RAINFED AGRICULTURE TECHNOLOGIES FOR DIFFERENT AGRO-ECO REGIONS OF ANDHRA PRADESH

PK Mishra, M Osman, KVGK Rao and VVN Murthy

भाकृअनुप
ICAR

Central Research Institute for Dryland Agriculture
Santoshnagar, Hyderabad - 500 059.

RAINFED AGRICULTURE TECHNOLOGIES FOR DIFFERENT AGRO-ECO REGIONS OF ANDHRA PRADESH

(Proceedings of the workshop held on 24th August 2004)

Editors:

P.K. Mishra
M. Osman
K.V.G.K. Rao
V.V.N. Murthy

CENTRAL RESEARCH INSTITUTE FOR DRYLAND AGRICULTURE
Santoshnagar, Hyderabad 500 059

First Printed : December 2004

Citation:

Mishra, P.K., Osman, M., Rao, K.V.G.K. and Murthy, V.V.N. 2004. Rainfed Agriculture Technologies for Different Agro-eco Regions of Andhra Pradesh, Central Research Institute for Dryland Agriculture, Hyderabad, India, P:166.

Price: Rs. 200/-

Disclaimer:

The editors have taken utmost care to avoid errors in this publication; however, they are not accountable for the views expressed by the contributors and for the authenticity of data or information.

Printed at:
Venu Enterprises, Chikkadpally,
Hyderabad-20. Ph.: 27661538

CONTENTS

Foreword

The A.P. Water Vision created by the Government of Andhra Pradesh through the Water Conservation Mission formulated an overview of the available water resources in the State alongwith the suggestions for their efficient utilization in different water sectors. Subsequent to the release of the A.P. Water Vision in year 2003, the Government of AP has taken steps to ensure that there is a follow-up of the vision by facilitating discussions and policy initiatives involved in various water sectors.

At present, more than 50% of the cultivated area in Andhra Pradesh has no provision for irrigation facilities. In the near future, substantial area in the state will continue to be rainfed in spite of the development of irrigation facilities. In order to assist the small and marginal farmers involved in rainfed agriculture, it is essential that extension, demonstration and advisory services need to be intensified for spreading the know-how on the rainfed technologies developed by the State, Central and International research institutions. The workshop sponsored by the Water Conservation Mission, GoAP and organized by the Central Research Institute for Dryland Agriculture of the Indian Council of Agricultural Research attempts to present the doable technologies that can be practiced by rainfed farmers of Andhra Pradesh.

It is hoped that the technologies presented during the workshop and consolidated in this publication will be very much useful in supplementing the efforts being undertaken by the Department of Agriculture as well as Rural Development and other developmental agencies & NGOs in the State. It is also hoped that the Department of Agriculture will strengthen the cooperation and coordination with research institutions like CRIDA, ANGRAU, ICRISAT, and others for benefiting the farmers involved in rainfed agriculture.

We wish to record our sincere appreciation for Mr. K. Raju, Commissioner Rural Development and CEO of the Water Conservation Mission for his keen interest in the workshop and support in bringing out this publication. Finally, I complement Drs. PK Mishra, Mohammed Osman, KVGK Rao and VVN Murthy conveners of the workshop in bringing out this publication in a short time.

(YS Ramakrishna)
Director, CRIDA

December 30, 2004
Hyderabad

Acknowledgements

This publication is an outcome of the State level workshop entitled "Rainfed Agriculture Technologies for Different Agro-Eco Regions of Andhra Pradesh" held on 24th August 2004 at Central Research Institute for Dryland Agriculture, Santoshnagar, Hyderabad. At the outset, AP Water Conservation Mission needs our due appreciation for moving the idea of holding the workshop and bringing out the publication relating to rainfed technologies for the benefit of line departments and extension personnel. We are grateful to Sri. K. Raju, Commissioner, Rural Development and CEO, WCM for active cooperation and generous funding for holding the workshop and for publication of the proceedings, which will benefit all interested in greening of grey areas. We extend our sincere thanks to Dr. Y.S. Ramakrishna, Director, CRIDA for consistent support in making this workshop a successful event. We are highly indebted to all the contributors from Central Research Institute for Dryland Agriculture (CRIDA), Acharya N.G. Ranga Agricultural University (ANGRAU) and International Crops Research Institute for Semi-arid Tropics (ICRISAT), who took pains in preparation of chapters encompassing various technologies useful for the rainfed areas of Andhra Pradesh. We are grateful to all the participants for their cooperation and kind sharing of their experience on various topics. We place on record and appreciate the help of Mr. S. Raghava Sarma and Kouser Afshan in type setting of this manuscript.

We hope this publication will bridge the gap between the researchers and extension personnel and expect that a feedback will enable us to improve upon further. We look forward for the valuable suggestions so that the common goal of making rainfed agriculture as a profitable enterprise is achieved.

Organisers
CRIDA and WCM,
Hyderabad

List of Contributors

CENTRAL RESEARCH INSTITUTE FOR DRYLAND AGRICULTRUE (CRIDA) SANTOSHNAGAR, HYDERABAD - 500 059

B. VENKATESWARULU
Principal Scientist (Microbiology)

G. SUBBA REDDY
Head, Division of Crop Science

G.G.S.N. RAO
Principal Scientist (Agro. met)

G.R. KORWAR
Head, Division of Resource Management

G. Srinivasa Rao
Research Associate

J.V. RAO
Principal Scientist (Agronomy)

K.P.R. VITTAL
Project Coordinator (Dryland)

K.V. SUBRAHMANYAM
Head, Section of Transfer of Technology

M. OSMAN
Senior Scientist (Agronomy)

M.V. PADMANABHAN
Principal Scientist (S&WCE)

PRASANTA KUMAR MISHRA
Principal Scientist (S&WCE) & Workshop Coordinator

V.M. MAYANDE
Principal Scientist (FMP)

V.S. RAO
Principal Scientist (Horticulture)

Y.G. PRASAD
Senior Scientist (Entomology)

Y.S. RAMAKRISHNA
Director

Y.V.R. REDDY
Head, Section of Design and Analysis

ACHARAYA N.G. RANGA AGRICULTURAL UNIVERSITY (ANGRAU) RAJENDRANAGAR, HYDERABAD - 500 030

A. SREENIVAS RAJU
Prof.& Head, Department of S.S.&A.L. C.A.,

AUM SHARMA
Agril Engineer, FIMSC, ARI

D. RAJI REDDY
Senior Scientist (Agromet)

L. G. GIRI RAO
Principal Scientist, (Agroforestry)

M. DEVENDAR REDDY
Principal Scientist (Agronomy)
AICRP on cropping systems

M. SINGA RAO
Professor (Soil physics)

V. SATYANARAYANA RAO
Asst. Professor, Plant Breeding,
AICRP on Forage crops, LRI

INTERNATIONAL CROPS RESEARCH INSTITUTE FOR SEMI-ARID TROPICS (ICRISAT), PATANCHERU - 502 324, A .P.

P. PATHAK
Principal Scientist
(Soil & Water Conservation Engineering)

K.P.C. RAO
Principal Scientist,
(Agricultural Economics)

ANDHRA PRADESH WATER VISION

V.V.N. MURTHY
Member, APWV, MSU,
Tilak Road, Hyderabad

K.V.G.K. RAO
Member, APWV
MSU, Tilak Road, Hyderabad.

Report on the Workshop 'Rainfed Agriculture-Technologies for Different Agro-Eco Regions of Andhra Pradesh'

Introduction

In Andhra Pradesh, it is estimated that nearly 60% of the cultivated area falls under dryland agriculture and rest is irrigated. The total cultivated area is 10.7 m ha and this is spread over various agro-climatic regions of the state (Fig. 1). Rainwater conservation through watershed development is emphasized in all the agro-ecological regions of the state. It is well known that Indian agriculture is today poised for a paradigm shift from emphasis on irrigated and production centered to dryland and watershed centered for enhancing livelihood security of land owners and landless.

A brief description of different agro-ecological regions is set out in Table-1, which highlights rainfall, soil type, length of growing period (LGP) potential evaporation (PET), mean temperature of different districts. Practice of appropriate dryland technologies and other allied activities along with the rainwater conservation will boost the production and productivity in these areas. Several Research Institutions in AP like CRIDA, ICRISAT and ANGRAU are actively conducting research and have developed practices for improving productivity of drylands. Considering the national mandate of dryland agriculture of CRIDA, APWCM entrusted the responsibility of organizing one-day workshop to synthesize these learnings and disseminate them in the form of practices for use by line departments and developmental agencies.

The agenda of the workshop was to encompass all the AER regions of Andhra Pradesh; with an objective of identifying low cost, farmer friendly practices / technologies for enhancing productivity from drylands. In this endeavor, all the related R&D organizations took active part and shared their information. Topics covered were related to different aspects of rainfed agriculture right from climate change to sustainable rural livelihoods.

Scientists from CRIDA, ICRISAT and ANGRAU and the representatives from agriculture, Rural Development Ground Water and Animal Husbandry departments, WCM, MSU, APARD, Sameti, CWS, CSA and AFPRO attended the workshop held on August 24, 2004 at CRIDA, Santoshnagar, Hyderabad. Detailed deliberations and discussions were made on different topics covering changing climate, soil and water conservation, crops and cropping system, alternate land uses, land use diversification and economics of different enterprises.

Table: 1 Extended Legend of Agro-ecological Subregions (AER) of Andhra Pradesh

Agro -eco region	Agro-eco sub region	Area (m ha)	L.G.P. (days)	Brief Description	Distribution	Rainfall (mm)	PET (mm)	Mean Temp. (°C)
3	3.0	4.9	60-90	Deccan (Karnataka) Plateau, hot arid ecosystem with mixed red and black soils and GP 60-90 days	A.P.: Anantapur	400-500	1800-1900	27-28
6	6.2	12.6	120-150	Deccan (E. Maharashtra), Northern Karnataka Plateau), hot semiarid ecosystem with shallow black soils (deep and medium black soils as inclusion) and GP 120-150 days	A.P.; Nizamabad, Adilabad	700-1000	1700-1900	26-27
7	7.1	3.9	90-120	Deccan (Telengana, Eastern Ghat) Plateau hot semi-arid ecosystem with mixed red and black soils and GP 90-120 days and GP 90-120 days	A.P.: Cuddapah, Kurnool	700-750	1800-1900	28-29
	7.2	9.2	120-150	Deccan Telengana, Plateau hot semi-arid ecosystem with mixed red and black soils and GP 120-150 days and GP 90-120 days	A.P.: Karimnagar, Ranga Reddy, Hyderabad, Warangal, Khammam, Mahboobnagar, Nalgonda, Medak	700-1000	1600-1800	25-29
	7.3	3.4	150-180	Eastern Ghat, hot, moist semi-arid dry sub humid ecosystem with mixed red and black soils and GP 150-180 days and GP	A.P. Western parts (highlands) of Eluru (W. Godavari and Krishna (Machilipatnam) Guntur and Ongole (Prakasam) and Nellore (NC parts)	800-1000	1500-1800	24-25
8	8.3	8.9	120-150	Eastern Ghat (T.N. Uplands), hot semi-arid ecosystem with Red Loamy soils and GP 120-150 days	A.P: Chittoor	550-1000	1400-1600	23-25
12	12.2	3.3	180-210	Eastern Ghat, hot moist sub humid ecosystem with Red and Lateritic soils and GP 180-210 days	A.P. Western highlands of Visakhapatnam	1400-1700	1400-1600	26-27
18	18.3	2.0	150-180	Eastern Coastal Andhra Plan, hot dry sub humid ecosystem with coastal and deltaic alluvium-derived soils and GP 150-180 days	A.P. Coastal plain of W. Godavari, Krishna and Guntur, Prakasam and Nellore	1000-1100	1700-1800	28-29
	18.4	3.2	180-210	Eastern Coastal (Utkal) Plain, hot dry sub humid ecosystem with coastal and deltaic alluvium-derived soil and GP 180-210 days	A.P Srikakulam, Coastal plains of E. Godavari (Kakinada), Visakhapatnam, Vizianagaram	1200-1500	1600-1700	26-27

Source: Abstracts from NBSS&LUP, Publication No:35

Fig. 1. Agro-Ecological Subregions of India and Andhra Pradesh

Source : NBSS & LUP, Nagpur

Workshop Sessions

During the inaugural address Shri K. Raju, IAS, Commissioner, RD conveyed that the State government has formulated Agriculture Commission to deal with the challenges and to guide the government. The government is fully aware of the disparity for dryland agriculture and would like to equate with the irrigated agriculture. The State government is having a concern for decline in growth rate of agriculture and would like to boost for achieving food security. Director CRIDA, Dr. Y. S. Ramakrishna informed that CRIDA is actively focusing on knowledge-based support to dryland farmers and is working on end to end solutions by actively collaborating with line department, ANGRAU, ICRISAT, NGOs, & Banks. Dr. P. K. Mishra, workshop coordinator, presented a brief of the topics covered in the workshop and their relevance to the Agriculture department in the context of action program of Water Conservation Mission.

Session I

Chairman : Sri K Raju, IAS, Commissioner RD & CEO, WCM
Co-Chairman : Dr. KVGK Rao Member, A.P. Water Vision Task Force
Rapporteur : Dr. GR Korwar Head, Division of Resource Management, CRIDA

During the Session there were five presentations, viz.:

1. Weather variability and its influence on Agriculture in AP. G.G.S.N. Rao (CRIDA) & D. Raji Reddy (ANGRAU)
2. Rainwater conservation and management for drought proofing in AP. P.K. Mishra (CRIDA), P. Pathak (ICRISAT) & M. Singa Rao (ANGRAU)
3. Appropriate crops and cropping systems for different AESRs of AP. M. Devender Reddy (ANGRAU) & G. Subba Reddy (CRIDA)
4. INM for efficient crop management in AP. A. Srinivas Raju (ANGRAU) & K.P.R. Vittal (CRIDA)
5. Rainfed horticulture in different AESRs of AP... J.V.Rao & V.S. Rao (CRIDA)

Dr GGSN Rao presenting on weather variability said in arid and semiarid regions temperature and radiation are not limiting for crop production, but the soil moisture is a critical limiting factor. The rainfall analysis shows increase in annual rainfall during 1990-1999 decade over the previous one. But, the distribution has changed, with July rainfall showing negative trend and September and October rains showing positive trends during the decade. These have significant effects on the crop yields. Viz., Sept. rains have positive influence on maize yields in Medak district, and in Anantapur district July rainfall is required for groundnut sowing, as the crop should come to reproductive stage in Sept. which is an assured rainfall month. In the discussion it came out that, actual rainfall in Anantapur has increased, but, the distribution in June, July and August is not favorable (more CV) and Sept. –Oct rainfall is reliable (less CV). In view of the decreased rainfall in Northern Telangana in recent years there is needed to work out strategies for better agricultural planning.

Dr PK Mishra discussed about in-situ (conservation furrows etc.) and ex-situ (dug out ponds etc.) rainwater conservation. A simple practice like across the slope cultivation resulted in 15% reduction in run-off. He discussed about the meteorological, hydrological and agricultural drought. He also emphasized about the watershed plus activities (livelihood options). Contour maps + Cadastral maps were more convincing to the farmers, than contour maps alone.

Dr. Devender Reddy spoke on the appropriate crops and systems for AP. Rice is for the coastal region, pearl millet for tribal zones and sorghum for the Rayalaseema region. Quoting an example of Mustabad Mandal where it rained only 464 mm to 640mm, as against 675 to 783 in Karimnagar for the years 1992 to 1994, he said our recommendations should be Mandalwise. Farming systems should consist of crops, trees, dairy, sheep, goat and back yard poultry.

Dr Sreenivasaraju speaking on INM said farmers are aware of fertilizers, manures and the ideal ratio of 4:2:1 of N, P_2O_5 and K_2O, however at all India level the consumption was in the ration of 6.8:2.5:1. In rainfed areas the fertilizer use is mostly monsoon dependent. Nutrient use efficiency is very low, N-40-60%, P-15-25%, K- 50% and Zn -2%. He suggested cropping with cereals + pulses to have net positive balance of NPK after cropping.

Dr JV Rao spoke on rainfed Horticulture. He laid emphasis on *in-situ* grafting in rainfed areas. He said the B: C ratios are highest with agri-horti systems as compared to other systems. In the discussion an important came up, viz., quantity of water required for different species in different regions.

