Improving the Management of India's Deep Black Soils

Cover photograph: Three of the 14 farmers from Taddanpalle, Andhra Pradesh, who have collaborated to develop their deep black soil watershed, tine-harrowing their young sorghum crop with a bullock-drawn tool carrier. The field layout is based on the broadbed-and-furrow system at a module width of 1.5 meters.

Improving the Management of India's Deep Black Soils

A general view of the Seminar in session.

PROCEEDINGS OF THE SEMINAR ON MANAGEMENT OF DEEP BLACK SOILS FOR INCREASED PRODUCTION OF CEREALS, PULSES, AND OILSEEDS, NEW DELHI, 21 MAY 1981

Rao Birendra Singh, Union Minister of Agriculture and Irrigation, addressing the final session of the Seminar. Left to right: Dr. J.S. Kanwar, Director of Research, ICRISAT; Dr. L.D. Swindale, Director General, ICRISAT; Rao Birendra Singh, Minister; Mr. S.S. Puri, Secretary, Department of Agriculture and Cooperation; Dr. O.P. Gautam, Secretary and Director General, ICAR.

Sponsored by the Indian Ministry of Agriculture, the Indian Council of Agricultural Research, and the International Crops Research Institute for the Semi-Arid Tropics

Published for the Sponsors by the
International Crops Research Institute for the Semi-Arid Tropics
ICRISAT Patancheru P.O., Andhra Pradesh 502 324, India

August 1981

CONTENTS

PREFACE

In the heartland of dryland agricultural areas of India where black soils predominate, agricultural administrators, research scientists, and extension workers have for many years been concerned to find ways by which the millions of farmers living in the region may increase crop production on these intractable soils.

Now, thanks to collaboration in India between State, national, and international research and development organizations, proposals have been drawn up for cooperative action by Central and State Departments of Agriculture, Agricultural Universities, the Indian Council of Agricultural Research, and the International Crops Research Institute for the Semi-Arid Tropics. These are focused on a land management system for growing two crops on deep black soils based on the watershed concept, and involving the use of high-yielding varieties and fertilizers.

I enjoyed my participation in the Seminar, and appreciate the proposals made in this publication because there is a great promise in the technology recommended for achieving a "quantum jump" in the production of the country's staple cereals, pulses, and oilseeds. All who will now be involved in the further verification and extension phases that arise from our policy-making Seminar in May 1981 are therefore urged to give their energetic support to the work involved.

Thanks are due to all agricultural scientists located in ICAR institutions, Agricultural Universities, and ICRISAT, who have contributed and continue to refine technology to increase and stablize production in the semi-arid tropics. I also record my appreciation of the efforts of agricultural administrators and extension specialists for the effective transfer of available technology to farmers' fields. My special acknowledgements are due to Indian farmers who have collaborated in recent years with the research and development staff responsible for developing and evaluating the technology. Without that collaboration our current expectations for increasing adoption of this promising technology could not have been realized.

Rao Birendra Singh
Minister of Agriculture and Irrigation

LIST OF PARTICIPANTS

Government of India

Shri S.S. Puri (Chairman),
Secretary, Agriculture
and Cooperation

Shri R.C. Sood,
Additional Secretary

Shri P.R. Dubhashi,
Additional Secretary

Shri Harbans Singh,
Agriculture Commissioner

Dr. G.S. Vidyarthi,
Joint Secretary

Shri H.L. Chawla,
Economics and Statistics
Adviser

Shri D.C. Das,
Joint Commissioner,
Soil Conservation

Shri A.C. Garg,
Joint Commissioner,
Projects

Shri P.D. Srivastava,
Director, Planning
and Coordination

Shri G.S. Baweja,
Joint Commissioner,
Extension

Dr. T.S. Bolaria,
Joint Commissioner,
Food Crops

Shri K.S. Yadav,
Joint Commissioner, Machinery

Dr. S.L. Seth,
Director, Water Conservation

Dr. B.M. Sharma,
Director, Pulses Development

Dr. B. Ganguly,
Director, Farm Advisory Unit

Dr. C.S.S. Rao,
Director, Farm Information,
Directorate of Extension

Shri N. Perumal,
Director, Training,
Directorate of Extension

Shri O. Rehman,
Director, Farm Extension,
Directorate of Extension

Shri M.D. Wasnik,
Director, Oilseeds Development

Shri P. Madhava Menon,
Director, Millets Development

Shri G.S. Madan,
Joint Director, Projects

Shri V.B. Ghai,
Director, Rice Development

Shri V. Bhanu Murthy,
Director, Publicity

Shri Y.P. Bali,
Project Officer,
All India Soil & Land Use Survey

Dr. O.P. Makhija,
Dy.Commissioner, Oilseeds

Dr. M.K. Mathur,
Dy.Commissioner, Cash Crops

Dr. B.K. Dhar,
Dy.Commissioner, Fertilizers

Shri P.P. Zacharia,
Asst.Commissioner,
High-Yielding Varieties Programme

Shri P.C. Sabharwal,
Sr. Tech. Assistant (Crops)

State Governments

Andhra Pradesh

Shri B.F. Dittia,
Agricultural Production
Commissioner

Shri N.A. Naidu,
Director of Agriculture

Gujarat

Shri R.L. Pathak,
Director of Agriculture

Shri K.L. Jadhav,
Managing Director,
Gujarat State Land Dev.Corpn.Ltd.

Karnataka

Shri R.A. Naik,
Development Commissioner

Shri B.M. Rampur,
Joint Director of Agriculture

Madhya Pradesh

Shri V.B. Singh,
Addl. Director of Agriculture

Shri R.B. Singh,
Joint Director of Agriculture

Maharashtra

Shri D.V. Dixit,
Joint Director of Agriculture

Tamil Nadu

Shri P.K. Radhakanth,
Chief Engineer

Shri G. Arumaisingh,
Dy. Chief Engineer

ICAR

Dr. O.P. Gautam,
Director General & Secretary
to the Government of India,
DARE

*Dr. N.S. Randhawa,
Dy. Director General
Soils Agronomy & Agril Engg

Dr. D.R. Bhumbla,
Project Director, Land to
Lab Programme

Dr. Y.N. Rao
Head of Agricultural Physics, IARI

*Dr. J. Venkateswarlu,
ADG-cum-Project Director (DF),
All India Coordinated Research
Project for Dryland Agriculture,
Hyderabad

*Dr. R.S. Murthy,
Project Director,
Land Use Survey Planning, Nagpur

*Contributed a paper

Agricultural Universities and Research Centers

Dr. R. Dwarkinath,
Vice Chancellor,
University of Agricultural Sciences,
Bangalore (Karnataka)

Dr. A. Venkataraman,
Vice-Chancellor,
Tamil Nadu Agricultural University,
Coimbatore (T.N.)

Dr. A. Appa Rao
Director of Research
Andhra Pradesh Agricultural University,
Hyderabad (A.P.)

Shri K.P. Garg,
Chief Scientist,
Dryland Research Centre, Indore

Dr. Ram Mohan Rao,
Chief Scientist,
Black Soils Research Centre,
Bellary (Karnataka)

*Dr. G.P. Verma,
Dean, College of Agriculture,
J.N.K.V.V.
Jabalpur (M.P.)

*Dr. S.R. Raje,
Associate Director,
Indo-UK Project on Dryland Agriculture,
Indore (M.P.)

Dr. Ranjodh Singh,
Senior Scientist, Dryland Agriculture,
Punjab Agricultural University,
Ludhiana

ICRISAT

*Dr. L.D. Swindale,
Director General

*Dr. J.S. Kanwar,
Director of Research

*Dr. S.M. Virmani,
Leader, Farming Systems Program

*Dr. R.W. Willey,
Principal Agronomist,
Farming Systems

*Dr. J.G. Ryan,
Leader, Economics Program

Shri S.S. Dhanoa,
Principal Government Liaison Officer

Dr. S.V.R. Shetty,
Agronomist, Farming Systems

*Dr. M.S. Reddy,
Agronomist, Farming Systems

National Cooperative Development Corporation

Shri V.B.L. Mathur,
Managing Director

Shri K.J.S. Bhatia,
General Manager

*Contributed a paper

SUMMARY OF THE PROCEEDINGS

The seminar was organized by the Department of Agriculture and Cooperation in collaboration with the ICAR and ICRISAT on 21 May 1981 in the Conference Room of the National Cooperative Development Corporation (NCDC), Hauz Khas, New Delhi, under the Chairmanship of Shri S.S. Puri. Rao Birendra Singh, Minister of Agriculture and Irrigation, addressed the concluding session.

The Chairman, at the outset, thanked the concerned organizations—ICRISAT, ICAR, and NCDC—for their cooperation in arranging the Seminar. He recalled the initial planning discussions that had taken place between the Department of Agriculture, ICAR, and ICRISAT, and hoped that the Seminar would provide an opportunity for interaction between research scientists, extension specialists, and policy makers. He believed that the Seminar would contribute substantially to the development of undeveloped or underdeveloped areas of India, particularly the deep black soil areas. But he called for a balanced development for all the areas of the country.

The Chairman stated that, despite considerable advances in technology, agriculture is still vulnerable to the vagaries of nature. He emphasized that agriculture, however, continues to be the king pin of the Indian economy. He mentioned that the black soils in India cover an area of about 72-82 million ha. These areas are generally rainfed and experience considerable fluctuations in crop production. If cultivation in these areas can be stabilized, the production of cereals, pulses, and oilseeds can be stepped up. While recollecting the severe drought of 1979-80, he hoped that such extremes of weather would not arise in the context of future research work in such organizations as ICAR, ICRISAT, etc. While welcoming the participants, he urged them to keep themselves abreast of the problems and constraints in the development of the deep black soils and to suggest appropriate remedial measures for such areas.

Dr. *O.P. Gautam*, ICAR, observed that black soils were next to alluvial soils in importance. He stated that considerable technology had been developed for black soil areas that could increase in selected areas current production levels by 50% to 100%, through the use of seeds of short-duration high-yielding varieties and the moderate use of inputs. Sufficient technical know-how was available for runoff water recycling, crop substitution, and the use of seed-cum-fertilizer drills.

Dr. *R.S. Murthy* described the distribution of black soils in India. According to him the area under Vertisols and associated soils in India is 72.9 million ha, which is about 22.2% of the total geographical area of the country. He pointed out that Vertisols comprise 38% of the black soil area, Inceptisols 37%, and Entisols 21%. In response to an enquiry he observed that no figures of the net sown deep black soil area were immediately available, but he promised that the requisite figures would be worked out and made available to the Government of India.

Dr. *L.D. Swindale*, ICRISAT, presented a global view of ICRISAT's research on the management of deep black soils. He stated that there are 180 million ha of black soils all over the world. ICRISAT has been engaged in evolving suitable technology for dryland/rainfed farming areas, including Vertisol regions, for the last 7 years. The technology is low-input and bullock-drawn. It is within the reach of small farmers in the rainfed semi-arid tropics. It is also in line with national goals to give greater emphasis to rainfed agriculture to reduce disparities of income between rainfed and irrigated farming areas. This is a technology that would create employment and is therefore socially relevant. He stressed that it is not really a technology for the drought-prone areas, which generally lie outside the region in which it should work best. He suggested that the participants may wish to visit ICRISAT's Center at Patancheru in July, August, or September to see the watershed development performance for themselves. He observed that ICRISAT placed emphasis on applied and practical research in order to understand the technical, social, and economic constraints faced by the farmers. ICRISAT's endeavor is to develop new techniques and ideas that can be adopted by small farmers as well as large. Seeds, manufactured inputs, and new implements are of this type. The credit institutions and supporting services for small and marginal farmers have to become effective. Cooperation among farmers will also have to be ensured for the implementation of soil and water conservation measures. Dr. Swindale made it clear that, unlike irrigated agriculture, dryland farming may not show dramatic gains; the technology developed may take a painfully slow journey from the research center to the land. No simple single answer can be found for the problems of farmers in the semi-arid tropics and no single package of technology can be developed to apply to all areas. He believed that the technology holds sufficient promise to be worth trying in such demonstration projects as the one that the Andhra Pradesh Department of Agriculture is undertaking in Medak district, or the Indo-UK Project at Indore.

Dr. *S.M. Virmani*, ICRISAT, summarized the components of the technology, as follows.

1. Land management practices that reduce runoff and erosion, and that give improved surface drainage with better aeration and workability of the soils.
2. Cropping system and crop management practices that establish a crop at the very beginning of the rainy season, that make efficient use of moisture throughout both the rainy and post-rainy seasons, and that give high, sustained levels of yields.
3. Implements for cultivation, seeding, and fertilizing that enable the required land and crop management practices to be efficiently carried out.

Dr. Virmani recommended the adoption of the broadbed-and-furrow system, the use of the bullock-drawn wheeled tool carrier, and dry sowing techniques. He stressed, however, that no single farming system would be universally applicable to all medium and high rainfall areas on the Vertisols.

Dr. *J.G. Ryan*, ICRISAT, observed that a yield of food grains of 3 tonnes/ha on the Vertisols could be achieved by improving field drainage, dry sowing ahead of the monsoon, use of high-yielding varieties and fertilizers, using improved seed-cum-fertilizer drills to ensure proper seed placement and a good crop stand, appropriate plant protection, timely harvesting, good postharvest technology, etc. The improved technology would also result in an increased demand for human and bullock labor, and would thus generate substantial employment in the country.

Dr. *J.S. Kanwar*, ICRISAT, observed that Maharashtra has 84% of its total area under black soils, Madhya Pradesh has 38%, Gujarat 48%, and Andhra Pradesh 26%. He summarized the problems and potentials of the deep black soils, and the technology required for realizing these potentials. He believed that steps need be taken not to leave deep black soils fallow during the kharif season.

The essential ingredients of the technology for the deep black soils suggested by Dr. Kanwar include the following.

1. Small-watershed resources-management to conserve moisture, reduce erosion, and drain off excess water. In the event of organizational difficulties on-site, the technology is adaptable to being established within existing farm boundaries.

2. Carrying out the first operations of land preparation for both postmonsoon as well as monsoon crops immediately after harvesting the previous crop, when the soil has adequate moisture and is friable.

3. Smoothing the land to give a uniform slope of 0.4-0.6%.

4. Plowing the land to facilitate the formation of broadbeds and furrows (with an amplitude of 150 cm) with a Tropicultor or a wheeled tool carrier. The Tropicultor is expensive, but possibilities exist for it to be used on a collective ownership basis or on hire. Cheaper versions of the Tropicultor are being developed so as to bring it within the reach of most farmers.

5. Application of moderate amounts of NP fertilizer with a fertilizer drill, followed by the dry sowing of two rows of sorghum or maize on the side of the bed and a central row of pigeonpea as an intercrop about 1 week before the expected date of onset of the monsoon. If a sequential crop of chickpea is to be planted, three rows of cereal can be sown. The right choice of crops and their varieties is essential for the successful implementation of the technology and the enhancing of production.

6. The drilling of the seed and fertilizer at a proper depth is necessary for obtaining successful crop establishment and good yields.

7. Interculturing and weeding, and taking appropriate measures to control pests and diseases. ICRISAT do not think that the use of pesticides is the answer. The development of disease-resistant varieties and the adoption of suitable agronomic practices to reduce disease incidence and pest attack is preferable.

Dr. Kanwar made suggestions for a *Plan of Action* to achieve the potentials of Vertisols. He felt that by adopting such a Plan, many of the deep black soils could be made to produce 2-3 tonnes/ha more cereals, pulses, and oilseeds in the next 5 years than at present under rainfed conditions. The suggested Plan of Action included the following.

Phase I: *1981-83*. a. Arrange for policy makers from the research, extension and development agencies of Madhya Pradesh, Maharashtra, Andhra Pradesh, Gujarat, Karnataka, and Tamil Nadu to visit ICRISAT and ICAR centers and their operational on-farm research projects in Medak district and elsewhere. A 1-3 day visit in July to September for a group of 5-10 persons from each State is suggested.

b. Select five typical Vertisol areas in the dependable rainfall regions (>750 mm/yr) of Madhya Pradesh, Maharashtra, Andhra Pradesh, and Gujarat and set up operational-scale research projects of 10-30 ha size in each region.

c. Test, evaluate, and modify the technology, and study the feasibility of its use. This should not take more than 2 years.

d. Use the operational project sites for training extension workers, soil conservationists, and farmers by encouraging frequent visits to the sites. ICRISAT can assist in a training program organized jointly with the All India Coordinated Research Project for Dryland Agriculture.

Phase II: *1983-86*. a. Develop a conceptual framework for the transfer of technology on pilot projects of about 10,000 ha each, preferably in the dependable rainfall areas of Madhya Pradesh, Maharashtra, Andhra Pradesh and Gujarat.

b. Identify staff for the implementation of the project and arrange for their training on the operational sites.

c. Identify collaborative villages and farmers, and develop watershed layout plans after surveying their land.

d. Prepare this land, using the graded broadbed-and-furrow system.

e. Develop cropping plans for each farm holding and arrange credit and supplies (fertilizer, seeds, etc.) including access to the wheeled tool carrier, a simpler version of the Tropicultor, or a seed-cum-fertilizer drill.

f. Implement the cropping system most suited to the needs of the farmers, involving the growing of varieties with high-yield potential under rainfed conditions.

g. Use these project sites for demonstration purposes. Arrange visits by other farmers to facilitate the exchange of knowledge and experience.

h. Extend the program to other areas.

Dr. Kanwar identified the following *research problems* that deserve high priority.

1. The technology for shallow and medium black soils that have low moisture-storage capacities has not yet been satisfactorily developed. It therefore needs further study. Likewise, for the red soils (Alfisols) that often occur in the same regions as black soils, the land development system needs further improvement.
2. The harvesting of water, and its reuse, needs more critical evaluation. Particular consideration should be given to the problem of sharing harvested water and to the development of techniques for reducing seepage of stored water from tanks.
3. The loss of nitrogen in the soil, and the efficient use of nitrogenous fertilizers.
4. The development of an efficient and economical weed management system.
5. The development of a seed-cum-fertilizer drill that permits the operator to place seeds and fertilizer with precision at varying depths according to soil moisture.
6. The Tropicultor or wheeled tool carrier and other similar implements should be tested under farm conditions so as to make them more suitable for farmers' needs.
7. Developing more productive cropping systems for dry areas.

The *Chairman invited comments* on the 7-point technology suggested by Dr. Kanwar. The participants generally accepted the watershed approach. Some doubts were also expressed with regard to the usefulness of farm ponds. Dr. Ryan pointed out that runoff on black soils is less than that from red soils. Therefore, water harvesting would be more attractive in red soil than in black soil areas. In answer to a question from Dr. Dwarkinath, Dr. Kanwar explained that the available technology was capable of producing two crops in high-rainfall deep black soil areas, whereas, in the case of low rainfall and medium and shallow soil areas, improved technology based on raising a single crop and obtaining a high level of production was available. Dr. Vidyarthi and Shri Dubhashi asked that the constraints in adopting the proposed technology by farmers should be dealt with in detail.

Dr. *N.S. Randhawa*, ICAR, traced the history of research work on black soils and observed that, in the past, significant headway could not be made mainly due to lack of appropriate biological material. He said that, out of the 23 dryland research centers functioning from 1970-71, eight were located in black soil regions, with low-, medium- and high-rainfall patterns. He made particular reference to the research work done at the Bellary and Indore dryland research centers. In comparison with an average rainfall of 510 mm/yr, Bellary received only 310 mm of rainfall during 1980-81. Fortunately, even with this meager rainfall, 25% of any watershed could be given life-saving irrigation. Graded bunds with grassed waterways on small watersheds of 8-10 ha had proved very useful there. At Indore, with the adoption of new technology, cropping intensity was increased for kharif crops and the increase in yield was 3-4 fold. Cotton is not a paying crop on these soils. Dr. Randhawa suggested that (a) the watershed approach should be adopted even if it demanded redistribution of land and the consolidation of holdings; (b) in areas where tanks have silted efforts should be made to improve, desilt, and maintain them; and (c) the growing of such crops as sorghum, beans, and safflower, and agroforestry practices, must be encouraged. Dr. Randhawa said that ICAR had decided to conduct National demonstrations in dryland areas of black soil regions. He stressed that dryland farmers must be provided with technical and financial assistance. He called for a bold policy by the Government. He pointed out that irrigation projects cost an investment of Rs.10,000 to Rs.30,000 per hectare for which farmers do not pay at all. But in dryland areas such assistance is not provided even for constructing farm ponds. He said that the cost of development in dryland areas was only Rs.6000 to Rs.7000 per hectare. The proposition is attractive enough to justify Government investment.

Dr. *J. Venkateswarlu*, All India Coordinated Research Project for Dryland Agriculture, Hyderabad, highlighted the results obtained at eight research centers located in Vertisol areas. He was of the opinion that the yield level from these areas could be increased from 0.5 tonne/ha to 3-4 tonnes/ha. However, he cautioned that we should not aim at such a big jump but increase productivity step by step. He strongly supported the watershed approach for the development of these areas. Dr. Venkateswarlu suggested that the Government should open seed banks, and that some pilot projects with water harvesting structures should be undertaken to demonstrate the usefulness of the technology that has been evolved by the ICRISAT and the ICAR Research Centers. The need for establishing such development projects was strongly recommended by the other participants as well.

Dr. *G.P. Verma* outlined his experience with the integrated multidisciplinary approach adopted for managing black soils at Indore under the Indo-UK Dry Farming Project. He observed that they laid stress on the watershed approach and, consequently, on (a) land and water management, (b) the cropping program, (c) farm machinery and implements, (d) livestock improvement. The results reported were encouraging. As a result of these efforts the area under kharif as well as rabi crops had increased significantly. Besides an increase in the intensity of cropping, they were able to achieve higher production and productivity per hectare. The income of farmers had increased considerably. The new technology was most suited to small farmers, who derived higher benefits than big farmers.

During detailed discussions Dr. *R.L. Pathak* referred to the watershed development work undertaken in his State. He pointed out that encouraging results have been obtained by adopting dry farming practices. Shri *Rampur* and Shri *Dixit* also expressed their support for the watershed approach. Shri *Venkataraman* wanted the work to be taken up on a pilot-project basis.

Dr. *Bhumbla* said that the watershed concept is a must for rainfed areas. It is necessary to identify what an individual farmer is required to do, and what work should be done on a community basis. He was of the opinion that the cost of drainage should be borne by the Government. He believed that water harvesting should be developed in the Saurashtra region of Gujarat for groundnut cultivation. Dr. Bhumbla observed that all watershed areas need not be cultivable and, therefore, that agroforestry should also be encouraged, to provide fuel and fodder and to improve the fertility of the soil. Dr. *Vidyarthi* suggested that some reasonably priced and effective seed-cum-fertilizer drill should be developed.

Summing up the discussions, Dr. *O.P. Gautam*, ICAR, suggested that the new technology for the development of deep black soils should first be tried on a pilot basis under development programs, and that Central and State Agricultural Departments should take up this program. The Government should find funds for implementing the said projects on a priority basis, because these projects were greatly needed for the development of Vertisol regions. He pinpointed various components of the new technology, such as the bed-on-flat and grade-on-flat systems of soil and water conservation, management of runoff water, the use of short-duration high-yielding and drought-resistant varieties for ensuring double cropping and intercropping, etc. He suggested that agroforestry should also be tried within the system.

The Chairman observed that the Department of Agriculture and Cooperation must have no difficulty in funding operational research projects to be implemented by State Departments of Agriculture to evolve a suitable technology for black soil areas. He agreed that the concerned officers from the State Governments and Government of India must visit the ICAR and ICRISAT Centers, to obtain first-hand knowledge. He believed that, with such followup action, in the next 3-4 years we may be able to make impressive achievements in the production of cereals, pulses, and oilseeds in these areas.

Rao Birendra Singh, Minister, joined the discussions in the late afternoon. The Chairman informed him of the progress so far made in the Seminar. The Minister, in his valedictory address, remarked that in order to avoid overlapping of efforts we need coordination between such institutions as ICAR, ICRISAT, and Departments of Agriculture. He was well aware of the problems of dryland areas, and sought their early solution. He was pleased that the Seminar had been organized and observed that it constituted a move in the right direction. Such seminars should be organized more often in order to achieve better coordination between various research and development organizations. He remarked that if the ICRISAT technology could promise to give a rate of return of 250% on the additional annual expenditure of about Rs.1200/ha over present traditional levels of cost, it should be tried on farmers' fields. He mentioned that the Government could give loans and grants to encourage the farmers. He believed that loans could be repaid quickly if the profits reaped were significant. He sought an early transformation in the life of the farmers. He asked that effective measures should be taken to overcome the problems of drainage, erosion, and residual moisture management. He suggested that attention should be given to afforestation and pasture development on the marginal and submarginal lands in the regions.

Dr. *Swindale* explained to the Minister the part that ICRISAT hoped to play in the watershed approach being recommended by them, and suggested that the new technology needs on-farm verification.

The Chairman thanked the Minister and all participants for attending this Seminar. Dr. *Gautam* thanked the Government of India on behalf of ICAR and ICRISAT for organizing such a useful Seminar. He also thanked the Chairman on behalf of the participants for so ably conducting the Seminar on such a complicated subject.

DISTRIBUTION AND PROPERTIES OF VERTISOLS AND ASSOCIATED SOILS

R.S. Murthy, ICAR

INTRODUCTION

"Vertisol" is one of the ten Orders in soil taxonomy. The formative element "vert" is derived from the Latin word "verto" meaning turn on invert. Inversion takes place in the soil because of the cracking that is a unique feature of the Vertisols, or deep black soils. Associated with the Vertisols are Inceptisols and Entisols, described as medium deep and shallow black soils. It is to be noted that, because Vertisols are necessarily deep, it is not appropriate to qualify them as "deep", or "shallow". If black soils are shallow, they cannot be classified as Vertisols.

DISTRIBUTION

Vertisols and associated soils occur in peninsular India between 8°45' and 26°0' N latitude, and 66°0' and 83°45'E longitude, covering an area of about 72.9 million ha. This hectarage constitutes roughly 22.2% of the total geographical area of the country. The map given on page 22 shows the distribution of Vertisols and associated soils. Table 1 lists the constituent 39 classification units that apply, and Table 2 gives distribution data by States, and for the country as a whole. As indicated, soils of this group are found in the States of Maharashtra, Madhya Pradesh, Gujarat, Andhra Pradesh, Karnataka, Tamil Nadu, Rajasthan, Orissa, Bihar, and Uttar Pradesh.

Table 2. Vertisols and associated soils: distribution

State	Total area under Vertisols and associated soils (m.ha)	Area under Vertisols and associated soils expressed as: % of gross Vertisols area in India	Area under Vertisols and associated soils expressed as: % of total geographical area in India
Maharashtra	29.9	35.5	7.9
Madhya Pradesh	16.7	23.0	5.1
Gujarat	8.2	11.9	2.6
Andhra Pradesh	7.2	10.0	2.2
Karnataka	6.9	9.4	2.1
Tamil Nadu	3.2	4.2	1.0
Rajasthan	2.3	3.0	0.7
Orissa	1.3	2.0	0.4
Bihar	0.7	1.0	0.2
Uttar Pradesh	Negligible	Negligible	Negligible

Table 1. Vertisols and associated soils in India: classification units. (Source: National Bureau of Soil Survey and Land Use Planning (ICAR), Nagpur.)

