance of soil variability in their field experimentation. The work carried out under SMSS, and IBSNAT and its earlier phase – the Benchmark Soils Project, has already proved the utility of the theme of the Forum i.e. agrotechnology transfer through soil taxonomy. Only those countries can benefit from this relatively new concept which use similar technical language in soil description and classification. Pakistan is better placed to use this technology because we have already completed the soil survey of all the agriculturally important areas of the country and have classified the soils according to the Soil Taxonomy – a basic system of soil classification for making and interpreting soil surveys. We have also benefitted from the Forum through the identification of our deficiencies in soil analytical data and soil classification. We sincerely hope that this session will not be the end of the whole exercise and that the recommendations so painstakingly formulated by the Forum Recommendations Committee and adopted by this session will be implemented leading to a meaningful and productive collaboration between Soil Survey of Pakistan and other national agriculture research organizations, and with the SMSS and IBSNAT.

In the end I want to thank the IBSNAT, and SMSS of the Soil Conservation Service, USDA for organizing the Forum in Pakistan. We are also grateful to the US AID Mission in Pakistan, PARC, NFDC, NFC and Millat Tractors for providing funds and operational support to the Forum.


PAKISTAN
GEOMORPHOLOGY
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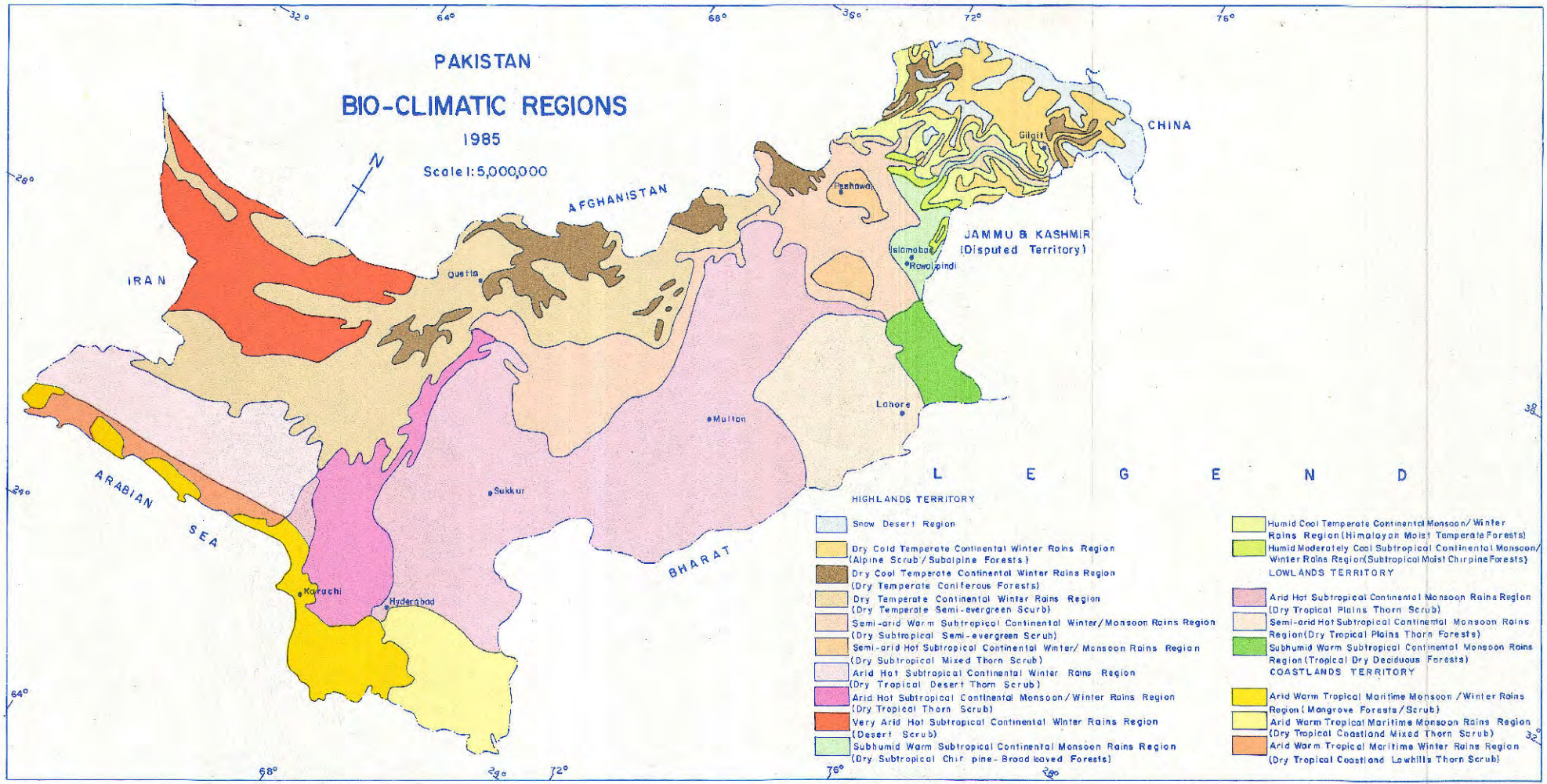
N
AFGHANISTAN
IRAN
CHINA
ARABIAN SEA
BHARAT
Jammu and Kashmir
(Disputed Territory)
Quetta
Karachi
Hyderabad
Multan
Indus
Jhelum
Chenab
Ravi
Sutlej
Lahore
Islamabad
Peshawar
River and active floodplain
Railway line
Road
Lake
International boundary
Town
L E G E N D
PLEISTOCENE RIVER TERRACES
Level Bar Uplands
Dissected Silty Terraces
Undulating Sandy Terraces
SUBRECENT LEVEL TERRACES
Kabul and Swat Terraces
FLOOD PLAINS
Recent Floodplains
Subrecent Floodplains
INDUS DELTA
Estuary plains
Coastal Belt
LOESS PLAINS
Level Plains
Dissected Plains
SANDY DESERTS
Thal
Cholistan
Thar Desert Margin
Kharan - Chagai Desert
Hab Sand Plain
PIEDMONT PLAINS
Bahadas
WEATHERED BEDROCK PLAINS
Undulating Plains
Ridge and Trough Plains
MOUNTAINS
32°
64°
68°
36°
72°
76°
28°
24°
64°
68°
24°
72°
76°
28°
36°
32°