Session II

Chairman : **Dr VVN Murthy**
Member, A.P. Water Vision Task Force

Co-Chairman : **Dr M Singa Rao, Professor (Soil Physics), ANGRAU**

Rapporteur : **Dr JV Rao, Principal Scientist (Agronomy), CRIDA, Hyderabad**

During the Session there were seven presentations, viz.:

6. Identification of efficient/appropriate fodder crops and trees for different AESRs in AP. G.R.Korwar (CRIDA) & Satyanarayana Rao (ANGRAU)
7. Land use diversification – agroforestry systems suiting different AESRs of AP. M.Osman (CRIDA) & L.G.Giri Rao (ANGRAU)
8. Efficient farm implements for different agricultural operations in rainfed areas of AP. V.M.Mayande (CRIDA) & Aum Sharma (ANGRAU)
9. Principles and practices for low external input sustainable agriculture in the context of AP. B.Venkateswarlu & Y.G.Prasad (CRIDA)
10. On-going efforts on NRM related livelihood issues. K.V.Subrahmanyam & Y.S.Ramakrishna (CRIDA)

11. Economic viability and acceptability of dry-farming technologies Y.V.R. Reddy (CRIDA)
12. Viability of Dryland Farming in AP. K.P.C. Rao (ICRISAT)

The presentations received much appreciation as evidenced from detailed discussion on each aspect. The major points emerging from the deliberations were:

- Shortage of fodder in many regions particularly where milch cattle population is more. The area under fodders should be raised substantially (at least to 5% from the present 1% area). Similarly quality seed of fodder crops is not readily available in sufficient quantities, eg: stylo/cenchrus, Guinea grass, Desmanthes. Awareness programmes need to be promoted for fodder development.
- Promotion of fodder yielding trees like Leucaena, *Hardwickia binata* on boundaries is needed. More awareness programmes and needed through training, extension, visits for promoting trees on farmers' fields.
- Open grazing by stray cattle is becoming a great menace and social awareness programmes are needed to protect the vegetation.
- Economic analysis of Alternative Land use Systems must be done to compare various production systems in drylands.
- It was suggested to promote selective mechanization and custom hire service so that small and marginal farmers also can afford it in view of shortage of draft power for important operations. Mechanization also should be promoted where the holding size is large.
- Encouragement should be given for weather-based insurance instead of crop based in dryland areas.

Wrap-up Session: Outcome of Workshop Deliberations

Chairman : Dr. SP Wani, Principal Scientist (Watersheds)

Co-Chairman : Dr. GR Korwar, Head, DRM

Rapporteur : Dr. M Osman, Senior Scientist (Agronomy), CRIDA, Hyderabad

About 350 million live below poverty line in India and urbanization is going to continue. Now China is facing a deficit in food production and a similar situation might arise if investment in rainfed agriculture is neglected. Quota system in the new World Trade agreement will go in 2005, garments industry is likely to benefit but not agriculture. Distortions have been brought to dryland agriculture by subsidizing paddy, even sorghum growers have moved over to paddy. Markets are also oriented to irrigated agriculture and the protection of irrigated crops has resulted in gross neglect of rainfed crops. Moreover there is a need of shift in thinking process and knowledge based support system is the need of hour. All farmers don't know all the technologies, more so with extension people, even Agricultural Universities need to up-date. We know what to do but don't know how do it, and how to scale them up.

A large investment has been made in major irrigation reservoirs but when it comes to watershed, insisting for contribution from poor farmers in different programmes is undesirable. Agriculture in rainfed areas is not a commercial enterprise and it is gambling with nature. Most farmers are in fact losing and are able to just make two meals from their hard labour. Support from private sector, industries, R&D organizations need to be encouraged, while work in isolation to be discouraged. More we hear about dryland agriculture more is the complexity. Generalization has to be avoided and same with the policies. Investment in capacity building and infrastructure has to go up. More deliberations and brain storming involving primary and secondary stakeholders is the need of hour for creating enabling environment and suitable policy frame work for upscaling relevant technologies. Demand is un-predictable as well as production but the technology has to be demand driven but not supply oriented. About 8 to 10 watersheds in the drought prone districts of Andhra Pradesh may be identified for use as laboratory for researchers and developmental workers as well. The field officials should take the advantage of ICRISAT, CRIDA and ANGRAU for translating and adoption of technology in a participatory mode.

The program ended with vote of thanks by Dr. M Osman.

Weather Variability and its Influence on Agriculture in Andhra Pradesh

G.G.S.N. Rao, D. Raji Reddy, Y.S. Ramakrishna and G. Srinivasa Rao

Abstract

Rainfall is the major limiting weather variable that plays an important role in deciding the yield levels of various crops. Andhra Pradesh represents a transition from tropical to sub tropical India and knowledge of rainfall characteristics is essential for better crop planning. The results of the study indicates that 68 per cent of annual rainfall is received during South West monsoon, 22 per cent during North East monsoon and 9 per cent during winter and hot weather months. A shift in rainfall pattern has been noticed in some regions of peninsular India and attempts have been made to investigate whether such shifts are also noticed in the districts of Andhra Pradesh. For this study, district-wise annual and monthly mean rainfall data of Andhra Pradesh over the past 40 years (1960 to 1999) was analyzed by working out 10 years moving average. The results revealed that in Northern Telangana districts, the annual rainfall increased over the years till 1989 and then the annual rainfall during the Decade – IV (1990 to 1999) decreased when compared either with the Decade – III (1980 to 1989) or with the three decadal mean (1960 to 1989). The rainfall trend in Coastal and Rayalaseema districts of Andhra Pradesh indicated that more or less there was an increase in rainfall during the decade III over IV and IV over three decadal mean, except in Anantapur district, where less variation observed. The results further indicated that though the annual rainfall is more or less similar in North Coastal and North Telangana districts, the assured rainfall is less (6 to 45 mm) in North Telangana districts particularly in the month of October compared to North Coastal districts where it ranged between 70 to 100 mm indicating the extended period of growing season (by a month). The dependable rainfall in Anantapur district is 90 mm only in September and 56 mm in October where as in other months the rainfall is more erratic.

Introduction

Crop growth and the sequence of crops grown during a year are determined by the interactions of climate, soil, plant and management practices. Any crop grows when a minimum requirement of plant growth factors such as water, energy, nutrients and mechanical support is available. Amongst the various factors, weather plays a major role, particularly rainfall, solar radiation and temperature. In rainfed agriculture, rainfall is the major limiting weather variable that plays a significant role in deciding the yield levels of various crops.

Table 1: Mean annual rainfall distribution in Andhra Pradesh

District	SW	NE	SM	SW+NE	ANNUAL
Srikakulam	771	311	129	1082	1211
Visakhapatnam	646	280	159	926	1085
Vizianagaram	712	260	169	972	1141
East Godavari	703	302	111	1005	1116
West Godavari	755	267	86	1022	1108
North Coastal (Avg.)	**717**	**284**	**131**	**1001**	**1132**
North Coastal (%)	**63**	**25**	**12**	**88**	**100**
Guntur	557	233	89	790	879
Krishna	669	238	88	907	995
Prakasam	355	314	111	669	780
Nellore	318	625	86	943	1029
South Coastal (Avg.)	**475**	**353**	**94**	**827**	**921**
South Coastal (%)	**52**	**38**	**10**	**90**	**100**
Coastal Andhra (Avg.)	**610**	**314**	**114**	**924**	**1038**
Coastal Andhra (%)	**59**	**30**	**11**	**89**	**100**
Chittore	414	357	140	771	911
Anantapur	304	149	87	453	540
Cuddapah	400	239	80	639	719
Kurnool	438	123	73	561	634
Rayalaseema (Avg.)	**389**	**217**	**95**	**606**	**701**
Rayalaseema (%)	**55**	**31**	**14**	**86**	**100**
Adilabad	938	78	49	1016	1065
Karimnagar	821	94	61	915	976
Medak	776	87	72	863	935
Nizamabad	922	70	56	992	1048
Warangal	878	114	74	992	1066
Khammam	943	127	98	1070	1168
North Telangana (Avg.)	**880**	**95**	**68**	**975**	**1043**
North Telangana (%)	**84**	**9**	**7**	**93**	**100**
Hyderabad	593	119	82	712	794
Mahabubnagar	628	88	54	716	770
Nalgonda	557	130	66	687	753
Ranga Reddy	704	104	67	808	875
South Telangana (Avg.)	**630**	**111**	**67**	**740**	**808**
South Telangana (%)	**78**	**14**	**8**	**92**	**100**
Telangana (Avg.)	**780**	**101**	**68**	**881**	**949**
Telangana (%)	**82**	**11**	**7**	**93**	**100**
Andhra Pradesh (Avg.)	**645**	**205**	**91**	**850**	**941**
Andhra Pradesh (%)	**68**	**22**	**10**	**90**	**100**

Andhra Pradesh represents a transition climate zone from tropical to sub tropical India. The climate is predominantly semi arid to arid except in the coastal belt, which has humid to sub humid climate. Occurrence of rainfall in Andhra Pradesh is influenced both by South West and North East monsoon. The annual normal rainfall of the state is 941 mm, varying from about 500 mm in Anantapur district of Rayalaseema region to 1200 mm in North Coastal and Northern Telangana districts of the state.

The South West monsoon establishes over Andhra Pradesh during the second week of June (normally by June 10). Withdrawal of South West monsoon begins from last week of September and it retreats South of Andhra Pradesh by the end of October. At about the same time, the North East monsoon sets in and the activity of the North East monsoon is generally confined to Coastal and Rayalaseema regions of Andhra Pradesh.

Knowledge of rainfall characteristics over a region is essential for better crop planning. In this direction an attempt has been made to analyze the rainfall characteristic features of Andhra Pradesh at district level.

The distribution of annual rainfall in the state as a whole is about 68 per cent during South West monsoon, 22 per cent during North East monsoon and 9 per cent during winter and hot weather months (Table 1).

Region-wise rainfall analysis indicate that Telangana, Coastal and Rayalaseema regions of the state receive 82, 59 and 55 per cent of the annual rainfall respectively during South West monsoon (Table 1). The North East monsoon contributes only 11 per cent in Telangana region while the Coastal and Rayalaseema region receive over 30 per cent of the annual rainfall during this period.

Rainfall pattern in different region of Andhra Pradesh

The South Coastal region receives an annual rainfall of 921 mm, of which about 475 mm is received in the South West monsoon, while North East monsoon rainfall contributes about 353 mm. In most of the years July, August and September months receive more than 150 mm per month in this region.

North Coastal region receives an annual rainfall of about 1132 mm, of which about 717 mm is received in the South West monsoon season, while North East monsoon contributes about 284 mm. The distribution of rainfall is better in North Coastal region as it benefits from both South West and North East monsoon and the average rainfall is in the range of 150-200 mm during these five months starting from June.

North Telangana region receives an amount of 1043 mm, of which about 85 per cent is derived from South West monsoon, while North East monsoon contributes only 9 per cent of annual rainfall. In this region, the rainy season abruptly ends by the first week of October. This region receive about 200-250 mm of rainfall during July and August months, June and September months more or less receive the same amount of rainfall of about 150 mm.

Similar to North Telangana, South Telangana region receives an annual rainfall of about 790 mm, of which major contribution is from South West monsoon. In most of the years (about 60% of the years) this zone does receive a rainfall about 150 mm per month for consecutive three months starting from July.

Rayalaseema region receives the lowest annual rainfall of about 666 mm in the state, of which about 56 per cent is derived from South West monsoon and 31 per cent from North East monsoon. September and October months are considered to be wettest months in the zone.

Rainfall pattern in different districts of Andhra Pradesh

North Coastal and North Telangana districts receive highest annual rainfall of about 950-1200 mm. Though the quantum of annual rainfall is same in both the regions, the distribution pattern is quite contrast. Rainfall is evenly distributed and continues up to November in North Coastal districts while in North Telangana districts, higher rainfall of 950-1200 mm is received in just four months.

Table 2. District-wise annual rainfall trends in Andhra Pradesh (1960 -99)

	1960-69	1970-79	1980-89	1990-99	Mean	Increase / decrease of rainfall (mm)			
District/Decade	I	II	III	IV	1960-89	II over I	III over II	IV over III	IV over 3Dec. Mean (1960-89)
East Godavari	1049	1122	1071	1351	1081	72	-50	280	270
Srikakulam	1083	1055	1123	1186	1087	-28	68	63	99
Visakhapatnam	959	1086	1053	1296	1032	128	-34	243	263
West Godavari	1065	1034	1108	1281	1069	-31	74	173	212
Guntur	915	840	837	998	864	-75	-3	161	134
Krishna	993	950	964	1057	969	-43	13	94	88
Nellore	1101	1067	1064	1236	1077	-34	-3	173	159
Ananthapur	531	573	563	555	556	42	-10	-8	-1
Cuddpah	660	747	671	755	693	88	-77	84	62
Chittore	774	890	832	1052	832	115	-58	220	220
Kurnool	568	703	653	710	641	134	-50	57	69
Medak	932	903	995	869	943	-29	92	-126	-75
Adilabad	1001	980	1211	1117	1064	-21	231	-94	53
Nizamabad	1001	989	1250	1061	1080	-12	261	-189	-19
Khammam	1056	1027	1157	1133	1080	-29	130	-24	53
Karimnagar	864	938	1048	932	950	75	110	-117	-18
Warangal	1072	938	1081	1000	1030	-134	143	-81	-30
Nalgonda	750	776	728	737	749	25	-56	17	-11
Mahabubnagar	734	730	692	681	718	-4	-38	-11	-38
Hyderabad	846	888	812	838	849	42	-76	26	-11

Long term data of Vizianagaram, East Godavari, Prakasam and Ranga Reddy districts is missing.

South Coastal districts receive an annual rainfall of 800-1000 mm. These districts are benefited both by South West and North East monsoons. In Prakasam district the contribution of South West and North East is almost equal while in Nellore the contribution of North East monsoon is about 60-65 per cent. Guntur and Krishna districts receive 75 per cent annual rainfall through South West and 25 per cent through North East monsoon. These districts are frequently prone to cyclones during November month.

Rayalaseema districts receive an annual rainfall of 500-900 mm, lowest is being at Anantapur district while the highest is in Chittoor district. The rainfall distribution in these districts is quite erratic. Anantapur district receive lowest rainfall in the state. Whereas, drought prone South Telangana districts viz., Nalgonda and Mahaboobnagar receive an annual rainfall of 800-850 mm and experience dry spells in most of the years.

In most of regions in the peninsular India, a shift in rainfall pattern has been noticed. Therefore an attempt has been made in this study to find out the districts where in such shifts are noticed.

To obtain this information, the district-wise annual and monthly mean rainfall data of Andhra Pradesh over the past 40 years (1960 to 1999) was analyzed by working out 10 years moving average and the results are presented in Tables 2 and 3. The 40 years period was divided into 4 decades i.e., Decade – I (1960 to 1969), Decade – II (1970 to 1979), Decade – III (1980 to 1989) and Decade – IV (1990 to 1999) for better comparison.

The results presented in Table 2 revealed that in Northern Telangana districts, the annual rainfall increased over the years till 1989. It is also interesting to note that the annual rainfall during the Decade – IV (1990 to 1999) was decreased when compared either with the Decade – III (1980 to 1989) or with the three decadal mean (1960 to 1989) in the above districts. It was also noticed that the rainfall variation was very high between III and IV decade. The annual rainfall trend pattern in Coastal and Rayalaseema districts, indicated that more or less there was an increase in rainfall during the decade III over IV and IV over three decadal mean, except Anantapur district, wherein less variation was observed. There was a decrease in rainfall trend during the decade II over I in the districts like Srikakulam, West Godavari, Krishna, Guntur and Nellore in Coastal AP, Medak, Adilabad, Nizamabad, Khammam and Warangal in Telangana districts. The analysis revealed that the year-to-year variation is very high in the districts like Hyderabad, Mahabubnagar, Nalgonda and all the four districts in Rayalaseema (Fig. 1 to 5).