1	Typic Ustorthents-Vertic Ustropepts
2	Vertic Ustochrepts-Typic Ustorthents
3	Vertic Ustropepts-Typic Ustorthents
4	Typic Chromusterts-Vertic Ustropepts-Typic Ustifluvents
5	Vertic Ustropepts-Typic Chromusterts
6	Vertic Ustochrepts-Typic Chromusterts-Typic Ustorthents
7	Typic Chromusterts-Vertic Ustochrepts
8	Typic Ustorthents-Vertic Ustochrepts
9	Typic Chromusterts-Vertic Ustropepts
10	Typic Chromusterts-Typic Pellusterts
11	Vertic Ustochrepts-Typic Chromusterts-Typic Ustifluvents
12	Vertic Hoploquepts-Typic Ustifluvents-Typic Chromusterts (saline phase)
13	Typic Pellusterts
14	Vertic Halaquepts-Typic Salorthids
15	Vertic Ustochrepts-Typic Chromusterts
16	Vertic Ustochrepts-Typic Chromusterts-Vertic Haplustalfs
17	Typic Chromusterts-Vertic Ustochrepts-Typic Ustifluvents
18	Typic Ustorthents-Vertic Ustropepts-Typic Chromusterts
19	Fluventic Ustochrepts-Vertic Ustochrepts-Typic Chromusterts
20	Vertic Ustropepts-Typic Pellusterts
21	Typic Pellusterts-Vertic Ustrochpepts
22	Typic Ustorthents-Vertic Ustochrepts-Typic Chromusterts
23	Vertic Halaquepts-Vertic Haplaquepts
24	Vertic Ustochrepts-Typic Ustorthents-Typic Chromusterts
25	Typic Pellusterts-Vertic Halaquepts-Vertic Tropaquepts
26	Vertic Ustochrepts-Fluventic Ustochrepts
27	Typic Chromusterts-Vertic Ustochrepts-Typic Ustorthents
28	Fluventic Ustochrepts-Typic Chromusterts
29	Vertic Ustochrepts-Typic Ustifluvents-Typic Chromusterts
30	Vertic Ustochrepts-Typic Ustifluvents-Typic Ustorthents
31	Vertic Haplaquepts-Vertic Ustochrepts
32	Typic Chromusterts-Vertic Ustochrepts-Fluventic Ustochrepts
33	Vertic Ustochrepts-Typic Ustochrepts
34	Typic Chromusterts-Vertic Halaquepts
35	Vertic Ustochrepts-Typic Chromusterts-Vertic Halaquepts
36	Vertic Ustochrepts-Vertic Haplustalfs-Typic Chromusterts
37	Typic Chromusterts-Typic Pellusterts-Vertic Ustropepts
38	Typic Chromusterts-Typic Ustochrepts-Fluventic Ustochrepts
39	Typic Chromusterts-Vertic Halaquepts-Fluventic Ustochrepts

Note. For detailed information on the distribution of these soils readers are referred to the Bureau's map Vertisols and Associated Soils in India (no date).

It will be noted that Maharashtra and Madhya Pradesh share a major portion of the Vertisols and their associates, accounting for 7.9 and 5.1% of the country's land area, respectively.

GEOMORPHIC SETTING AND SOIL TAXONOMIC UNITS

The major geomorphic units and their relation to soil distribution are presented in Table 3.

Table 3. Vertisols and associated soils: geomorphic units (subgroup level).

Major landforms	Soil units (subgroup)
Plateau, mesas, pediments, piedmont	Typic Ustorthents- Vertic Ustropepts
Plateau, piedmont, valley-bottom	Vertic Ustochrepts- Typic Ustorthents
Plateau, pediment, valley-bottom	Vertic Ustropepts- Typic Ustorthents
Piedmont, intervening basin, floodplain	Typic Chromusterts- Vertic Ustropepts Typic Ustifluvents
Plateau, piedmont, valley-bottom, floodplain	Vertic Ustropepts- Typic Chromusterts
Plateau, piedmont, intervening basin, floodplain	Vertic Ustochrepts- Typic Chromusterts- Typic Ustorthents
Floodplain, valley-bottom	Typic Chromusterts- Vertic Ustochrepts
Escarpment, mesas, buttes, plateau, pediment, intervening basin	Typic Ustorthents- Vertic Ustochrepts
Pediment, piedmont, valley-bottom	Typic Chromusterts- Vertic Ustropepts

Typic Ustorthents and Vertic subgroups of Ustropepts and Ustochrepts dominantly occur on plateaux, pediments, and piedmonts, covering 20.5% of the black soil area as a whole. Associations (a) of Vertic subgroups of Ustropepts, Ustochrepts, and Typic subgroups of Pellusterts/Chromusterts and their associates, (b) Vertic subgroups of Ustropepts/Ustochrepts,

(c) Typic Ustorthents and associates of Typic Pellusterts and (d) Typic Chromusterts, occupy the plateaux, piedmonts, intervening basins, floodplains, and valley-bottoms to the extent of 13.9, 12.6, 12.4 and 5.5% of the black soil area, respectively. The rest of the black soils are classified as associations of Vertisols and Vertic subgroups of Halaquepts/Haplaquepts and Tropaquepts, the saline phase of Vertisols, Typic subgroups of Ustifluvents and of Salorthids in the low-lying areas along the coast and in deltaic plains in Tamil Nadu, Andhra Pradesh, and Gujarat.

Deltas, floodplains and intervening basins with Typic Pellusterts constitute the major black soil area in Tamil Nadu, accounting for 7.6% of the land area. Pediment-piedmont plains and valley bottoms, with associations of Vertic Ustropepts and Typic Pellusterts, rank next (at 6.7%). The coastal area in the same State, with associations of Typic Pellusterts, Vertic Halaquepts, and Vertic Tropaquepts, comprise nearly 3.5% of the total black soil area in the State, while the elements of eroded landforms constitute about 3.1% having a soilscape of Typic Ustorthents and Vertic Ustropepts.

In Karnataka it is observed that the pediment-piedmont plain, merging to an old floodplain, comprises associations of Typic Chromusterts and Vertic Ustropepts (17.6%) while gently sloping plateaux, pediments, and scrap faces, with Typic Ustorthents and Vertic Ustropept associations, total to 10.9%. The lower piedmont, gradually merging to floodplain, covers limited areas (2.4%) under Typic Pellusterts. Intervening shallow basins, together with floodplains with Typic Chromusterts and Typic Pellusterts, occupy 9.1% of Andhra Pradesh. Other soils occurring in the lower delta of the Godavari and Krishna rivers, and the coastal plain, comprise associations of saline phases of Typic Chromusterts, Vertic Haplaquepts, and Typic Ustifluvents (5.8%).

In Maharashtra such landforms as mesas, buttes, escarpments, and gently rolling to level plateaux, with Typic Ustorthents and Vertic Ustropepts, and Vertic Ustropepts and Typic Ustorthents occupy 31.5 and 17.3% of the total black soil area. Similar landscapes and black soil associations also occur in Madhya Pradesh and Gujarat.

In can be generally concluded that Vertisols, with subgroups of Typic Chromusterts or Typic Pellusterts in association with Vertic subgroups of Ustropepts or Ustochrepts, are confined to lower piedmont plains and floodplains in almost all the States listed in Table 2, while Vertic subgroups of Ustropepts and Ustochrepts form the main soils on pediments and upper piedmont plains. The extensive and flat areas of dark heavy soil in Saurashtra of Gujarat State, popularly known as "bhal", consist of Typic Chromusterts and Vertic Halaquepts. The coastal plain along the Gulf of Cambay contains an association of Vertic Halaquepts and Vertic Haplaquepts, and an association of Typic Salorthids and Vertic Halaquepts, covering 3.4 and 7.8% respectively.

MORPHOLOGY

Vertisols and soils of Vertic subgroups have certain unusual morphological features in comparison with other soils. These are broadly indicated in Table 4.

Table 4. Vertisols and associated soils: morphological characteristics.

Horizon	Color	Texture	Structure	Special features	Width of cracks (cm)	Remarks
			T. Chromusterts/T.Pellusterts			
Ap/A11-A12	10YR 3/2, 4/2	C	Sbk-Abk		2-5	Gilgai lime ±
	10YR 2/1, 3/1	C		Intersecting Slickensides		
A13-A14	-do-	C	Abk	-do-	1.5-2	lime ±
AC	10YR 3/4, 4/4	9C-C	Sbk-Abk	Massive/Blocky	0.5-1	-do-
C	10YR 4/4, 5/4	9C-C	-do-	-do-	-	-do-
			V. Ustochrepts/V. Ustropepts			
Ap/A1	10YR 4/3, 5/2	Scl-cl	Sbk	Prismatic	2-2.5	lime ±
B1/B2	10YR 4/3, 3/3	cl-c	Sbk-Abk	-do-	1.5-0.5	-do-
B3	10YR 6/3, 3/2	gcl-c	-do-	Slickensides		-do-
C	10YR 7/6, 4/4	gl-gscl	-do-			

A Vertisol profile is characterized by a cyclic or intermittent A1 horizon of varying thickness with microknolls and microdepressions of gilgai relief within the pedon. This grades to the C horizon through a transitionary AC horizon. The associated soils of Vertic subgroups may have ABC profiles and the thickness of the horizons is uniform within the pedon. The A1 horizon in Vertisols is normally very thick and consists of 2 or 3 subhorizons differing from each other in color, pedality, and consistency. The AC horizon between A1 and C shows interdigitating tongues of A and C horizons, but in some cases the AC horizon may be missing. Vertisols invariably have wide and deep shrinkage cracks and gilgai microrelief on the surface that changes with variations in the soil moisture regime. The cracks, however, remain open depending on the accretion and reduction of soil moisture by evapotranspiration.

These cracks normally remain open for more than 150 days and, in certain places, for 90-150 days in most years. In some soils open cracks remain covered by a 2-3 cm thick very dark gray pulverized mulch layer, while in others the covering is absent. Soils of Vertic subgroups generally have shrinkage cracks on the surface that extend through depth. Although they show no gilgai formation as such, at some locations the weak development of gilgai microrelief can be observed.

The structural development of the upper 40 cm, including the A11 and A12 horizon, is generally prismatic, separating to subangular to angular blocky peds with shiny pressure faces. Shear planes are distributed from 30 cm depth down to 1.3-1.8 m. Such inclined shear planes are observed in A13, A14, and AC horizons, extending up to 1.6 m deep, or even more at some locations. These shear planes develop unique pedality, showing prolet dispheric intersecting slickensides in the upper part, forming parallelepipeds with long axes tilted 30-60° from the horizontal at depth. These compact compound structural aggregates separate to angular blocky peds with shiny pressure faces. Calcium carbonate is either absent in A1 and Ac horizons, or it is distributed irregularly throughout as a powdery or indurated nodular mass. In associated soils of Vertic subgroups, conspicuously enough the intersecting slickensides are absent.

The color of the A1 horizon is dominantly 10 YR and 2.5 Y in hue with a value 3 units higher when moist and 1 or 2 units higher when dry. The chroma in Pellusterts is less than 1.5, and in Chromusterts normally ranges between 2 and 3. The color is related to depth, compactness, and drainage conditions. Subsoil layers in low-lying situations have mottles with chroma of 1 or less. The AC horizon, as compared with A1, is somewhat lighter. Where the hue remains the same, value and chroma may differ widely. Normally the AC horizon shows a mottled color due to interdigitating tongues within the horizon, or to the presence of hydromorphic properties caused by low-saturated hydraulic conductivity.

The color of the C horizon depends on the nature of the parent material and the degree of weathering. Mottled color patterns reflect the wetness and poor drainage. At places the intensity of haploidization may lead to the formation of slickensides that separate into angular blocky peds.

PHYSICAL AND CHEMICAL PROPERTIES

Data on physical and chemical properties are presented in Table 5.

The texture in Vertisols is generally clay loam, silty clay loam, silty clay, and clay. The clay content ranges from 40% to 60%, occasionally rising to as high as 80%. The organic carbon content remains low ranging from 0.3% to 0.7%.

The pH is related to the nature of the parent material, climate, and topography. Normally it ranges from 7.5 to 8.6 and, where there are signs of sodicity, from 9.0 to 9.5. Increasing trends in pH are observed in low-lying situations in arid, semi-arid and dry subhumid areas caused by an increase in $CaCO_3$ and salt in subsoil layers.

The bulk density is usually high in Vertisols: 1.5 to 1.8 g/cc. It may reach higher figures, 2.05 to 2.1 having been observed in some pedons.

The cation exchange capacity ranges from 35 to 50 me/100g. It is high where the fine clay fraction is high.

Among other properties mention may be made of the high liquid limit, the high plasticity index (COLE value more than 0.09), the high activity number (A), the high volume shrinkage (more than or equal to 50%) and the high POLE number. The Vertic subgroups have similar values in those horizons that have Vertisol characteristics.

MINERALOGY

Varying rainfall and topography have a direct bearing on the development and mineralogy of Vertisols in basaltic terrain. High annual rainfall and strongly expressed wet and dry seasons give rise to soils with high kaolinite and low smectite contents. Semi-arid and subhumid climates with strongly alternating wet and dry seasons give rise to smectite-rich clays. The SiO_2/R_2O_3 ratio in Vertisols ranges from 2.89 to 3.79. In environments saturated with divalent cations, basic schistose rocks having readily weatherable ferromagnesium minerals alter to smectite.

Table 5. Vertisols and associated soils: physical and chemical properties.

Horizon	Clay (%)	CEC (me/100g)	pH (1:2 water)	Bulk density (g/cc)	COLE (mean)
			Typic Chromusterts		
Ap/A11	43-73	35-70	8.2-8.6	1.6-1.8	0.12
A12	42-64	35-62	8.1-8.6	1.5-1.9	0.12
A13	49-74	35-65	8.1-8.4	1.7-2.0	0.15
A14	40-76	35-60	8.1-8.6	1.9-2.0	0.14
AC	52-71	35-65	8.1-8.7	1.8-2.0	0.12
C	31-64	35-55	8.2-8.7	1.6-1.9	0.11
			Typic Pellusterts		
Ap/A11	40-68	25-50	8.0-9.0	N.A.	0.10
A12	45-70	25-65	8.0-9.2	-do-	-do-
A13	48-72	30-60	8.0-9.6	-do-	-do-
A14	45-65	35-60	8.0-9.3	-do-	-do-
AC	35-65	30-65	8.0-9.3	-do-	-do-
C	35-60	20-55	7.8-9.1	-do-	-do-
			Vertic Ustochrepts		
Ap/A1	20-55	20-60	7.5-8.2	1.3-1.7	
B1	33-55	25-65	7.7-8.6	1.3-1.6	
B2	40-55	35-65	7.6-8.7	1.5-1.7	
B3	25-40	28-48	7.6-8.7	1.4-1.7	
			Vertic Ustropepts		
Ap/A11	30-55	30-55	7.1-7.9	1.3-1.7	0.08
B2	35-65	32-60	7.1-8.0	1.4-1.6	0.10
B3	26-45	25-45	7.5-8.1	1.3-1.5	0.08
C	15-30	10-20	7.3-8.2	1.2-1.4	0.07

AN OVERVIEW OF ICRISAT'S RESEARCH ON THE MANAGEMENT OF DEEP BLACK SOILS

L.D. Swindale, ICRISAT

Dr. Murthy has described to us the properties and distribution of the Vertisols of India. But these soils are not confined to the subcontinent; they also occur in large areas in northern Australia, Sudan, and Ethiopia. They occur in smaller areas throughout sub-Saharan Africa, particularly in Chad, in Tanzania south of Lake Victoria, and elsewhere in east and central Africa. Smaller areas of these soils occur in Mexico, and central America, in Venezuela, in Bolivia, and Paraguay.

There are two major groupings of these soils, the one called Chromusterts and the other called Pellusterts. Chromusterts are the most extensive; they tend to occur in slightly better drained conditions than the Pellusterts with which they are usually contiguous. The soils at ICRISAT are Pellusterts. It is worth noting that large areas of Chromusterts occur in arid areas outside the semi-arid tropics, particularly in Sudan. Although the regions in which they occur are arid, these soils, because of their better water-holding capacity, appear to be semi-arid, and crops can be grown on them whenever there is enough water to fill the soil profile.

My point in describing the global distribution of these soils is to remind us of the international status of ICRISAT. We hope that the technologies we are developing for use on these soils in India will also be useful in Sudan, Ethiopia, Chad, and other developing countries.

We do not know how well Vertisols in these countries will respond to the application of the technology we will be discussing today. We do not know in any detail the rainfall distribution across the vast areas of these soils which lie in remote areas. We do not know much about the socioeconomic and institutional constraints that new technology would encounter.

We can expect, if the technology proves useful in India, that representatives from these other countries will be interested in knowing about it and in coming to visit the scene in due course.

Let me now provide some information about the background to today's meeting as we in ICRISAT understand it. The Governing Board of our Institute has a subcommittee known as the Technology Transfer Committee. It examines new technologies developed by the Institute's scientists and recommends to the Board those that appear ready for dissemination. In March 1980 the Technology Transfer Committee discussed the results of 7 years of work on farming systems. The discussion paper was the predecessor to the paper by Binswanger, Virmani and Kampen, entitled "Farming Systems Components for Selected Areas in India: Evidence from ICRISAT"[1] which has been included in the papers presented

[1] ICRISAT's Research Bulletin No.1, 1980.

to you. As a result of this discussion the Committee reported to the Governing Board that the strongest case for transfer was undoubtedly with the technology for deep and medium-deep black soils. It is suggested that pilot studies might be undertaken.

The Governing Board of ICRISAT acted upon the subcommittee's report by proposing that a seminar be developed with top-level policy makers in India to acquaint them with this technology. Dr. Swaminathan, who was at that time the Secretary of Agriculture and Cooperation, and who proposed that the seminar be held, suggested that the Government and the ICAR might cosponsor it. In the Board's discussion it was clarified that ICRISAT would not itself undertake pilot studies, but would assist and support national programs that did. Dr. Gautam pointed out the vital role of the national programs in the transfer of technology from the international centers.

In accordance with the Board's resolution, I wrote to the Minister of Agriculture informing him that ICRISAT was of the view that technology for the rainy season cropping of the rainfed deep black soils of central India merited examination by top-level policy makers in a 1-day seminar to be sponsored by the Government and the ICAR. After further discussion with Mr. Puri and Dr. Gautam, it was agreed to hold the meeting here today. We are very pleased to be here to share with ICAR the task of bringing you up to date with technologies that hold much promise for increasing the cropping intensities in rainfed farming.

ICRISAT will concentrate its presentation on the Vertisols in what we define as "dependable rainfall zones." The Binswanger, Virmani and Kampen Bulletin to which I have made already reference also discusses farming systems components for other areas as well. We would be pleased to discuss these with you at another time or when next you visit ICRISAT. And let me stress the importance we attach to your visiting ICRISAT.

I do not doubt that there will be questions raised today that would not need to be raised were you able to be out in the fields at ICRISAT watching the watersheds perform. People with your experience can appreciate and understand a lot at a glance, making extra words on explanations unnecessary. The month of May is however not the time. It is much too hot and dry. In July, August or September, we hope you will come to see for yourselves. We think it is important for you to do so. We can assure for you a friendly and enthusiastic welcome, and we believe that you will become enthusiastic about what you see.

Our donors have given ICRISAT a mandate to emphasize technology for small farmers working with limited inputs in the rainfed areas of the semi-arid tropics. We accept that mandate and design our research accordingly. This means that we emphasize applied and rather practical research, and research to understand the technical, social, and economic constraints faced by farmers. In our research we endeavor to develop new technologies and ideas that will lead the small farmer into the future, but will be within his reach; appropriate technology in the positive, forward-looking meaning of that phrase. The normal research approach to the small farmer is through technological components that are technically neutral to scale, i.e., that can be adopted by small farmers as well as large. Seed, manufactured inputs, and new implements are of this type. But technical neutrality to scale is not sufficient, if credit institutions and supporting services are biased towards the larger farmer. Even if the institutions are not biased, any technology that includes soil and water conservation measures which require cooperation among farmers is not neutral to scale. Furthermore, small farmers appear to require larger benefit-to-cost ratios to take the risks involved in accepting new technologies. For any one or combination of these reasons, extra efforts are needed to ensure that the small farmer is the beneficiary of new technology.

A research focus on the problems of semi-arid tropical agriculture particularly on rainfed agriculture and low-input farming by small farmers is relatively new even in India. Drs. Randhawa and Venkateswarlu, in a paper given at a symposium on "Development and Transfer of Technology for Rainfed Agriculture and the SAT Farmer" held at ICRISAT in 1979, said that the earliest work was started in 1933 and lasted for about 10 years. Soil conservation research centers were started in the mid 1950s. The All India Coordinated Research Program on Dryland Agriculture commenced in 1970. Unlike irrigated agriculture, dryland farming may not show dramatic gains; the technology developed may take a painfully slow journey from lab to land. No simple; single answer can be found for the problems of farmers in the semi-arid tropics, and no single package of technology can be developed to apply to all areas in the semi-arid tropics. Indeed we fully recognize that several technologies differing in details can be successful and exist side by side within a single region in the semi-arid tropics.

The technology that we will describe to you has been developed at ICRISAT with advice and assistance from scientists of ICAR, of the Agricultural Universities, and from many other people. It is low-input, bullock-drawn technology, within reach of the small farmer in the rainfed semi-arid tropics. It is in line with national goals to give greater emphasis to rainfed agriculture to reduce disparities of income between rainfed and irrigated areas. It is a technology that will create employment and is, therefore, socially relevant.

Like the programs for the drought-prone areas, it is based upon the concept of the watershed as the basic resource management unit. But it is not really a technology for the drought-prone areas, which generally lie outside the region in which the technology should work best. Nevertheless this region, too, is subject to drought; about 1 year in 5 according to our calculations. V. Subramaniam in the book "Parched Earth: The Maharashtra Drought 1970-73" described how few crops survived to harvest in Marathwada in 1972-73. Part of Marathwada is suited to the new technology. The crops at ICRISAT did survive to harvest in 1973 without irrigation on these soils and in 1979 and again in 1980. They also survived in the wet years of 1975 and 1978. This record of double cropping the deep black soils for 7 years without loss through drought years and floods is really the best reason that I can give you for asking the Secretary to ask you to come here today.

We do not believe that this technology is without fault or weakness. We do not believe that it is yet ready for large-scale adoption. We do believe that it holds sufficient promise to be worth trying in local demonstration projects like the one that the Andhra Pradesh Department of Agriculture is undertaking in Medak District, or in larger part-research, part-demonstration pilot projects, like the Indo-UK Project at Indore, where similar conclusions to ours on the possibilities for double cropping have been obtained. We hope that following this meeting, and subsequent visits to ICRISAT, you will be interested in trying out demonstrations and pilot projects of your own; working with the small farmer in a management partnership as the Minister of Agriculture Rao Birendra Singh has advocated. The small farmer is much preoccupied by drought. He plans for the bad year. If he can be persuaded even to plan for the average year, let alone the good year, he and the Nation will benefit.

Let me close by quoting from the Keynote address by Sir John Crawford at the Golden Jubilee Symposium of ICAR. Sir John is a great believer in the importance and value of agricultural research, a great believer in the work of ICRISAT, and was a great believer in the 1960s that an agricultural miracle could be performed, as it has been, in India. He said, "There is no way that research can be translated into productive action at the farm level, except via national or macro-policies and micro, that is, locally adapted policies and programs which make that translation possible." We are pleased to be able to inform you about some interesting and promising research. We leave it to you to do what Sir John says will now be necessary.

PROBLEMS, PROSPECTS, AND TECHNOLOGY FOR INCREASING CEREAL AND PULSE PRODUCTION FROM DEEP BLACK SOILS

S.M. Virmani, R.W. Willey, and M.S. Reddy, ICRISAT

INTRODUCTION

On the Indian deep black soils farmers who use the traditional farming system leave the land fallow during the rainy season and crop it only during the postrainy season on the residual soil moisture. In the areas of low (<750 mm/yr) and undependable rainfall, this system has developed because there is usually insufficient moisture to support both a rainy-season and a postrainy-season crop. And the farmer has long recognized that trying to grow a crop during the erratic rainfall of the rainy season is a less assured practice than trying to grow a postrainy-season crop on moisture that has already been safely stored in the soil profile. But, in the medium to high rainfall areas (750-1250 mm/yr), especially where rainfall is reasonably dependable, lack of moisture is not in itself a reason for fallowing during the rainy season. In these areas there is potentially enough moisture to sustain cropping throughout both the rainy and postrainy seasons.

The geographical location of these medium to high, dependable rainfall areas is depicted in the series of maps in Figure 1. Figure 1a shows the extent of the Vertisol areas; it can be seen that these lie mainly in Maharashtra, Gujarat, Rajasthan, and Uttar Pradesh. Figure 1b indicates which of the Vertisol areas have medium to high rainfall (750-1250 mm/yr); these are concentrated in Maharashtra, Madhya Pradesh, Gujarat, and Andhra Pradesh. Figure 1c defines the areas where rainfall is reasonably dependable, i.e., where there is more than a 70% probability of rain in more than half the weeks of the growing season (Virmani et al. 1978). The similarity of the areas defined in Figure 1b and Figure 1c indicates that the areas of higher rainfall are usually also areas of dependable rainfall.

It must be emphasized, however, that even the dependable rainfall areas show considerable within-season and between-season variation in the amounts of rainfall actually received. ICRISAT Center lies just within the dependable rainfall area and yet Table 1 shows the wide variation that has occurred during the last 6 years. Total rainfall during the growing season has ranged from 534 mm to 1076 mm, while during the single month of August it has varied from 101 mm to 516 mm.

In these medium to high, dependable rainfall areas it is the nature of the soil itself that has largely resulted in the system of rainy-season fallowing. The Vertisols have a high content of montmorillonitic clay (Table 2), that makes them very difficult to manage. They are very hard when dry and extremely sticky when wet, and thus it is within only a limited range of moisture conditions that they can be easily cultivated. Although in some areas the farmer may practice deep-plowing during the dry season, he is usually unable to work the hard soil into a satisfactory seedbed before the arrival of

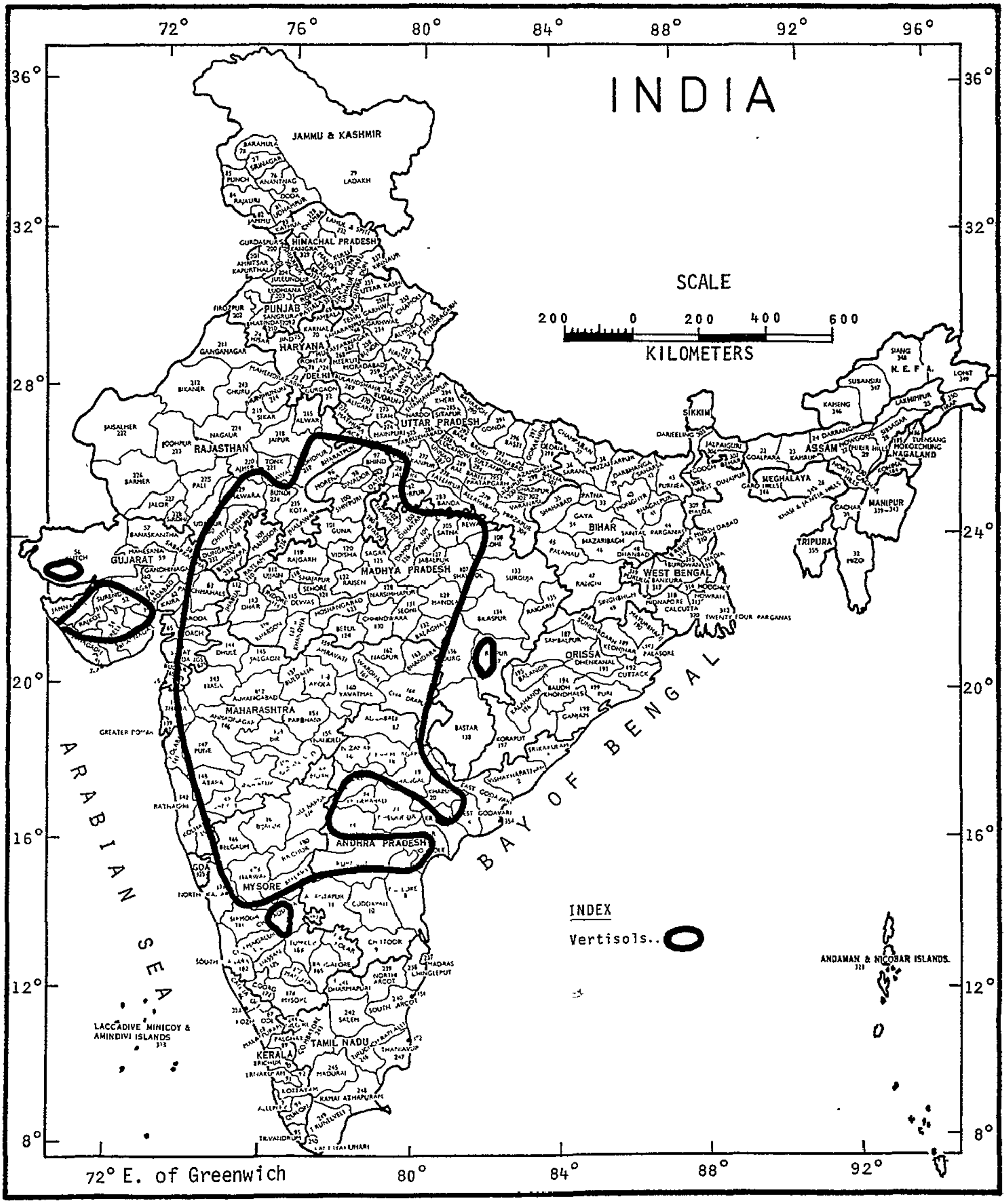


Figure 1a. Extent of the Vertisol areas in India.