PAKISTAN
BIO-CLIMATIC REGIONS
1985
Scale 1:5,000,000
N
AFGHANISTAN
IRAN
CHINA
JAMMU & KASHMIR
(Disputed Territory)
ARABIAN SEA
BHARAT
Quetta
Peshawar
Gilgit
Islamabad
Rawalpindi
Lahore
Multan
Sukkur
Karachi
Hyderabad
32°
64°
68°
36°
72°
76°
28°
24°
LEGEND
HIGHLANDS TERRITORY
Snow Desert Region
Dry Cold Temperate Continental Winter Rains Region (Alpine Scrub/Subalpine Forests)
Dry Cool Temperate Continental Winter Rains Region (Dry Temperate Coniferous Forests)
Dry Temperate Continental Winter Rains Region (Dry Temperate Semi-evergreen Scrub)
Semi-arid Warm Subtropical Continental Winter/Monsoon Rains Region (Dry Subtropical Semi-evergreen Scrub)
Semi-arid Hot Subtropical Continental Winter/Monsoon Rains Region (Dry Subtropical Mixed Thorn Scrub)
Arid Hot Subtropical Continental Winter Rains Region (Dry Tropical Desert Thorn Scrub)
Arid Hot Subtropical Continental Monsoon/Winter Rains Region (Dry Tropical Thorn Scrub)
Very Arid Hot Subtropical Continental Winter Rains Region (Desert Scrub)
Subhumid Warm Subtropical Continental Monsoon Rains Region (Dry Subtropical Chir pine-Broad leaved Forests)
Humid Cool Temperate Continental Monsoon/Winter Rains Region (Himalayan Moist Temperate Forests)
Humid Moderately Cool Subtropical Continental Monsoon/Winter Rains Region (Subtropical Moist Chirpine Forests)
LOWLANDS TERRITORY
Arid Hot Subtropical Continental Monsoon Rains Region (Dry Tropical Plains Thorn Scrub)
Semi-arid Hot Subtropical Continental Monsoon Rains Region (Dry Tropical Plains Thorn Forests)
Subhumid Warm Subtropical Continental Monsoon Rains Region (Tropical Dry Deciduous Forests)
COASTLANDS TERRITORY
Arid Warm Tropical Maritime Monsoon/Winter Rains Region (Mangrove Forests/Scrub)
Arid Warm Tropical Maritime Monsoon Rains Region (Dry Tropical Coastland Mixed Thorn Scrub)
Arid Warm Tropical Maritime Winter Rains Region (Dry Tropical Coastland Lowhills Thorn Scrub)