Monthly rainfall trends

Decadal variability of monthly rainfall is presented in Table 3 and is explained below:

A) June:

Month-wise rainfall deviation indicated that there was a decrease in rainfall in the districts of Hyderabad, Medak, Nizamabad, Karimnagar, Warangal and Nalgonda during

Table 3: District-wise monthly rainfall trends in Andhra Pradesh (1960-99)

District/Decade	1960-69	1970-79	1980-89	1990-99	Mean of	Increase / decrease of rainfall (mm)			
	I	II	III	IV	1960-89	II over I	III over II	IV over III	IV over 3 Dec. Mean
June									
Srikakulam	138	147	143	134	143	9	-3	-9	-9
Visakhampatam	100	138	117	141	118	38	-21	24	23
East Godavari	110	136	127	137	1240	26	-9	10	13
West Godavari	112	134	131	126	125	22	-3	-5	1
Krishna	116	122	105	103	114	6	-16	-2	-11
Guntur	93	86	88	89	89	-7	2	0	-1
Nellore	54	42	34	68	43	-13	-8	35	25
Chittoor	58	60	50	94	56	2	-11	45	38
Cuddapah	63	63	53	82	60	0	-10	30	23
Anantapur	48	44	52	62	48	-3	8	10	14
Kurnool	70	75	71	84	72	6	-4	13	12
Mahaboobnagar	107	83	81	80	90	-24	-2	-1	-10
Hyderabad	105	123	128	94	119	18	5	-34	-25
Medak	112	138	145	110	132	25	8	-35	-22
Nizamabad	132	150	191	162	158	17	41	-29	4
Adilabad	144	164	173	195	160	20	9	22	35
Karimnagar	109	155	163	146	142	45	9	-17	4
Warangal	143	145	169	126	153	2	24	-43	-27
Khammam	138	159	148	137	148	21	-10	-11	-11
Nalgonda	98	108	106	78	104	9	-1	-28	-26
July									
Srikakulam	208	160	191	186	186	-48	31	-5	0
Visakhampatam	152	132	173	188	152	-19	41	15	-35
East Godavari	223	169	220	218	204	-54	51	-5	-14
West Godavari	257	174	250	242	227	-83	76	-7	-16
Krishna	22	16	24	18	21	-6	8	-6	3
Guntur	135	120	195	130	150	-15	75	-64	20
Nellore	90	87	103	85	93	-3	16	-18	8
Chittoor	80	108	118	90	102	28	10	-28	12
Cuddapah	101	91	118	81	103	-10	27	-37	23
Anantapur	57	51	89	53	65	-6	38	-36	12
Kurnool	101	91	137	88	110	-10	46	-38	11
Mahaboobnagar	191	121	173	126	162	-70	51	-47	36
Hyderabad	212	151	201	150	188	-62	51	-52	38

District/Decade	1960-69	1970-79	1980-89	1990-99	Mean of	Increase / decrease of rainfall (mm)			
	I	II	III	IV	1960-89	II over I	III over II	IV over III	IV over 3 Dec. Mean
Medak	264	191	279	176	245	-73	88	-103	69
Nizamabad	307	238	364	253	303	-69	125	-111	50
Adilabad	274	261	378	289	304	-12	117	-89	15
Karimnagar	216	227	314	241	252	12	87	-83	11
Warangal	299	237	316	256	284	-62	79	-60	28
Khammam	307	253	324	286	295	-54	71	-38	9
Nalgonda	148	124	180	127	151	-23	56	-53	23
August									
Srikakulam	166	191	184	180	180	25	-7	-4	0
Visakhampatam	112	172	172	180	152	61	0	8	28
East Godavari	147	189	221	187	186	42	33	-35	1
West Godavari	175	207	258	214	213	32	51	-44	1
Krishna	161	189	198	186	183	28	9	-12	3
Guntur	108	155	143	159	135	47	-12	16	23
Nellore	79	93	101	89	91	14	7	-12	-2
Chittoor	83	108	96	122	96	25	-11	26	26
Cuddapah	82	115	105	109	101	33	-10	4	8
Anantapur	93	70	73	88	78	-22	2	15	9
Kurnool	90	131	130	139	116	44	-1	10	23
Mahaboobnagar	137	181	138	138	152	43	-43	1	-13
Hyderabad	130	219	157	195	169	89	-62	39	27
Medak	155	241	240	229	212	86	-1	-10	18
Nizamabad	209	300	337	287	282	91	37	-51	5
Adilabad	242	267	343	294	284	26	76	-49	10
Karimnagar	172	219	279	217	223	47	60	-62	-7
Warangal	204	208	268	228	227	4	60	-40	1
Khammam	203	229	303	253	245	25	74	-50	8
Nalgonda	117	163	137	135	139	47	-27	-1	-4
September									
Srikakulam	210	176	185	196	190	-35	9	11	6
Visakhampatam	217	202	200	213	206	-15	-2	14	7
Nalgonda	90	128	83	129	100	38	-45	46	29
October									
Srikakulam	210	176	185	196	190	-35	9	11	6
Visakhampatam	217	202	200	213	206	-15	-2	14	7
East Godavari	193	211	169	261	191	18	-42	92	70

District/Decade	1960-69	1970-79	1980-89	1990-99	Mean of	Increase / decrease of rainfall (mm)			
	I	II	III	IV	1960-89	II over I	III over II	IV over III	IV over 3 Dec. Mean
West Godavari	151	174	149	221	158	23	-25	71	62
Krishna	154	159	127	210	147	5	-32	84	64
Guntur	133	147	115	188	132	14	-32	73	56
Nellore	225	302	191	283	239	77	-112	93	44
Chittoor	145	186	119	190	150	41	-67	71	39
Cuddapah	123	161	101	150	128	38	-60	49	22
Anantapur	99	128	77	127	101	29	-51	50	26
Kurnool	80	133	72	147	95	53	-61	75	51
Mahaboobnagar	63	113	62	117	80	50	-51	55	38
Hyderabad	58	136	85	135	93	78	-52	51	42
Medak	75	96	70	122	80	22	-27	52	41
Nizamabad	48	87	79	150	72	39	-8	70	78
Adilabad	68	85	68	119	73	17	-17	52	46
Karimnagar	68	100	65	100	78	32	-35	35	22
Warangal	84	108	82	107	91	24	-26	25	16
Khammam	91	113	105	136	103	22	-8	31	33
Nalgonda	90	128	83	129	100	38	-45	46	29
East Godavari	193	211	169	261	191	18	-42	92	70
West Godavari	151	174	149	221	158	23	-25	71	62
Krishna	154	159	127	210	147	5	-32	84	64
Guntur	133	147	115	188	132	14	-32	73	56
Nellore	225	302	191	283	239	77	-112	93	44
Chittoor	145	186	119	190	150	41	-67	71	39
Cuddapah	123	161	101	150	128	38	-60	49	22
Anantapur	99	128	77	127	101	29	-51	50	26
Kurnool	90	133	72	147	92	53	-61	75	51
Mahaboobnagar	63	113	62	117	80	50	-51	55	38
Hyderabad	56	136	85	135	93	78	-52	51	42
Medak	75	96	70	122	80	22	-27	52	41
Nizamabad	48	87	79	150	72	39	-8	70	78
Adilabad	68	85	68	119	73	17	-17	52	46
Karimnagar	68	100	65	100	78	32	-35	35	22
Warangal	84	108	82	107	91	24	-26	25	16
Khammam	91	113	105	136	103	22	-8	31	33

the IV decade ending 1999 over III decade ending 1989. The districts of Hyderabad, Medak, Warangal and Nalgonda received less rainfall during the IV decade over the three decadal mean.

B) July:

Decrease in rainfall has been observed in almost all the districts except in 5 North Coastal districts and Krishna in South Coastal zone during the decade IV over the III decade. However, the same is not reflected when compared with 3 decadal mean.

C) August:

The districts of East and West Godavari, Krishna, Nellore, Medak, Nizamabad, Karimnagar, Warangal and Khammam did receive low rainfall during the IV decade compared to III decade. There was not much variation between IV and three decadal mean.

D) September and October:

All the districts in the state did receive increasing rainfall during the decade ending 1999 over the decade ending 1989 and three decadal mean during both the months.

Dependable rainfall in different districts of Andhra Pradesh

Since monthly mean rainfall may not provide clear picture for agricultural planning, the dependable rainfall as per Hargreaves (1984) approach was worked out for each month (district-wise) to indicate the minimum possible or assured rainfall (Yegeswara Rao and Raji Reddy, 1993) of the district in a month and the results are presented in Table 4. Seventy five per cent probability is generally accepted as a reasonable risk value for most of the agricultural management decisions (Raji Reddy, 1995). The results of the analysis indicated that though the mean annual rainfall is more or less similar in North Coastal and North Telangana districts the assured rainfall is less (6 to 45 mm) in North Telangana districts particularly in the month of October compared to North Coastal districts where it ranged between 70 to 100 mm indicating the extended period of growing season (by a month). The dependable rainfall in Anantapur district is 90 mm only in September and 56 mm in October where as in other months the rainfall is more erratic.

Relationship between rainfall and yields of selected crops

As a case study, relationship between yield and rainfall was worked out in respect of Medak and Anantapur are presented hereunder.

A) Maize:

The relationship between grain yield of maize and September rainfall of Medak district indicated that there was a close and positive association between rainfall and final grain yield, which normally coincides with critical reproductive phase i.e., silking and grain filling stages (Fig. 6).

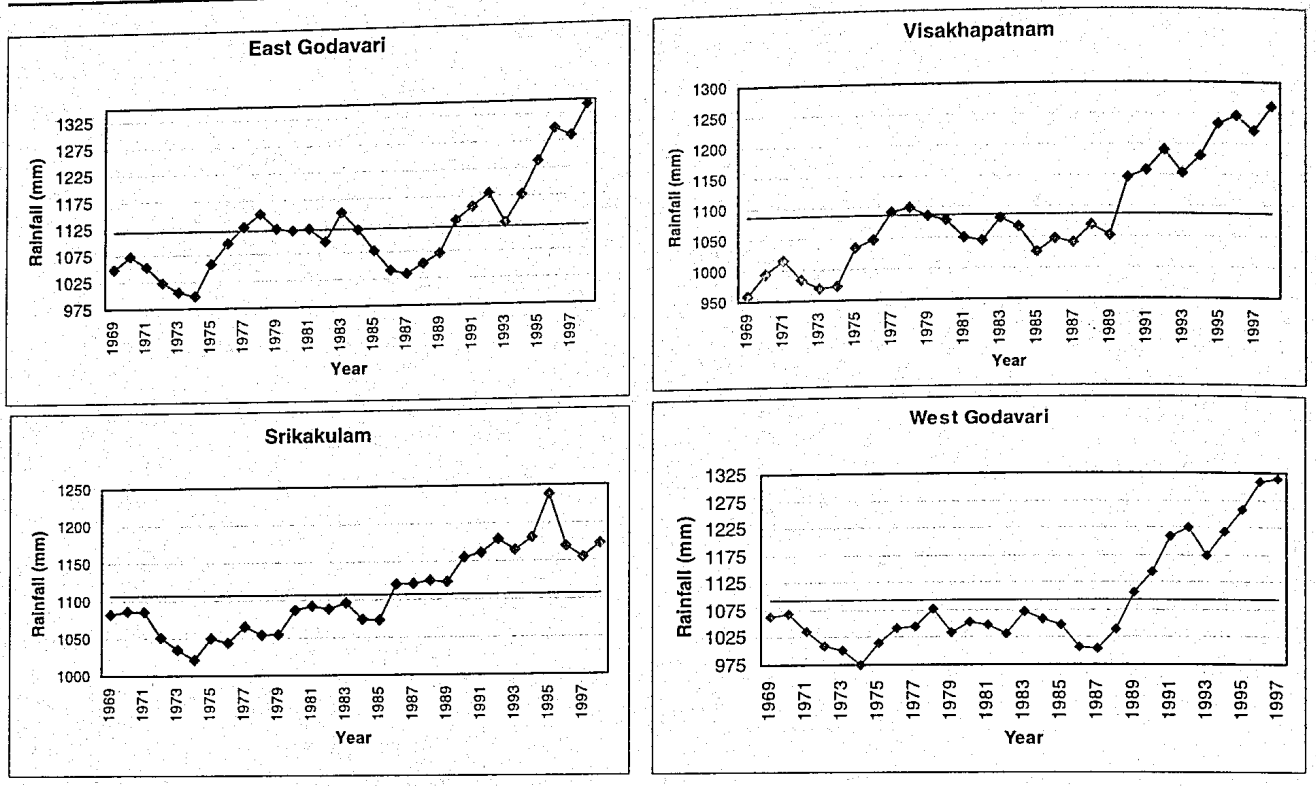


Fig. 1. Rainfall Trends in North Coastal Districts (10 year moving average)

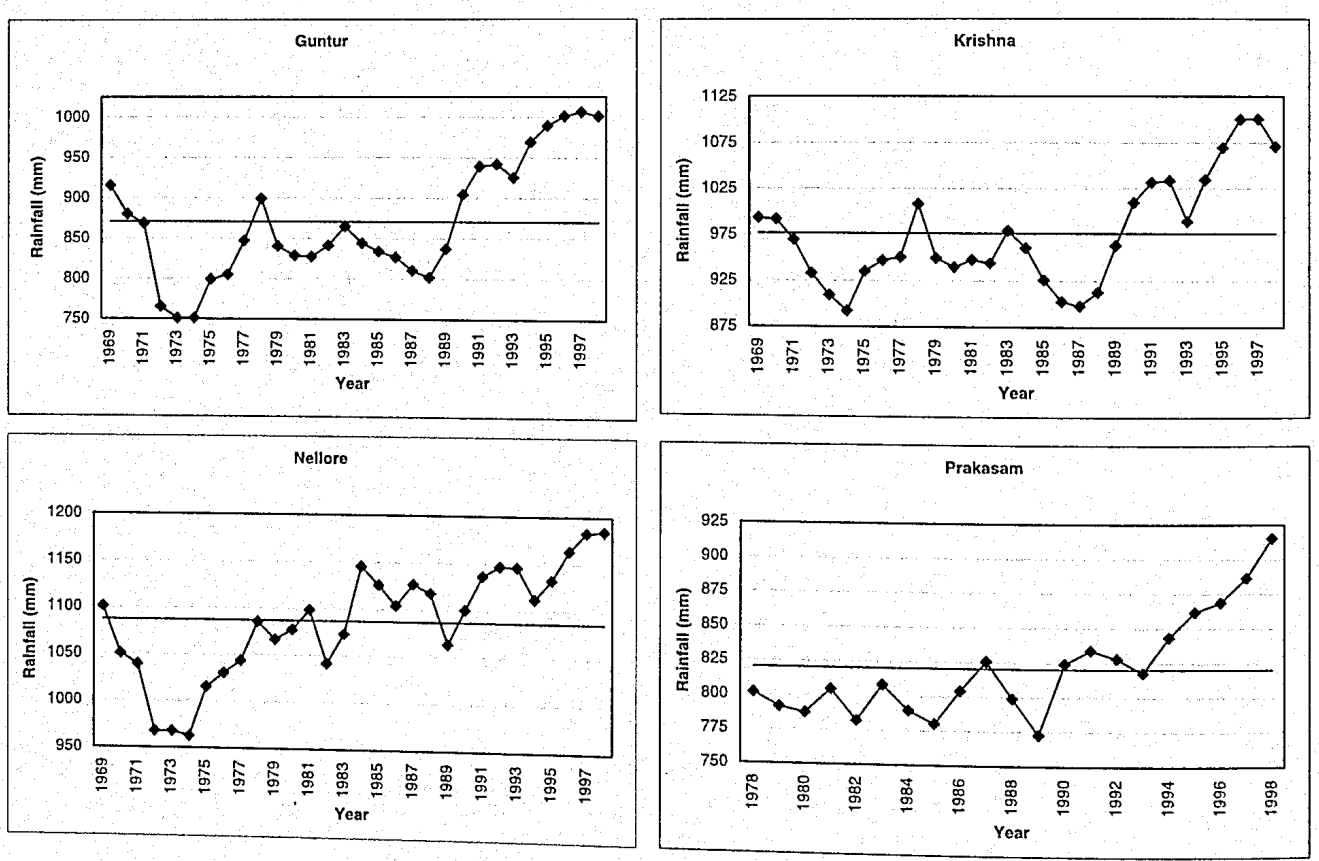


Fig. 2. Rainfall Trends in South Coastal Districts (10 year moving average)

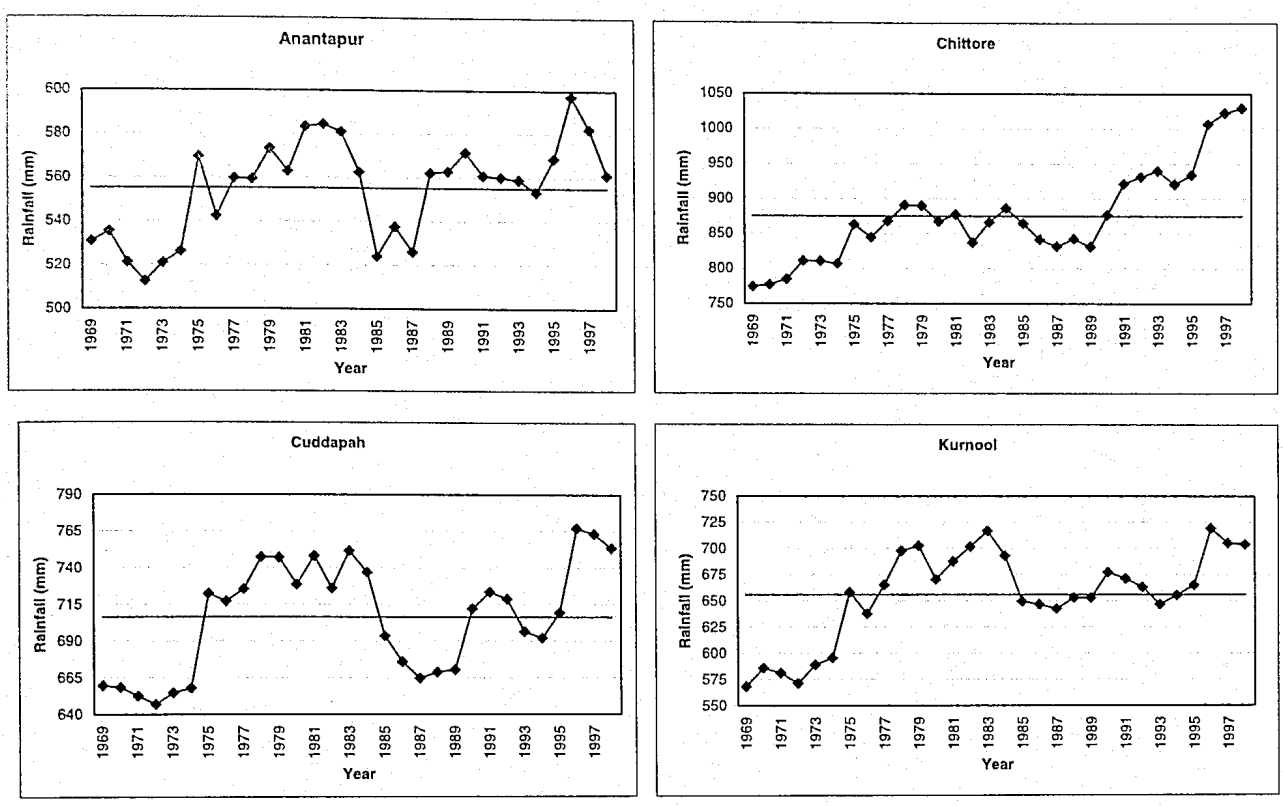


Fig. 3. Rainfall Trends in Rayalaseema Districts (10 year moving average)