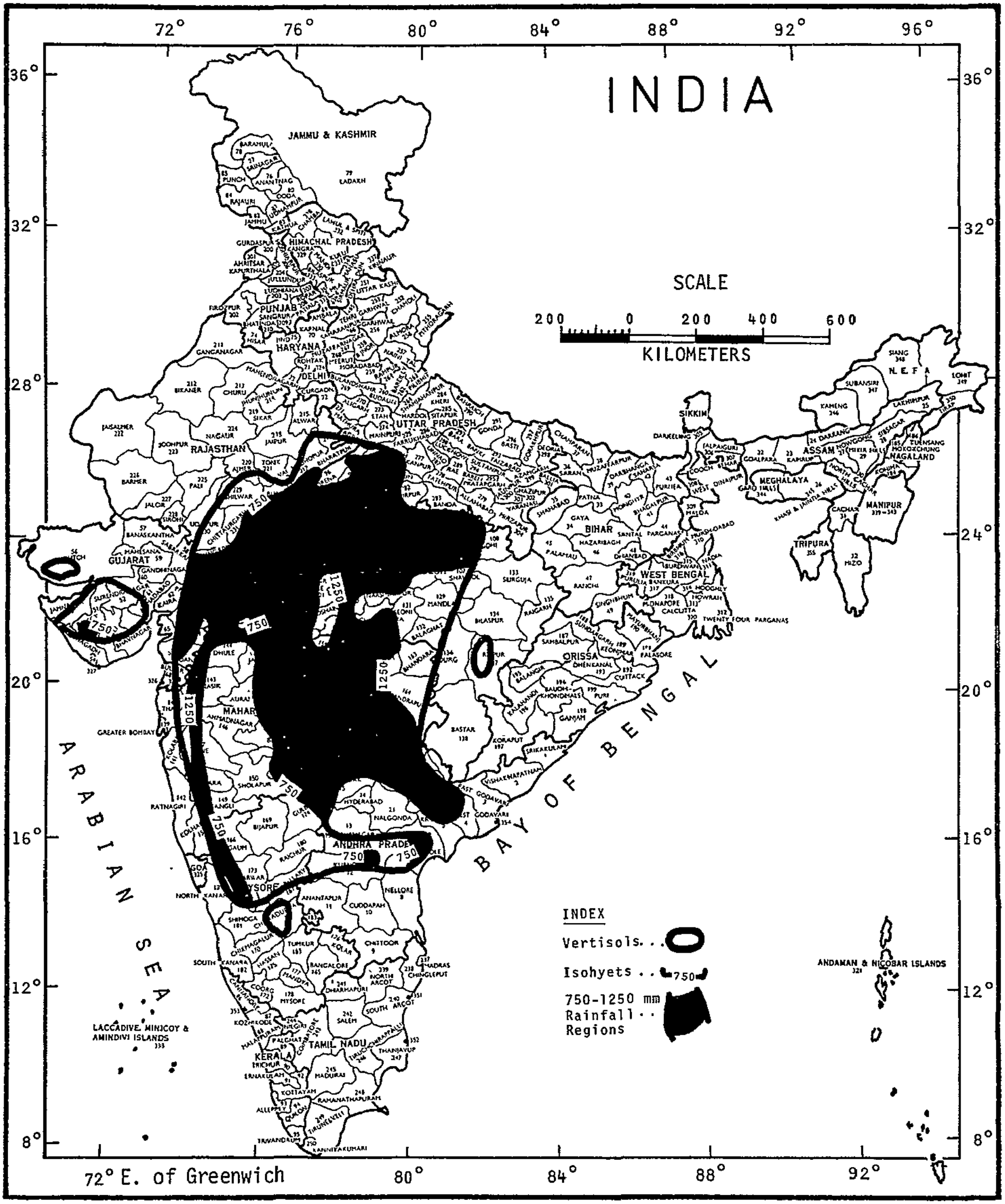


Figure 1b. The distribution of medium to high rainfall (750-1250 mm/yr) in the Vertisol areas of India.

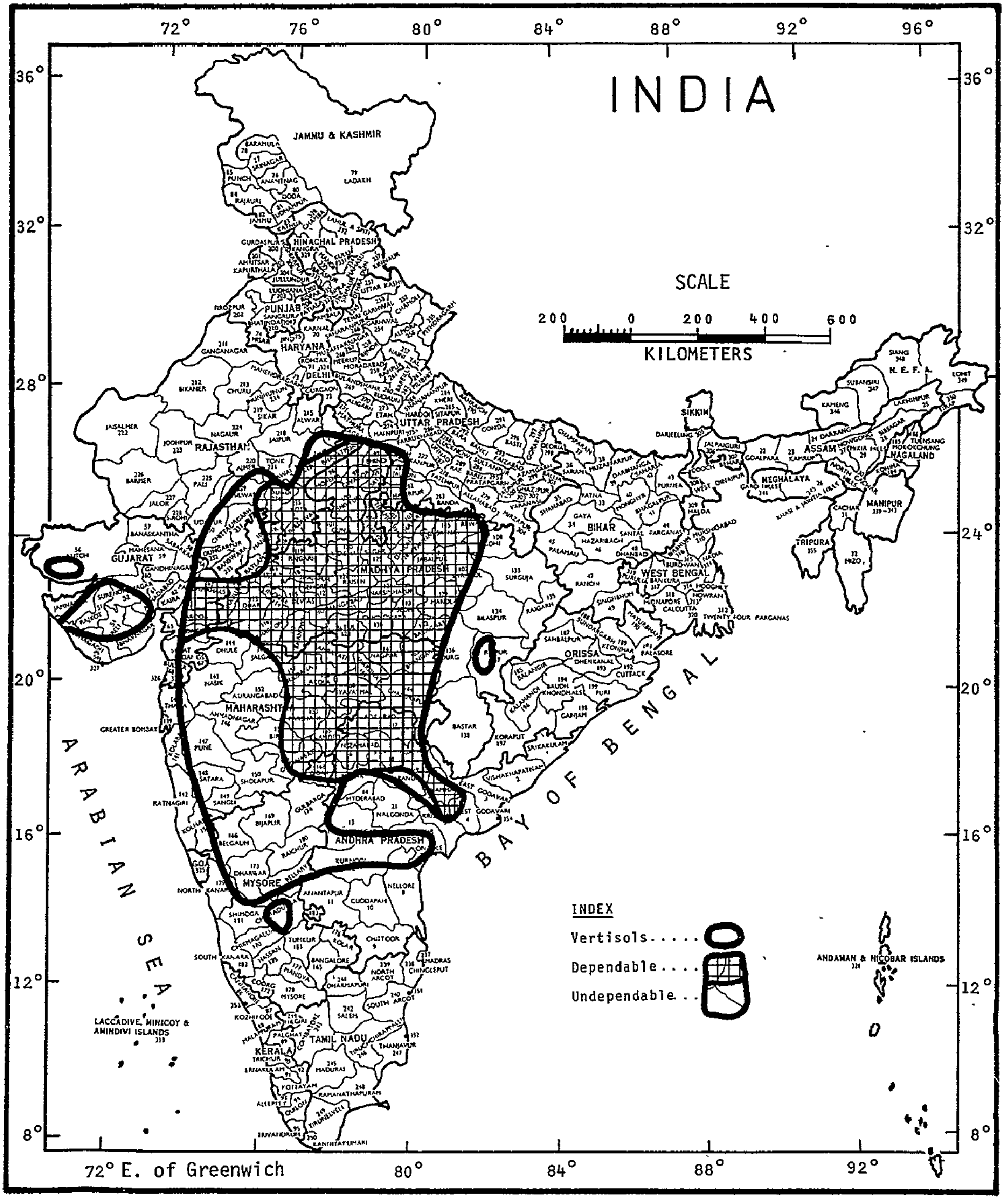


Figure 1c. The Vertisol areas of India where rainfall is dependable and undependable.

Table 1. Cropping-season rainfall (mm) at ICRISAT Center for 1975-80.

Year	June	July	August	September	October	Seasonal total
1975	98	195	139	422	173	1027
1976	86	219	299	74	1	679
1977	66	183	196	40	49	534
1978	181	228	516	81	70	1076
1979	58	107	101	344	20	630
1980	141	127	306	153	6	733

the rains. And, once the rains have started, the soil rapidly becomes too sticky for cultivation and sowing. If the rains are heavy, crop waterlogging may occur. Weeds are also a problem: in his traditional fallow system the farmer uses the brief dry periods to control weeds with his blade harrow; but if he tries to grow a crop during the rainy season the limited workability of the soil restricts his opportunity for timely weed control.

In addition to representing a loss in potential cropping, the fallow has other disadvantages. The rainfall characteristics of these areas are such that there is a high probability of high-intensity storms causing runoff and erosion, and these problems are intensified by the lack of a vegetative cover to protect the soil. Moreover, where the traditional fallow system is used the potential utilization of total rainfall is limited to the moisture that can be stored in the soil profile for postrainy-season use. Hydrologic studies over 6 years at ICRISAT have indicated that, of the total rainfall potentially available, approximately 25% is lost through runoff, 25% is lost through evaporation from the bare soil of the fallow, 9% is lost through deep percolation and only 41% is potentially available for postrainy-season crop growth (Table 3). By contrast, when crops are grown during the rainy season, runoff is reduced, on average, to less than 15% of the annual rainfall.

A further characteristic of the Vertisols is that they are low in crop nutrients, especially nitrogen and phosphorus (Table 2). Again, the rainy-season fallow system has traditionally been advantageous for the small farmer in that it makes relatively little demand on the soil because only one crop a year is grown. Also, the mineralization of nitrogen during the fallow period can provide an accumulation of some available nitrogen for the postrainy-season crop. Cropping throughout both the rainy and postrainy-seasons will be much more demanding on soil nutrients and, in such a system, good yields are likely to be sustained only with adequate input of nutrients. However, the potential of these double cropping systems looks extremely attractive for the medium to high rainfall areas. Given appropriate input of nutrients it has been estimated that, on the basis of rainfall, they are capable of sustaining total yields of 3000-5000 kg/ha compared with the 500-1000 kg/ha currently being attained.

Table 2. Physical and chemical characteristics of a Vertisol at ICRISAT Center.

Depth (cm)	Mechanical composition: Coarse sand (%)	Fine sand (%)	Silt (%)	Clay (%)	Field capacity (θ_v)	Wilting point (θ_v)	Organic carbon (%)	pH 1:2.5	Bulk density (g/cc)	Cation exchange (me/100 g)	Available nutrients: N (ppm)	P (ppm)	K (ppm)
0-25	4.0	18.3	16.5	61.1	.44	.28	.45	7.6	1.3	57.6	65.6	2.8	237
25-75	6.0	17.3	14.1	62.6	.44	.28	.12	7.5	1.4	52.9	55.3	1.0	186

(Source: Sardar Singh and Krantz 1976.)

Table 3. Estimated water-balance components observed in studies of the traditional rainy-season fallow system on Vertisols at ICRISAT.

Water balance component (mm)	Year						1973-78
	1973-74	74-75	75-76	76-77	77-78	78-79	(%)
Runoff[a]	60	210	250	210	50	410	25.3
Deep percolation	100	15	140	20	0	160	9.2
Evaporation (rainy-season fallow)	300	175	225	145	140	190	24.9
Evapotranspiration (postrainy-season cropping)	280	375	350	290	325	290	40.6
Rainfall	740	775	965	665	515	1050	100.0

[a]When crops are grown during the rainy season runoff is reduced, on average, to less than 15% of the annual rainfall.

THE TYPE OF FARMING SYSTEM REQUIRED FOR THE MEDIUM TO HIGH RAINFALL AREAS

It is evident that the farmer's basic requirement is for a system that will enable him to grow crops throughout both the rainy and postrainy seasons. It is equally evident that this will be possible only by means of a technology that will give him improved workability of his soils and adequate control of moisture. The essential components of this technology can be summarized as follows.

a. Land management practices that reduce runoff and erosion, and that give improved surface drainage and better aeration and workability of the soil.

b. Cropping systems and crop management practices that establish a crop at the very beginning of the rainy season, that make efficient use of moisture throughout both the rainy and postrainy seasons, and that give high, sustained levels of yield.

c. Implements for cultivation, seeding and fertilizing that enable the required land and crop management practices to be efficiently carried out.

THE ICRISAT APPROACH

It must first be stressed that no single farming system will be universally applicable to all medium and high rainfall areas of the Vertisols. The system specifically suited to a given region will depend on the local climatic, biological, and socioeconomic environment, and this will always be location-specific. The ICRISAT approach is thus to emphasize the basic principles of a suitable system so that it may serve as a foundation from which more specific systems can be developed for particular areas.

The broadbed-and-furrow system

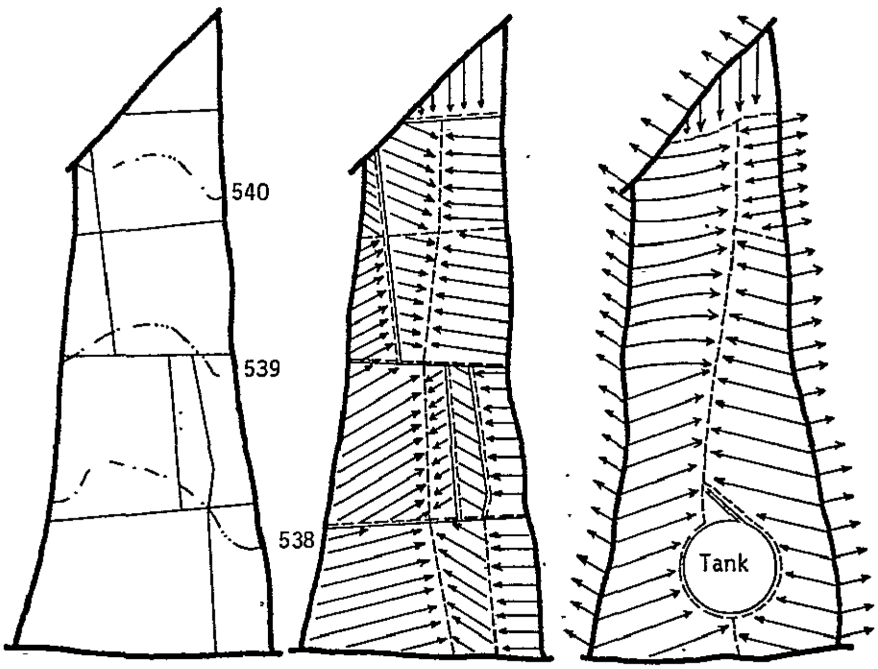
The basis of the ICRISAT approach is a system of semi-permanent broadbeds and furrows that are laid out on a gradual slope (usually 0.4-0.8%). Each bed (approximately 100 cm in width) is slightly raised, acting as an in situ "bund" for good moisture conservation and erosion control. The furrow (about 50 cm in width) is shallow (15 cm deep) but provides good surface drainage to prevent the waterlogging of the crops growing on the bed. Excess water is led off through a system of field drains and grassed waterways. Compared with contour bunding, the broadbed-and-furrow system is laid out in small natural watersheds, or "catchments", but it can be laid out within a farmer's existing field boundaries where adequate drainage is provided.

The essential steps in laying out the broadbed-and-furrow system are, first a survey to define the local topographic detail and to plan the layout of surface drains. The direction of beds and furrows is marked out in relation to these drains. Secondly, some land-smoothing is usually necessary to remove small depressions and high spots. At ICRISAT this smoothing is done entirely with animal drawn equipment and can usually be done at a lower cost, and with much less surface soil disturbance, than terracing or other forms of land levelling. The necessary field drains and waterways for the safe disposal of excess water are then prepared and, finally, the beds are formed. A diagramatic layout of an experimental watershed at ICRISAT is given in Figure 2.

A further feature of the broadbed-and-furrow system is that the runoff water can be "harvested" in a tank and then recycled later for supplemental irrigation. On Vertisols with relatively dependable rainfall the probability of moisture stress at critical stages of crop growth is relatively low for the rainy-season crops. However, supplemental irrigation may be worthwhile for the establishment of the postrainy-season crop in those years when the rains have ended early and the upper soil layers are too dry for good germination; this harvested water could also be profitably used for irrigating small areas of high-value crops. Where irrigation is used, the furrows of the broadbed-and-furrow system provide suitable irrigation channels along which the water can be conveniently run.

The wheeled tool-carrier

Another essential component of the ICRISAT approach has been the adaptation of an animal-drawn wheeled tool carrier to carry out all the operations of cultivation, sowing, fertilizing, and weeding required within the broadbed-and-furrow system (ICRISAT 1981). The first wheeled tool carrier to be successfully used at ICRISAT was the Tropicultor, designed by a French engineer. The basic frame has a toolbar onto which a variety of implements can be attached with simple clamps. Two ridgers and a bed-former are used in the initial formation, or reshaping, of the beds. Other appropriate implements are used for seeding, fertilizing, and soil cultivation. The working depth can be adjusted to meet operational requirements. A lifting mechanism is provided to raise the implements into the transport position, or to lower them into the working position.



a. Contour bunds.

b. Broadbed-and-furrow system at 0.6% within field boundaries.

c. Broadbed-and-furrow system at 0.6% with grassed waterways and a tank.

→ Bed and furrow direction
—— Field bunds
---- Grassed waterways
═══ Elevated inlet
—··— Contour bunds

Figure 2. A Vertisol watershed with three alternative soil and water conservation and management practices illustrated for the same watershed. The broadbed (150 cm)-and-furrow system at 0.6% slope within the field boundaries (Layout b) was established five years ago and still exists. Layout 'c' shows the same permanent broadbed-and-furrow system with field boundaries removed, a grassed waterway and a tank. Contour bunds (Layout a) are seldom allowed by farmers as they do not want their small fields bisected. Therefore, the bunds are placed on the field boundaries, and problems of water stagnation and bund breaching occur.

Experience has shown that all operations with the wheeled tool carrier can normally be done with a medium-size pair of bullocks (300 kg each). The equipment offers considerable time-saving advantages to the farmer. A traditional wooden plow in India with a maximum working width of 15 cm requires 66.7 km of travel by the farmer and his bullock to cover 1 ha. A 75-cm blade harrow requires 13.3 km of travel. In the broadbed-and-furrow system, where the machinery working width is 150 cm, the distance traveled per hectare is only 6.7 km—10% that required of the traditional plow. As a bonus, the wheeled tool carrier can be used as a cart to provide transportation.

Operation of the system

It has already been emphasized that tillage operations are difficult on the Vertisols once the rains have started and the soils are wet. Delays in sowing are undesirable because of the loss in effective growing period and the possibility of increased pest attack (e.g. sorghum shootfly). However, the raised broadbed in the ICRISAT system maintains a relatively open structure that allows some primary tillage during the dry season. At ICRISAT all primary tillage can be done on the beds without any rain although it is naturally easier if there is an occasional shower. The draft required for tillage on the beds is about 2/3 of that required for tillage on flat cultivation under dry conditions. This primary tillage during the dry season allows crops to be sown dry just prior to the onset of the rains. Seeds are sown deep (5-7 cm) so that germination is not induced by light prerainy-season showers. Fertilizer application is also done in the dry seedbed, either as a separate operation prior to seeding or as a combined operation with seeding. At ICRISAT, rainy-season crops have been satisfactorily established in this way for the last 8 years, though in 1979, when the onset of rains was delayed, reseeding was necessary because of rat damage to the initial sowing. Optimum sowing time is considered to be just before there is a 70% probability of rain.

This dry-sowing technique offers a considerable advantage in terms of ensuring an early start to the cropping period, but it does rely on a reasonable dependability of early rainfall in the cropping season. Figure 3 shows the Vertisols areas divided into "high-risk" and "low-risk" areas for dry-seeding, the "low-risk" areas being defined as those where there is a reasonable dependability of the onset and continuance of the early rains. ICRISAT Center lies in the low-risk area, which accounts for the success of the dry-seeding technique there. In contrast, Solapur district lies in the high-risk area. This explains why, despite a rainfall total similar to Hyderabad, attempts to dry-seed in an on-farm situation there have largely failed.

As soon as heavier showers arrive (providing about 25 mm or more rainfall over 1-2 days) germination occurs and the crops make a rapid start in the growing season. Interrow weeding can be carried out with a steerable tool bar attached to carrier, and hand operations such as top-dressing and within-row weeding can be carried out in the normal way.

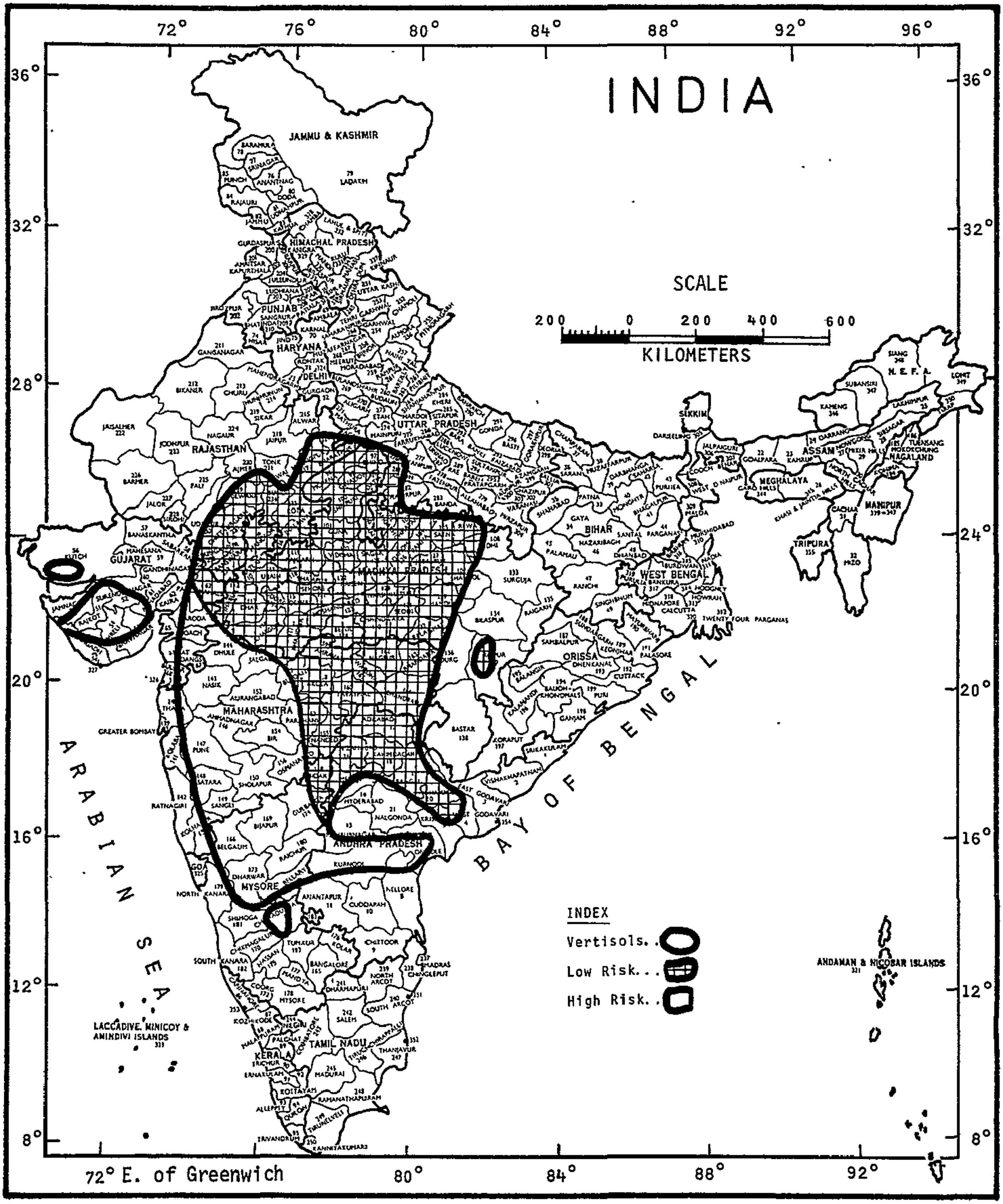


Figure 3. Vertisol areas divided into "high-risk" and "low-risk" areas for dry-seeding.

Immediately after the postrainy-season harvest, advantage is taken of any remaining soil moisture and the beds are cultivated. This is done using moldboard plow attachments on the tool carrier to uproot the crop stubble and to kill any weeds that occur. This leaves the center of the bed cloddy, which makes it receptive to any rain that occurs during the dry season. When showers do occur, final land preparation and reforming of the beds can be done and the beds are again ready for the prerainy-season dry seeding.

The cropping systems

The broadbeds are adaptable to a wide range of sowing arrangements to accommodate different crops; at ICRISAT the number of rows per bed usually varies from one to four, giving effective row arrangements from 150 to 30 cm. With the individual seeder units on the tool carrier, it is just as easy to sow an intercrop as a sole crop. Some typical sowing patterns are illustrated in Figure 4.

In the experimental watersheds at ICRISAT the two major cropping systems that have been developed to utilize both the rainy and postrainy seasons are

a. a 'sequential' system of rainy-season maize (2 rows per broadbed) followed by postrainy-season chickpea (4 rows per broadbed), and

b. an intercrop system of maize/pigeonpea (one row of pigeonpea down the middle of the bed and one row of maize on either side).

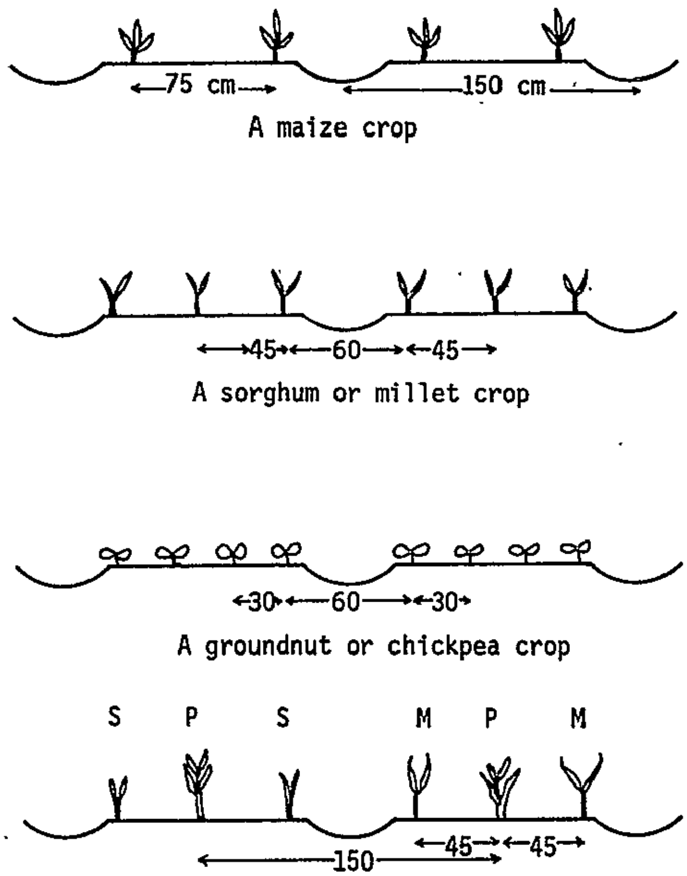
Maize has been the preferred cereal in these systems because its cultivation has fewer problems than the cultivation of sorghum: it does not suffer from shootfly, it does not suffer from the head molds that can be a problem when sorghum is sown sufficiently early to permit a second crop to be grown, and it does not ratoon, which can be a problem in sorghum when it is followed by a second crop.

The yields of these two systems over 4 years at ICRISAT, from operational watersheds of several hectares, are given in Table 4. Improved seeds

Table 4. Grain yields (kg/ha) from a maize/pigeonpea intercrop system and a maize-chickpea sequential system compared with traditional rainy-season fallowing from deep Vertisol operational-scale watersheds at ICRISAT Center.

	1976-77	1977-78	1978-79	1980-81	Mean
Maize/pigeonpea intercrop system					
Maize	3291	2813	2140	2918	2791
Pigeonpea	783	1318	1171	968	1060
Maize/chickpea sequential system					
Maize	3116	3338	2150	4185	3197
Chickpea	650	1128	1340	786	976
Traditional fallow and single postrainy-season crop					
Chickpea	543	865	532	596	634
Sorghum	436	377	555	563	483

Broadbeds and furrows are adapted to many row spacings:



A pigeonpea/sorghum intercrop or a pigeonpea/maize intercrop

Figure 4. Alternative cropping systems and row arrangements on broadbeds (150 cm). All dimensions in cm.

and fertilizers were used as part of the technology, and it can be seen that yields were substantial; averaged over the 4 years they were 3197 kg/ha of maize and 976 kg/ha of chickpea in the sequential system, and 2791 kg/ha of maize and 1060 kg/ha of pigeonpea in the intercrop system. Both these systems very substantially outyielded the traditional rainy-season fallow system in which only a postrainy-season crop of chickpea or sorghum was grown without the benefit of broadbeds or improved seed and fertilizer (634 kg/ha for chickpea and 483 kg/ha for sorghum: see Table 4).

In comparing these two improved systems, the good performance of the intercrop is worth noting. It gave only a little less maize but rather more pulse than the sequential system, and gross returns were very similar. But in practical terms the intercrop may be particularly attractive in that both crops are established in one operation at the beginning of the rainy season. This single operation avoids a potential problem with the sequential system in which the postrainy-season crop has to be established at the end of the rains when the upper soil layers may have dried out, and when the farmer has a peak labor demand for harvesting his rainy-season crop. This is one of the reasons why the intercrop system has given more stable net returns than the sequential system in these operational watersheds (Ryan et al. 1979).

Possible alternative cropping systems: evidence from small plots

A wider range of cropping systems has been examined for a number of years in small plots at ICRISAT Center. This coming season the more promising ones will be tested on an operational scale.

Some of the results are presented in Figure 5. It can be seen that, as well as chickpea, postrainy-season crops of sorghum or pigeonpea can be successfully grown after a rainy-season crop of maize. For all three post-rainy-season crops, the rainy-season maize causes little or no reduction in yield compared with bare fallowing. In these small plots, sorghum has proved a viable alternative to maize as a rainy-season crop, though the subsequent postrainy-season yields have been a little lower than after maize. However, in farming practice the regrowth of sorghum stubble may present a problem in sequential systems, so this is now being examined in some detail in operational-scale plots at ICRISAT Center.

A sorghum/pigeonpea intercrop has proved to be as good as the maize/pigeonpea intercrop, and for this combination there is very good evidence from other sources of the improved stability of intercropping referred to earlier. If crop "failure" is based on a gross return of less than Rs.1000/-, then data from 98 experiments throughout India indicate that sole pigeonpea fails 1 year in 5, sole sorghum 1 year in 8, but a sorghum/pigeonpea inter-crop fails only 1 year in 36 (Rao and Willey 1980).

The importance of the fertilizer component in improved farming systems

The ICRISAT approach has been to try to bring together several components of improved technology because it is recognized that the improvement of only one component may have little or no effect on yields if other components are

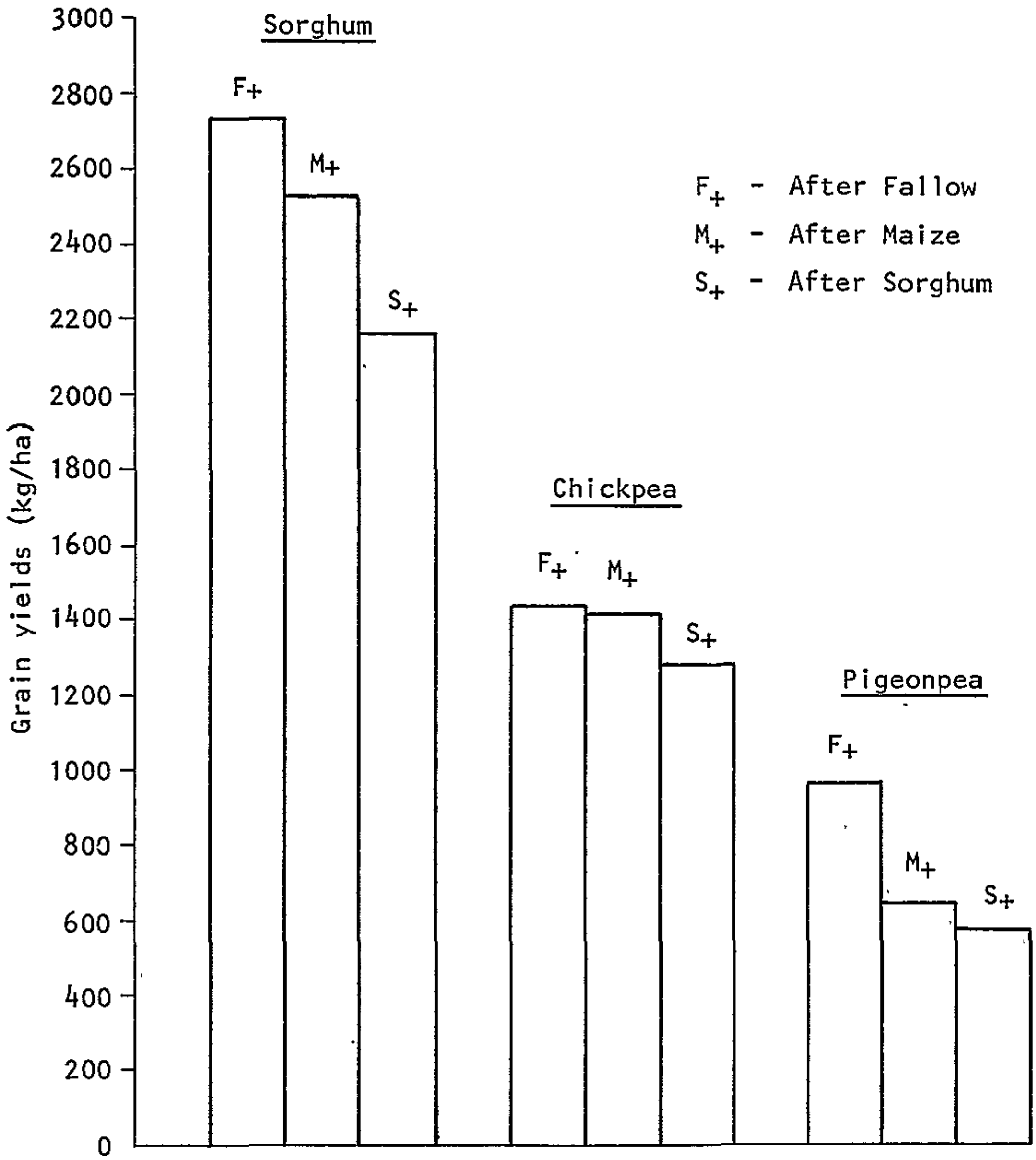


Figure 5. Grain yields (kg/ha) of postrainy-season sorghum, chickpea, and pigeonpea after rainy-season fallow, maize or sorghum grown in small plots on Vertisols at ICRISAT Center (Average of 2 years, 1979-80).

still limiting. The high yields obtained from the maize-chickpea sequential system and the maize/pigeonpea intercrop system on the ICRISAT operational watersheds were the combined effects of several factors: improved cropping systems, higher fertilizer inputs, improved genotypes, and the use of better implements to achieve improved management of land and crops.

Some of the individual effects of different components have also been examined at ICRISAT in a series of experiments on "Steps in Improved Technology". For any given cropping system, the three components that have received most attention have been improved genotype, improved management of both land and crops, and use of fertilizer. Again one of the cropping systems examined has been a maize/pigeonpea intercrop; this was grown for 2 years (1976 and 1978). Taking the mean maize yield over both years, improving only the genotype (from a local variety to an improved hybrid) had no effect on yield if neither fertilizer nor management was improved. Similarly, improving only the land and crop management had relatively little effect on yield (an increase of 35%) if neither genotype nor fertilizer was improved. In contrast, applying fertilizer approximately doubled yields even when neither genotype nor land and crop management was improved. Even more striking, however, were the effects when the different improved components were combined. Thus, when fertilizer was combined either with improved management or improved genotype, the yields were increased two- to three-fold; when all three factors were combined the yields increased more than four-fold. The intercropped pigeonpea showed less response than the maize, though again the biggest response (75%) occurred when all three components were combined.

These results highlighted the importance of the fertilizer component. This re-emphasizes the point made earlier, that the Vertisols are inherently low in fertility and that fertilizer inputs are required if high yields are to be sustained. But the results also highlight the important complementary effects that can occur between components, emphasizing that highest yields are likely to be obtained when several components are simultaneously improved and combined into one overall farming system.

REFERENCES

ICRISAT. 1981. The animal-drawn wheeled tool carrier. Information Bulletin No.8. Patancheru, A.P., India: International Crops Research Institute for the Semi-Arid Tropics.

Rao, M.R., and Willey, R.W. 1980. Evaluation of yield stability in intercropping: studies on sorghum/pigeonpea. Experimental Agriculture 16:105-116.

Ryan, J.G., Sarin, R., and Pereira, M. 1979. Assessment of prospective soil-, water-, and crop-management technologies for the semi-arid tropics of peninsular India. Pages 52-72 in Proceedings of the International Workshop on Socioeconomic Constraints to Development of Semi-Arid Tropical Agriculture, Hyderabad, India, 19-23 February 1979. Patancheru, A.P., India: International Crops Research Institute for the Semi-Arid Tropics.

Sardar Singh, and Krantz, B.A. 1976. A brief description of the soils of ICRISAT. An informal report of ICRISAT.

Virmani, S.M., Sivakumar, M.V.K., and Reddy, S.J. 1978. Rainfall probability estimates for selected locations of semi-arid India. Research Bulletin No.1, Patancheru, A.P., India: International Crops Research Institute for the Semi-Arid Tropics.

ECONOMICS OF TECHNOLOGY OPTIONS FOR VERTISOLS IN THE RELATIVELY DEPENDABLE RAINFALL REGIONS OF THE INDIAN SEMI-ARID TROPICS

James G. Ryan and R. Sarin*, ICRISAT

INTRODUCTION

Since 1976 research has been conducted at ICRISAT Center, Patancheru, on operational-scale Vertisol watersheds and subwatersheds of from 1 to 5 ha. One of the primary objectives has been to develop improved soil, water, and crop management technology options which would enable profitable crops to be grown both in the rainy and postrainy seasons. In many of the Vertisol regions of India the land is left fallowed in the rainy season and cropped only in the postrainy season to crops such as sorghum, chickpea, wheat, and safflower (Figure 1).[1] These crops occupy an area of approximately 14.8 million ha in the six states represented at this Seminar (Table 1).

States which have the largest areas of kharif fallowing are Madhya Pradesh, Maharashtra, and Andhra Pradesh (Table 2). Among them they have almost 12.3 million ha of land left fallow in the rainy season. This is 26% of their current net sown area. Malone (1974) earlier estimated that some 26.2 million ha of rainy-season fallow existed in India. Of this we estimate some 12 million ha are in the Vertisols of the semi-arid tropics (SAT). If a 2 tonnes/ha food-grain crop could be grown on these rainy-season Vertisol fallows it would add some 24 million tonnes to India's food-grain production. This would represent almost a 20% increase. In addition, the crop cover provided by rainy-season crops on these Vertisols could reduce soil erosion by approximately 80% (Binswanger et al. 1980b, p.34).

Results from research at ICRISAT Center suggest that there is potential for food-grain production increases of more than 3 tonnes/ha on the Vertisols. This can be achieved by:

- improving field drainage,
- dry sowing ahead of the monsoon,
- use of HYVs, and fertilizers,
- using improved seed and fertilizer drills to ensure proper placement and stand,
- appropriate plant protection,
- timely harvesting,
- postharvest cultivation.

---

*The authors are grateful to their colleagues J. Kampen, B.A. Krantz, S.K. Sharma, S.M. Miranda, S.V.R. Shetty, G.E. Thierstein, G. Michaels, and their assistants, who were responisble for the much of the research on which this analysis is based. The comments of V.S. Doherty, J.S. Kanwar, and K.L. Srivastava on an earlier draft are appreciated. The authors alone are responsible for the content that remains.

[1]The graph was compiled by G. Michaels, previously Research Scholar in the Economics Program at ICRISAT.

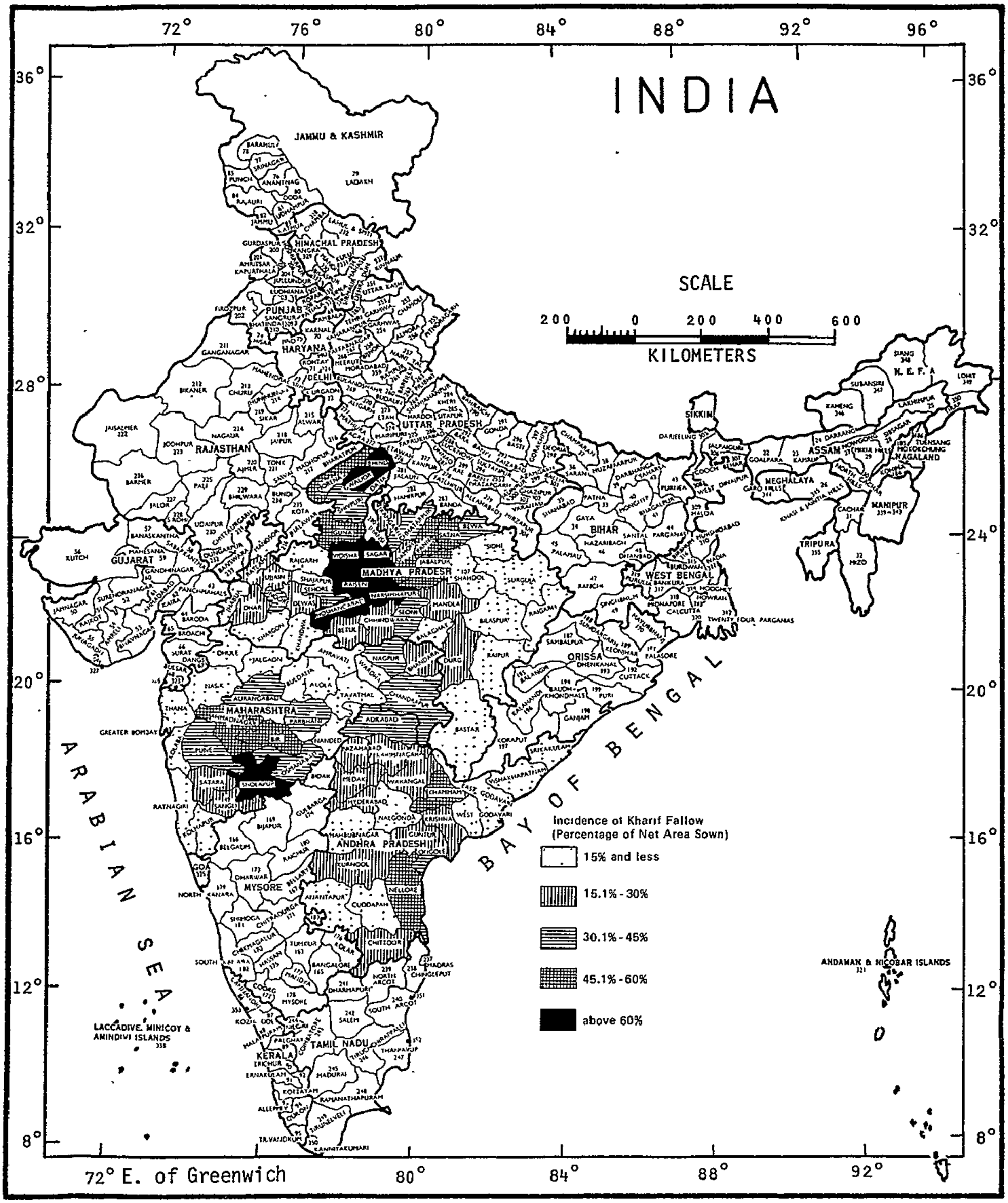


Figure 1. Extent of rainy-season fallows in selected areas of India. (Data are not available for the unshaded areas.)

Table 1. Average annual area of postrainy-season crops in six Indian states 1975-78 ('000 ha).

Crops	STATES						
	Andhra Pradesh	Gujarat	Karnataka	Madhya Pradesh	Maharashtra	Tamil Nadu	TOTAL
Sorghum	1088	168	1037	18	3373	156	5840
Wheat	27	699	378	3244	1195	2	5545
Chickpea	83	75	173	1982	452	11	2776
Safflower	16	0	168	1	499	0	684
TOTAL	1214	942	1756	5245	5519	169	14845

Source: Directorate of Economics and Statistics (1979).

Table 2. Estimates of extent of rainy-season fallow in India.

State	Years	Average annual area of rainy-season fallow ('000 ha)	% of net sown area fallowed in rainy-season
Madhya Pradesh	1971-78	5378	29
Maharashtra	1971-75	4642	27
Andhra Pradesh	1972-78	2253	20
Total 3 states	--	12273	26
India	1970-71	26200	19

Sources: Compiled by G. Michaels from data in Directorate of Agriculture (various years), Bureau of Economics (various years) and Government of Maharashtra (various years) and Malone (1974).

All Vertisol regions in India will not be suitable for this type of technology. It is possible only in the relatively high (> 750 mm/yr) and dependable rainfall areas with Vertisols. S.M. Virmani and his colleagues at ICRISAT have mapped the regions where this technology is likely to have most promise.

In this paper we discuss the economics of the improved technologies that have been evolving from research at ICRISAT Center and in villages aimed at enabling crops to be grown in Vertisols in the rainy season.

PROFITS FROM IMPROVED TECHNOLOGY

Joint research of the Farming Systems and Economics Programs from 1976 to 1981 has shown that such an improved watershed-based technology based on maize intercropped with pigeonpea can increase profits by about 600% compared with a traditional system based on rainy-season fallow followed by postrainy-season sorghum and chickpea. This improved system utilizing graded broadbeds and furrows has generated profits averaging Rs.3650/ha/yr over 5 years. This compares with a figure of only Rs.500/ha/yr from the traditional system (Table 3). These profits represent a return to land, capital, and management, as the costs of all human and animal labor, fertilizers, seeds, and implements have been deducted. For an extra annual cost of about Rs.1200/ha a farmer changing from the traditional system could earn an additional profit of about Rs.3100/ha. This represents a rate of return on the increased working expenditure of about 250% — a most attractive figure.

The capital cost of a wheeled tool carrier with a full set of attachments is Rs.8000-10000. This implement permits the formation of the graded broadbeds and furrows and greatly facilitates the improved placement and distribution of seeds and fertilizers. Our estimates are that one unit could effectively serve 12-15 ha. Based on these figures the extra profits from the new system could pay for the wheeled tool carrier in 1 year provided it was utilized along with the improved technology on at least 4 ha.

On the Vertisols at ICRISAT Center the data in Table 3 show that the graded broadbeds and furrows increase profits by about 30% compared with a flat cultivation system using a maize/pigeonpea intercrop. With the maize-chickpea sequential system the graded broadbeds and furrows have a 20% profit advantage. If farmers were able to achieve improved placement of seed and fertilizers with their traditional implements, these results suggest that the wheeled tool carrier would still be profitable for forming the broadbeds and furrows. With additions to profits of Rs.500-800/ha the wheeled tool carrier could be paid for in 1-2 years from the extra income generated by the broadbeds and furrows.

If for some season broadbeds and furrows were not used, but all other components of the improved technology were, profits could still be increased by more than 400% compared with the traditional system (Table 3).

Table 3. Economics of improved technology on Vertisols at ICRISAT Center: annual averages 1976-81.

Crops	Soil and crop management	Gross returns	Costs[b]	Gross profits
		----------Rs/ha----------		
1. Maize/pigeonpea intercrop	Broadbeds and furrows, HYVs[a], chemical fertilizers, wheeled tool carrier, plant protection	5380	1730	3650 (975)[c]
2. "	Flat cultivation, HYVs[a], chemical fertilizers, wheeled tool carrier, plant protection	4607	1771	2836 (606)
3. Maize/chickpea sequence	Broadbeds and furrows, HYVs[a], chemical fertilizers, wheeled tool carrier, plant protection	5304	2241	3063 (1527)
4. "	Flat cultivation, HYVs[a], chemical fertilizers, wheeled tool carrier, plant protection	4811	2254	2557 (1469)
5. Rainy-season fallow, post-rainy-season sorghum and chickpea	Flat cultivation, local varieties, farmyard manure, local implements	1083	589	494 (270)

[a]A variety of cultivars have been used: maize - Deccan Hybrid 101, SB23, 51-54, Vitthal; Pigeonpea - Sharada, ICP-1; Chickpea - local.

[b]Costs include all materials, human and animal labor, and annual costs of implements.

[c]Figures in parentheses are the standard deviations of gross profits. They are based on 15 observations for the improved broadbed technologies, and 7 for all others.

The improved technologies do not seem to increase risk compared with the traditional practice if we define risk as the ratio of standard deviation of profits as a percentage of average profits (CV). The standard deviation of profits rises from Rs.270 to Rs.975/ha with the improved technology, but the coefficient of variation (CV) falls from 55% for the traditional to 27% for the improved maize/pigeonpea intercrop system based on broadbeds and furrows. Besides being more profitable, the improved maize/pigeonpea intercrop systems also have involved a much lower level of profit risk (CVs of 21, 27%) than the improved maize-chickpea sequence (50, 57%). This helps explain why most semi-arid tropical farmers in India practice intercropping extensively.

HUMAN LABOR USE WITH IMPROVED TECHNOLOGY

The improved technology results in a greatly increased demand for human and bullock labor. This is desirable because it will allow landless laborers and cultivators who rely on wage earnings for a substantial part of their income to share in the additional income streams that the improved technology can generate.

The improved technologies can imply an increase in human labor use of more than 250% (Table 4). The traditional rainy-season fallow, post-rainy-season cropped fields at ICRISAT Center used a little more than 300 man-equivalent hours/ha. This compares well with the figure of 268 derived from our village-level studies in the Solapur region (Ryan et al. 1980). The improved intercrop technologies could increase this to more than 1000 man-equivalent hours/ha.

The operations where much of the increased human labor demand would be required are threshing, harvesting, weeding, and sowing (Figures 2 and 3). The substantial labor peaks which could result would tend to put upward pressure on agricultural wages, which could be of benefit to laborers. However, as we have observed in some village-level studies, pressure on wages will encourage selective mechanization such as the use of threshing machines. Hence these peaks may be dampened in practice by such developments. Also it is unlikely that single-cropping patterns, such as are illustrated in Figures 2 and 3, would be maintained in villages. In practice farmers would be likely to grow a range of crops in different cropping patterns. The extent to which they do so would mean a further dampening of the projected labor peaks.

BULLOCK LABOR USE WITH IMPROVED TECHNOLOGY

The improved technology can mean an increased use of bullocks by 50% on average, if it is based on an intercrop system, and by 70% if a sequential crop system is employed (Table 4). The main reasons for the increased use of bullocks are (a) the additional land preparation, including initial smoothing of fields, plowing, forming and maintaining broadbeds and furrows[2], and (b) the sowing of an additional crop in the case of the sequential system.

---

[2]The time taken for such initial capital development activities has been prorated over the 5-year period in Table 4 and Figures 4 and 5.

Table 4. Human and animal labor use with improved technology on Vertisols at ICRISAT Center, 1976-81.

Crops	Soil and crop management	Bullock pair hours per net sown ha	Human labor hours per net sown ha[a]	
			Excluding threshing	Including threshing
1. Maize/pigeonpea intercrop	Broadbeds and furrows, HYVs, chemical fertilizers, wheeled tool carrier, plant protection	81	604	1220
2. "	Flat cultivation, HYVs, chemical fertilizers, wheeled tool carrier, plant protection	76	537	1041
3. Maize-chickpea sequence	Broadbeds and furrows, HYVs, chemical fertilizers, wheeled tool carrier, plant protection	90	701	1140
4. "	Flat cultivation, HYVs, chemical fertilizers, wheeled tool carrier, plant protection	89	732	1203
5. Rainy-season fallow, postrainy-season sorghum and chickpea	Flat cultivation, local varieties, farmyard manure, local implements	53	193	317

[a]Expressed in terms of male-equivalent hours.

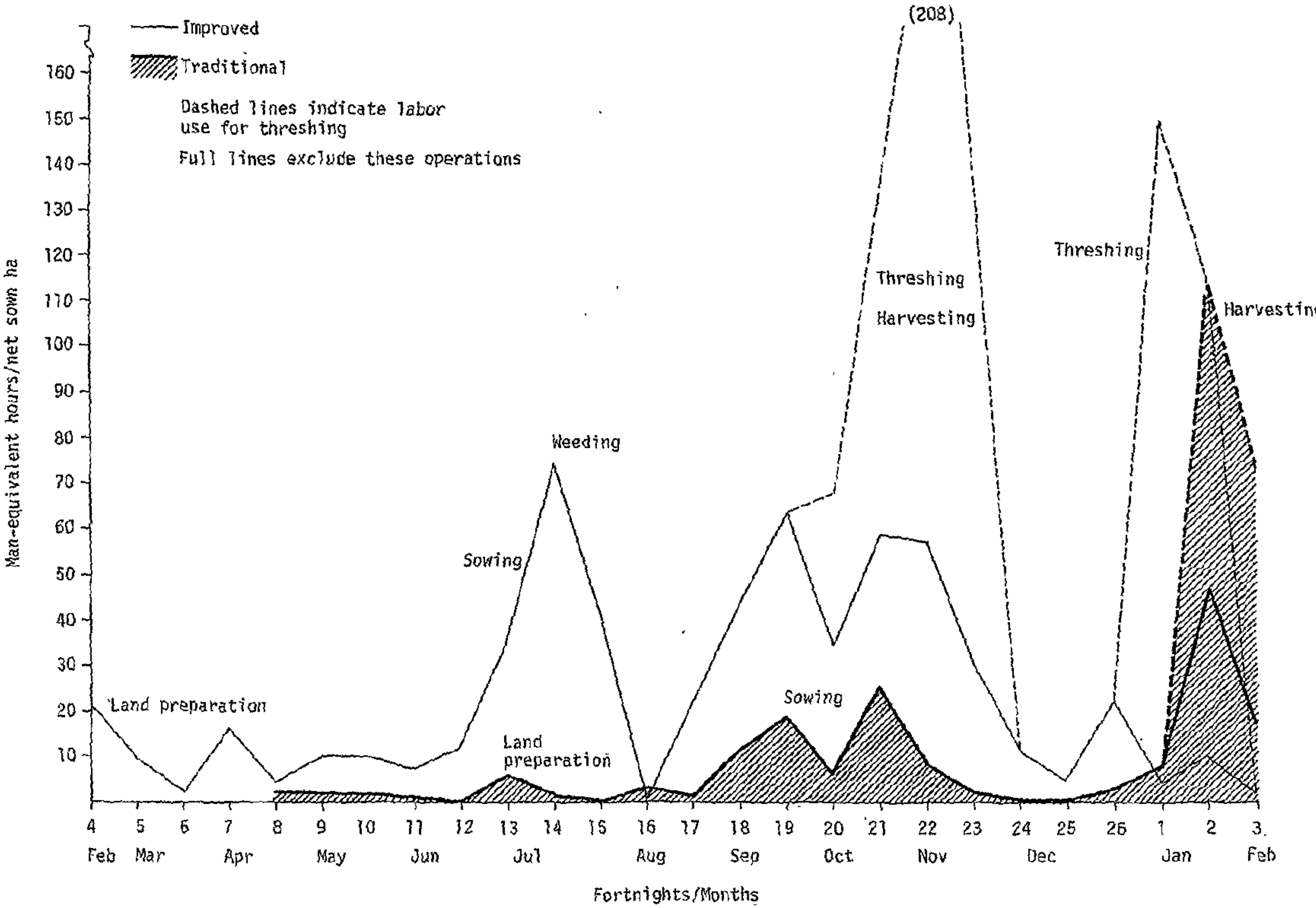


Figure 2. Average seasonal use of human labor with improved maize/pigeonpea intercrop versus traditional rainy-season fallow with postrainy-season sorghum and chickpea on *Vertisols* at ICRISAT Center, 1976-81.