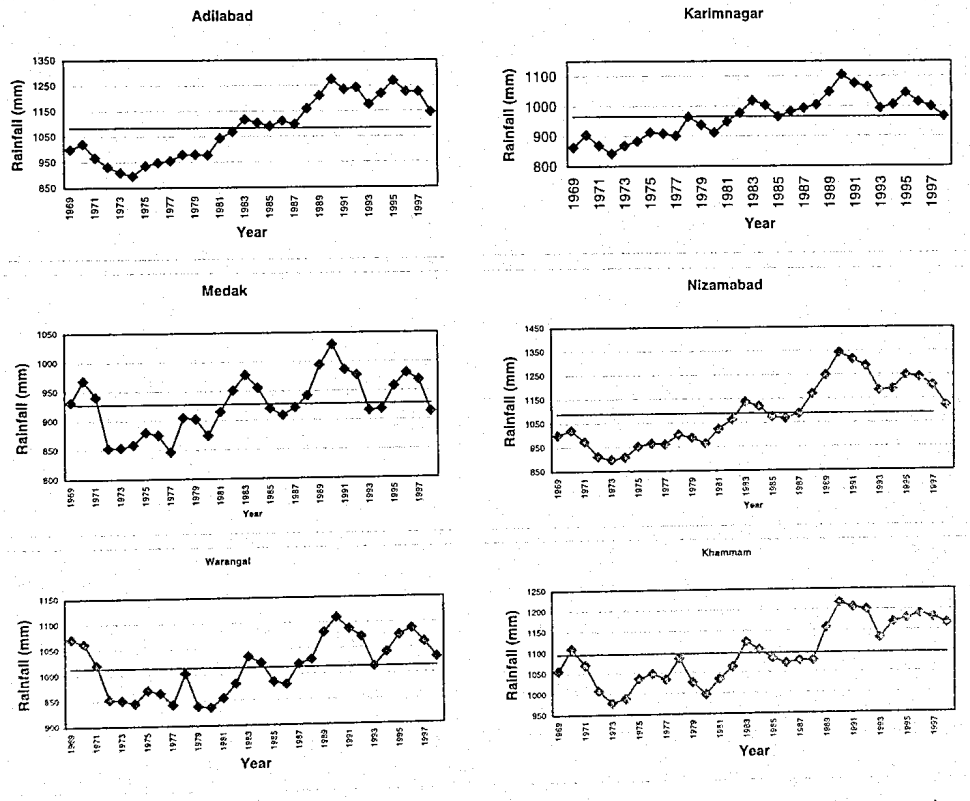


Fig. 4. Rainfall Trends in North Telangana Districts (10 year moving average)

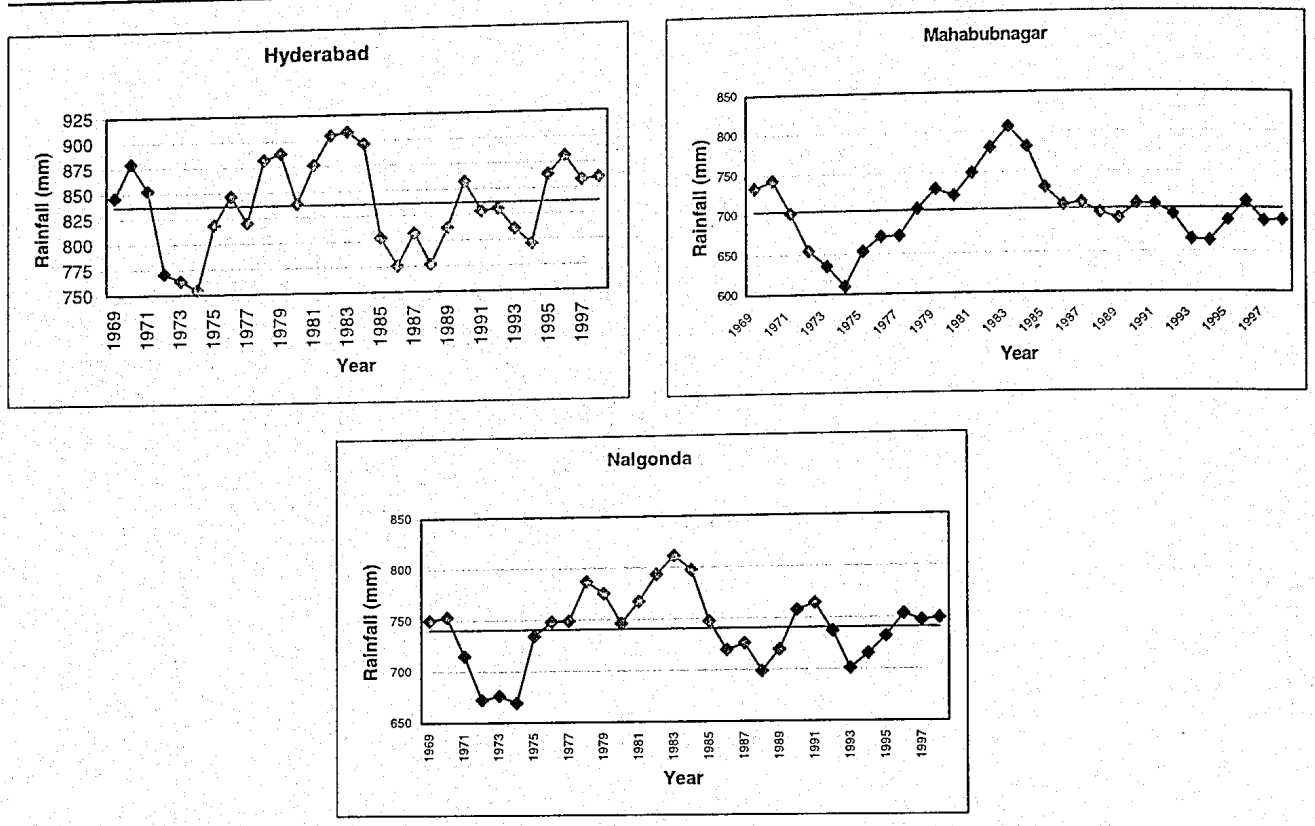


Fig. 5. Rainfall Trends in South Telangana Districts (10 year moving average)

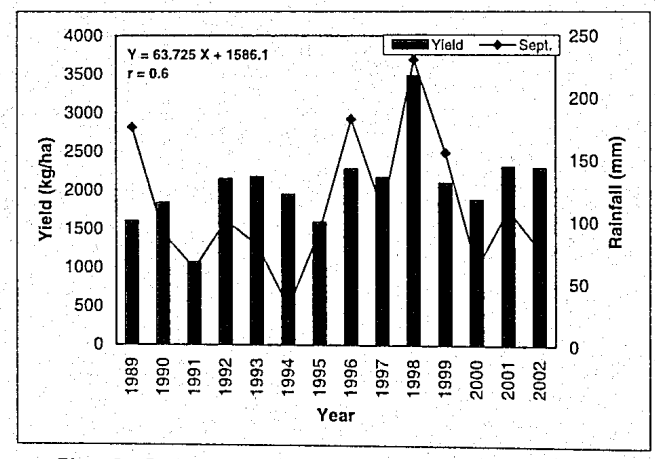


Fig. 6. Relationship between September rainfall and grain yield of Maize in Medak district.

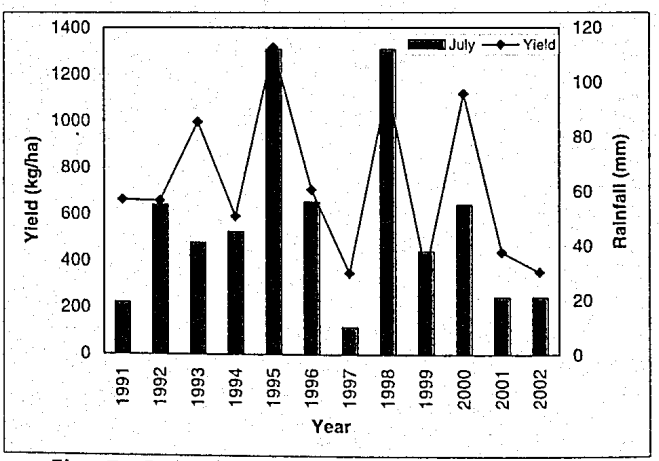


Fig. 7- Relationship between July rainfall and pod yield of groundnut in Anantapur district

Table 4. Mean monthly rainfall and dependable rainfall (mm) in various districts of Andhra Pradesh

District	JUNE		JULY		AUGUST		SEPTEMBER		OCTOBER		NOVEMBER	
	Mean	PD	Mean	PD	Mean	PD	Mean	PD	Mean	PD	Mean	PD
North Coastal districts												
Srikakulam	142.6	96.5	186.2	135.5	180.3	131.6	200.8	146.9	180.5	95.0	68.6	4.6
Visakhapatnam	118.0	88.9	152.4	118.3	152.0	106.6	175.9	126.5	206.4	80.3	80.7	7.4
East Godavari	124.0	77.0	204.0	135.5	185.8	117.5	182.2	118.6	187.8	69.1	86.7	11.9
West Godavari	125.4	75.1	226.7	154.6	213.3	150.4	177.9	112.1	155.4	70.5	64.9	10.5
South Coastal districts												
Guntur	89.2	58.5	149.8	94.4	135.3	69.5	158.2	79.7	131.7	56.5	111.8	11.5
Krishna	114.3	74.0	205.2	134.6	182.5	128.0	171.0	97.7	146.7	65.0	67.8	10.0
Nellore	43.4	27.5	94.6	59.8	91.0	39.4	118.1	67.4	239.3	104.6	317.4	145.0
Rayalaseema districts												
Chittore	56.0	41.5	101.8	66.1	95.6	48.0	139.8	105.2	150.1	81.0	141.3	65.6
Anantapur	48.0	27.4	65.4	29.2	78.5	25.5	142.4	89.7	101.2	56.0	34.9	6.5
Cuddapah	59.6	32.8	103.4	61.0	100.9	43.7	129.7	62.0	128.2	65.7	85.9	32.0
Kurnool	72.0	58.4	109.6	63.2	116.3	58.0	143.5	77.5	95.2	47.8	31.1	7.9
North Telangana districts												
Adilabad	160.4	110.6	304.3	226.7	277.8	180.3	166.1	94.2	73.4	5.9	14.0	0.0
Karimnagar	142.6	96.3	252.4	156.6	233.1	142.5	171.1	95.6	77.6	20.5	22.1	0.0
Medak	131.9	83.7	244.6	151.6	211.6	132.0	186.0	91.5	80.4	14.8	17.0	0.0
Nizamabad	157.0	103.0	299.8	223.9	285.3	168.0	191.4	94.2	71.7	12.0	17.4	0.0
Warangal	152.2	102.8	283.9	180.0	226.8	143.1	172.0	84.0	91.0	26.0	25.5	0.9
Khammam	148.0	104.0	294.8	212.4	244.7	150.4	179.4	128.6	103.3	45.7	29.1	1.6
South Telangana districts												
Hyderabad	118.6	85.5	188.0	109.3	168.6	100.5	187.9	84.8	93.0	25.0	21.1	0.5
Mahabubnagar	90.5	64.7	159.6	110.0	15.2	87.4	145.6	84.5	80.3	19.8	19.5	0.0
Nalgonda	104.1	62.1	147.5	83.0	138.9	106.7	157.0	80.3	100.1	28.0	34.3	2.0

PD = Dependable rainfall

Table 5. Historical records of temperature

Month	Mean Maximum Temperature (°C)	Highest Mean Temperature ever recorded °C)	Extreme Temperature (°C) recorded so far	Temperature in 2003 (°C)
Cuddapah (Rayalaseema)				
April	40.1	42.5	45.0	
May	40.0	43.1	46.1	44.9
June	36.7	40.4	45.0	
Kurnool (Rayalaseema)				
April	39.7	42.3	44.6	
May	39.8	42.9	45.6	45.1
June	35.6	40.1	44.4	
Hyderabad (Telangana)				
April	37.6	40.4	43.3	
May	38.8	41.7	44.4	43.9
June	34.4	39.5	45.5	
Mahabubnagar (Telangana)				
April	38.0	41.0	45.3	
May	38.9	42.4	44.9	44.8
June	34.4	39.7	43.4	
Nizamabad (Telangana)				
April	39.8	42.8	45.4	
May	41.5	44.2	47.2	46.4
June	36.4	42.0	46.1	
Nellore (Coastal AP)				
April	37.2	41.1	45.6	
May	39.4	43.4	45.6	46.5
June	37.9	41.8	46.7	

Table 6. Damage of orchards caused due to heat wave during May 2003

Orchard	Damaged Area (ha)	Number of plants damaged
Mango	7323	6,66,233
Sapota	28	2,297
Sweet Orange	12741	21,96,347
Acid Lime	2658	2,52,066
Cashewnut	307	23,085
Pomogranate	19	3,800
Total	23075	31,43,828

(Source: Commissioner of Horticulture, Govt. of Andhra Pradesh)

B) **Groundnut:**

Relationship between pod yield of groundnut and July rainfall of Anantapur district indicated that there was a close and positive association between pod yield and July rainfall. The reason attributed here is that July is the critical month for sowing of the crop. If the sowings are completed by the end of July, the reproductive stage (i.e., pod filling) of groundnut crop falls in the 2nd fortnight of September, which is the assured rainfall period for Anantapur district (Fig. 7).

Next to moisture regime, thermal regime is important fro crop growth. Any extreme conditions will affect the crop. An example of heat wave of 2003 is discussed here under;

Impacts of heat wave on orchards

Higher air temperature wave has deleterious impacts on plants. Excessive heat results in loss of turgor in leaves due to high transpiration. The loss of turgor is maximum during the windy hours of the day and causes desiccation resulting in dehydration of the plant during the day, which is not regained by the night. This impact causes widespread damage to crop.

Damaging effect appears to be caused by the rapid dissipation of reserve carbohydrates that slow down new leaf production and poor recovery from defoliation. The simplest kind of metabolic injury due to heat is starvation because of the higher optimum temperature for respiration than for photosynthesis. Simultaneously, dry winds promote desiccation through higher rates of water loss by transpiration (GoAP, 2004). The symptoms noticed due to heat waves are:

- Yellowing of leaves
- Scorching of leaves
- Drying of leaves and branches
- Drying up of new flush that emerges, affecting subsequent crop growth particularly in Mango plantations.

The high temperature and low relative humidity experienced in the state during May 2003 caused total depletion of moisture from leaves and led to the drying of leaves, and finally the whole tree, particularly in Sweet Orange and Mango (Table 5). Most of the orchards in coastal regions dried up irrespective of their age. In areas where there was an irrigation source, the percentage of damage was very low causing only scorching of leaves and wilting.

According to the president of Andhra Pradesh Poultry Federation, about 20 lakh birds (broilers and layers) died in the months of May – June 2003 due to severe heat stress. Highest number of birds died in the districts of East Godavari (about 7 lakhs) followed by West Godavari (approximately 5 lakhs) and Ranga Reddy (4 lakhs); Guntur, Krishna and Nalgonda. The egg production in the state was also decreased on an average by 25%. The drop in egg production in the state was about 90 lakhs per day for over 30 days (total loss of egg production was about 27 crores).

Major inferences

- Crop planning should be such that the variety should be tolerant to dry spells for the initial period of 60 to 70 days in view of uncertainties of rainfall in June, July and August months
- There is an increasing trend in rainfall during the months of September and October
- There is a need to examine further the reasons for decreased rainfall in Northern Telangana districts in recent years for working out strategies for better agricultural planning

References

GoAP. 2004. State level interim report on heat wave conditions in Andhra Pradesh state. Revenue Department (Disaster Management), Government of Andhra Pradesh.

Hargreaves. 1984. Climatic zoning for agricultural production in Northeast Brazil. U. S. Agency for International Development, Utah State University.

Raji Reddy, D. 1995. Rainfall patterns as a prelude to crop management in rainfed farming with special reference to Andhra Pradesh. Paper presented at the seminar on Improvement on rainfed Agriculture in Andhra Pradesh, EEI, ANGRAU, Hyderabad, 5 May 1995.

Yogeswara Rao, A. and Raji Reddy, D. 1993. Crop production as influenced by rainfall in Telangana districts. Paper presented at the seminar on Agricultural Development of Telangana Districts, Jubilee Hall, Hyderabad, 5-7, January.

Rainwater Conservation and Management for Drought Proofing in Andhra Pradesh – CRIDA's Experience

Prasanta Kumar Mishra and M.V. Padmanabhan

Abstract

Currently, the Ministry of Agriculture, Ministry of Rural Development, Ministry of Environment and Forest, NABARD etc have taken up a nation wide watershed program. Through this program the appropriate measures such as conservation of rainwater in micro-watersheds, promotion of *in situ* moisture conservation on arable and non-arable lands, treatment of drainage lines and development of multi-tier vegetation consisting of grasses, shrubs and trees etc. in a participatory mode are being implemented The salient features of these programmes are promotion of low cost and eco-friendly technology, integrated watershed management approach, farming systems development, people's participation through suitable institutional arrangements, management of common property resources and cost-benefit sharing, long-term sustainability and human resource development. The field activities include: treatment of arable land, treatment of non-arable land and drainage lines, production systems involving crop demonstrations, dryland horticulture, agroforestry, seeding of grasses, fodder cultivation, planting trees and shrubs, livestock development including health and household production systems for marginal farmers and landless villagers. CRIDA's experience relating to rain water conservation and management is presented in this paper.

Introduction

Government of India undertook a Model Watershed Programme in the eighties for testing and implementing the integrated watershed approach for sustainable dryland farming. The action plans of the watersheds were prepared by the two ICAR Institutes: (i) Central Soil and Water Conservation Research & Training Institute, Dehradun; and (ii) Central Research Institute for Dryland Agriculture, Hyderabad. The programme implementation was carried out through respective state governments. During the initiation phase of the watershed programme, ICAR considered natural resources development and its utilization as the first and foremost strategy. The entire agriculture development revolved around this strategy.

A review of the model watershed programme towards 1988 revealed that the watershed approach has helped mitigating the effect of 1987 – drought to a considerable extent as a result of cumulative improvement of surface and groundwater resources due to construction of conservation structures. About 80 to 90 per cent of the area could be sown in the watersheds in the drought year, compared to 30 to 50 per cent outside. As a consequence of the overall improvement of hydrology and cropping

programme including judicious fertilizer application, significant gain in crop yield was recorded in the model watersheds. Thus, there was encouraging trend of over-all rural development in most locations.

Soil & water conservation measures

Soil and water conservation measures are categorized as follows.

- Hardware treatment : Long term measures
- Medium software treatment : Medium term measures
- Software treatment : Short term measures

Hardware treatments

Hardware treatments are generally of permanent type provided for improvement of relief, physiography and drainage features of watershed. These are executed with major Government support with the purpose to check soil erosion, regulate overland flow and reduce peak flow. At times, these are imposed to completely divert the upland run-off from running into downstream fertile lands. Such treatments include waterways, gully control structures, bunds and terraces.

Waterways: High runoff volumes are generally observed on steep sloppy areas, even in dry lands. To the extent possible, this runoff should be channelised through few waterways either by alignment along field boundaries or by newly developing them. The waterways would help in the establishment of multipurpose trees when planted along the waterway.

Bunds: These are low height earthen embankments constructed across the slope in cultivated lands after deciding location of waterways. The bunds function to intercept runoff, increase infiltration opportunity time and dispose excess rainfall safely. Such bunds can be either contour bunds or graded bunds.

Contour bunds are recommended in dry farming areas with light textured soils of slopes upto 6 per cent and where annual rainfall does not exceed 600 mm. They are designed for an expected runoff of 24 hours duration at 10 years frequency. Surplussing arrangements (waste weirs) are provided to dispose of the excess runoff beyond the design storage. The cross section area of contour bunds follows the depth and type of soil; however, 0.5 m^2 is minimum. (Bali, 1988).

Graded bunds are constructed in medium to high rainfall areas in poor permeable soils (vertisols), having 2 to 6 per cent slope. They are also quite suitable for the soils having crust formation tendency like red 'chalka' soils of Telengana region of Andhra Pradesh. By and large, graded bunds with 0.3 to 0.5 m^2 section are constructed with longitudinal gradient of 0.2 to 0.4 per cent depending on the site condition. Graded bunds along with waterways and water harvesting structures not only check soil erosion, but they also provide an ideal water management system for many watershed situations.

Terracing: Cultivated lands having land slopes above 10 per cent particularly in hilly areas should be put under bench terracing by converting the lands into series of platforms. The width of bench terrace depends on the land slope and the permissible depth of cuts; however, minimum width is 3 m. Bench terracing is very much effective in reducing soil erosion in hilly areas. At places where scattered stones are available, loose stonewalls can be made to act as risers for bench terrace construction.

Medium software treatments

Medium softwares comprise of different inter-bund treatments, where field sizes are large and conventional bunds are constructed along field boundaries. Such treatments are usually of semi-permanent type and are adopted to minimise the velocity of overland flow. They may need major initiative from farmers with support grants from the Government organization. Such measures may last 2 to 10 years. Vegetative components and land configurations may also provide some direct returns on short-term basis. However, they need to be modified at times to obtain effectiveness for erosion control and moisture conservation, and also to minimise risk of providing shelter to harmful pests in and around these measures. Small section/key line bunds, strip leveling, live beds and vegetative barriers may comprise such interventions.

Small section/key line bunds: A small section bund may be created across the slope at half of the vertical bund spacing. Such bunds can be nearly 0.1 m^2 in section; may be renovated at an interval of 2 to 3 years.

Strip levelling: About 4 to 5 m strip of land above the bund across the major land slope may be leveled for the purpose. Similarly, one or more strips can be created at middle length of slope. Running blade harrows after ploughing the field with mould board or disc plough can create such strips. Such minor rough levelling programme may be taken up after every 2 to 4 years.

Live beds: One or two live beds (2-3 m wide) can be created either on contour or on grade in the inter bund space. The vegetation on the beds may be according to the liking of cultivator; it can be annual or perennial or a combination of both. The vegetation may be cut two or three times during the year.

Vegetative/live barriers: One or two barriers of close growing grasses or legumes can be created along bunds as well as at the middle length of slope to filter the runoff water or slow down overland flow. Khus (vetiver) could be one of such vegetations. Other promising grass species that serve as valuable fodder for cattle can also be grown as an alternative to khus grass. A miniature bund at lower side of barrier is recommended to help in the development of live barriers, particularly in the initial stages.

Software treatments

As already stated hardware treatments are useful for safe runoff disposal and similarly, medium software are required to slow down the velocity of overland flow in

cultivated fields. However, on several occasions, these measures are found inadequate in obtaining equitable moisture distribution for crop growth. In such cases software treatments are taken up for ensuring fairly uniform soil moisture for satisfactory crop performances. By and large, software treatments are temporary in nature; and therefore are required to be remade or renovated every year. The entire cost of applying such treatments is to be met by the farmers. Because of favourable economics, some of these treatments have gained wide acceptance in the recent years. Contour farming, compartmental bunds, broad bed and furrows, ridge and furrows, conservation furrows and mulching practices are some of the example of software treatments.

Contour farming: Contour farming is one of the easiest and most effective and low cost method of controlling erosion and conserving moisture. With contour farming, tillage operations are carried out along contours. It creates numerous ridges and furrows for harvesting substantial amount of runoff inside the field itself. Simple measures like across the slope cultivation is highly effective in containing resource losses. Results of a rainfall simulator study at CRIDA shows the effectiveness of across the slope cultivation (Table 1).

Table1. Effectiveness of across slope furrowings on the hydrologic parameters

Treatment	Time to initiation of runoff (min)	Time to peak runoff (min)	% runoff from saturated soil	Sediment loss from a single event of 40 mm (t/ha)
Furrows across the slope at 30 cm spacing	5	19	54	0.6
Furrows along the slope at 30 cm spacing	1	9	69	1.8
Bare land	1	11	63	1.3

NB: Land slope: 3%, Soil: Alfisol, Rain intensity: 80mm/hr, Rain amount: 40mm, Soil antecedent moisture condition: Saturated

Compartmental bunds: Compartmental bunds, converting the area into square/ rectangular parcels are useful for temporary impounding of water for improving moisture status of the soil. These are made using bund formers. In medium deep black soil, they are found advantageous in storing the rainfall received during the rainy season in the soil profile-there-by augmenting the soil moisture for use by rabi crops. The size of the compartments may be fixed considering the size, of the inter-bunded land.

Broad bed and furrows: Broad bed and furrow system implies shaping alternate bed and furrows. This technique is especially suited to black soils, where crops are sown on pre-formed beds. This system is made before the season and is maintained year after year. The planting is done on the bed. Generally, the depth of each furrow is kept 0.15 m and the inter furrow spacing is maintained at 1.5 m.

Dead furrows/ Conservation furrows: They are laid across the land slope in rolling lands to intercept the runoff. The spacing between dead furrows varies between 2 to 5 m or 4 to 7 crop rows. This system works well in *Alfisols* (Singh and Rao, 1988).

Tillage: Tillage operations help in rainwater infiltration. Off-season tillage, in particular, has been found quite useful in most rainfed areas. The tillage operations make the soil receptive to rainfall. This practice is very useful in light soils, often prone to crusting.

Mulching: Surface mulching protects soil against beating action of raindrops and it also increases water infiltration into the soil. Further it helps in minimizing water evaporation from soil surface. Sometimes dry soil mulch created simply by stirring the soil has been found effective for good performance of crops.

Soil and water conservation in non-arable lands

Controlled grazing is one of the basic measures for reducing soil loss from denuded sloping lands. As seen from the experiences of Operation Research Projects, soil and moisture conservation measures are required even in the non-agricultural lands. These practices include contour and staggered trenches and contour furrows. They help in accelerating vegetation establishment, encouraging natural regeneration of species and controlling soil erosion. Contour and staggered trenches are usually spaced 10 to 20 m apart across the slope for raising forest species. In general, 0.45 m wide trenches with 0.45 m depth are made at regular intervals. Sometimes in place of trenches, contour furrows are formed at a spacing of 2 to 10 m (Singh *et al*, 1990). In rocky areas, crescent bunds of loose boulders are useful in place of trenches. All the above stated measures are useful in slowly regaining the lost vegetative cover and fertility of degraded grasslands. These efforts can succeed only through community mobilization.

Water harvesting measures

Water harvesting by ways of development of water bodies and *in situ* runoff concentration is the appropriate approach that can help the three most important components of dryland farming i.e., arable farming, animal husbandry and amelioration of degraded lands. To realise this, fullest participation of the farmers in the watershed programme is absolutely necessary by dovetailing the farming systems approach (Singh and Subba Reddy, 1998).

Since time immemorial, several kinds of water harvesting structures are being practiced in India. Till recently, local wisdom and precedence were utilized for designing these structures. In order to bring cost effectiveness, efforts need to be directed to harmonize the designing of water harvesting structures based upon both traditional wisdom and research findings. In fact, farm ponds, surface water tanks and percolation tanks need also to be viewed as conservation structures in addition to their utility for supplemental irrigation. In real watershed situations, ponds may be located in conjunction with waterways. In selected pockets, integrated catchment-cum-command approach could be followed. To ensure proper storage in light soils, the ponds can be lined with sealant materials. When located in proper eco-cultural hydrologic matrix, in conjunction with other factors, ponds also help in reducing load on ground water aquifer. The water harvesting structures can perform the following functions.

- Water storage for supplemental and off-season irrigation
- Silt detention
- Recharge of ground water
- Aquaculture
- Recreation and allied agricultural uses.

Watershed based minor irrigation tanks: In micro-watersheds, water harvesting bundhies, similar to small-scale irrigation tanks are constructed. Spillways are provided to take care of additional runoff.

Farm ponds: Farm ponds are typical water harvesting structures constructed by raising an embankment across the flow direction or by excavating a pit or a combination of both. Dug out ponds in light soils require lining of the sides as well as the bottom with suitable sealants. This is not the case with heavy black soil. Considering the benefit of the harvested water, different type of linings, viz., brick concrete, HDPE, etc., may be used.

Percolation tanks: Percolation tanks are located in the Nalas having permeable formations with the primary objective of recharging the groundwater. A strict regulation on the silt load entering the downstream reservoirs is an additional advantage of percolation tanks. The percolation tanks encourage the digging up of wells downstream of recharged area for irrigation purposes.

Stop dams: Stop dams are permanent engineering structures for raising the water level in the Nala for the purpose of providing life saving irrigation during drought periods. These are located over flat Nalas at narrow gorges carrying high discharge of long durations.

Rainfall-runoff process – Case study at micro-scale

It has been observed that in the red soils of Hyderabad about 60% of the annual rainfall cause runoff events; annually, nearly 12 major rainstorms are received over a period of 5 to 7 months. However, by having conservation measures, runoff is reduced to about 2% of the total rainfall whereas in general field conditions, about 15-20% runoff may be expected from such agricultural land. Apart from *in-situ* moisture conservation measures, a few low cost water storage structures are also necessary. In one case study at Hyderabad, it was found that the water harvesting system was economically feasible even with brick lined pond. With a pond of 500 cum, the benefit cost ratio is 1.5 (with tomato as test crop) with pay back period of 10 years. It was found that by following furrow irrigation, water use efficiency can be increased considerably, particularly when water is applied at 50% open pan evaporation value. The water use efficiency can also be further increased if drip irrigation is practised and thereby the area under vegetable crop may also be doubled.

Modern action learning tool for selecting technology options

The modern and innovative techniques of Action Learning Application through an ICAR-ACIAR collaborative research program on resource conservation have been initiated at CRIDA. The farmers in their field tried simple conservation options like mulching, furrowings, FYM incorporation etc., and the rainfall simulator (an action learning tool) was run in presence of the focus group farmers to understand about the runoff and soil loss from individual treatments. This created enough awareness among the farmers to put the research program on-farm with their active involvement. Few of the introduced options that may invite attention are:

- Lopping of plants like *Gliricidia* and *Leucaena* when spread between the crop rows after planting as land cover can reduce runoff, improve water intake, suppress weed growth and control evaporation. Incorporation of this material in soil after 30-50 DAS (Days after sowing) depending upon canopy cover, can build up soil organic matter. Such vegetation can be raised on field boundaries or in other agro-forestry systems and on wastelands. Thus, a multitude of benefits accrue from a single technology.
- Composting is an old practice being recommended in India since 60s. Yet it is not adopted. Results reporting use of FYM @ 10-15 t ha^{-1} for maintaining soil fertility and increasing crop yields are frequently appearing in scientific literature. Is it feasible for dryland farmer to apply such large quantities of FYM? The researchers have not looked into this question. But this gap can be bridged. Composting of organic wastes (including animal unpalatable weeds) with animal excreta in 4 or 5:1 ratio can solve this limitation. This way, 1 tonne of FYM is converted into 5 tonnes of compost, which a dryland farmer can afford to apply. Moreover, such composting is a novel approach to put in place the crop residue and waste recycling, so much warranted for maintenance and upgrading soil quality for plant production in drylands.

The following methodology has been found effective in obtaining peoples participation in resource conservation programme.

- Participatory resource appraisal
- Demonstration of land degradation processes (water and soil loss) through tools like a portable rainfall simulator
- Focus group interactions to clearly obtain (i) farmers perceptions on land degradation issues, (ii) "what is watershed and how relevant?", and (iii) sustainability of dryland farming
- Identification and listing of indigenous technical knowledge: to this effect at National level projects on ITKs have been devised.

The limitations to the success of the programme implementation and operation can be attributed to various bio-physical, socio-economic and extension related constraints. Enough opportunities like national awareness, good research net-work, NGO network, multi-Institutional partnership, rainwater resource, local wisdom, value added products, private sector R&D initiatives etc. exist to ride over the weakness.

Portable rainfall simulator - An action learning tool

- Demonstration of land degradation processes
- Focus group interactions
- Listing of indigenous technical knowledge (ITK)

- Discussion with villagers on soil loss after rainfall simulator run
- Runoff reduced by 60% and soil loss by 80% compared to bare soil by mulching

Some popular technologies:

Some of the popular technologies designed, developed and widely practiced by CRIDA relating to soil and water conservation are presented as follows.

CRIDA terrace

The practice of contour or graded bunding with large cross sections for soil and water conservation is cost-intensive. Besides, partitioning of fields and area lost for cultivation by such bunds hinder their adoption by the farmers. Since soil and water conservation is of paramount importance for maintaining the land productivity, research has been going on to reduce cost and develop systems that are more acceptable to the farmers. CRIDA terrace is the result of this research. CRIDA terrace (Padmanabhan and Sharma, 1996) is a terrace-level soil and water conservation package essentially consisting of a small section (0.1–0.2 sqm) bund strengthened at valley lines or depressions and stabilized with vegetation of farmer's choice. It can also be aligned on field boundaries. The special features of the technology package are: (i) it can be formed by running a tractor-drawn reversible plough to cover large areas per unit time (1.0 ha/hr); the channel on the upstream side of the bund made by reversible plough is helpful to enhance the runoff handling capacity of the terrace while the terrace gets

stabilized (ii) the terrace can be utilized to grow fodder grasses such as hybrid napier and guinea grass to enhance fodder availability or for raising green manure crop like Gliricidia to meet the nutrient requirement of the crop or it can even be stabilized with natural vegetation (iii) surplussing systems at individual terrace level can be accommodated either at outlets near waterways or at local valley lines depending on the level difference between them, when the bund is required to be aligned on field boundaries. The cost of construction is about Rs. 300-500 per ha and the pay back period is 2-3 years.

Water harvesting check dam

Crop failure due to moisture stress/drought is common in drylands. Water harvesting for providing supplemental or life saving irrigation to crops is an important component of watershed management. The water harvested in such structures can also be used as drinking water for grazing cattle and for agricultural purposes such as spraying of insecticide/pesticide in fields away from village. Depending on the availability of water, they can also be used to grow post-monsoon crops. The water harvesting check dam is essentially a masonry structure consisting of a head wall, head wall extension, cut off wall, sidewall, wing wall toe wall and downstream apron. The dimensions of various components will depend upon the width and depth of the Nala at the selected site, the type of soil and the foundation conditions. Most importantly a spillway (generally rectangular) should be constructed as part of the head wall for surplussing the design peak flow from the watershed area above the structure after the reservoir created by the check dam is full. The cost of water harvesting check dam will depend on the dimensions of the structure, materials used and its location. A rough estimate for a pucca check dam is Rs.4,000/- per m length of check dam. The pay back period is 4-6 years. Depending on runoff and the storage created, assured crops can be taken with supplemental irrigation in a couple of hectares. In Chevella (black soil) watershed in Medak district of Andhra Pradesh, an 18 m long, 3 m high check dam was found to create storage of 1200 cu m in the ephemeral stream. This structure with watershed area of 35 ha has enough water to provide supplemental irrigation for 2.0 ha area in kharif season and 0.5 ha in *rabi*. These structures have found acceptance widely in the National Watershed Programme as farmers have derived substantial benefits from them. Water harvesting check dams are generally constructed under watershed development programs because they are cost intensive.