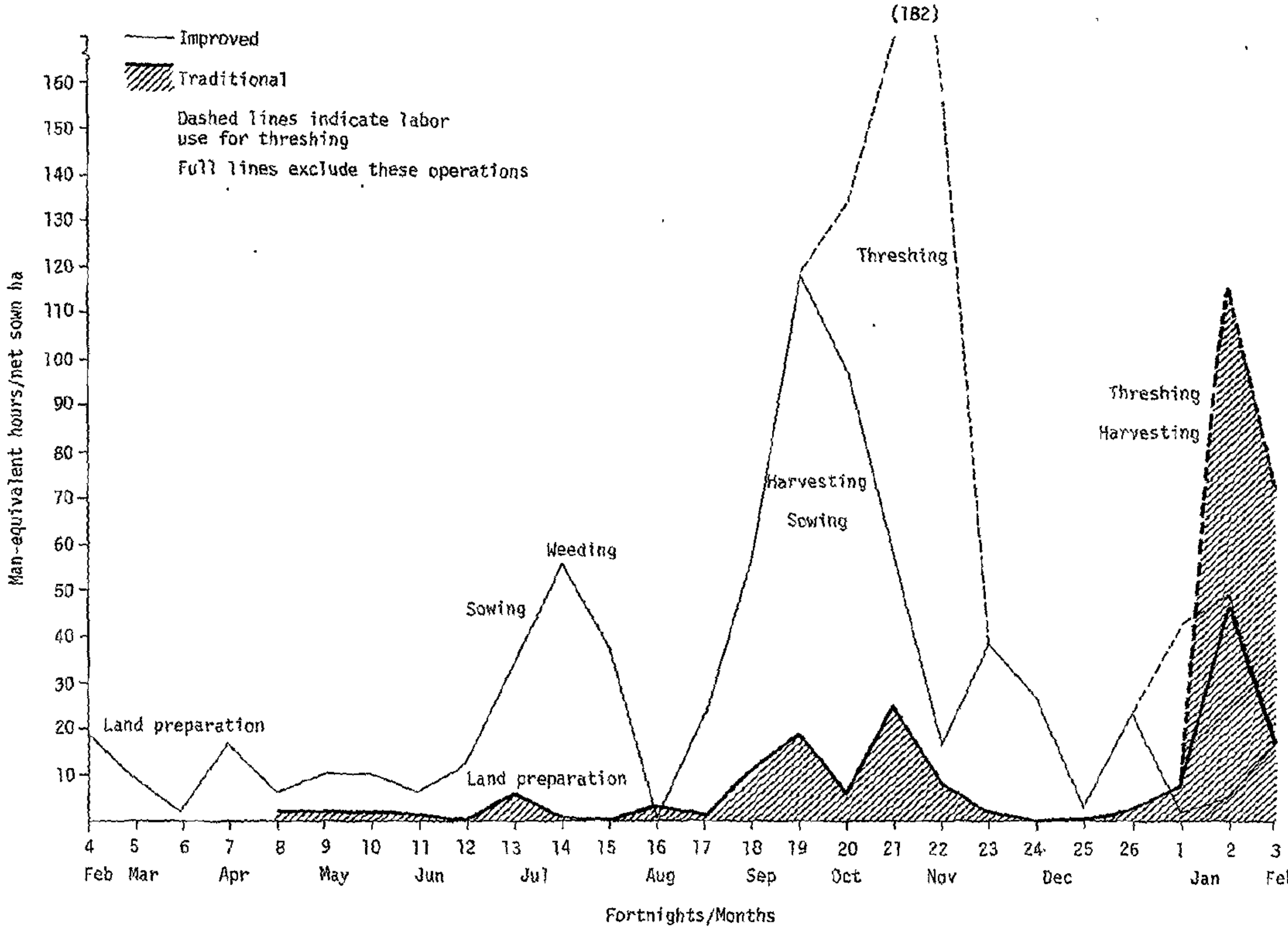


Figure 3. Average seasonal use of human labor with improved maize-chickpea sequence versus traditional rainy-season fallow with postrainy-season sorghum and chickpea on Vertisols at ICRISAT Center, 1976-81.

The seasonal pattern of bullock power utilization is substantially altered with the intercrop or double-crop system (Figures 4 and 5). 70-80% of the bullock labor occurs between February and May with the improved broadbed-and-furrow systems, whereas 85% of it occurs after June with the traditional systems. As a result it is likely that the availability of fodder for animals may be more of a constraint with the improved systems, particularly in the hot season from March to May. However, the improved systems would generate increased quantities of fodder, so the major problem would be in the initial year when watersheds are being developed, using bullock power, but before additional fodder has been produced.

The wheeled tool carrier can perform operations at a rate 2-3 times more quickly than that of traditional implements. That is primarily because of the greater width of the tool carrier. For some operations, such as bed forming, ridging, and interculture, two operators are usually required with the tool carrier, whereas only one is required for such traditional operations as cultivating, harrowing, and interculture. Our experience in the villages where we have been experimenting with improved technology is that in the 1st year (1979-80) in the Vertisols the total bullock requirements for the improved system were about double those of the traditional system (Table 5). This is mostly because of development operations. This average of 132 hours is inflated by the fact that traditional implements were used for most of the development operations in Kanzara village in Akola district. If we look at the figures for Shirapur village in Solapur district, where the wheeled tool carrier was used for development, the total bullock requirements were only 91 hours in the 1st year. Even so, this figure was almost 90% higher than the traditional bullock labor use of 48 pair hours/ha.[3]

In the 2nd year (1980-81) in Shirapur bullock labor use fell by 15% but was still 30% higher than the traditional figure. In Kanzara in the 2nd year of the improved technology bullock requirements fell dramatically. From being double traditional levels of use in the 1st year they declined to a figure of around 60%. The contrasting results in Shirapur and Kanzara suggest that the extent to which the development operations of plowing, chiseling, harrowing, ridging, and bed-forming have to be repeated after a number of years may mean that overall average bullock requirements might not be much less with the improved system. Recent experience in the Vertisol villages suggests that weed control under broadbeds and furrows may be more difficult to achieve than in traditional systems, particularly in the dry season. This was the case especially in Shirapur. It may be necessary to completely cultivate over the broadbeds each year and re-form them in order to control weeds properly.

---

[3]Note that none of the village experiments in Table 4 compares improved double cropping or intercropping with postrainy-season cropping as in Table 4. In Table 5 all comparisons are for similar cropping patterns.

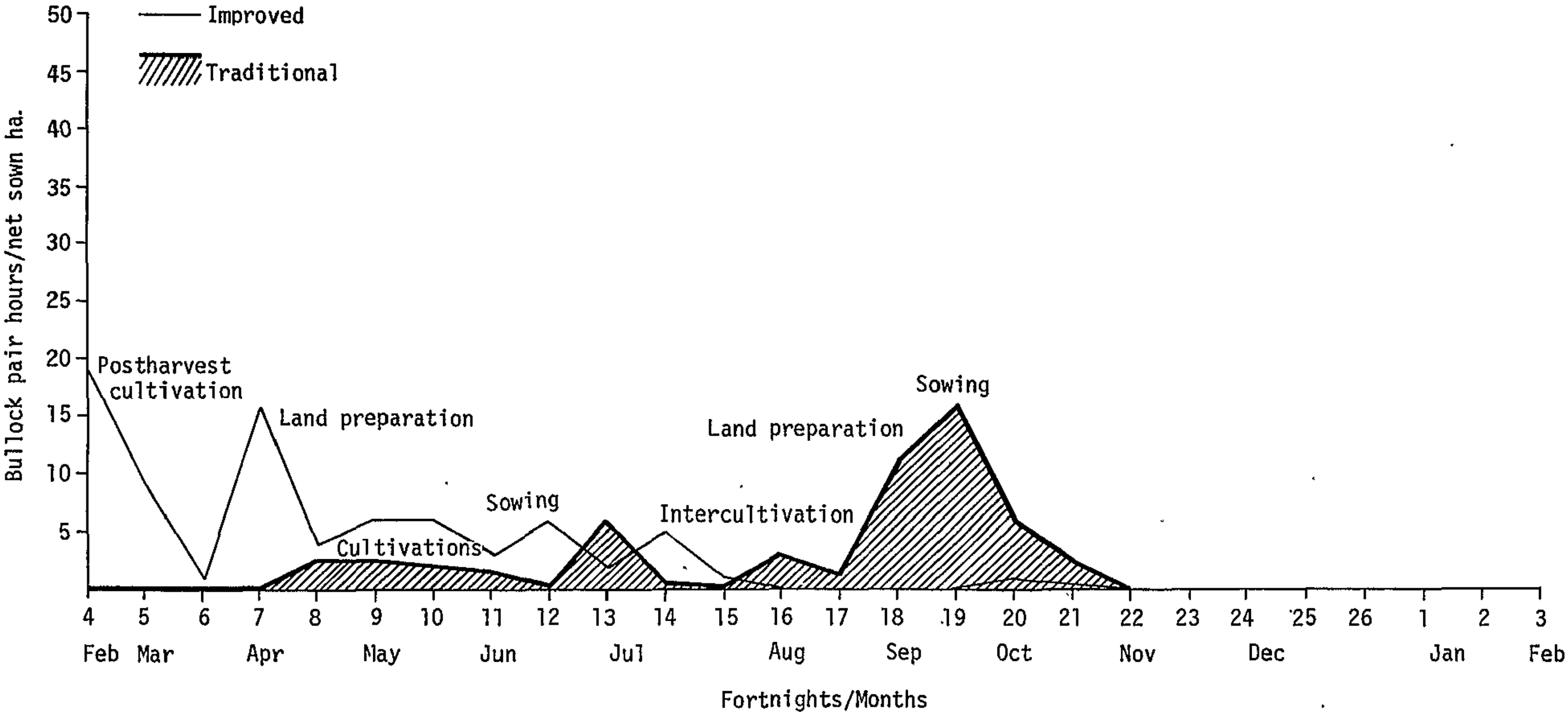


Figure 4. Average seasonal use of bullock labor with improved maize/pigeonpea intercrop versus traditional rainy-season fallow with postrainy-season sorghum and chickpea on Vertisols at ICRISAT Center, 1976-81.

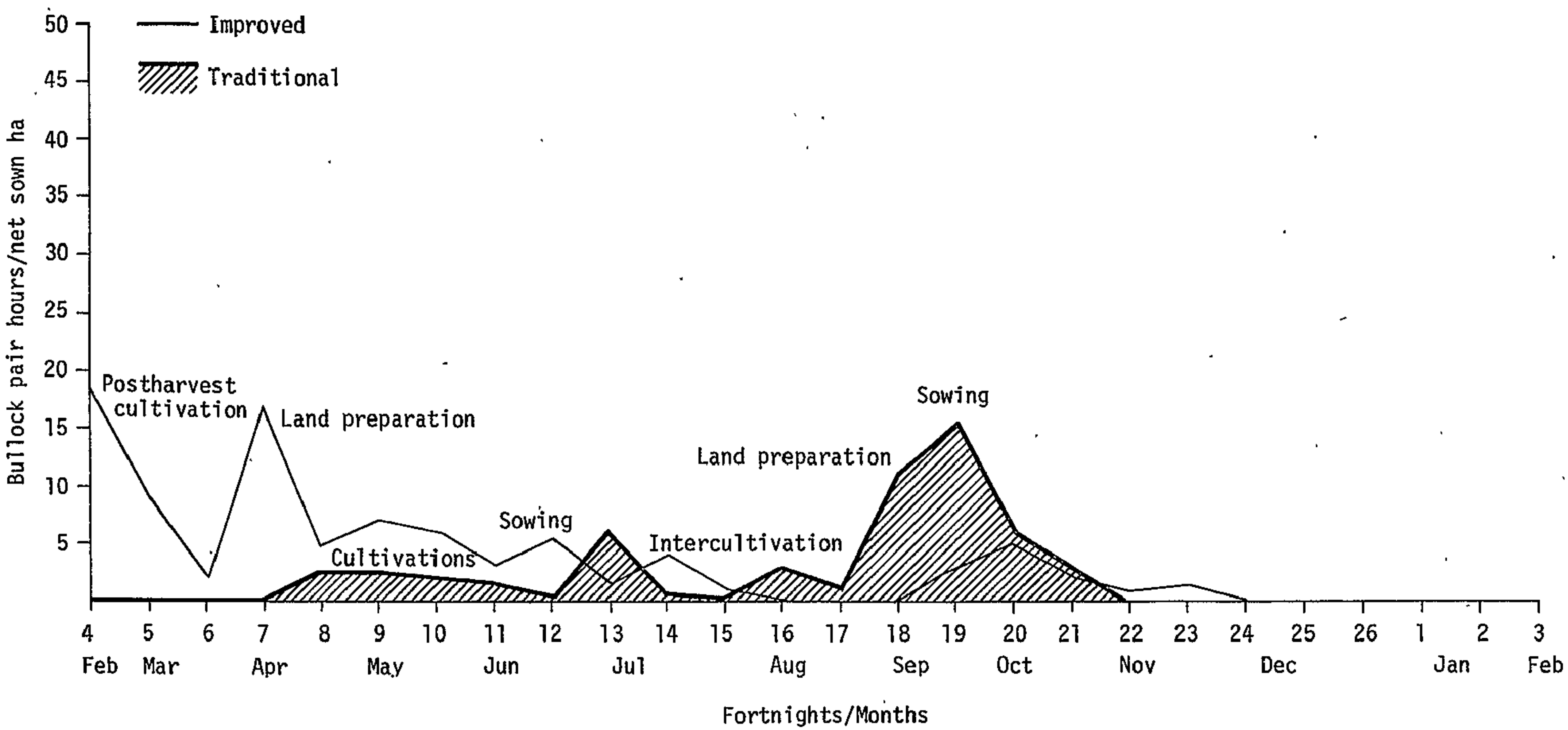


Figure 5. Average seasonal use of bullock labor with improved maize-chickpea sequence versus traditional rainy-season fallow with postrainy-season sorghum and chickpea on Vertisols at ICRISAT Center, 1976-81.

Table 5. Use of bullock labor in village operational-scale experiments.[a]

District/Village/Crop	Technology: Improved with wheeled tool carrier, 1st year 1979-80	Technology: Improved with wheeled tool carrier, 2nd year 1980-81	Technology: Traditional with local implements 1975-78	Ratio of improved/traditional 1975-78: 1979-80	Ratio of improved/traditional 1975-78: 1980-81
	-----Bullock pair hours/ha-----				
VERTISOLS					
Solapur/Shirapur					
Postrainy-season sorghum	91	63	48	1.89	1.31
Akola/Kanzara					
Groundnut	154[b]	42	70	2.22	0.60
Cotton/sorghum/pigeonpea	139[b]	42	79	1.77	0.53
HYV sorghum/pigeonpea	145[b]	47	68	2.13	0.69
Average for Vertisols	132	49	66	2.00	0.74
ALFISOLS					
Mahbubnagar/Aurepalle					
Groundnut	59	51	200	0.29	0.26
Sorghum intercrop mixture	54	46	80	0.67	0.58
Castor	73	61	108	0.80	0.56
Average for Alfisols	62	53	129	0.51	0.47

[a]See footnote 3 in the text

[b]All development operations prior to bed formation in Akola were carried out with local implements. This explains the much higher figures.

We have recently commenced a cooperative project with the Andhra Pradesh Department of Agriculture, the All India Coordinated Research Project for Dryland Agriculture (AICRPDA), and Andhra Pradesh Agricultural University (APAU), in Taddanpalle village, Medak district. The aim is to introduce the broadbed-and-furrow system on a small Vertisol watershed of about 15.5 ha involving 14 farmers. Traditionally most of this area is fallowed in the rainy season and such crops as sorghum, chickpea, chillies, and safflower are grown in the postrainy season. Farmers intend to double-crop under the improved system, utilizing both rainy and postrainy seasons, planting a range of crops suited to their individual preferences. Among the cropping patterns are sorghum or maize intercropped with pigeonpea, sorghum or maize followed by chickpea or safflower, and mung bean followed by chillies.

Development activities began in February 1981 with surveying and design. Field development operations have not yet been completed, but up to 2 May 1981 have involved 19 bullock pair hours/ha and 27 man-hours. Total development costs so far (excluding surveying and design) amount to Rs.85/ha. The development work is not yet completed because more ridging and bed-forming are required, along with the construction of drains and grassed waterways. Total costs are expected to range between Rs.300 and Rs.500/ha.

PROSPECTS FOR OTHER REGIONS

The ICRISAT Center Vertisol research supports the results achieved by AICRPDA in the Indo-UK Project at Indore in Madhya Pradesh. AICRPDA has amply demonstrated that by improving the drainage of the Vertisols in that region it is possible to grow crops in the rainy season and substantially increase profits. It is in the higher rainfall areas with Vertisols and a relatively dependable monsoon that the potential for greatly increasing cropping intensity lies. Districts such as Raisen, Vidisha, Hoshangabad, Sagar, Damoh, Jabalpur, Indore, and Narsinghpur in Madhya Pradesh seem to have such potential (Table 6).

AICRPDA and ICRISAT experience in Solapur suggests that the monsoon rains are too uncertain to sustain rainy-season crops there. As hypothesized, we have been unable to grow rainy-season crops successfully in Shirapur village of Solapur district in 2 of the last 3 years due to inadequate soil moisture. This experience supports the conclusions from the rainfall analysis of Binswanger et al. (1980b), which shows that, although average annual rainfall in Solapur is almost the same that of Hyderabad, the probability of adequate moisture for rainy-season cropping in Solapur is much less. However, we have been able to demonstrate substantial increases in yields (170%) and profits (140%) from the use of improved technology on the postrainy-season crops in the same village (Figure 6).[4] We could not demonstrate large increases in either yields (0-30%) or profits (20%) in Kanzara village in Akola district, where at present such crops as cotton, sorghum, and pigeonpea

---

[4] In an analysis of yields and returns of postrainy-season sorghum in traditional fields in Shirapur from 1975-76 to 1979-80, T.S. Walker found the mean gross profit to be only Rs.280/ha. The mode was -Rs.50, indicating a strong positive skewness in the yield and profit distributions. During the same period R.P. Singh, and M. Asokan have calculated that the average net income per net sown hectare from all crops ranged from a low of Rs.245 on small farms in Aurepalle village in Andhra Pradesh to a high of Rs.1004 on large farms in Dokur in Andhra Pradesh. Net incomes of small and large farmers from the Vertisol villages in Maharashtra were between these extremes, ranging from Rs.293 to Rs.604 per net sown hectare.

Table 6. Examples of areas with high and low potential for improved rainy-season crop technology in Vertisols.

Districts	Average area of rainy-season fallow ('000 ha)	Rainy-season fallow as % of net sown area
High potential in Madhya Pradesh (due to high and dependable rainfall)		
Raisen	319	81
Vidisha	382	77
Sagar	355	70
Damoh	164	59
Jabalpur	229	50
Indore	114	45
Narsinghpur	173	64
Low potential in Maharashtra (due to low and undependable rainfall)		
Solapur	773	73
Osmanabad	322	30
Bhir	336	46
Ahmadnagar	680	57
Aurangabad	475	40
Sangli	130	23

Source: G. Michaels, using data from Directorate of Agriculture (various years) and Government of Maharashtra (various years).

Table 7. Average annual availability of bullock power in six SAT villages in south India, 1975-78.[a]

Item	District/Village			
	Mahbubnagar		Solapur	Akola
	Aurepalle	Dokur		
Bullocks (no.)/ha				
Small farmers:				
Lowest year	0.22	0.29	0.07	0.21
Mean	0.36	0.43	0.13	0.26
Highest year	0.50	0.64	0.21	0.30
Large farmers:				
Lowest year	0.32	0.30	0.14	0.24
Mean	0.34	0.34	0.14	0.24
Highest year	0.37	0.40	0.15	0.25
Value of bullocks (Rs.)/ha				
Small farmers:				
Lowest year	132	87	28	77
Mean	186	184	98	93
Highest year	302	279	187	115
Large farmers:				
Lowest year	157	214	117	140
Mean	174	235	129	145
Highest year	208	264	150	148

[a]Data for the two villages in Solapur district and the two in Akola district have been averaged here.

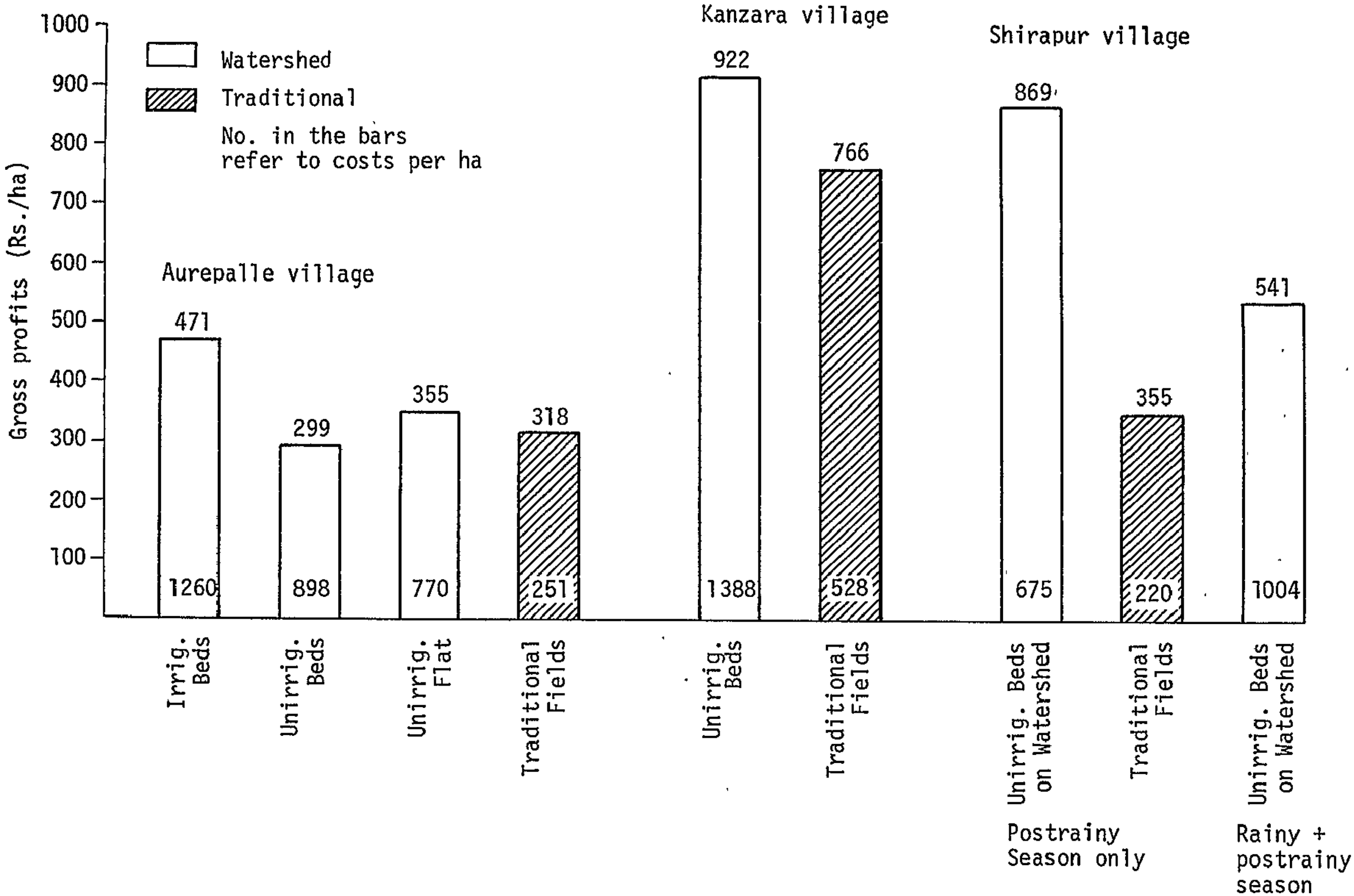


Figure 6. Gross profits from various systems in village on-farm watershed experiments, 1979-80.

are mostly grown in the rainy season on medium deep black soils. Neither was there substantial extra profit from the improved technology in the Alfisol and uncertain rainfall village of Aurepalle in Andhra Pradesh in 1979-80. We have been able to achieve yields which were 2-4 times higher than those on traditional fields in Aurepalle, but extra costs of labor, seeds, and fertilizers have largely offset these yield gains.

POLICY ISSUES

The most promising areas for the technology outlined in this paper are where rains are dependable and exceed an annual average of about 750 mm and where there are deep black soils. However, before this promise can be called a real potential there are some policy questions which arise.

1. Availability of bullock power. In the 1st year when the improved drainage and broadbeds and furrows are being introduced, there will be an increased demand for bullock power compared with present utilization patterns. While evidence from our village studies suggests small farmers have about the same average number of bullocks per operated hectare as large farmers, bullock availability for small farmers varies much more from year to year than it does for large farmers (Table 7). Also, in most cases small farmers have lower-valued and less sturdy bullocks than large farmers. If this is true in the high-potential areas, the data suggest that particular attention will have to be paid to draft power availability for small farmers. In a number of the high-potential areas in Madhya Pradesh tractor numbers have been increasing. In 1974-75 our estimates are that there were nearly 0.60 bullocks per net sown hectare in these areas. In addition tractors provided the equivalent of 0.30 bullocks per ha, a much higher figure than for all M.P. (0.04).[5] This suggests that draft availability in the high-potential regions may be much greater than in some of the areas where we have been working (Table 7). However, this needs to be more fully investigated to ensure that small farmers are able to gain access to the required draft power to implement the technology. If banks presently do not provide loans for the custom-hiring of animals or machines, policies may be required to enable this to be done.

2. Community works. To effect improved drainage it is almost always necessary to improve existing field drains or to construct new ones. When such drains are within a farmer's own field, our experience so far in Taddanpalle is that they may be willing to construct them themselves. However, where drains are outside their fields and/or involve drainage flows of many farmers, it probably will be necessary to pay farmers and laborers to construct them. The question arises of how to finance such works? In Andhra Pradesh the soil conservation program has some provision for such work, but it is not clear whether there are sufficient resources to mount a large-scale program under the soil conservation programs in high-potential areas. The Food for Work and National Rural Employment Programs could be utilized. However, they are mostly for drought-prone areas, and the high-potential regions for the technology described in this paper are in the high and relatively dependable rainfall zones. Hence there may be need to consider some special programs for these regions in order to effect the community works.

---

[5]Assuming one bullock pair is equivalent to one horse power.

3. Farmer loans. Many farmers may not be in a position to provide their own labor and bullocks to effect land improvements required by the technology, even on their own farms. They may need the income they presently earn from wages off their farms to sustain them during the dry season. In such cases it may prove difficult to implement the technology without payment to farmers. Perhaps these payments could be given as a Soil Conservation loan to be repaid in the same manner as the regular loans for bunding, etc. Recall that the rainy-season crop cover which the improved technology allows has a substantial effect in reducing soil erosion.

4. Infrastructure and fertilizer supplies. One of the key elements in the improved technology is increased use of fertilizers on unirrigated crops. Currently the bulk fertilizer consumption in India is concentrated in irrigated areas. Jha and Sarin (1980, p.4) estimated that in 1977-79 those districts in the Indian SAT with more than 25% irrigation used an average of 57.5 kg/gross cropped ha/year of ($N + P_2O_5 + K_2O$). This compared with a figure of 18.5 for those SAT districts with less than 25% of irrigation. Our calculations from Jha and Sarin's original data show that those areas with the largest extent of rainy-season fallow in the states of Madhya Pradesh, Maharashtra, and Andhra Pradesh have levels of fertilizer use (Table 8) much below the national average of 28kg/gross cropped ha/year. Madhya Pradesh and Maharashtra have little irrigation and their consumption figures are well below the 18.5 figure for the less irrigated SAT districts. All this suggests there seems to be considerable potential for increasing the use of fertilizers in the high-potential SAT areas. This will require investments in improving fertilizer distribution networks in the dryland Vertisol regions. Experience shows that unless fertilizer of the desired type is physically available and accessible to dryland farmers, they will not use it.