Dug-out farm pond

Rainwater collection through farm ponds is very much essential for efficient utilization of excess rainfall for the benefit of the crops & environment. When designed properly the stored water can effectively be utilized during the off-season for growing cash crop like vegetables, irrigating plantation crop. Also, during the season depending on the frequency of filling and availability, the water can be utilized for one or two life saving/ supplemental irrigation to crops in the nearby fields during dry spells. The farm ponds are constructed at the lower side of the fields. The runoff from the contributing fields is canalized into the pond. In light soil the dugout ponds can be lined to improve the storage efficiency by containing the seepage losses. Considering an average of two fillings in a year the capacity of farm ponds may be designed to store 100 to 200 m^3 of runoff per hectare of contributing area in a semi-arid environment. In order to minimize the seepage area as well as evaporation losses a dugout farm pond (Figure) can be best designed for a given storage volume (V), depth (D) and side slope Z: 1 (Z horizontal to 1 vertical) using the following equations (Mishra & Sharma, 1994).

$$X = (0.5/C)\ [\ \sqrt{\{DZ\ (1+C)\ \}^2 - 4C\ \{2D^2Z^2 - (V/D)\}}\ - DZ\ (1+C)] \qquad \text{...(Eq. 1)}$$

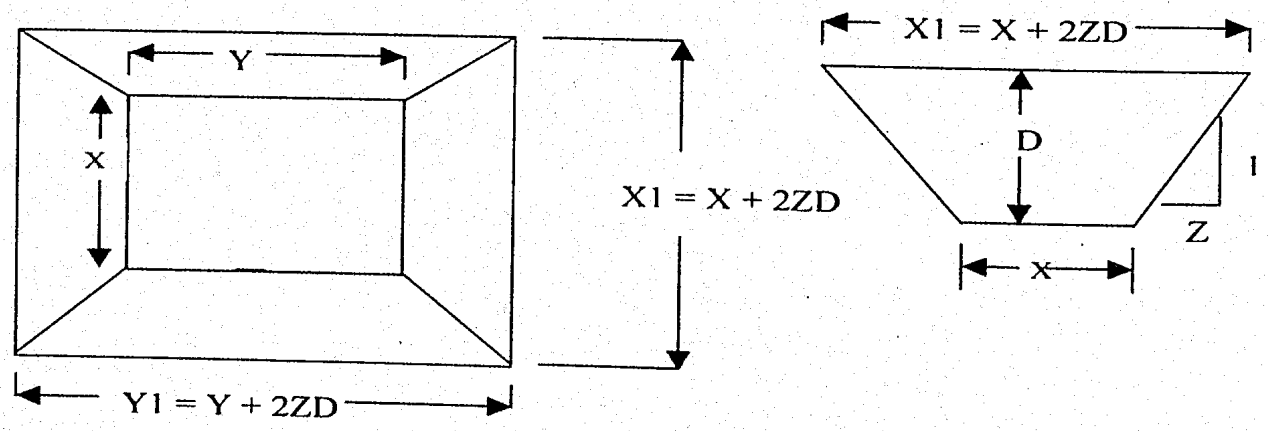
Where, X, Y=Two sides of the dug out pond (rectangular) at the bottom and C = Y/X

For a square section (C=1, i.e. X=Y) the above equation is simplified as follows:

$$X = \sqrt{[\ (V/D) - D^2Z^2]}\ - DZ \qquad \text{..... (Eq. 2)}$$

For a square bottom section having side slope 1:1 (Z=1) the Eq.2 can be further simplified as

$$X = \sqrt{[\ (V/D) - D^2]}\ - D \qquad \text{..... (Eq. 3)}$$



Dugout Farm Pond

The experience at farm level has shown enough potential of farm pond (brick lined) technology in growing vegetables in the off-season by satisfying water requirement at 50% of weekly evaporation. An economic analysis of the above pond with tomato as test crop shows a pay back period of 10 years with BCR 1.5 and IRR 18.9%. This technology will be more viable and economical in *vertisols* where lining is not essential. The BCR will certainly be higher if intangible benefits are quantified and the use of water during the season (if any) is also considered. The poor farmers find it difficult to go for high initial investment to adopt this technology for which institutional subsidized credit support is needed. The spread of bore wells has affected the potential of farm ponds. Farmers get tempted for more borewells; in spite of the fact that many of them prove to be failures.

Conservation furrows

High intensity rainstorms during monsoon season cause high runoff rates, poor soil moisture storage / low groundwater recharge and significant loss of topsoil both in the Alfisols and Vertisols in the semi - arid region. Estimates show that 10-17 % rainfall is lost as runoff from cropped Alfisols in a few storms of high intensity. Therefore, concerted efforts are absolutely necessary to conserve and utilize every drop of rainwater effectively for grain and biomass production, as the success of dryland agriculture lies in rainwater conservation. Conservation furrows have proved successful as a measure of rainwater conservation and runoff management in the rainfed regions. Conservation furrows/ dead furrows are opened parallel to the rainfed crop rows across the prevailing land slope, employing a country plough, 3-4 weeks after the sowing / germination of the main crop. These furrows are 20-25 cm wide at top, 25-30 cm deep and are spaced at 0.9-3.0 m regular horizontal interval depending upon the soil physical characteristics and nature of the crop (close growing, row crops, etc.). During runoff causing rainfall events, the rainwater gets concentrated within these furrows, infiltrates into the soil (root zone) and is available to the crop for meeting the evapotranspiration demand for a longer duration compared to the control. The conservation furrows are temporary and therefore are required to be opened every season / year with *kharif* crops. The conservation furrow fields store 4-38 % additional soil moisture over control throughout the growing season, thereby resulting in 12-23 percent higher crop yields fetching an additional economic return of Rs. 600-800 ha^{-1}. The technology has proved its worth in on-farm studies during last five years and has been adopted widely in the rainfed regions of India.

Emerging issues

The important issues that are emerging in the context of rainwater conservation and management are:

- Watershed research vis-à-vis rainfed agriculture
- Decision support system for planning and development of resource conservation programme
- Socio-economic and institutional issues
- Participatory watershed development and management
- Sustainability and replicability
- Equity issues
- Supply driven vs. demand driven models
- Capacity building
- Livelihood issues
- Institutional issues
- Administrative issues
- Cost sharing/contribution
- Conflict resolution
- Monitoring and evaluation

References

Bali, Y.P. 1988. A review of soil and water conservation strategies. Proc. 1st Meeting of Working Group on Soil and Water Conservation for Formulation of Eighth Plan.

Mishra, P.K. and Sharma, S. 1994. Theoretical considerations in design of farm ponds for minimising evaporation and seepage losses. Indian J. Dryland Agri. Res. & Dev., 9(1): 114-120.

Padmanabhan, M.V. and Shriniwas Sharma, 1996. CRIDA terrace - A low cost technology for soil and water conservation. Indian J. Dryland Agric. Res. & Dev., 11(1): 1-5.

Singh, H.P. and Subba Reddy, G. 1998. Rainwater harvesting and management for enhanced agricultural production in rainfed areas through people's participation, Workshop on "People's Participation in Irrigation Systems Management to Enhance Agricultural Production's", April 22-25, DWMR, Patna.

Singh, S.P. and Rao, U.M.B. 1988. Rain water management for stabilizing productivity of drylands. Indian J. Drylands Agri. Res. & Dev., 3(3): 203-214.

Improved Land and Water Management for Achieving Food Security in the Rainfed Areas

Prabhakar Pathak

Abstract

Most of the existing land and water management systems on Vertisols and Alfisols in rainfed areas often result in high runoff, soil loss and reduced groundwater recharge leading to low rainwater use efficiency and low and unstable crop yields. This paper discusses the soil related physical constraints and the developments that have been made in land and water management for increasing productivity and sustainable natural resource utilization of Alfisols and Vertisols in rainfed areas.

Various components of improved technologies for Vertisols have been discussed. This includes watershed-based development, improved surface drainage, broadbed and furrow land management, dry season tillage, dry sowing, improved cropping system, use of high yielding varieties, and improved fertility and pest management. The improved Vertisol management technology has increased the agricultural productivity by 300%, reduced runoff by 43% and soil loss by 76% compared to the traditional management.

For Alfisols, we discuss several promising land and water management practices. For Alfisols having slopes greater than 1.5%, a modified contour bund with gated-outlet has shown good potential to increase crop yields compared to conventional contour or field bund system. The lands having slope less than 1.5%, several other land management systems viz. contour cultivation with conservation furrows, scoops, off-season tillage and crop residue management were found to be promising. Finally ICRISAT's model of on-farm participatory and consortium approach of watershed development and management is mentioned.

Introduction

By definition, the dominant characteristic of drylands is an insufficient water supply to support stable agriculture. Not only is there insufficient rainfall but its occurrence is also highly erratic between years, during any one year, and spatially, during any single rainfall event. In general, the variability of the rainfall pattern increases as the annual mean decreases.

Much of the rains in dryland areas falls in high intensities, causing runoff and soil erosion and thus, a significant part of the already-inadequate amount of water does not enter the soil. This happens even though the moisture storage capacity of the soil is far from full. It is not generally realized that runoff losses from a field can amount to 20-40% of storm rainfall. While an increase of agricultural production depends on

numerous factors, the development of land and water management technology that will enable farmers to make more efficient use of the available water and conserve soil is therefore an essential pre-requisite (Pathak and Laryea, 1995a).

Alfisols, Vertisols and associated soils are the major soil orders that are extensively used for dryland agriculture in India. Soil-related constraints limit the potential productivity of these soils. Out of a total area of about 100-105 million ha under dryland agriculture in the country, nearly 30% is covered by Alfisols and associated soils, 35 percent by Vertisols and associated soils. The production of most rainfed crops averages between 400 and 900 kg ha^{-1} (Pathak and Laryea, 1995). This paper discusses the results from studies on the physical constraints and the developments that have been made in land and water management for increasing productivity of Alfisols and Vertisols under dryland conditions.

Management of Vertisols

Physical Constraints

The most important physical constraints to rainfed crop production on Vertisols are their (i) narrow range of soil water content for tillage, (ii) high erodibility, (iii) tendency to become water-logged and (iv) poor trafficability (Kampen and Burford, 1980). Vertisols are hard when dry and have very plastic consistency when wet. Tillage at an inappropriate moisture content leads to compaction of the sub-soil. Traditionally, rainy season fallowing is quite common on these soils. Reasons for rainy season fallowing of Vertisols are the difficulties farmers encounter in preparing the hard dry soil prior to the onset of the rainy season and/or the sticky nature of the wet soil after onset of the rainy season, which does not permit timely sowing and management of crops. There is common threat of flooding when heavy rains are received, and the possibility that rainy season cropping may reduce soil moisture available for growing post-rainy season crops are also some of the reasons for fallowing Vertisol during the rainy season.

Components of the improved Vertisol technology

The components of improved technology for Vertisol includes:

- **Land and water management**

  Improved practices were developed to alleviate physical constraints of Vertisols and to promote the intake of water, improve the aeration and workability, reduce soil erosion and runoff and facilitate safe disposal of excess water. Runoff utilization is improved by developing a watershed.

- **Land configuration**

  Land shaping reduces and controls runoff. The broadbed and furrows (BBF) are prepared at 0.4 to 0.6 percent gradient (Fig. 1). This BBF method helps to reduce runoff and conserves more water in the soil profile and also drains excess water safely away from the crops.

❖ **Dry season tillage**

Primary tillage operations are carried out soon after harvest of post-rainy season crops to loosen the soil. During summer, the clods formed gradually disintegrate due to pre-monsoon rains. The clods are easily shattered by blade harrowing soon after the pre-monsoon rains.

❖ **Dry sowing ahead of the rainy season**

Crops are planted in the dry soil just before the onset of the monsoon rains to ensure establishment and avoid inconvenience and difficulty of planting in the wet, sticky soils.

❖ **Improved cropping systems**

Crop yields can be increased and high returns can be obtained by inclusion of legumes in the cropping system. Cereals derive benefit of nitrogen fixed by the legumes. Legumes improve the soil fertility and increase the yield of the following crop.

❖ **Use of high yielding varieties**

High-yielding stress tolerant varieties of crops help in increasing systems productivity. Selection of appropriate varieties, which can fit in the system, also enable to make efficient use of the available resources such as water.

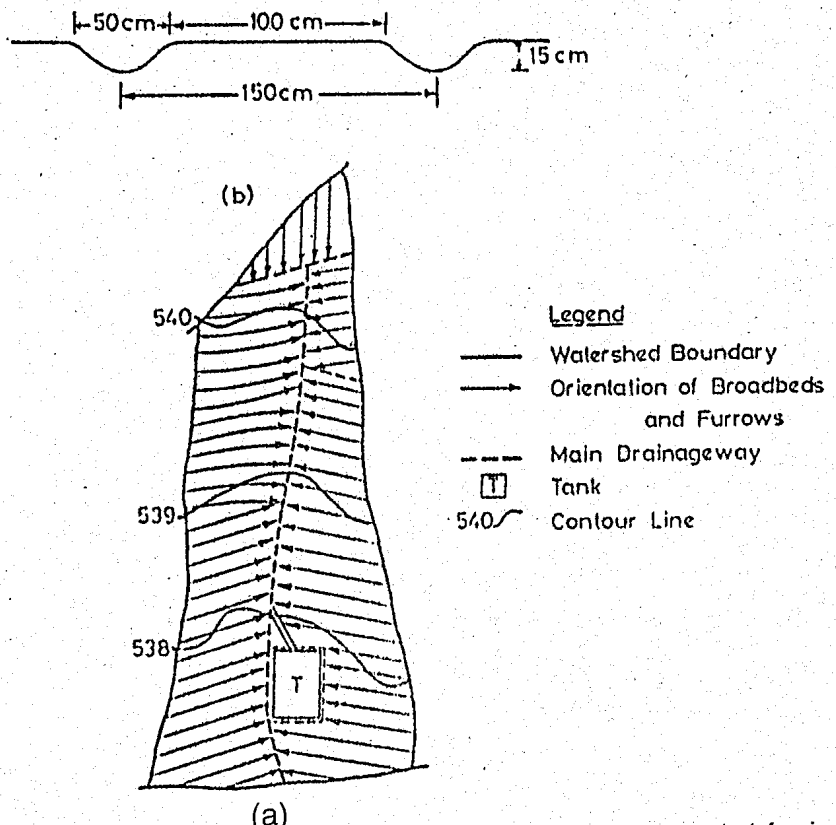


Fig 1. A section of the broadbed and furrow (BBF) configuration recommended for improved management of Vertisols. (b) A schematic sketch of a watershed-based farm design for improved land and water management.

❖ **Improved fertility management and pest management**

Productivity and sustainability

Grain yields were found to be more in improved system compared to traditional system. Sorghum and pigeonpea together could record an average yield of 4 t ha^{-1} in the improved system whereas in the traditional system, sorghum alone could record an average yield of 0.9 t ha^{-1}. Annual gain of grain yield in improved system is about 78 kg ha^{-1} $year^{-1}$ and in the traditional system the annual gain is only 26 kg ha^{-1} $year^{-1}$ as shown in the Figure 2.

With an increase in productivity there is also improvement in soil quality. In the improved system 67% of the rainfall is being used by the crops, lost only 14% of rainfall as runoff and 19% as evaporation and deep percolation whereas in the traditional system, only 30% of the total rainfall is used by the crops, 25% is lost as runoff and 45% as soil evaporation and deep percolation. The soil loss in improved system is only 1.5 t ha^{-1} $year^{-1}$ compared to traditional system where the soil loss is 6.4 t ha^{-1} $year^{-1}$ as shown in the Table 1.

On the whole, the improved system with broadbed and furrows could reduce the average annual runoff to one-half and soil loss to about one-fourth when compared to traditional flat land systems and crops can be grown in rainy season also. Crop yields were substantially improved in a Vertisol watershed by increased rainwater use efficiency and sustained by better land and water and crop management practices.