Table 8. Average annual fertilizer use per gross cropped hectare in three states of India, 1975-77 (kg/ha).

States	% of rainy-season fallow[a]		
	<15	15.1-45	>45
Madhya Pradesh	6.2	5.3	7.0
Maharashtra	21.7	13.2	12.1
Andhra Pradesh	28.1	31.0	21.2

[a]Districts in each of the three states were classified according to the three ranges of fallow extent and their fertilizer consumption averaged.

5. New cropping patterns. There may be a need for farmers to grow new crops for the technology to express itself. For example, the AICRPDA experience with maize at Indore, and ICRISAT's similar experience at Patancheru, suggest this crop could find a prominent place in new cropping patterns. Soybeans is another possibility. The market for maize is somewhat limited at present in many areas. Consideration needs to be given to marketing policies that may be required to ensure the additional produce can be sold at attractive prices, although ICRISAT experience suggests that the improved system could still be highly attractive even if prices fell 50%. If maize prices could be contained by large increases

in production this might give considerable impetus to dairy and poultry production in India. Milch buffaloes and cows, and poultry birds, could utilize increased maize grain provided prices were reasonable. Bullocks could also be fed maize grain to improve their draft capabilities.

In many of the high-potential areas wheat is the dominant crop in the post-rainy season following the rainy-season fallow. More research is required on cropping systems that would enable a rainy-season crop to be grown and harvested without adversely affecting the wheat crop. It is unlikely that a cereal crop such as sorghum could fill that role. It is more likely to be a legume crop such as soybeans. Perhaps sorghum with a pigeonpea intercrop or sorghum followed by chickpea would be more profitable than fallow followed by wheat in any case?

6. Wheeled tool carrier. The wheeled tool carrier offers promise in improving seed and fertilizer placement, making broadbeds and furrows, saving bullock power, and in providing a more efficient form of transport. However, it is expensive (Rs.8000-10000) and probably beyond the reach of individual small farmers. Entrepreneurs who would custom-hire the tool carrier may have to be encouraged by appropriate policies. One possibility would be extension of the Educated Unemployed Schemes to include financing the purchase of tool carriers by diplomates and graduates. Calculations suggest that rental rates of Rs.30-35 per 8-hour day for the tool carrier alone, and Rs.50-60 including bullocks and a driver, would generate an attractive return to an entrepreneur if they were utilized for 180 days per year (Binswanger et al. 1980a, p.209). These latter rates are 3-4 times higher than the costs of hiring a pair of bullocks with local implements and a driver. All our results show, however, the potential extra returns could more than justify hiring the tool carrier by small farmers. Besides credit arrangements for entrepreneurs, though, small farmers will require credit to finance the hiring cost of the tool carrier, which in the initial year could amount to Rs.350/ha or more, depending on whether or not he has bullocks which can draw it.

7. On-farm verification. The conclusion that there seems to be great potential for profitable cropping in the rainy season in Vertisol areas having relatively dependable and high rainfall has been based largely on research conducted at ICRISAT Center. The conclusion is of course supported by the success of AICRPDA's Indo-UK project at Indore, in Madhya Pradesh. The ICRISAT results have not yet been fully tested in on-farm situations in the high-potential areas. The Kanzara (Akola district) and Shirapur (Solapur district) on-farm tests reported in the paper were in areas with low potential. The former area has relatively high and dependable rainfall, but the black soils are not deep. The latter area has deep black soils but meager and uncertain rainfall.

The current on-farm testing in Taddanpalle village of Andhra Pradesh is in a high-potential area and will give us more confidence about the variability of the technology. However, there is an urgent need for on-farm verification in other high-potential areas, as identified by S.M. Virmani and his colleagues.

8. Training. To implement the broadbed-and-furrow technology requires considerable surveying, design, and engineering expertise. Soil conservation officers have the basic skills required, but they have to be trained to use them in a different way for designing and implementing the improvements required to achieve the benefits reported in this paper. Training of Agricultural Officers in the use of the wheeled tool carrier will also be required so that they can train farmers.

Close working relationships are going to be required between the Soil Conservation and Agricultural wings of state Departments of Agriculture if these technology options are to be extended. Improved soil and crop management are both necessary to achieve the food-grain production increases and reduced erosion reported here. This suggests the need for training the Soil Conservation and Agricultural Officers as a team, with each being exposed to the others' particular role in extending the options.

The word options is used purposely here. There is no one "package of practices" with this technology. Experience in village studies clearly shows that we must take the time to sit down and discuss at length the nature of the technology with farmers. We should of course begin with the basic concept. However, there must be options at hand which will allow us to modify the nature and timing of the technology to meet farmers' various constraints. Some will not have bullocks, others will have defaulted on previous loans and be ineligible for additional credit, and some may have irrigated land that they give preference to. Recommending one package under such circumstances may be like pushing on a string. Identification of watershed-based technology options requires on-the-job training in villages. If we take farmers into our confidence and spend the time to explain the nature of the technology to them we find they are willing to adopt it. A rigid approach to farmers will not work.

REFERENCES

Binswanger, H.P., Ghodake, R.D., and Thierstein, G.E. 1980a. Observations on the economics of tractors, bullocks, and wheeled tool carriers in the semi-arid tropics of India. Pages 173-192 in Proceedings of the International Workshop on Socioeconomic Constraints to Development of Semi-Arid Tropical Agriculture, 19-23 February 1979, ICRISAT, Patancheru, A.P., India.

Binswanger, H.P., Virmani, S.M., and Kampen, J. 1980b. Farming systems components for selected areas in India: evidence from ICRISAT. ICRISAT Research Bulletin No. 2, Patancheru, A.P., India.

Bureau of Economics and Statistics (various years). Season and crop report, Andhra Pradesh. Government of Andhra Pradesh, Hyderabad, A.P., India.

Directorate of Agriculture (various years). Agricultural statistics, Madhya Pradesh. Government of Madhya Pradesh, Bhopal, M.P., India.

Directorate of Economics and Statistics. 1979. Estimates of area and production of principal crops in India 1977-78. Ministry of Agriculture and Irrigation, Government of India.

Government of Maharashtra (various years). Season and crop report, Maharashtra State. Government Printing and Stationery, Bombay, Maharashtra, India.

Jha, D., and Sarin, R. 1980. Fertilizer consumption and growth in Semi-Arid Tropical India: a district-level analysis. ICRISAT Economics Program Progress Report No. 10, Patancheru, A.P., India.

Malone, C. 1974. Indian agriculture: progress in production and equity. New Delhi, India: The Ford Foundation.

Ryan, J.G., Ghodake, R.D., and Sarin, R. 1980. Labor use and labor markets in semi-arid tropical rural villages of peninsular India. Pages 352-379 in Proceedings of the International Workshop on Socioeconomic Constraints to Development of Semi-Arid Tropical Agriculture, 19-23 February 1979, ICRISAT, Patancheru, A.P., India.

PROBLEMS AND POTENTIALS OF THE BLACK SOILS OF INDIA: SOME SUGGESTIONS FOR AN ACTION PLAN

J.S. Kanwar, ICRISAT

Drs. Virmani, Ryan, and Swindale have in their presentations focused attention on the problems and potentialities of the deep black soils and discussed the appropriate technology for realizing these potentials. I now want to summarize some of the points that have been made, and make suggestions for a plan of action.

MAGNITUDE OF THE PROBLEM

According to Dr. Murthy, the black soils (Vertisols) and associated soils with Vertic characteristics, cover 73 million ha or about 22% of the area of the country.

About 80% of the black soil region of India lies in Maharashtra, Madhya Pradesh, Gujarat, and Andhra Pradesh, and 13% in Karnataka and Tamil Nadu and only 7% in Uttar Pradesh, Rajasthan, and Orissa. Maharashtra has 84% of its total area under this group of soils, Madhya Pradesh has 38%, Gujarat 48%, and Andhra Pradesh 26%.

It is thus no exaggeration to state that the future of agriculture in these six states lies in the technology of management of black soils. Unique features of the black soil region are that it is mostly nonirrigated, it has only 2-4½ wet months in the year, and the remaining months are dry.

Virmani and his associates have divided the black soil region into two climatic groups: (1) with dependable medium to high rainfall areas with a mean rainfall ranging from 750 to 1250 mm/yr, and (2) undependable rainfall areas with rainfall lower than 750 mm/yr and frequent long drought periods. Temperatures are conducive to cropping all the year round; but the major constraint in the realization of the region's cropping potential is the limitation of available moisture. With scientific management of soil and rainwater, however, production can be increased very considerably.

PROBLEMS AND POTENTIALS OF THE VERTISOLS

Out of 73 million ha of black soils and associated soils, 38%, or 26 million ha, are classified into the group of deep black soils or Vertisols. Their main problems have been discussed by previous speakers. I sum them up as follows.

a. Cracking when dry and swelling when wet makes them difficult to manage, unless they are cultivated at appropriate soil moisture levels and with suitable implements.

b. Optimum conditions for tillage occur immediately after harvesting when the surface soil is still moist.

c. The timeliness of the tillage holds the key to successful cropping. After the monsoons recede the subsoil of deep black soils still holds a good amount of moisture. But when the surface becomes dry, the farmer fails to utilize this subsoil moisture.

d. Kharif fallowing in dependable rainfall areas (750 mm-1250 mm/yr) means (i) considerable loss of water through runoff, (ii) considerable loss of nutrients, and (iii) considerable soil erosion, and (iv) the loss of one crop.

e. It is not widely appreciated that in the deep black soils kharif crops often suffer because of poor drainage and waterlogging when it rains and from moisture stress when there is a drought. Thus excess of water, as well as shortage of it, are twin problems of these areas.

f. Black soils have low fertility and are poor in organic matter, nitrogen, available phosphorus, and zinc. The use of fertilizers and manures produces the most beneficial effect on crop yields. A recent study by Jha and associates (1980) has shown that the consumption of fertilizers in rainfed areas of the SAT is very low. It is one of the most serious factors responsible for low production. The loss of N through weeds, soil erosion, and denitrification aggravates the problem.

g. The deep black soils, because of their high clay content, nature of clay and depth have a very high water-holding capacity and a high cation exchange capacity, have high potentiality for crop production even under unirrigated conditions. It is unfortunate that this potential is not being exploited and they are producing only 300 to 800 kg/ha annually. Experimental evidence from ICAR and ICRISAT shows that these soils are capable of producing 2500 to 3500 kg/ha.

IMPORTANCE OF VERTISOLS FOR CROPS AND CROPPING SYSTEMS

Dr. Ryan in his presentation emphasized that in Maharashtra, Madhya Pradesh, and Andhra Pradesh 20-29% of the net sown area remain fallow during the rainy season. Interestingly enough most of this area is of black soil. We find that, out of the 26 million ha of cultivated but kharif-fallowed areas in India, 12 million ha lie in the black soil region. This constitutes 46% of the total fallow hectarage in the country. It is a huge area. There is no reason why many million hectares of these deep black soils, in medium to high and dependable rainfall regions, where rainfall exceeds 750 mm/yr and the probability of successful double cropping is high, should remain fallow during the kharif season. To my mind some of the reasons for the current situation are the following.

a. Lack of appropriate technology and means for managing soil and rainwater.

b. Poor soil fertility and the inadequate use of fertilizer and manures under rainfed farming systems.

c. The use of low-value cereal seed.

d. The lack of high-yielding varieties, and highly unstable yields particularly from oilseeds and pulses.

e. The cultivation of wheat, chickpea or sorghum on conserved moisture during the postmonsoon season.

When we look at the cropping patterns of the black soil region, we find that cereals (sorghum, maize, millet, upland paddy, rabi wheat, and sorghum), pulses (soybean, pigeonpea, chickpea) and other legumes, oilseeds (groundnut and safflower), and fiber crops e.g., cotton, are commonly grown without agricultural inputs and suitable management and technology. 92% of the sorghum, 88% of the groundnut, 56% of the pigeonpea and 24% of the chickpea in India is produced in the six states that have most of the black soils. Many of these crops are grown in intercropping systems that constitute risk-covering devices by subsistence farmers. With scientific management they can become highly productive systems.

Evidence exists that sole-cropped sorghum fails once in 8 years and pigeonpea once in 5 years, but that a sorghum/pigeonpea intercrop fails only once in 36 years. Thus improving the yield stability of intercropping systems in the Vertisols would mean improving and stabilizing crop production. Cultivation of pulses or oilseeds, whether as intercrops or in sequence, can improve the intensity of cropping and the profitability of agriculture in these states where black soils are the dominant group.

Dr. Virmani in his presentation has discussed the technology suited to this situation. Most of the production of pulses and oilseeds in India comes from these soils, but their yields are low and highly variable. Thus the solution to the problem of shortage of pulses and oilseeds lies in the improved management of black soils.

Evidence has been presented that the technology based on the graded broadbed-and-furrow system in the deep black soils facilitates the intercropping of cereals and pulses (maize/pigeonpea or sorghum/pigeonpea) or the sequential cropping of cereal-pulse-oilseed, that it increases yields by 3-5 times, and that it ensures the efficient use of the environment under rainfed agriculture.

In areas with less dependable rainfall (<750 mm/yr) postrainy-season cropping is preferred to rainy-season cropping because of the better soil moisture situation. However, the yields of postrainy-season crops can be considerably increased through an efficient system of soil and crop management, including moisture conservation and weed management. There are a number of agricultural practices that need to be changed, including the selection of varieties, choosing the date of sowing, applying fertilizer, etc., to make the best use of the environments.

ICRISAT climatologists, using data of rainfall probability and of the moisture-retention capacity of medium to deep black soils (Vertisols), have made out a case for dry-sowing in these soils where rainfall exceeds 750 mm/yr. Most of these areas are in 34 districts of Madhya Pradesh, 12 districts of Maharashtra, 6 districts of Andhra Pradesh and 3 districts of Gujarat. There is no reason why the deep black soils in these areas should not grow two crops instead of one, and produce 3-5 times more food than at present.

The experience at ICRISAT Center, that is confirmed by operational-scale tests in relevant black soil areas in villages in Maharashtra and Andhra Pradesh and the Indo-UK Project in Madhya Pradesh, suggests a high probability of successful farming in this way.

The time has now come for the transfer of this technology through its scientific testing, evaluation, and modification in the real-world situation of farmers in these states.

INGREDIENTS OF TECHNOLOGY OF BLACK SOILS

The essential ingredients of the new technology for deep black soils are the following.

1. Small watershed resource management to conserve moisture, reduce erosion, and drain off excess water. In the event of organizational difficulties on-site, the technology is adaptable to being established within the existing farm boundaries.
2. Carrying out first operations for land preparation for both post-monsoon as well as monsoon crops immediately after harvesting the previous crop, when the soil has adequate moisture and is friable.
3. Smoothing the land to give a uniform slope of 0.4-0.6%.
4. Plowing the land to facilitate the formation of broadbeds and furrows with an amplitude of 150 cm, with a Tropicultor or a wheeled tool carrier. We realize that the Tropicultor is expensive; but possibilities exist for it to be used on a collective ownership basis, or on hire. Cheaper versions of the Tropicultor are being developed so as to bring it within the reach of farmers with poor means.
5. Application of moderate amounts of NP fertilizer with a fertilizer drill, followed by the dry-sowing of two rows of sorghum or maize on the side of the bed and a central row of pigeonpea as an intercrop about a week before the expected date of onset of the monsoon. If a sequential crop of chickpea is to be planted, three rows of cereal can be sown. The right choice of crops and their varieties is essential for the successful implementation of the technology and the enhancing of production.
6. Likewise, the drilling of the seed and fertilizer at a proper depth is necessary for obtaining successful crop establishment and good yields.
7. Interculturing and weeding, and taking appropriate measures to control pests and diseases. We do not think that the use of pesticides is the answer. The development of disease-resistant varieties and the adoption of suitable agronomic practices to reduce disease incidence and pest attack is preferable.

SOME SUGGESTIONS FOR AN ACTION PLAN

PHASE I: 1981-83

1. Arrange for policy makers from the research, extension, and development agencies of Madhya Pradesh, Maharashtra, Andhra Pradesh, Gujarat, Karnataka, and Tamil Nadu to visit ICRISAT and ICAR centers and their operational on-farm research projects in Medak district and elsewhere. A 1-3 day visit in July to September for a group of 5-10 persons from each state is suggested.

2. Select five typical Vertisol areas in dependable rainfall regions (> 750 mm/yr) of Madhya Pradesh, Maharashtra, Andhra Pradesh, and Gujarat and set up operational-scale research projects of 10-30 ha size in each region. Possible districts are the following.

Andhra Pradesh	: Adilabad, Karimnagar, Khammam, Medak, Nizamabad, Warangal.
Gujarat	: Baroda, Bharoch, Panchmahal.
Maharashtra (12 districts)	: Amaravati, Akola, Buldona, Bhandara, Bhir, Chandrapur, Nanded, Nagpur, Osmanabad, Parbhani, Wardha, Joatmal.
Madhya Pradesh (34 districts)	: such as Bhopal, Indore, Hoshangabad, Raisen, Vidisha Sagar, Damoh, Narsinghpur, Jabalpur, etc.

These should be enterprises jointly organized by agricultural universities, the Department of Agriculture, and the Indian Council of agricultural Research.

3. Test, evaluate, and modify the technology, and study the feasibility of its use. This should not take more than 2 years.

4. Use the operational project sites for training extension workers, soil conservationists, and farmers by encouraging frequent visits to the sites. ICRISAT can help in a training program organized jointly with the All India Coordinated Research Project for Dryland Agriculture.

PHASE II: 1983-86

1. Develop a conceptual framework for the transfer of technology on pilot projects of about 10,000 ha each, preferably in the dependable rainfall areas of Madhya Pradesh, Maharashtra, Andhra Pradesh, and Gujarat.

2. Identify staff for the implementation of the project and arrange for their training on the operational sites.

3. Identify collaborative villages and farmers, and develop watershed layout plans after surveying their land.

4. Prepare this land using the graded broadbed-and-furrow system.

5. Develop cropping plans for each farm holding and arrange credit and supplies (fertilizer, seeds, etc.), including access to the wheeled tool carrier, a simpler version of the Tropicultor, or a seed-cum-fertilizer drill.

6. Implement the cropping system most suited to the needs of the farmers, involving the growing of varieties with high-yield potential under rainfed conditions.

7. Use these project sites for demonstration purposes. Arrange visits by other farmers to facilitate the exchange of knowledge and experience.

8. Extend the program to other areas.

Output
It is felt that, by adopting such a plan, in 5 years many of the deep black soils could be made to produce 2-3 tonnes/ha more cereals, pulses, and oilseeds than at present under rainfed conditions.

SOME SUGGESTIONS FOR RESEARCH

I have so far spoken only about the transfer of technology. But I now want to identify research problems that deserve high priority.

1. To begin with, it is necessary to mention that the technology for shallow and medium black soils which have low moisture-storage capacities has not yet been satisfactorily developed. It therefore needs further study. Likewise, for the red soils (Alfisols) that often occur in the same regions as black soils, the land development system needs further improvement.

2. The harvesting of water, and its reuse, needs more critical evaluation. Particular consideration should be given to the problem of sharing harvested water and to the development of techniques for reducing seepage of stored water from tanks.

3. The loss of nitrogen in the soil, and the efficient use of nitrogenous fertilizers, is another area of high-priority research.

4. The development of an efficient and economical weed management system calls for immediate attention.

5. The development of a seed-cum-fertilizer drill, which permits the operator to place seeds and fertilizer with precision at varying depths according to soil moisture is of urgent necessity.

6. The Tropicultor or wheeled tool carrier, and other similar implements, should be tested under farm conditions so as to make them more suitable for farmers' needs in these black soil areas.

7. Developing more production cropping systems for dry areas.

CONCLUSION

I feel that a technology capable of producing a real breakthrough in agricultural production in black soil regions is now available, and that it can be evaluated and modified to meet the local needs. It offers a good base from which to make a quantum jump in the production of coarse grains, pulses, and oilseeds in the black soil regions of India.

It would of course be a mistake to assume that the technology to which I am referring is perfect and can be handled in a routine way. Its principles are sound, but more location-specific experience of its application is required for its refinement. It calls for the use of newer skills, precision implements, timely operations and monetary inputs. In its development we must expect a few problems of organization, some social and economic constraints, including the need to influence and change attitudes.

The dryland farmers in the black soil regions will need to be persuaded to change from traditional subsistence farming to market-oriented farming, and to be prepared to work for more weeks than before and use bullock power more frequently. The reward is much higher production, more economic returns, and more gainful employment.

I have no doubt that Indian agriculture can take a new leap forward and transform millions of hectares of black soils into granaries of the country and make this achievement without costly irrigation projects.

REFERENCE

Jha, D., Raheja, S.K., Sarin, R., and Mehotra, P.C. 1981. Fertilizer use in semi-arid tropical India: the case of high-yielding varieties of sorghum and pearl millet. ICRISAT Economics Program Progress Report 22, Patancheru, A.P., India.

MANAGEMENT OF DEEP BLACK SOILS FOR IMPROVING PRODUCTION LEVELS OF CEREALS, OILSEEDS, AND PULSES IN THE SEMI-ARID REGION

N.S. Randhawa and M.S. Rama Mohan Rao*, ICAR

Black soils that constitute 23.1% of rainfed lands in the country possess great production potentials. Some of them occur in undependable rainfall areas with rainfall ranging from 500 to 700 mm/yr. Poverty is endemic and widespread in these areas largely due to unsatisfactory management of two precious resources — soil and water. Research carried out so far in the region has demonstrated that it is possible to upgrade the economy of the farming community by putting these two resources to their best use through appropriate technologies.

SOIL-CLIMATE-CROP

The black soils occur on a rolling plateau with slopes varying from 0.5 to 5.0%. They are clayey with their depth varying from 30 to over 90 cm. The soils are highly erodible because of poor aggregation. The infiltration rates are extremely low (< 1 mm/hr) over vast tracts, as in Bellary region. Soils are alkaline in reaction and have a zone of salt accumulation in the profile. They are low in nitrogen and phosphorus but fairly rich in other nutrients. Such a high potential fertility is however offset by the adverse physical properties like hygroscopic coefficient, wilting point, and volume expansion, all of which restrict the movement of water within and into the soil.

The geographical position of the Deccan plateau is itself responsible for the low and erratic rainfall whose effectiveness is further reduced by heavy runoff, high winds, low humidity, bright sunshine, and high temperatures. Soaking rains commence sometime in September and continue until end of October in intense showers over short intervals. This combined with the characteristic physical properties of black soils, aggravates runoff (10 to 20% of annual rainfall) and depletes our valuable heritage — the fertile top soil through sheet and gully erosion.

*Deputy Director General (SAE), Indian Council of Agricultural Research, New Delhi, and Scientist S3 (Soil Science), Central Soil and Water Conservation Research and Training Institute, Research Centre, Bellary-2 (Karnataka), 583 102.

These soils are cropped from late August or September, mostly on stored moisture, as crop production in the kharif season becomes risky and hazardous in the major parts of Vertisols, except in some sporadic pockets of shallow and medium soils. Water budget analysis indicates that the region suffers from water deficit throughout the year, but to a lesser extent in September and October (CSWCRTI 1980). Analysis for the decennial frequency of drought occurrence using a 100-year rainfall and seasonal aridity index for the period August to February revealed that rabi crops experience five droughts of different intensities in a normal decade (Table 1).

Table 1. Decennial frequency of drought occurrence in Bellary.

Decennial period	Moderate	Large	Severe	Disastrous	Total
1870-71 - 1879-80	2	4	-	1	7
1880-81 - 1889-90	3	1	1	1	6
1890-91 - 1899-1900	3	-	-	2	5
1900-01 - 1909-10	4	2	-	1	7
1910-11 - 1919-20	1	1	-	-	2
1920-21 - 1929-30	-	2	1	1	4
1930-31 - 1939-40	1	1	2	-	4
1940-41 - 1949-50	3	-	1	1	5
1950-51 - 1959-60	1	3	2	-	6
1960-61 - 1969-70	2	1	1	1	5

In view of low variations in temperature, the kharif and rabi seasons are not distinct in the region; it is a kharif-rabi continuum. Contribution of dew is almost negligible. Thus, moisture is the prime constraint to agricultural production in the region.

In view of the above limitations, traditional crop production in rainfed black soils is essentially oriented towards risk minimization at uneconomic levels of production. Theoretically speaking the water demand for a 100-day crop in rabi will be around 300 mm. Paradoxically, though the area receives roughly the same amount of rain, it is the moisture shortage that limits crop yields. This limitation could be alleviated by conserving soil and moisture and their efficient management brings stability to producrion levels.

The major problem in black soils is one of increasing efficiency of otherwise low rainfall and ensuring safe disposal of inevitable runoff with minimum soil loss. In black soils, an annual runoff to the extent of 10 to 20% of the rainfall occurs, carrying with it 10 to 43 tonnes/ha per annum of top fertile soil depending upon locations. These twin objectives are best achieved by adopting suitable mechanical structures at specified vertical intervals, along with supporting practices in the inter-terraced areas. These are the following.

1. Mechanical Structures

Research studies conducted at Bellary over years showed that contour bunds are highly unsuited to black soils because of water stagnation, loss of area, and breaches of bunds resulting in the formation of fresh gullies. Among various structures evaluated, the drainage-type of terraces, namely, graded bunds proved most efficient. Bunds of 0.8 m^2 cross section at vertical intervals of 0.7 m with a channel (grade of 0.1 to 0.25%) on the upstream side connected to a grass waterway have been advocated (Chittarañjan et al. 1980). Areas treated with these structures not only brought down soil losses from 12 tonnes/ha per year to around 1 tonne/ha per year but also increased crop yields considerably (Table 2).

Table 2. Influence of various mechanical structures on crop yields at Bellary.

Crop		Average yields (kg/ha)			
		Unbunded	Contour bunds	Graded bunds	Broad-based terraces
Rabi Sorghum	Grain	245	184	280	362
	Straw	543	480	1650	1102
Cotton		131	92	163	154
Safflower		192	117	215	584

Water harvesting

The runoff at Bellary that is in general 10% of the annual rainfall can be easily harvested and stored in dug-out ponds. Based on the studies conducted at Bellary, a farm pond of 3 to 5 m depth (1.5:1 side slope), having a capacity of 0.25 to 0.3 ha m is recommended for every 8 to 10 ha catchment. The cost of making such a pond works out at Rs.6000/- to 7000/-. The water so harvested can be recycled to 80% of the catchment in the form of one life-saving irrigation of 5 cm (Chittaranjan and Rama Mohan Rao 1980). Seepage losses from such storage structures were generally found to be negligible in black soils. Experience at Solapur shows that seepage losses, wherever becoming a problem, can be reduced considerably by lining the ponds with soil, cowdung, and straw in the ratio 10:1:1, or preferably with a 10-cm thick plastering of saline sodic soil.

2. Inter-terrace Treatments

Contour cultivation

Cultivation-on-contour alone increased crop yields by about 34% in growing sorghum across seasons as it arrests runoff and erosion by offering more time for the rain water to penetrate through innumerable miniature barriers created in the form of contour furrows, when compared to up-and-down cultivation.

Tillage. Movement of rain water into black soils takes place initially via cracks, charging the subsoil with moisture. But once the cracks are superficially closed further movement is governed by the intake rate. This rate, being very low, often results in a dry layer sandwiched between two wet layers leading to crop failure.

Neither shallow nor deep tillage conferred any increase in crop yields and total moisture intake, when compared to traditional harrowing of 3 to 4 times to check weeds and create dust mulch.

Altering land topography to enhance profile moisture by increasing opportunity time through compartmental bunds, ridge furrows, listing and corrugations in less permeable soils either resulted in water stagnation and low yields or met with little success by increasing sorghum yields by 2 to 18% over three seasons (CSWCRTI 1980). In soils of high permeability (5 to 6 mm/hr) these practices did not result in any additional yield increases (Kanitkar 1960).

The intake rate in black soils was found to be highly dependent upon exchangeable sodium percentage. The intake rates in such soils could be improved and maintained by reducing the exchangeable sodium percentage to less than 7.0 through gypsum application (Rama Mohan Rao and Seshachalam 1976).

Vertical Mulching. Keeping sorghum stubbles as vertical mulch in trenches 40 cm deep, 15 cm wide and protruding 10 cm above the ground level enhanced the available soil moisture by 4 to 5 cm, and thereby improved grain yields by as much as 400 to 500% in drought years and 40 to 50% in normal years over unmulched plots (Table 3). At Bellary, such beneficial effects of vertical mulches lasted for four consecutive seasons.

Table 3. Influence of vertical mulch on yields of sorghum (kg/ha).

Treatment	Location					
	Bellary (1973-76)		Solapur (1974-76)		*Bijapur (1973-74)	
	Grain	Straw	Grain	Straw	Grain	Straw
Control	836	2157	840	4774	1661	NA
Vertical mulches at 2 m interval	1172	2961	1237	6276	-	NA
Vertical mulches at 4 m interval	1281	3037	1266	6445	2050	NA
Vertical mulches at 8 m interval	1186	2927	1123	6231	1823	NA

*Tested at 5 and 10 m spacing. NA = Not available.

CROPS, VARIETIES AND AGRONOMIC PRACTICES FOR DRYLAND AREAS

Conservation of rainfall is of little practical value unless it is put to productive use through efficient management of other resources. This can be achieved by a combination of right choice of crop, variety, and improved agronomic techniques.

1. Efficient Crop Varieties

The erstwhile Bombay or Madras dry farming practices did not enthuse farmers as the yield improvements from those practices were marginal, primarily due to poor crop varieties in vogue at that time. Based on screening trials conducted over a number of locations, superior genetic materials that can exploit moisture and costly inputs better than their traditional counterparts, and yield on an average 15 to 20 q/ha in sorghum, 10-15 q/ha in safflower, and 6-10 q/ha in chickpea, have been identified for different areas in the region (Table 4).

Table 4. Recommended crop varieties for rabi black soils.

Crop	Region		
	Bellary	Bijapur	Solapur
Sorghum	SPV-86	CSH-8R/5-4-1	CSH-7R/SPV-86
Safflower	A-1	A-1	A-1/S-144
Gram	A-1/N.52	A-1	N-52/N-59

Crop choice. The relative potential of various traditional crop varieties was compared with a view to replacing some of the less productive crops with more efficient ones. According to these studies, sorghum turned out to be the most remunerative crop for black soils. Safflower, which is seldom grown as a pure crop, outweighed cotton in Bellary, wheat in Solapur, and wheat and chickpea at Bijapur (Table 5). Safflower registered 3 to 4 times the average net returns obtained from dryland cotton even on farmers' fields (Ranga Rao and Ramachandram 1975). As compared to other crops, safflower also possesses good salt tolerance

Table 5. Relative efficiency of different crops in rabi black soil areas.

Crop	Region (yield kg/ha)		
	Bellary	Bijapur	Solapur
Sorghum grain	2674	2034	1558
Cotton	494	1048	NT
Safflower	1168	1790	1376
Chickpea	NT	943	1400
Wheat	NT	804	901
Sunflower	NT	NT	943
Linseed	NT	707	NT

NT = Not tried.

as it gave nearly normal yields on saline soils while sorghum and cotton failed (Krishnamoorthy et al. 1966). This practice would not only improve the economy of the farmers but would also help raise oil output and help meet the national goal of self-sufficiency in edible oils.

Among other rabi crops, yields of chickpea are unstable and low. Besides, it suffers from wilt in years of adequate rainfall. At Bellary, short-duration varieties of field beans gave higher yields than chickpea, both in the wet and the dry season (Table 6). Hence popularization of Dolichos in the tract helps greatly in stabilizing production of grain legumes and improving nutritional standards of people (Ramachandram and Ranga Rao 1981).

Table 6. Yields of chickpea vis-a-vis field beans.

Crop	Variety	Yield (kg/ha)				
		1973 Drought year	1974 Normal year	1975 Below normal year	1976 Wet season	1978 Drought year
Dolichos lablab (field beans)	CO-6	330	1220	970	1750	187
	CO-7	130	1650	1110	2170	507
Chickpea	A-1	80	980	1040	Failed due to wilt	137

2. Agronomic Practices

(a) Planting time

Traditionally farmers begin sowing the rabi crops after the cessation of rains sometime in October, resulting in poor stands and moisture stress at or before flowering. Time of planting studies revealed that advancing sorghum sowings by 20 to 30 days gives spectacular yield increases due to higher moisture availability and better utilization of nutrients (Table 7). Response to early seeding is more pronounced with improved genotypes of

Table 7. Effect of seeding dates in rabi crops.

Crop	Seeding time	Yield (kg/ha)		
		Bellary	Bijapur	Solapur
Sorghum	August, 2nd fortnight	NT	NT	2080
	September, 1st fortnight	NT	1906	2144
	September, 2nd fortnight	3993	2127	-
	October, 1st fortnight	2908	1444	1293
	October, 2nd fortnight	1952	894	884
	November, 1st fortnight	532		
Safflower	September, 1st fortnight	330	2237	1271
	September, 2nd fortnight	870	1393	915
	October, 1st fortnight	2231	1098	708
	October, 2nd fortnight	2130	750	462

NT = Not tried.

rabi sorghum than traditional types. Early seeding is also beneficial for other rabi crops. The best sowing time for safflower is September for Solapur and Bijapur and the 1st fortnight of October for Bellary region.

(b) Plant populations and row spacings

Farmers from Vertisol areas generally adopt low seed rates, primarily as an insurance against rainfall failure. While such a practice is well suited to nonresponsive traditional varieties, it results in below-optimum yields in the case of newly available improved crop varieties, particularly at high levels of inputs and stored moisture. Highest yields with improved rabi sorghum genotypes is obtained at 1 lakh to 1.35 lakh plants/ha under favorable moisture conditions (Table 8). In years of low rainfall and poor soil moisture, plant stands higher than 50,000 or 60,000 per ha exerted negative influences on sorghum yields even in the case of improved genotypes. In contrast to sorghum, safflower showed no response

Table 8. Grain yields of sorghum as influenced by plant stand.

Crop	Plant population (x 1000/ha)	Region (yield kg/ha)		
		Bellary	Bijapur	Solapur
Sorghum	45	1822	2738	1545
	90	2285	3038	1720
	135	2467	2977	1758
	180	2341	3010	1483
Safflower	30	NT	1650	NT
	50	1240	NT	402
	60	-	1663	NT
	90	1230	1739	NT
	100	NT	NT	256
	120	-	1748	NT
	135/150	1200 (135)	NT	220 (150)

NT = Not tried.

to plant density over a range of 3 to 5 plants/m^2 owing to its multiple branching habit. Sorghum and safflower should be seeded at 6 kg/ha at Solapur and 5 kg/ha at Bellary for obtaining the required plant stands. Investigations conducted at Bellary showed that a seed rate of 50 to 60 kg/ha for chickpea and 10 to 12 kg/ha for coriander is optimum. However, these stands are seldom achieved due to defective seeding methods. Use of improved ferti-seed-drills that can place the seed in the moist zone and establish contact with it ensures better stands and thereby higher yields to the extent of 150-188 kg/ha sorghum over local seeding methods.

Yields remain nearly the same even if the row-to-row distance is widened from 45 to 90+ cm in sorghum and 45 to 90 cm in safflower, 30-45 cm in chickpea and coriander, and 45 to 60 cm in field beans. Hence, a row-to-row spacing of 60 to 75 cm (Bellary and Bijapur) or 60-90 cm (Solapur) for sorghum, 60 to 90 cm for safflower, 60 to 75 cm for field beans, and 45 cm for chickpea and coriander is ideal from the point of operational convenience in interculture and rate of coverage of area during seeding and intercultivation.

Fertilizer application. Next to inadequate moisture it is only the lack of nutrients that limits the realization of full potentials from improved cultivars under good management. Under conditions of early seeding and adequate plant stands, fertilizer application resulted in 100% yield increase even in rainfed areas. Optimum levels of fertilizer nitrogen ranged from as low as 30 kg/ha in scanty moisture areas and situations to 60 kg/ha or 75 kg/ha in areas and/or years of assured moisture (Table 9).

The dependence of nutrient responses on soil moisture is clearly brought out by the data presented in Table 10.

Table 9. Response of rabi crops to N application.

Crop	Level of N kg/ha	Yield (kg/ha) Bellary	Bijapur	Solapur
Sorghum	0	833	1602	850
	30	1401	2117	1360
	60	1593	2350	1770
	90	1722	2317	1900
Safflower	0		1338	603 (0 N)
	30		2032	997 (25 N)
	60		2005	1100 (50 N)
	90		1923	1402 (75 N)

Table 10. Response of sorghum to nitrogen at different levels of soil moisture availability (Solapur).

Soil depth (cm)	Available soil moisture (mm)	Grain yields (kg/ha) N levels (kg/ha)			
		0	25	50	75
30	50	656	1225	1295	1302
60	110	1604	1784	2132	2332

Based on these results, a dose of 30 kg N and 30 kg P_2O_5/ha for Bellary, 30 kg N and 25 kg P_2O_5/ha for Bijapur, and 50 kg N and 25 kg P_2O_5/ha for Solapur regions is recommended for rabi sorghum as well as safflower to derive maximum returns for every rupee invested. Fertilizer should be drilled at 5 to 10 cm below the soil for efficient use.

Contingency plans for evading drought. All the practices outlined above are applicable to situations and seasons with normal or evenly distributed rainfall. Use of optimum seed rates devised for normal and favorable seasons leads to higher plant populations than otherwise required under insufficient and erratic rains; and results in moisture stress at critical phases of crop growth. Under these circumstances, removing every alternate row or 3rd row or an equivalent number of weaklings, and disease- and insect-affected plants before mid to end October proved very successful under Bellary conditions in reducing yield losses in dry seasons (Table 11).

Table 11. Effect of thinning on sorghum yields under drought conditions.

Practice	Final plant stand (x 1000/ha)	Yield (kg/ha)	
		Grain	Straw
Full population	130	541	3650
Alternate row removed	65	1208	2662
Every 3rd row removed	87	924	3034

In spite of low rainfall, considerable amounts of it flow as runoff because of the characteristics of black soils. This runoff could be collected into farm ponds and recycled as minimal irrigation to save crops from moisture stress and thereby stabilize their yields. Application of one irrigation of 4 to 6 cm enhanced sorghum yields remarkably by 831 to 1568 kg/ha over control in different locations.

Since runoff water is insufficient to cater for the entire catchment, a combination of suitable cropping patterns and life-saving practices will help to minimize risks of crop failures and achieve efficient use of water resources.

Low monetary inputs for maximizing returns from costly inputs

In the improved technology suggested above, fertilizers alone account for 60 to 70% of total cultivation costs. Inputs and high-level management practices such as choice of good varieties, adoption of optimum times of seeding and seed rates, timely weeding and interculture etc., that involve little or no extra expenditure, play very crucial roles in fully utilizing the applied nutrients for maximum returns. For instance, the efficiency of fertilizer nitrogen applied to sorghum increased 2-3 times simply by switching over from traditional practice to low-cost techniques (Table 12).

Table 12. Effect of management on fertilizer nitrogen efficiency at Solapur.

Level of N (kg/ha)	Local management: Grain yield (kg/ha)	Local management: Response (kg of gram/ kg N/ha)	Improved management: Grain yield (kg/ha)	Improved management: Response (kg of gram/ kg N/ha)
0	663	-	1050	-
25	840	7.1	1713	26.5
50	1514	17.0	2312	25.2

Even in the absence of fertilizers and plant protection measures, farmers can still realize 50 to 70% more yields than from their traditional system just by resorting to improved management (Umrani 1979). Emphasis should therefore be more on low monetary inputs rather than on the conventional package approach in view of the low risk-bearing capacity of most farmers.

Production potential of improved technology

Experience on farmers' fields over some years (Table 13) showed that it is possible to raise the average yields and incomes of farmers in these

Table 13. Economics of improved technology for rabi jowar on farmers' fields.

Particulars	Levels of technology: Traditional*	Low monetary inputs**	Low plus high monetary inputs
1. Yield (kg/ha)			
Grain	304	834	1253
Straw	1282	1220	2683
2. Returns (Rs/ha)			
Gross	557.10	1184	1906.05
Net	178.69	727.77	1259.91
3. Net returns per rupee invested (Rs)	0.47	1.60	1.95

*Data based on average of 10 years (1970-1979)

**Data based on average of 2 years (1977-1979) areas two- or threefold over the existing levels by the adoption of various improved farming practices outlined above. Evidently, chronically drought-prone black soil areas in Deccan rabi offer tremendous scope for elevating their production potentials and thereby the economy of the farming community in the region.

The above results clearly indicate that soil conservation starts and ends with good soil and farm management. So far the tendency has been not to link soil conservation studies with farm management in conserving our resources. This has to be stopped, which means that cooperation and coordination between service-related departments engaged in soil and water conservation is a sine qua non.

Acknowledgement

The authors gratefully acknowledge the results drawn from the annual reports of the All India Coordinated Research Project for Dryland Agriculture of Bellary, Bijapur, and Solapur Centres presented in this paper.

REFERENCES

CSWCRTI..1980. Twenty-five Years Research in Soil and Water Conservation in Semi-Arid Deep Black Soils. Monograph No.1. Central Soil and Water Conservation Research and Training Institute, Dehra Dun.

Chittaranjan, S., Ramanath, B.,and Rama Mohan Rao, M.S. 1980. Mechanical structures for soil conservation on deep black soils. Extn. Bull. No.1. Central Soil and Water Conservation Research and Training Institute, Research Centre, Bellary-2.

Chittaranjan, S., and Rama Mohan Rao, M.S. 1980. Run-off harvesting and recycling on Vertisols for increasing crop production. Indian Journal of Soil Conservation (accepted).

Krishnamoorthy, Ch., Chattopadhyay, S.,and Rao, S.B.P. 1966. Safflower for better utilization of shallow and medium black cotton soils of Bellary area. Annals of Arid Zone 5(1):44-48.

Kanitkar, N.V. 1960. Dry Farming in India. New Delhi: ICAR.

Ranga Rao, V.,and Ramachandram, M. 1975. Safflower opens new vistas for stable returns in drylands of Bellary region. Paper presented at the Crop Management Seminar held at Hyderabad, 15-18 April 1975.

Rama Mohan Rao, and Seshachalam, N. 1976. Improvement of intake rate in problem black soils. Mysore Journal of Agricultural Sciences 10:52-58.

Ramanath, B., Arjun Prasad, Chittaranjan, S. and Rama Mohan Rao, M.S. 1980. Cropping systems under dry-cum-wet irrigation. Bellary Extn. Bull.No.2. Central Soil and Water Conservation Research and Training Institute. Research Centre, Bellary-2.

Ramachandram, M., and Ranga Rao, V. 1981. Performance of some grain legumes in rainfed black soils of Bellary. Paper presented at the Symposium on Land Use Potentials of Karnataka held at the University of Agricultural Sciences Campus, Raichur, 5-6 February 1981.

Umrani, N.K. 1979. Research achievements with special reference to fertilizer use in dry lands. Paper presented at the Group Discussion on Fertilizer Use in Dry Lands, organized by the Fertilizer Association of India, New Delhi, 17-18 August 1979.

MANAGEMENT OF DEEP BLACK SOILS FOR INCREASED PRODUCTION OF CEREALS, OILSEEDS, AND PULSES

J. Venkateswarlu, AICRPDA

RESOURCES

Land

In India, the black soils are widely distributed over 72.9 million ha. The area covers central and western Madhya Pradesh, almost the whole of Maharashtra, southern districts of Orissa, southern and coastal Andhra Pradesh and the northern districts of Karnataka. It also occurs in parts of Rajasthan and Bundelkhand division of Uttar Pradesh and central and southern parts of Tamil Nadu.

These soils vary in depth (from 15 to 240 cm and above). They are generally high in clay content that varies from 30 to 70% or more. Subsoil salinity in lower parts of the slope is not uncommon. They have about a 30% water-holding capacity. Due to the soils' strong swelling and shrinking properties, water loss is considerable as cracks develop when crops are grown under receding moisture conditions. Because of the high clay content, water intake is low. The soils are easily dispersed and, therefore, are highly erodible. The underlying murrum is variable. At Bellary it is calcareous and impermeable, while at Solapur, Akola, and Indore it is highly permeable, being of trap origin.

Drainage is a problem in lower levels of the topography. It is for this reason that soil and water conservation measures become extremely important in the management of black soils. Graded bunding is preferred for all the black soils, irrespective of rainfall. All the interbunded areas must be well graded for successful farming.

Black soils are generally deficient in nitrogen. The soils of granitic origin are also frequently deficient in phosphorus. The supply of potassium is adequate.

Depending on the rainfall pattern, the black soils are cropped in the rainy season (kharif) as in Rajkot, Kovilpatti, and Akola, or in the postrainy season (rabi) as in Bellary, Bijapur, and Solapur. In Indore, Udaipur, and Rewa they are cropped in both seasons.

Rainfall

The deep black soils (> 90 cm) occur both in situ and in lower parts of the slope. There are 8 research centers of the Dryland Project (Table 1) situated in the deep black soils of India. In that table the growing seasons have been grouped on the basis of the rainfall pattern, to show the duration of the cropping season in each center.

Problems in Land Management

Land management problems in these deep black soils are many. In Bellary, with a rainfall of 510 mm/yr, only rabi cropping is possible. The soils are low in

Previous Page Blank

infiltration. The soils develop cracks within about 6 weeks of the last rains. Subsoil salinity, with high boron, is not uncommon. In Bijapur, with 630 mm/yr rainfall, similar problems to those of Bellary are observed. At Solapur (760 mm/yr rainfall) the deep soils are situated in the lower part of the slopes. They therefore become stagnant during the kharif. If adequate drainage is provided these soils can be used for double cropping. In Udaipur (680 mm/yr rainfall) two crops are possible if a short-duration kharif crop is grown. In Akola (830 mm/yr rainfall) and Kovilpatti (730 mm/yr rainfall) the soils are erodible. In Akola double cropping is possible when a short-duration kharif crop is grown. In the high rainfall regions of Indore (990 mm/yr) and Rewa (1080 mm/yr) the erosion problem is serious. Crop drainage is necessary. Common problems in these black soils are high P-fixation and the difficulty of establishing good plant stands for the second crop.

PRODUCTION POTENTIAL

The production potential of the deep black soils is much higher than that of the red soils. The data in Table 2 show the great scope for increasing crop yields in farmers' fields.

A 3-4 fold increase is possible by adopting improved methods of crop husbandry. Among other requirements these include better moisture conservation and use, timely preparatory and seeding operations, the establishment of adequate plant stands, satisfactory weed control, and efficient fertilizer use (at 40-50 kg N and 30-40 kg P_2O_5/ha) with new cropping patterns.

CROPS AND CROPPING PATTERNS

Crops

High-yielding varieties and hybrids of crops have consistently proved their superiority in these regions. Being of short duration, they reach the dough stage before the soil cracks develop and moisture losses occur. Only in respect of rabi sorghum is there unlikely to be a real breakthrough. For cropping improvement, however, crop substitution is more important. More efficient crops than those grown traditionally have been identified for cultivation in these black soils. Examples are the following:

Region	Traditional crop	Efficient substitution crop
Bellary	Cotton	Sorghum (rabi)
Bijapur	Wheat	Safflower
Indore	Wheat	Safflower
	Mung bean	Soybean

Cropping Pattern

Normally the deep black soils are cropped once a year. The farmers take crops on the principle of recouped fertility. Sometimes intercropping is practiced, but not efficiently.

It has been possible to suggest increased crop intensity in different parts of the deep black soil areas.

Intercropping. The most efficient intercropping in the Deccan region is a pearl millet/pigeonpea mixture (Table 3).

In the high rainfall areas sorghum/mung bean or sorghum/pigeonpea mixtures are found to be efficient. These systems have shown higher efficiency, both temporally and spatially, leading to a high land equivalent ratio (LER). It is necessary to remember that the high productivities are possible only when the soil fertility is well maintained.

Sequential cropping. Some of the crop sequences for these deep black soils are given in Table 4.

The data clearly show that there is immense scope to improve the productivity of these drylands. However, these systems need more investment through inputs and animal draft. Also, establishing the second crop in time often poses problems (e.g., preparation of a good seedbed).

Two crop sequences are possible, however, particularly in areas receiving 800 mm/yr rainfall and above, with a growing season of 25 weeks and above.

Alternate Crop Strategies

As the monsoon progresses there is a need to consider alternate crop strategies.

For example in the Deccan rabi region, with the delay in sowing, cropping moves from sorghum to safflower to chickpea. In the Vidarbha region the pattern is: dry sowing of cotton followed by groundnut and sorghum in kharif and safflower followed by chickpea in rabi. In the Malwa plateau dry sowing of cotton is followed by sorghum to maize to soybean and groundnut in kharif and safflower followed by chickpea in rabi.

SOIL MANAGEMENT PRACTICES

Rain is the main source of water for these deep black soils. Entry of rain water into the soil profile is through the surface of the soil. And efforts made to keep the soil open to receive more and more of the rain water would lead to more efficient crop production. Among other things, the methods include: (a) advancing the sowing time; (b) use of mulches; (c) crop drainage; (d) farming on graded fields. The last aspect is being separately discussed.

Advancing the Sowing Time in the Deccan Region

In this region crops are sown after the cessation of the rains. Approximately, growing begins in the last week of September in Bijapur, in the 1st week of October in Solapur, and in the 2nd week of October in Bellary. This timing occurs despite the heavy rains that are received in the 1st fortnight of September in all these districts. By advancing the sowing, and by providing crop drainage, the crops are grown partly with rainfed moisture. The resulting advantages are seen to be quite substantial (see Table 5).

Use of Mulches

Organic mulches have been found to be effective in improving moisture intake. But their use is very limited due to the practice of using the crop residues as cattle feed or as fuel. However, for the short-term carryover of moisture, use of grasses or even crop residues as a mulch, and subsequently for cattle feed, can be recommended for rabi crops.

In the Bellary region, where the rainfall is low, the problem of the entry of the rain water into the profile is further accentuated by sodiumization. It was found that, even at 8 Exchangeable Sodium Percentage the infiltration rates were very low, leading to runoff and erosion. In such situations vertical mulching (the provision of 45-cm deep and 22.5 cm-wide furrows across the slope at 4 or 8 m intervals and packing them with sorghum stalks to extend 15 cm above surface) was found to lead to better in situ water harvesting and higher yields (Table 6).

Crop Drainage

In Indore, the high rainfall leads to water stagnation. In fact, only about 30% of the land was used for kharif cropping. But with improved crop drainage kharif cropping increased to 70%. With the selection of short-duration high-yielding varieties of crops, and harvesting at physiological maturity, it has now become possible to grow two crops in these soils.

Farm Machinery for Seeding and Fertilizer Placement

Dry sowing of bold seeded crops, particularly cotton, is an existing practice in the Vidarbha and Malwa plateau during the kharif season. For other crops it is necessary to sow them in the moist zone after the beginning of the rains. Seeding and fertilizer placement can be dovetailed. For these operations it is necessary to have improved farm machinery. Since most of the farmers in the region are small, and marginal, it is essential to have low-cost tools available, preferably in the form of attachments to the existing tools.

Such studies have been in progress at all the research centers, and attachments to single- or multitined seed drills for fertilizer placement have been developed.

PROFITABILITY OF RAINFED FARMING

Improved rainfed farming systems lead to increased working costs due to the use of high-yielding varieties and other inputs, such as fertilizers and pesticides, and to the cost of efficient weeding. Extensive trials on farmers fields have been organized on deep black soils by the Agro-Economic group of the Dryland Project in the Drought-Prone Areas. The improved practices, as developed by the Research Centers, have been tested in comparison with traditional methods. The yield, working cost, and net return are given in Table 7.

It is apparent that the additional working cost comes to Rs.200-400, depending on the crop. The increase in yields have been 200-400% in many instances. The average net returns in terms of rupees per rupee invested are listed in Table 8.

The data consistently indicate the superiority of improved dryland farming practices over the traditional systems, except in the case of sorghum where it is marginally superior.

GENERATION OF EMPLOYMENT POTENTIAL

The improved crop production in dryland areas also leads to increased labor requirements. The data are given in Table 9.

As an average over the traditional system, 25% of additional human labor and 15% bullock power would be needed in the improved dryland crop production technology for individual crops.

When double cropping is practiced, particularly in those deep black soils receiving 800 mm/yr rainfall and above, the employment potential is further enhanced, as can be seen in Table 10.

SOME CONSTRAINTS IN ADOPTION OF IMPROVED DRYLAND PRODUCTION PRACTICES

The facts presented above suggest that there is a need for increased investments to harvest better productivity under rainfed situations. Unfortunately many a farmer in dryland areas uses recouped soil fertility in his cropping. In fact, the data presented in Tables 11 and 12 suggest the following.

a. About 70-80% farmers have small holdings. These holdings are again fragmented.

b. The irrigated area in these regions is low.

c. In other words, the investment capacity of the farmers is also low. This may possibly be a primary constraint in the adoption of improved dryland farming practices for increasing productivity if adequate credit resources are not available.

d. However, since the irrigated area is very low, the farmers should invest more of their time and effort in managing the drylands in their farms.

e. An important point that has been brought out during the benchmark survey of some of the clusters of villages attached to the Research Stations in these black soil areas is the non-availability of draft power (Tables 13 and 14).

It is clear that the availability of draft power is meager and many more small farmers than big farmers have relatively more labor available to work on their own farms. In other words, the availability of draft itself might be another constraint for the timely operations that are important under rainfed conditions.

In many of these black soil regions erodibility and crop drainage are a serious problem. To improve the situation community action is required, either to provide graded bunds and/or to provide regulated waterways. It appears to be necessary for the Government to consider investing in these works for the permanent benefit of the small and marginal farmers who predominate in these regions.

SUMMARY

Black soils are widely distributed in India and low water intake, erodibility, swelling and shrinking are their characteristics. With low rainfall deep black soils can be cropped only in the rabi season. Medium-rainfall areas can be cropped in the kharif. But those in the high rainfall zones can be cropped in both seasons.

The untapped yield potential is 200-400%. High-yielding short-duration varieties are better suited for rabi situations. Cropping intensity can be increased by intercropping (e.g. pearl millet/pigeonpea and sorghum/pigeonpea) in medium-rainfall areas, and by double cropping in high rainfall areas (e.g. Indore, Rewa). To meet weather aberrations, alternate crop strategies have been worked out.

By advancing the sowing date, or using vertical mulches, crops may benefit from more rain water in the Deccan rabi region. By providing crop drainage, more area can be brought under kharif cropping as well, in medium/high rainfall areas. For sowing and fertilizer placement, low-cost farm machinery, in the form of attachments to single- or multitine seed drills, have been developed to suit small and marginal farmers.

Rainfed farming by improved technological methods is profitable, even though higher investments are required than in traditional farming. About 25% additional human labor and 15% bullock power is needed for improved crop management practices.

The important constraint in the adoption of the new technology is the poor investment capacity of the small and marginal farmers prevalent in the region. So the provision of credit is crucial. The other constraint is the lack of adequate draft power for timely operations. There is a need to provide waterways and graded bunds at Government cost, to permanently improve the productivity of the deep black soils.

Acknowledgements

The data used for preparing this paper are from various cooperators of the All India Coordinated Research Project for Dryland Agriculture over the last decade, and are gratefully acknowledged.

Table 1. Research centers with deep black soils.

Rainfall	Growing season (weeks)	Centers
Low	≤ 20	Bellary (8)[a]; Bijapur (17)
Medium	20-30	Solapur (23); Udaipur (22); Akola (27); Kovilpatti (21)
High	> 30	Indore (36); Rewa (36)

[a]Figures in parentheses indicate duration of cropping season in weeks.

Table 2. Crop production potentials.