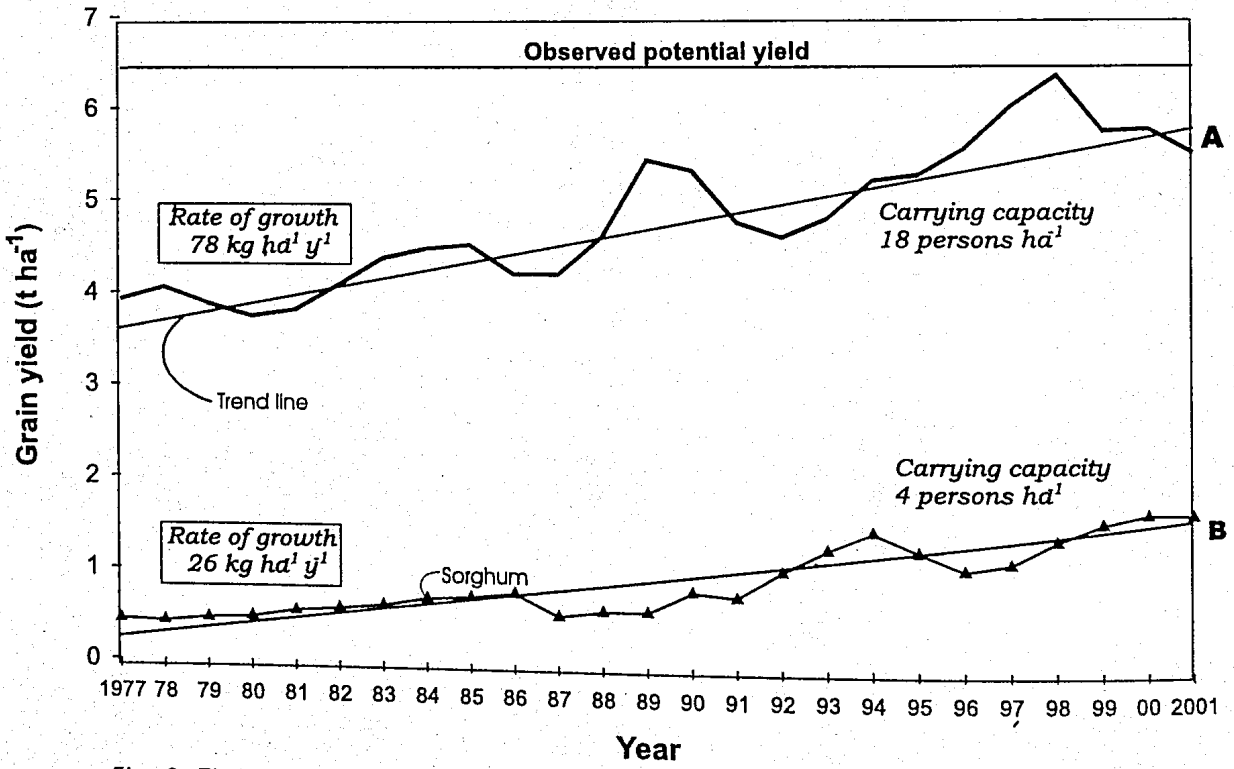


Fig. 2. Three year moving average of grain yield under improved (A) and traditional (B) technologies on a Vertisol watershed at ICRISAT (1977-2001).

Table 1. **Annual water balance and soil loss for traditional and improved technologies in Vertisol watersheds, ICRISAT Center.**

Farming system technology	Water balance component				
	Annual rainfall (mm)	Water used by crops (mm)	Water lost as surface runoff (mm)	Water lost as bare-soil evaporation and deep percolation (mm)	Soil loss (t ha^{-1})
Improved system:					
Double cropping on broadbed and furrows	904	602 (67)[1]	130 (14)	17 2 (19)	1.5
Traditional system:					
Single crop in post-rainy season, and cultivation on flat	904	271 (30)	227 (25)	406 (45)	6.4

1. Values in parentheses are amounts of water used or lost expressed as percentage of total rainfall.

Management of Alfisols

Constraints to crop production

The following are some of the main problems to crop production in Alfisols.

- Poor crop stand due to crust, rapid drying of surface soil, and high soil temperature.
- Poor crop growth due to unreliable soil moisture supply, low soil fertility, soil workability problems, and compact sub-soil layer (argillic horizon)
- Declining land productivity resulting from high soil loss due to poor crop canopy, and crusting, sealing and consolidation.

In the long-term, the most serious problem of Alfisols is soil erosion. Multiple, diversified sloping topography and the unstable nature of the soil structure resulting in low depression storage, surface slaking, compaction, crusting, sealing and consolidation of soil profile causes greater runoff and soil loss from Alfisols (Pathak *et. al.*, 1987). This is exhibited by the presence of low crop cover due to poor crop growth.

In summary the problems of crop production on Alfisols in the semi-arid tropics (SAT) are numerous and complex. Most of the problems are related to the physical and chemical characteristics of the soils.

Land management systems

For Alfisols having slopes more than 1.5%, a modified contour bund system is found to be the promising (Fig. 3). In modified contour bund system, the original system is modified by installing gated outlets in the lower field sections, land smoothing, and planting on grade instead of on contour, which allow runoff water to be stored above

Fig. 3. A modified contour bund with gated outlet for SAT Alfisols.

the bund for a certain period and then released at the desired rate through the gated outlet. Most of the erosional sediments are deposited so that relatively sediment-free water drains through the outlet and releasing excess water considerably reduces water logging. This system when compared with alternative land management systems on watersheds at ICRISAT Center, consistently produced the highest crop yields, while still providing adequate control on runoff and soil loss.

For lands having slopes less than 1.5%, the flat on grade system or contour cultivation with conservation furrows or dead furrows at every 5 m apart are found to be quite effective in reducing runoff and soil loss and in increasing crop yields. Raised land configurations (broadbed and furrow, and narrow ridge and furrow) offered no particular advantages in terms of runoff, soil loss, and yield over the flat on grade system or contour cultivation. They also posed problems resulting from low stability and complications in accommodating certain crop combinations.

Scoops have been found quite effective in improving *in-situ* soil and water conservation in the SAT Alfisols (Fig. 4). The machineries, which can make small scoops or pits on the soil surface are simple, less expensive and can be easily fabricated with local materials. The main aim of making small scoops is to provide more time for rain water to infiltrate into the soil. The other aim of these scoops is to reduce soil loss by trapping the eroded sediments that would otherwise be lost as soil loss from the field. A study conducted at ICRISAT revealed that the scoops reduced seasonal runoff by 69%, and soil loss by 53% when compared to the flat land surface. There was a significant increase

Fig.4. Scoops system for Alfisols

in pearl millet grain yield in the 20 mm storage capacity scoops (2.42 t ha^{-1}) over flat seed bed (1.79 t ha^{-1}) (Pathak and Laryea, 1995b).

Tillage

Off-season tillage: On Alfisols the off-season tillage should be done whenever feasible. It has been found to be helpful in increasing the rainwater infiltration and in decreasing weeds problem. It minimizes stored-water evaporation by a "Mulching" effect and allows the acceleration of planting operations thereby permitting earlier sowing and extension of the growing season. Experiments at ICRISAT center have shown that in most of the years off-season tillage alone can increase the crop yields by 7-9% and reduces runoff by 10-15%.

No-tillage: In many areas the no-tillage/minimum tillage is found to be quite effective in reducing runoff and soil loss and increasing crop productivity. In the long-term this system improves the soil quality.

Crop residue management

In long-term, a 'farming systems' design, which assures the generation and maintenance of favorable structural conditions, would be critical to the successful use of Alfisols. The incorporation of beneficial organic matter can be a likely means of achieving favorable soil organic matter contents and in turn a better structure in the SAT Alfisols. The use of organic matter as surface mulch and incorporation into the soil in subsequent

years has been useful for achieving favorable rainfall infiltration, reduced soil erosion, and structural stability. The studies conducted at ICRISAT, reported that the mulch rate of 10 t ha^{-1} reduced the seasonal runoff by 74% and soil loss by 80% when compared with no mulch treatment. The crop yield of sorghum was increased by 9% and pigeonpea was 35% in 10 t ha^{-1} mulched treatment over no mulch treatment.

On-farm participatory watershed research

The current model of on-farm watershed research at ICRISAT is to link on-station research watersheds and on-farm watersheds. On-farm watersheds vary from 500 - 10,000 ha. The development of these watersheds is being done by executing agencies such as NGOs, government departments, and state agricultural universities. Participation of people is essential for the success of the watershed programs. Participatory watershed management is a process, which aims to create a self-supporting system essential for sustainability. The concept of participatory watershed management emphasizes a multi-disciplinary and multi-institutional approach. The process begins with the management of land and water, which eventually leads to the development of other resources. Major emphasis is given on human resource development and large-scale community participation, since finally the rural people have to manage their resources.

Summary

Alfisols, Vertisols and their associated soils constitute major soil orders in the dryland agricultural region of India. Present farming systems on these soils in the dryland areas are characterized by low and undependable yields and by an inefficient use of the rains and the soil. The risks to dependable crop production are high: farmers therefore rarely use fertilizers, high yielding crop varieties, or adopt improved soil conservation effective farming techniques. In this paper, the soil-related limitations of Alfisols and Vertisols for sustainable resource utilization are discussed. The soil related major problems in dryland areas have been highlighted and appropriate land management systems for Vertisols and Alfisols have been suggested as technological improvements had immediate and positive benefits over the traditional management systems. These include highly economic increases in crop yields, amenability to small farmer's requirements, marked reduction in soil erosion and substantially low runoff losses.

References

Kampen, J. and Burford, J.R. 1980. Production systems soil-related constraints and potentials in the semi-arid tropics with special references to India. Priorities for Alleviating Soil Related Constraints to Food Production in the Tropics Symposium Proceedings, IRRI, Los Banos, Laguna, Philippines, pp: 141-145.

Pathak, P., Singh, S. and Sudi, R. 1987. Soil and water management alternatives for increased productivity on SAT Alfisols. In: Soil Conservation and Productivity Proceedings

of the IV International Conference on Soil Conservation, Soil Conservation Society of Venezuela, Maracay, Venezuela, pp: 533-550, Nov 3-9, 1985.

Pathak P. and Laryea, K.B. 1995a. Soil and water conservation in the Indian SAT: principles and improved practices. In: Singh, R.P. (ed.) pp: 83-94. Sustainable Development of Dryland Agriculture in India. Scientific Publishers, Jodhpur, India.

Pathak, P. and Laryea, K.B. 1995b. Soil and water management options to increase infiltration and productivity on SAT soils. In: Mukuru, S.Z. and King, S.B. (eds.) pp: 103-111. Eighth EARSAM Regional Workshop on Sorghum and Millets. ICRISAT, Patancheru 502 324, A.P., India.

Pathak, P. and Laryea, K.B. 1995b. Soil and water management options to increase infiltration and productivity on SAT soils. In: Mukuru, S.Z. and King, S.B. (eds.) pp: 103-111. Eighth EARSAM Regional Workshop on Sorghum and Millets. ICRISAT, Patancheru 502 324, A.P., India.

Improved Rain Water Conservation and Management Practices for Drought Mitigation in Andhra Pradesh

M. Singa Rao

Abstract

Drought is a very common feature in Andhra Pradesh, particularly in rainfed areas. Conservation of rain water, *in situ* and *ex situ* is essential to reduce the adverse effects of drought. In Alfisols contour vegetative barriers reduced the runoff losses by about 60% and the associated soil loss was reduced by 65%. The available soil moisture was also increased considerably. Conservation furrows on contours acted as temporary reservoir of rainwater. There by runoff was reduced and hence soil loss was also reduced (1.22 t/ha.). Deep tillage loosens the soil and facilitates increased infiltration of rainwater into the soil resulting in higher moisture. The yield increase due to contour vegetative barriers was 22.1%. in sorghum, 21.3% in redgram and 22% in castor. The runoff can be harvested and used for life saving irrigation. In light textured soils clay mixing improved the soil physical environment and increased the yield of crops. Incorporation of paddy husk @ 50 q ha^{-1} in red sandy loam soils improved soil structure and increased the moisture retention.

Introduction

In Andhra Pradesh nearly 65% of the area is under rainfed agriculture. The vagaries of monsoon decide quantum of agriculture output. The commonest limitation in agricultural production is the shortness of the rainy season, its variability from year to year, its erratic distribution and loss of considerable water by runoff during intense rains. In A.P. the rainy season is around four months. Eighty percent of the precipitation comes in about 100 days usually between June and October.

The rainfall in A.P. varies from about 300mm in Southern Agroclimatic zone to above >1000mm in High Altitude zone. Out of an average of 896 mm of rainfall in our state, nearly 67% is received during southwest monsoon, 22% during northeast monsoon, 3% in winter and 8% in summer. Duration of the southwest monsoon is short (June-September) *i.e.,* less than 4 months. Efficient management of rainwater on watershed basis is crucial for the improvement of rainfed areas. The soils in rainfed areas are not only thirsty but also hungry. It is reported that as high as 40% of rain water goes as runoff causing soil and nutrient loss, 41% as evapotranspiration, 9% gets percolated to ground water bodies and only 10% gets retained as soil moisture. For sustainable agriculture, proper soil and rainwater management is a hall mark in rainfed areas.

The rainwater can be used effectively by reducing the runoff losses (through *in situ* conservation, water harvesting and reuse), selection of appropriate crops and cropping systems (cover, phenology), and soil management practices (through increasing surface roughness, increasing porosity, improving soil structure through organic matter addition).

The *in situ* water conservation is more feasible and practicable proposition under most situations. These practices can broadly be grouped into agronomic practices, like summer ploughing, contour cultivation, contour ridging, conservation furrows, deep ploughing, vegetative barriers, clay mixing, crop residue incorporation, suitable crop and variety, intercropping, strip cropping *etc*. and engineering practices, like land leveling, bunding (stone/gravel, contour bunds, graded bunds), terraces, contour trenches *etc*.

Conservation through soil surface modifications

On red sandy loam soils with 2-3% slope underlined with *murram* (soft gravel admixed with clay, high bulk density layer) cutting the slope effect through contour cultivation, vegetative barriers, contour ridges, conservation furrows and breaking the sub-soil *murram* layer through deep tillage using sub-soiler and their combinations were found to be effective in conserving the rain water in Southern Telangana zone (Singa Rao *et al*, 1995 and Prabhu Prasadini *et al.,* 2001).

Contour ridges and furrows facilitate collection of rainwater in the furrows to a great extent resulting in reduced runoff, consequently reducing the soil loss. There is more infiltration time and more water enters the soil resulting in higher soil moisture. Conservation furrows on contours act as temporary reservoirs of rainwater, retains the water till they are full. So the runoff is reduced and hence the soil loss is also low (Table 1). Deep tillage loosens the soil and thus facilitate more infiltration of rainwater in to the soil resulting in higher soil moisture (Table 2). As the clay admixed with murram also contributes to water storage, deep tillage is suggested to facilitate root penetration by loosening the sub-surface *murram* layer. Care should be taken to avoid inversion *i.e.,* preventing the sub surface *murram* to get mixed with the surface soil. Sub-soiler, which opens or just breaks the sub-surface hard murram is suggested for deep tillage. Vegetative barrier reduces the velocity of running water, thus giving more opportunity time for infiltration. With higher soil moisture regime in the conservation treatments (Table 2), the yield of crops increases (Table 3). The extra yield the farmer could obtain with improved practices is also shown in Table 4.

Vegetative barrier

The runoff losses of the rainwater were reduced by about 60% there by the associated soil loss was reduced by about 65% and the soil moisture content

available for the crop was increased. The average soil moisture content during the growth period of rainfed crops was higher when the vegetative barrier was planted on contours (Table 2). The cumulative beneficial effect of higher moisture content was reflected on the yields of rainfed crops (Table 3).

Table 1: Effect of soil surface modifications on run off, soil loss and castor yield (1993-94)

Treatment	Runoff (mm)	Soil loss (t/ha)	Castor Yield (q/ha)
Contour cultivation	30.8	2.54	8.14
Vegetative barrier	10.55	0.62	8.79
Conservation furrow	16.44	1.22	8.73
Conservation furrow + vegetative barrier	7.18	0.36	9.23
Ridges and furrows + vegetative barrier	4.05	0.24	9.75
Sowing along the slope	35.14	2.98	7.47
Rainfall during the crop period (mm)		234.1	

(Singa Rao et al., 1995)

Table 2: Effect of surface modifications on soil moisture (% w/w) in 0-45 cm depth averaged over castor growth period

Treatment	1997-98	1998-99
	% increase over sowing along the slope	
Contour cultivation	6.1	8.1
Vegetative barrier	9.8	11.3
Conservation furrow	9.1	11.2
Conservation furrow + vegetative barrier	16.0	18.2
Ridges and furrows	19.9	23.7
Ridges and furrows + vegetative barrier	23.7	28.2
Deep tillage	26.6	22.9
Deep tillage + vegetative barrier	28.9	25.9
Rainfall in the crop period (mm)	307.4	931.3

(Singa Rao et al., 1995)

Table 3: Effect of *in situ* conservation practices on the yield of rainfed crops yield

Treatment	% Yield increase over control			
	1996-97	1997-98	1998-99 (Intercrop 2:1)	
	Castor	Sorghum	Sorghum	Pigeonpea
T1- Contour cultivation	15.1	16.4	16	14.2
T2- T1+ vegetative barrier	19.9	23.9	20.8	20.2
T3- Conservation furrow	20.0	23.3	21	20.9
T4- T3 + Vegetative barrier	26.9	28.8	26.8	25.9
T5-Ridges and Furrows	30.1	33.6	31.1	29.4
T6- T5 + vegetative barrier	35.9	39	35.2	34.3
T7 – Deep tillage	29.9	41.1	32.1	32.0
T8- Deep tillage + Vegetative barrier 33.0 33.0			50.7	33.9
Control–sowing along the slope (kg/ha)	705	1460	1201	402
Rainfall during the crop season (mm)	726.9	307.4	931.3 no rain after harvest of Sorghum)	

(Prabhu Prasadini et al., 2001)

Table 4: Extra yield per unit quantity of extra water conserved (kg/ha/mm) through soil management

Treatment	1996-97 (Castor)	1997-98 (Sorghum)	1998-99 (Sorghum)
Sowing along the slope	-	-	-
T1- Contour cultivation	12.3	88.8	41.5
T2- T1+ vegetative barrier	3.5	29.3	12.6
T3- Conservation furrow	4	33.1	13.9
T4- T3 + Vegetative barrier	4.1	30.0	13.6
T5-Ridges and Furrows	4.9	37.9	16.8
T6- T5 + vegetative barrier	4.9	36.8	16.1
T7 – Deep tillage	14.8	110.5	45.6
T8- Deep tillage + Vegetative barrier	10.24	41.2	21.4

(Prabhu Prasadini et al., 2001)

Effective use of collected runoff

The excess rain water over and above the intake rate of soils which goes as runoff is to be harvested and channeled through grassed water ways safely to different storage structures, like farm ponds, check dams, percolation tanks, small and medium tanks etc. The harvested water should be used for life saving irrigation (Table 5) and for high value crops through efficient irrigation methods (Table 6).