Center	Crop	Average yield (kg/ha)	
		Research station	Farmers' fields
	Low rainfall region		
Bellary	Sorghum (rabi)	1400	300
	Safflower	1200	200
Bijapur	Sorghum	2100	300
	Medium rainfall region		
Solapur	Sorghum (rabi)	2100	400
	Pearl millet	1600	300
	Pigeonpea	1400	300
	Chickpea	1300	300
Udaipur	Sorghum	2900	600
	Maize	1800	900
Akola	Sorghum	1800	200
Kovilpatti	Pearl millet	2500	700
	Sorghum	2000	200
	High rainfall region		
Indore	Maize	4300	1200
	Soybean	2700	1000
	Safflower	2400	
Rewa	Rice	2900	600
	Sorghum	3000	1000
	Chickpea	1300	700

Table 3. Some intercropping systems developed for deep black soils.

Region	System	Average yield of crops (kg/ha)	
		Base crop	Intercrop
Bijapur	Pearl millet	1410	
	Pearl millet/pigeonpea (2:1)	1160	800
Solapur	Pearl millet	1800	
	Pearl millet/pigeonpea (2:1)	1830	1700
Akola	Sorghum	3350	
	Sorghum/mung bean (1:1)	3080	730
Rewa	Sorghum	2540	
	Sorghum/pigeonpea (2:1)	2230	470

Table 4. Some crop sequences for deep black soil regions.

Region	Crop sequence	Average yield (kg/ha)	
		First crop	Second crop
Bijapur	Mung bean-safflower	750	1060
Akola	Sorghum-safflower	4540	1410
Indore	Maize-safflower	2950	1080
	Sorghum-chickpea	3210	1390
	Maize-chickpea	3350	1430

Table 5. Advancing sowing date for rabi cropping (Bellary).

Year	Yield of sorghum (kg/ha)	
	Normal sowing	Advanced sowing
1974	1680	3010
1975	240	1070
1976	740	1650

Table 6. Vertical mulching and sorghum yields (Bellary).

Interval of vertical mulch	Grain yield (kg/ha)				
	1972-73	1973-74	1974-75	1975-76	1977-78
4 m	400	1690	1780	1250	1540
8 m	280	1610	1770	1120	1920
Control	20	1120	1100	1080	1470

Table 7. Profitability of rainfed farming.

Center	Crop		Av.yield (kg/ha) on farmers' fields	Working cost (Rs./ha)	Net return (Rs./ha)
Bellary	Sorghum	I[a]	690	627	334
	(rabi)	T	320	308	127
	Chickpea	I	450	732	325
		T	190	346	72
	Safflower	I	440	593	345
		T	160	256	60
Bijapur	Sorghum	I	900	583	758
	(rabi)	T	290	236	214
	Mung bean	I	630	639	1038
		T	180	255	207
	Chickpea	I	680	761	1145
		T	200	403	110
	Safflower	I	520	532	813
		T	150	273	143
	Pearl millet/	I	580 + 170	712	448
	pigeonpea	T	180	305	80
Solapur	Sorghum	I	940	498	1014
	(rabi)	T	450	247	454
	Chickpea	I	300	278	284
		T	100	180	-76
	Safflower	I	340	538	270
		T	240	380	138
	Pearl millet/	I	530 + 180	591	449
	Pigeonpea	T	120 + 110	217	232
Akola	Sorghum	I	2460	1295	1185
	(kharif)	T	1400	884	604
	Urd	I	300	579	134
	(black gram)	T	240	512	146
Kovilpatti	Sorghum	I	1920	1147	810
	(kharif)	T	1100	720	364
	Cotton/urd	I	320 + 180	1107	642
		T	200 + 80	703	348
Indore	Sorghum	I	1770	1121	917
	(kharif)	T	NA	NA	NA
	Maize	I	1300	654	524
		T	NA	NA	NA

[a]I = improved; T = traditional.

Table 8. Profitability of rainfed farming.

Crop	Average net return (Re/Re invested)	
	Improved	Traditional
Sorghum (kharif)	0.81	0.60
Sorghum (rabi)	1.22	1.03
Mung bean	1.62	0.81
Chickpea	0.99	0.28
Safflower	0.86	0.37
Pearl millet/pigeonpea	0.69	0.29

Table 9. Improved crop production and labor requirements.

Crop	System[a]	Human labor (days)	Bullock pairs (days)
Sorghum (kharif)	I	70	18
	T	56	15
Sorghum (rabi)	I	63	15
	T	55	14
Maize	I	100	24
	T	89	23
Mung bean	I	59	12
	T	30	7
Chickpea	I	45	14
	T	35	13
Safflower	I	36	8
	T	29	8

[a] I = improved; T = traditional.

Table 10. Double cropping: employment generation (Akola).

System	Average labor hours	
	Human	Bullock
Mung bean	413	60
Mung bean - safflower	706	139
Mung bean - chickpea	850	131

Table 11. Distribution of size groups of farmers.

Center	Size group (%)			
	<2 ha	2-4 ha	4-8 ha	>8 ha
Bijapur	22	25	24	29
Solapur	20	21	33	26
Akola	43	22	20	15
Kovilpatti	46	22	19	13
Indore	23	19	24	34

Table 12. Average land holdings, fragments, and irrigated area.

Center	Average holding (ha)	Average no. of fragments	Irrigated area (%)
Bijapur	4.8	2.0	3.2
Solapur	5.7	2.7	7.1
Akola	5.4	3.2	3.8
Kovilpatti	3.7	3.6	-
Indore	7.5	3.6	9.1

Table 13. Draft power availability.

Center	No. of hectares	
	Per man	Per bullock pair
Kovilpatti	1.9	15.0
Akola	1.1	7.7
Indore	1.3	6.8

Table 14. Relative availability of draft power (Indore).

Size group (ha)	Available draft/ha	
	Men	Bullock pairs
< 2	3.4	1.8
2-4	1.3	3.9
4-8	0.6	5.8
> 8	0.4	8.2

INTEGRATED MULTIDISCIPLINARY APPROACH FOR THE MANAGEMENT OF BLACK SOILS OF MADHYA PRADESH TO INCREASE AND STABLIZE AGRICULTURAL PRODUCTION

G.P. Verma, JNKVV, Rewa, and S.R. Raje, Indo-UK Project, Indore

INTRODUCTION

Madhya Pradesh covers 13% of the net cropped area of the Indian Union, producing roughly 10% of the total food grains. Thus the production of food grains is below the national level, mainly because 84% of paddy crop and 80% of wheat crop is entirely dependent upon vagaries of the monsoon. The average yields of sorghum, chickpea, and pigeonpea are also below 1000 kg/ha. The main reason for low yields in all these crops is the lack of irrigation on 89% of the cropped area where appropriate technology for rainfed farming has not been adopted.

The findings of 5 years of Indo-UK Operational Research Project on Dryland Agriculture (ICAR) on deep black soils at Indore, involving the efforts of a multidisciplinary team, reveal that the black soils have a high potential for increasing agricultural production, particularly where annual rainfall is >700 mm.

PROBLEMS

1. The black soils are problematic, being almost impermeable under saturated conditions, and developing deep and wide cracks on drying. All these are highly erodible and washes, rills, and gullies are formed, particularly under clean-cultivated fallow conditions prevalent on less than 50-85% of the total cropped area (Table 1).

2. The cultivated area kept fallow during the kharif season is without cover, and desi plows and blade harrows are operated occasionally to get a clean seedbed for rabi crops. This no doubt helps to conserve profile-stored soil moisture, but causes severe soil erosion resulting in low yields.

3. The annual average rainfall varies from 700 mm to greater than 1200 mm. The rainfall, though sufficient, is fluctuating with several high-intensity storms occurring even in drought years that frequently cause waterlogging and soil erosion. About 90% of the total rain is received during a short rainy season from July to September.

4. The soil erosion problem is still accentuated by ineffective field bunding done previously. This has resulted in waterlogging, excessively concentrated runoff, and severe gullying on breaching, because the soil is highly vulnerable under saturated conditions.

5. The most frequently grown crops are long-duration indigenous varieties of sorghum, wheat, chickpea, black soybean, etc., but their yields are low because of the erratic rainfall over their long growth period, and the almost nonexistent use of fertilizers.

6. The per hectare resource position in respect of family labor, and the bullock power available for farmers, varies with size of the holding. The family labor availability per ha ranges from 3.0 persons in the lowest size group (up to 2.0 ha) to 0.3 person in the largest size group (above 12 ha). Similarly, bullock power availability decreases from 0.55/ha in the smallest size group (up to 2 ha) to 0.10/ha in the largest group (above 12 ha). In other words, one pair of bullocks covers only 1.8 ha on small farms, but as much as 10.1 ha on the largest farms.

7. The general condition of cattle health is not satisfactory, resulting in low draft power and low milk yields. This is further aggravated by the high calf mortality rates and the scarcity of fodder.

AVAILABLE TECHNOLOGY

Land and water management

Although there is no soil conservation research center for black soils with high (>700 mm/yr) rainfall, technology is available from other parts of the country and abroad where there exist similar situations of soil, rainfall and cropping patterns. Such structures as grassed storm drains coupled with grassed waterways, graded bunds, waste weirs, diversion boxes and spurs, gabion structures, temporary pole and bush structures, graded bunds, loose boulder structures, semi-permanent structures, and water harvesting tanks, can be easily adopted wherever necessary in the management of black soils. Aerial photographs can be used for the interpretation of drainage patterns, crest lines, wetted areas, natural vegetation, etc., and also for making rapid land resources surveys.

Cropping program

Much information of practical value about local crops is available from the All India Coordinated Research Project on Dryland Agriculture, Main Centre, Indore. Cropping information from other centers in similar agroecological zones of India is also available for consultation.

Improved short-duration high-yielding varieties are available for the kharif season for such crops as sorghum, maize, soybean, etc., that can be grown as first quick kharif crops before the second rabi crop. Improved high-yielding varieties are also available for cotton, sunflower, groundnut, etc., where double cropping is not possible. Improved rabi crop varieties are also available for wheat, chickpea, linseed, safflower, etc., that can tolerate moisture stress, respond to fertilizer, and give high yields. Also, valuable information on more remunerative crop sequences, intercropping and mixed cropping, about appropriate dates of sowing for different crops, and about improved packages of cropping practices has been derived from the research work conducted under the All India Coordinated Research Project on Dryland Agriculture.

Farm machinery and implements

Enough improved implements for tilling black soils in high rainfall areas have not yet been developed. However, some improved implements, in vogue under similar conditions and found suitable elsewhere in India and abroad for (a) quick seedbed preparation, (b) the eradication of perennial weeds, (c) the efficient sowing of sole crops, mixed crops and intercrops at given seed and fertilizer rates, (d) interculturing for the effective conservation of moisture, (e) the destruction of weeds, (f) drilling and fertilizing at the same time, (g) earthing crop rows, (h) harvesting, and (i) threshing operations, have been tested. Some useful implements have been identified.

Livestock improvement

Research information and improved practices in vogue elsewhere in similar conditions are available in respect of forage crop production, pasture development, and the establishment of plantations for fuel, fodder and fruits. Also, reliable information on the health and the upgrading of cattle is similarly available.

SUCCESSFUL APPROACH FOR TECHNOLOGY TRANSFER

The maximum possible conversion of kharif fallow areas into kharif-cropped areas involves as a project strategy, making the best use of land and water resources available to farmers so far as the improvement and stabilization of crop production are concerned. Hence, kharif-season activities were given the main thrust, so as to simultaneously raise farm income and preserve from erosion the most scarce resource of agriculture -- i.e., the soil.

Rabi as second crop was encouraged in terms of safflower, chickpea, and wheat on deep soils under rainfed conditions with supplemental irrigation.

Incentives

To motivate farmers, the following incentives were provided at project cost.

1. Demonstrations supported by the supply of improved seed and fertilizer in the 1st year.

2. Demonstrations supported by the supply of improved seed to those who purchased their own fertilizer during the 2nd year.

3. Demonstrations supported by the supply of improved seed on an exchange basis to those purchasing their fertilizer requirements themselves during the 3rd year.

4. Hybrid seeds and fodder sorghum seeds as the subsidy during the 4th year where farmers had applied the basal dose of fertilizer in the presence of project.staff.

Discipline guidelines

The technical guidelines for each discipline, to proceed with their approved programs, were as follows:

Land and water management

1. Drain excess water from upper reaches away from the fields.
2. Provide overall drainage for the area through grassed waterways along natural depressions.
3. Provide safe inlets so that field runoff may flow into the waterways through waste weirs.
4. Reclaim gullies and stabilize waterways through gabion structures.
5. Construct broad-based bunds in fields with flat topography that have problems of waterlogging and water stagnation.

Appropriate land use

1. On bare hill slopes, plant trees and grasses.
2. On shallow soils:

   with >3% slopes, plant grasses and trees;
   with 0-3% slopes, plant short-duration crop varieties, preferably on a grade, in the kharif season.

3. On deep soils:

   with >3% slopes, plant grasses and trees for fuel, fodder, and fruits;
   with 1-3% slopes, plant kharif crops followed by rabi crops, intercropping short-duration kharif crops with long-duration crops;
   with <1% slopes, plant kharif crops, with good land treatment, or leave fallow in the kharif to prepare for good rabi crops.

Cropping program

1. Put the maximum possible area under kharif.
2. Replace the long-duration local varieties of kharif crops with short-duration high-yielding improved varieties.
3. Use recommended doses of fertilizer.
4. Sow the crop at the night time according to the weather and available soil moisture, and establish a good stand.

5. Watch out for insect/pest attack and use plant protection measures when necessary.

6. Harvest the crops at physiological maturity.

Livestock improvement

1. Introduce improved methods for feeding and managing local cattle at first.

2. Attend to common animal ailments.

3. Control contagious animal disease by prophylatic vaccination.

4. Upgrade cattle through cross-breeding by A.I. and by natural servicing by halfbred Jersey bulls.

Farm machinery program

1. Introduce appropriate tillage systems, for timely operations, backed up by the available power.

2. Introduce sufficient seeding equipment for uniform stands and good plant populations.

3. Popularize threshing equipment for the timely harvesting of crops and safe grain storage to minimize postharvest losses.

4. Educate farmers on the proper operation and maintenance of their improved machines.

5. Emphasize interculture in kharif crops up to the later stages of crop growth, and introduce suitable improved implements.

ACHIEVEMENTS

Dryland technology, evolved by research, has been tried in the Indo-UK Dry Farming Project (ICAR) area, and the highlights of achievements were as follows:

Land and water management practices

The land and water management practices adopted in the project area have led to:

a. the stabilization of waterways and the reclamation of washes and gullies;

b. considerable reduction in soil loss, not only as a result of the use of mechanical structures such as water diversion bunds, graded bunds, loose boulder structures, etc., but also of the establishment of good soil cover provided by well-fed crops.

Changes in the cropping pattern

Increase in area under kharif crops. The data presented in Table 1 show that the area under kharif increased progressively over recent years.

Table 1. Area under kharif crops in the project area (ha).

Crop	1975-76	1976-77	1977-78	1978-79	1979-80
Sorghum	173	169	320	320	368
Soybean	85	127	119	228	341
Maize	64	80	115	105	70
% of net cultivated area	38	54	68	65	67
Wheat (irrigated)	126	174	197	217	255
(rainfed)	546	543	508	417	532
Chickpea (irrigated)	16	29	21	30	27
(rainfed)	628	670	570	550	525
% net cultivated area	73	76	70	69	72

Introduction of improved/high-yielding crop varieties. Local varieties have been replaced by short-duration improved and high-yielding varieties (Table 2).

Table 2. Replacement of varieties.

Crops	Traditional varieties	Improved/high-yielding varieties
Sorghum	Desi, piliaola	CSH-5, CSH-6
Soybean	Kalitur	T-49, JS-2, Ankur, JS 72-44
Maize	Satha	Chandan-3, Gange 5
Wheat	Pissi, malwi	Narmada 4, Narmada 112
Chickpea	Desi	Ujjain 21, Ujjain 24

Increase in the double-cropped area. Normally double cropping is practiced where irrigation is available. But with the transfer of technology to farmers' fields the double-cropped area under rainfed conditions progressively increased with the time as shown in Table 3.

Table 3. Area under double cropping (ha).

	1975-76	1976-77	1977-78	1978-79	1979-80
Area	190	850	1050	98[a]	1224[b]
Percentage	40	68	52	49	61

[a]Late rains during September 1978 did not occur.

[b]Rains occurred during November 1979.

Increased use of fertilizer (nutrients). Fertilizer consumption increased tremendously, through introduction of improved varieties responsive to fertilizer application (Table 4).

Table 4. Fertilizer use (kg of nutrients).

Nutrient	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80
N	4260	15931	4714	16630	46126	42309
P_2O_5	3326	10630	10832	10845	51624	60372
K_2O	712	648	4090	840	1241	2708

Note: 1. Due to the high content of potash in soils, potash was not recommended. However, due to the use of IFFCO, the amount has increased.

2. Nonapplication of urea in top dressings, due to unfavorable weather conditions, resulted in less N consumption.

Adoption of intercropping. Intercropping was readily popularized as it has long been a traditional theme of Indian agriculture. Amongst the improved high-yielding varieties the following combinations became popular: sorghum (CSH-5)/pigeonpea (Hyd.2); sorghum (CSH-6)/soybean (T-49); sorghum (CSH-5)/soybean (JS-2); sorghum (CSH-2)/soybean (T-49); sorghum (CSH-6)/ soybean (JS-2); and maize (Ganga-5)/soybean (JS-2).

Increase in the average yields of kharif and rabi crops. Average yields of improved varieties of kharif and rabi crops increased considerably, as is evident from Table 5.

Table 5. Increase in the average yield (kg/ha) of principal crops.

Crop	Variety	1975-76	1976-77	1977-78	1978-79[a]	1979-80[b]
Sorghum	Local	400	420	430	250	338
	Improved	680	1770	2030	1850	1003
Maize	Local	380	417	550	350	257
	Improved	860	1300	1500	1350	572
Soybean	Local	420	417	670	550	441
	Improved	560	933	856	975	630

[a]The September rain failed.

[b]Late rains were received in November.

Average yields of main crops in the Project area vs District and State averages. Average yields of important crops in the project area, when compared with those of Indore district, and State data, were found to be higher, as revealed in Table 6.

Increase in cropping intensity. The cropping intensity increased tremendously through the adoption of appropriate technology for dryland agriculture, as shown in Table 7.

Table 6. Comparison of average crop yields in the State, Indore district, and the project area (kg/ha), 1975-76 to 1979-80.

	Sorghum	Maize	Soybean	Wheat	Chickpea
1975-76					
State	684	1150	838	854	640
District	799	720	678	719	569
Project Area:					
All varieties	540	620	490	936	508
Imp. varieties	680	860	560	1155	578
1976-77					
State	682	1101	553	766	520
District	752	941	472	1029	380
Project Area:					
All varieties	1095	859	675	1033	508
Imp. varieties	1770	1300	933	1291	575
1977-78					
State	754	831	725	911	510
District	734	641	647	1092	494
Project Area:					
All varieties	1230	1025	816	1017	538
Imp. varieties	2030	1500	889	1275	625
1978-79					
State	689	862	671	973	594
District	602	765	646	1129	704
Project Area:					
All varieties	1050	850	785	1211	583
Imp. varieties	1850	1350	863	1544	705
1979-80					
State	NA	NA	NA	NA	NA
District	NA	NA	NA	NA	NA
Project Area:					
All varieties	695	380	515	NA	NA
Imp. varieties	1003	441	534	NA	NA

NA = Not available.

Table 7. Cropping intensity % of project area vs Indore district, from project commencement.

	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80
Project area	103	108	114	131	140	131	139
Indore district	110	110	113	114	116	112	114

The cropping program on miscellaneous land

The planting of grasses, and of trees for fodder, fuel, and fruits, on steep hill slopes has resulted not only in the increase of biomass from hillocks, but also in the reduction of the rates of runoff as compared with that from bare hill slopes.

Recommended trees and shrubs.

For fodder and fuel: *Lucaena lecucocephala* (koobabool), *Sesbania aegytica*, *S. grandiflora*, *Albizzia lebek*, *A. amara*, *Acacia nilotica*, *Desmonthus virgalus*

Fruits:
- Custard apple
- Guava
- Grafted plum (ber)
- Anola, jamun, mango

Recommended grasses.

Nonlegumes:
- *Pennisetum pedicellatum* (dinanath)
- *Cenchrus ciliaris* (anjan)
- *Dicanthuim* sp. (kel)
- *Iseilema lascum* (mushel)
- *Sehima nervosum* (ponia)

Perennial legumes:
- *Stylosanthes hamata* (very aggressive)
- *S. sebra* (most drought-resistant)
- *S. guyanensis* (fast in establishment)
- Siratro
- Clitoristernato
- *Atylosia* sp.

Useful implements

The following implements were tested, evaluated, and demonstrated on farmers' fields, and were found to be suitable.

Bullock-drawn implements

Kenmore toolbar with tillage attachments
Ridgers
Moldboard plow
Disk harrows
Kenmore toolbar with tillage attachments (UK)
Agricart with tillage attachments (ICRISAT)
Tamil Nadu sweep as tillage implement
Kenmore toolbar with SISIS seeder (UK)
Agricart with Ebra planters (ICRISAT)
MP seed-cum-fertilizer drill
Tillplanter
Potato digger

Manually operated implements

Jalo cultivator (UK)
Rotary hoes
Maize sheller

Livestock improvement

Feeding. The following varieties of fodders, grasses and trees were tested, evaluated, and found to be successful.

Kharif fodder crops:	
Single cut	Sorghum Vidisha 60-1;
Multicut	Sorghum M.P. Chari, Sweet Sudan 59/3; Teosinte; and J-69.
Rabi fodder crops:	
Oats	Kent;
Berseem	Diploid and tetraploid;
Lucerne	T-9.

Increase in milk yield. Milk production, as a result of better feeding, increased by 0.40 liter/day for cows and 0.65 liter/day for buffaloes.

Upgrading of livestock. Jersey cross-breeding for local cows; Murrah cross-breeding for local buffaloes.

INCREASE IN AGRICULTURAL PRODUCTIVITY AND FARMERS' INCOME

1. Average yields of sorghum increased by over 500%, and of wheat by over 140%.

2. Investment on crops increased from Rs.388/ha to Rs.700/ha, the gross income from Rs.560/ha to Rs.1300/ha, and net income from Rs.172/ha to more than Rs.600/ha.

3. The human labor and bullock power utilization increased by over 50%. An additional utilization of about 24000 man-days and about 6000 bullock-pair days was created during 1974-75 and 1978-79.

4. The new technology requiring more labor and bullock power is better suited to small farmers, who, therefore, derived higher benefits than big farmers (Table 8).

Table 8. Benefits derived by farmers in different size groups.

Size group (ha)	Intensity of cropping (%)	Total expenditure (Rs./ha)	Gross income (Rs./ha)	Net income (Rs./ha)
Up to 2.0	163	792	1696	905
2.1-4.0	150	702	1461	759
4.1-8.0	142	736	1423	687
8.1-12.0	127	716	1283	568
Above 12.0	110	528	1035	508

5. Milk production increased by 0.40 liter/day for cows and 0.65 liter/day for buffaloes.

6. The Cooperative Society, defunct because of overdues of Rs.600,000/-, started functioning again as most dues had been paid.

7. Investment in permanent improvements increased, as indicated by the digging of about 40 new open wells.

8. The number of power threshers increased from 3 to 45. The farmers have learnt to operate and maintain their power threshers themselves.

9. Twenty cross-bred calves/heifers were produced through A.I.

CONCLUSION

Viable technology for developing mixed farming on rainfed areas of Madhya Pradesh is now available. The technology consists of a multidisciplinary approach for exploiting land and water resources on a catchment basis, by adopting appropriate land and water management practices to control soil erosion and waterlogging and to control runoff and recycle it, by the growing of crops in kharif over as much area as possible, by choosing crop varieties according to soil depth and land slope, and by improving the livestock by better feeding and upgrading it through breeding.

REFERENCES

Anonymous. 1980. Final Report (Phase I), Indo-UK Dry Farming Project (ICAR), 1974-75 to 1979-80. Indore, M.P.: J.N. Krishi Vishwa Vidyalaya Campus College of Agriculture.

Verma, G.P. 1981. Technology for rainfed farming in M.P. (unpublished).

RECOMMENDATIONS FOR ACTION

1. The available dryland farming technology is capable of producing two crops in the dependable rainfall areas of deep black soils, and of raising a single crop in the case of low-rainfall and medium and shallow black soil areas. The new technology should first be tried on a pilot basis under a development program and Central and State Agricultural Departments should take up this program. Dryland farmers must be provided with technical and financial assistance. The Government could give loans and grants to encourage the farmers. The loans could be repaid quickly if the profits reaped were significant. Credit institutions and supporting services should be made effective in benefitting small and marginal farmers. Cooperation among farmers will also have to be ensured for the implementation of soil and water conservation measures.

2. Demonstration projects, similar to the one that the Andhra Pradesh Department of Agriculture is undertaking in Medak district, or the Indo-UK Project at Indore, may be initiated. For the transfer of technology within this conceptual framework, pilot-project areas of about 10,000 ha each, preferably in the dependable rainfall areas of Madhya Pradesh, Maharashtra, Andhra Pradesh, Karnataka, and Gujarat, may also be developed. It will be worthwhile to develop cropping plans for each farm holding and arrange credit and supplies (fertilizer, seeds, etc.), including access to the wheeled tool carrier or a seed-cum-fertilizer drill that could be used on a collective ownership basis or on hire. These project sites could also be used for demonstrations to farmers, to facilitate the exchange of knowledge and experience. There is an urgent need to fabricate cheaper versions of the wheeled tool carrier developed by ICRISAT.

3. Policy-makers from the research, extension, and development agencies of Madhya Pradesh, Maharashtra, Andhra Pradesh, Gujarat, Karnataka, and Tamil Nadu should visit ICRISAT and ICAR Centers and their operational on-farm research projects in Medak district and elsewhere. A 1-3 day visit in July to September 1981 for a group of 5-10 persons from each State is suggested. This program may be coordinated by the Directorate of Extension in separate negotiation with ICRISAT in regard to the utilization of this facility for training, etc.

4. Five typical Vertisol areas in the dependable rainfall regions (>750 mm/yr) of Madhya Pradesh, Maharashtra, Andhra Pradesh, and Gujarat may be selected for setting up operational-scale research projects on different crops according to the agroclimatic conditions of the respective regions. An area of about 10-30 ha in each region is recommended. The operational project sites may also be used for the training of extension workers, soil conservationists, and farmers, by encouraging frequent visits to the sites. ICRISAT can assist in a training program organized jointly with the All India Coordinated Research Project for Dryland Agriculture.

5. The watershed approach may be adopted for the development of rainfed areas for maximum rain-harvesting and the preservation of runoff. Treatments such as the graded broadbed-and-furrow system, that facilitate the intercropping of cereals and pulses or the sequential cropping of cereal-pulse-oilseed, may be advocated because they increase the production per unit area considerably. Such development may be assisted by adopting a community approach on small holdings and an individual approach on large holdings. State Governments would identify areas wherever the above recommendations can be implemented.

6. Other components of the technology may include the following.

a. Land management practices that reduce runoff and erosion, and that give improved surface drainage with better aeration and workability of the soils.

b. Cropping systems and crop management practices that permit the establishment of the crop at the very beginning of the rainy season, make efficient use of moisture throughout the rainy and postrainy seasons, and give high sustained levels of yields.

c. Implements for cultivation, seeding, and fertilizing that enable the required land and crop management practices to be efficiently carried out.

7. Scientists of ICRISAT are of the opinion that this technology may result in achieving a food grains yield potential of at least 3 tonnes/ha on the Vertisols, provided there has been improved field drainage, dry sowing ahead of the monsoon, use of high-yielding varieties and fertilizers, use of improved seed-cum-fertilizer drills (to ensure proper seed placement and good stands), appropriate plant protection, timely harvesting, good post-harvest technology, etc.

8. Some pilot projects should be undertaken with water-harvesting structures to demonstrate the usefulness of the technology that has been evolved by ICRISAT and the ICAR Research Centers. Water harvesting might also be useful for groundnut cultivation in the Saurashtra region of Gujarat.

9. ICAR and ICRISAT may also intensify their research activities on rainfed farming and may be in constant touch with State and Central Government Departments of Agriculture for their feedback on the subject. To ensure good coordination between relevant institutions—eg., ICAR, ICRISAT, the Departments of Agriculture—Seminars such as the one currently reported should be organized more often.

ICR 81-0086