Table 5: Impact of life saving irrigation

Region	Crop	Yield (q/ha)	
		Without irrigation	With life saving
Bijapur	Sorghum	16.5	23.6
Sholapur	Sorghum	9.8	18.2
Rewa	Upland rice	16.2	27.8
	Wheat	5.7	18.8
Ludhiana	Wheat	19.2	41.1

(Padma Raju et al., *2002)*

Table 6:Efficient use of harvested water through drip irrigation

Treatment	Quantity of water applied (ha cu)	Per cent water saving	Yield (q/ha)
Drip at IW/CPE of 1.0	15.88	43.3	94.7
Drip at IW/CPE of 0.8	12.71	54.6	93.2
Drip at IW/CPE of 0.6	9.53	66	86.6
Surface flooding	28.00	-	74.6

(Padma Raju et al., *2002)*

Clay mixing technology in rain water conservation

In A.P. about 40% of the total cultivated area is occupied by light textured red sandy loam to loamy sand type of soils. The clay content of these soils is low (<15 per cent) with low water holding capacity (5-10 cm m^{-1} depth) and are susceptible to leaching losses. As these soils are mostly (around 80 per cent) under rainfed cultivation, their low water storage capacity is a major constraint for crop production. Studies were made to reduce the percolation losses and improve water holding capacity by mixing locally available tank silt or heavy textured soil in the surface 0-15 cm soil.

Considering operational feasibility and economics, addition of heavy textured soil to increase clay content by 2 per cent at a time, or over a period of 2 to 3 years is recommended to farmers. On farm trials were carried out in farmers' fields in Ranga Reddy district to demonstrate the beneficial effect of clay mixing. Clay mixing modified the soil physical environment in terms of bulk density, hydraulic conductivity, infiltration and water retention. It decreased bulk density by about 0.03 to 0.07 g cm^{-3} and increased soil moisture content by 6.5 to 23.5 per cent. Thus, the improved soil physical conditions resulted in higher yields of tomato and bhendi by 10.8 and 10.5 per cent, respectively (Table 7).

The benefit cost ratio worked out was 1.37 in Ranga Reddy district in the very first crop. The beneficial effect of clay addition is permanent as it modifies the soil texture.

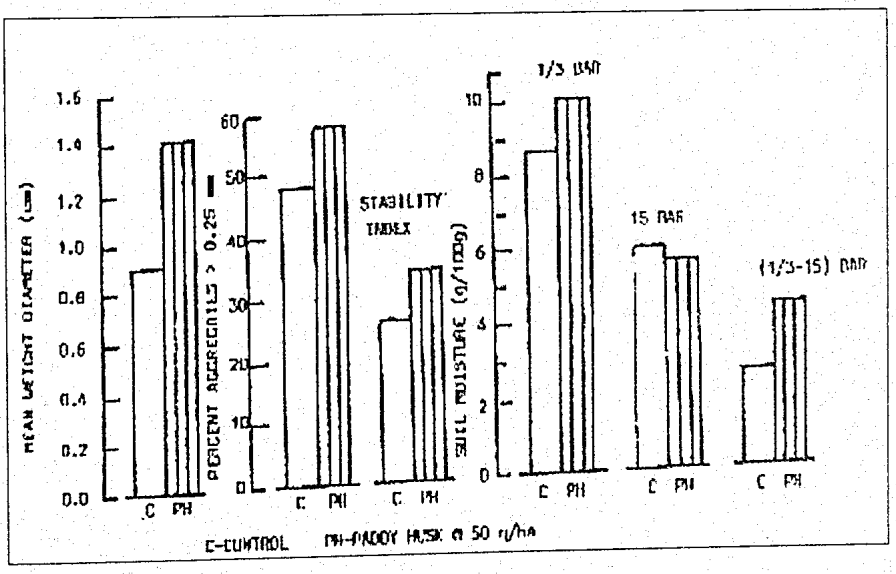
Table 7: Effect of Clay mixing on water retention and yield of rainfed crops in Alfisols

Parameter	No clay	Increase of clay by 2%
1. Tomato (pusa early dwarf) at rajendranagar, Hyderabad		
Soil moisture at flowering stage (%w/w)	9.74	10.37
Yield (t/ha)	10.19	11.29
2. Bhendi (pusa sawani) at mankhal, R. R. District		
Soil moisture at 30DAS (%w/w)	9.17	10.27
Soil moisture at 60DAS (%w/w)	9.07	11.2
Soil moisture at harvest (%w/w)	6.83	7.9
Yield (t/ha)	10.66	11.78

(Singa Rao et al., 1995)

Crop residue incorporation technology in rain water conservation

Red sandy loam soils (chalka) become very hard on drying as a result subsequent rain water is lost as runoff and growth of crops is adversely affected in rainfed areas. In these soils incorporation of slowly decomposing crop residues like paddy husk, powdered groundnut shells is recommended which keep the soil porus and increase the intake rate of the rain water. In the farmers' field trials, the influence of incorporation of paddy husk @ 50qha^{-1} in red sandy loam soil and its residual effect upto 2 years on soil properties and crop yields was studied. During first year of incorporation, sorghum (CSH-5) was taken as test crop and residual effect was studied with castor (2nd year) and sorghum (3rd year). Incorporation of paddy husk reduced the bulk density of 0-15 and 15-30 cm layers, increased the amount of moisture retained in these layers by 1.8 per cent and 2 per cent respectively. The effect of incorporation of paddy husk persisted upto the harvest of crops. The mean weight diameter, percentage



Effect of incorporation of paddy husk in sandy loam on aggregation and soil moisture retention

of aggregates greater than 0.25 mm diameter and aggregate stability of soil in 0-15 cm layer increased with the incorporation of paddy husk (Figure 1).The amount of moisture retained in 0-15 cm layer at 0.033 MPa increased, it decreased slightly at 1.5 MPa and available moisture (0.033-1.5 MPa) increased with the incorporation of paddy husk. The final infiltration rate increased from 8.2 to 11.0 cm ha^{-1} and the cumulative infiltration from 45.9 to 57.7 cm with the incorporation of paddy husk. This improvement in soil structure may remain for longer period as per cent organic carbon content was increased significantly by 0.06% with one incorporation. Yields of sorghum (1st year), castor (2nd year) and sorghum (3rd year) were increased by 33.08, 22.99 and 13.56 per cent with the incorporation of paddy husk indicating its residual effect. The benefit cost ratio was 3.09. Most of these technologies are cost effective and within the reach of the farmers. They should adopt these technologies to reduce the adverse effect of drought and increase the yield of crops.

References

Padma Raju, A. Singa Rao, M. and Prabhu Prasadini, P. 2002. Technologies for efficient water management in agriculture paper presented at the workshop on the water crisis – hope and action for humanity's future on 29th November 2002 at National Geo-Physical Research Institute, Hyderabad, INDIA.

Prabhu Prasadini, P. Nagender Rao, C. and Jayasree, G. 2001. Resource characterization and management and soils of Andhra Pradesh. AICRP on soil physics, ANGRAU.

Singa Rao, M. Prabhu Prasadini, P. Nagender Rao, C. and Jayasree, G. 1995. Soil physical constraints and their management for increasing crop production in Andhra Pradesh, AICRP on soil physics, ANGRAU.

Appropriate Rainfed Crops, Cropping Systems and Farming Systems for Different Agro-eco Sub-regions of Andhra Pradesh

M. Devender Reddy and G.Subba Reddy

Abstract

In Andhra Pradesh, rice, jowar, bajra, maize and ragi occupy 42.4, 6.8, 1.2, 5.2 and 1.0 lakh ha respectively. These crops account for 5, 63, 75, 69 and 25 percent of the total cropped area respectively under rainfed conditions. Oilseeds and pulses are grown in 28.30 and 19.03 lakh ha and of which 24.07 and 18.82 lakh ha are cultivated under rainfed conditions. The crop diversification has taken place since 1955-56 and major loss in the cropped area was experienced in the dry land crops and commercial crops largely replaced millets.

The crop strategies to be adopted for successful rainfed crop cultivation and improvement of income to the farmer are by encouraging traditional food crops, sowing the crops with early showers, exploring medicinal and aromatic plants, adoption of farming systems and cropping systems approach in relation to soil and season. The uncultivated area under tanks has to be sown with rainfed crops and irrigated whenever water is available which improves the productivity of water. The crops and cropping systems for the tankfed areas of Andhra Pradesh are suggested. Further, the potential farming systems for seven agro-climatic zones of Andhra Pradesh such as agriculture + livestock / sericulture / apiculture / fisheries have been presented in the paper.

Introduction

Crops and cropping systems in a given area depend on climatic condition, availability of irrigation, and type of soil, market price fluctuation, technological developments and socio-economic condition of the farmers. Further, change in cropping systems are necessitated by incidence of certain diseases or insect pest in epidemic form in a component crop, changes in cost of cultivation due to labour availability patterns because of social or economic changes. The price structure of inputs or products, development of new genotypes in preferential crops and making their cultivation feasible in non-traditional areas, creation of demand for certain commercial crops which require development of processing industry or international trade and change in food habits of the people also decide the cropping systems.

Rainfall

The rainfall distribution in the three regions of the state differs with monsoon season. The Coastal Andhra Pradesh receives 900-1200 mm; Telangana 800 to 900 mm and Rayalaseema 500-700 mm (Fig. 1). The influence of South-West Monsoon is predominant in Telangana region (780 mm) followed by Coastal Andhra (610 mm) and Rayalaseema (389 mm). On the other hand, Coastal Andhra receives high amount of rainfall (314 mm) followed by Rayalaseema (217 mm) and Telangana (101 mm) during NE monsoon period. There are no significant differences in the distribution of rainfall during the winter and hot weather periods among the three regions.

Rainfed area in the State

The total cropped area in A.P. increased from 12.3 million ha in 1955-56 to 13.55 million ha by 2000-01. Of this, 5.92 million ha is irrigated. The rainfed area in the state is 7.63 million ha which accounts for 56.8 per cent of the total gross cropped area.

In Andhra Pradesh, rice, jowar, bajra, maize and ragi occupy 42.4, 6.8, 1.2, 5.2 and 1.0 lakh ha respectively. These crops are grown in 5, 63, 75, 69 and 25 per cent of the total cropped area respectively under rainfed conditions. Oil seeds and pulses are grown in 28.30 and 19.03 lakh ha and of which 24.07 and 18.82 lakh ha are cultivated under rainfed conditions.

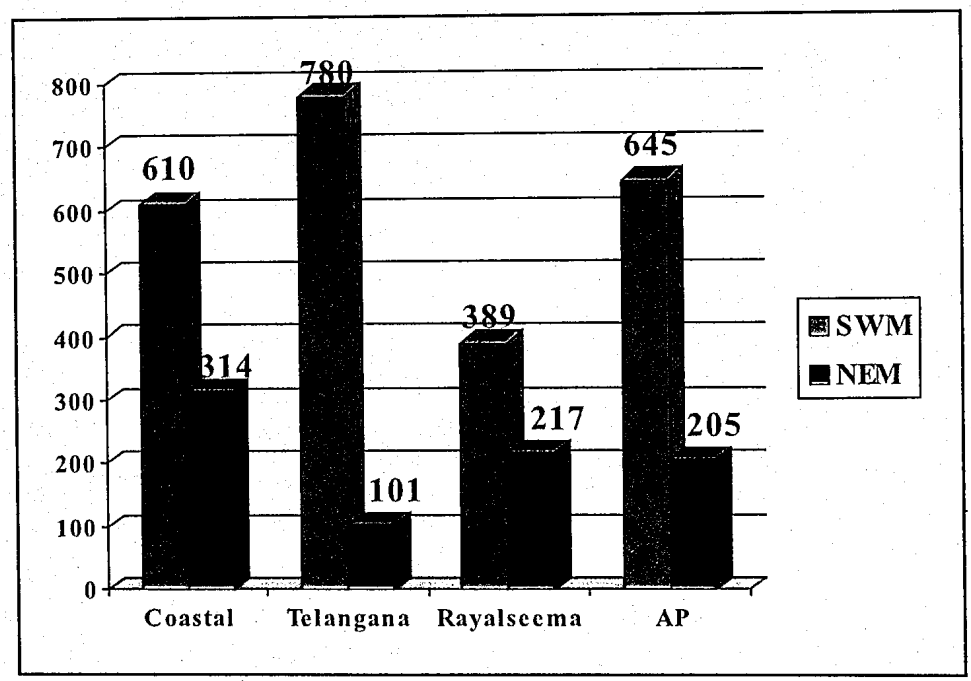


Fig. 1: Rainfall distribution in three regions of Andhra Pradesh

Irrigation

During 1955-56, the net area irrigated in A.P. was only 27.47 lakh ha and it increased to 45.27 lakh ha by 2000-01 (41.4%). The increase in irrigated area was contributed by exploitation of ground water (Table 1). The major source of irrigation in the state was canals followed by tanks in 1955-56. The two sources together accounted for 85.27%, while well irrigation accounted for small area. By the turn of 1980, wells gained the prominence and occupied 2nd position. At present, in A.P. 98.8% of Sugarcane, 95.8% of Turmerice, 95.2% of Rice, 64.2% of Chillies and 12.7% of Cotton is irrigated. However, rice consumes 67%, groundnut 8.4% and sugarcane 5.4% of irrigation water.

There are six major soil groups – Red soil (66%); black soil (25%); alluvial clay loam soil (5%); coastal sands (3%) and problem soils (1%) in the state.

Region wise change in crops and cropped area

The state of Andhra Pradesh has been delineated into seven agro climatic zones based on soil type, irrigation facilities and climatic conditions: Krishna - Godavari Zone, North - Coastal Zone, Southern Zone and Scarce Rainfall Zone, Northern Telangana Zone, Southern Telangana Zone and High altitude and tribal Zone. Zone wise important crops grown, and the crop shifts are discussed here under.

The crop diversification has taken place since 1955-56 and major loss in cropped area was experienced in dry land crops; commercial crops largely replaced millets (Table 2). These shifts were not scientifically planned but were mostly price driven. These shifts in cropped area were mainly due to neglect of millets in price support. Inter cropping and mixed cropping has given way to monocropping with increased use of chemical fertilizers and pesticides.

In Coastal Andhra Pradesh, the canals irrigate greater area followed by tanks and wells. On the other hand, in Rayalaseema and Telangana the wells irrigate more area followed by canals and tanks. In Andhra Pradesh the wells irrigate more area followed by canals and tanks.

Table 1: Area irrigated source wise (lakh ha) 2000-2001

District	Net area irrigated by					Total	Area irrigated more than once	Gross area irrigated
	Canals	Tanks	Tube wells	Other wells	Other sources			
Coastal Andhra	12.24	4.01	3.41	1.31	1.23	22.21	6.74	28.96
Rayalaseema	1.24	0.55	2.61	1.68	0.13	6.23	1.54	7.78
Telenga	3.00	2.69	4.63	5.88	0.60	16.82	5.59	22.41
A.P.	16.49	7.26	10.66	8.87	1.97	45.27	13.88	59.16

Table 2: Percent change in area of different crops in different regions of Andhra Pradesh (1999-2000 over 1955-56)

Crops	Region					
	Coastal Andhra		Rayalaseema		Telangana	
	Area 1955-56 (Lakh ha)	% change 1999-2000	Area 1955-56 (Lakh ha)	% change 1999-2000	Area 1955-56 (Lakh ha)	% change 1999-2000
Total food grains	32.43	2.5	21.46	-190.8	35.35	-12.9
Rice	16.6	213.3	2.77	4.2	7.85	75.8
Maize	0.075	616.3	-	98.1	1.82	116.5
Jowar	5.55	-97.4	6.18	-273.1	13.82	-59.8
Bajra	1.98	-76.0	2.39	-879.0	2.14	-79.2
Ragi	1.22	-53.3	1.35	-666.7	0.62	-64.3
Pulses	3.79	103.9	2.30	-10.2	7.09	-6.0
Cotton	0.33	626.4	2.70	-91.6	1.06	540.0
Sugarcane	0.36	251.0	0.13	97.1	0.21	1880
Oilseeds	3.50	2.2	6.64	57.4	9.80	-29.5

Source: Directorate of Economics and Statistics, A.P.

Other than rice, millets, oilseeds and pulses are grown under rainfed conditions. Only 25 – 37% of the cropped area in these crops is irrigated. The 56, 36 and 7.5 per cent of rice grown respectively in Coastal Andhra, Rayalaseema and Telangana regions under irrigated conditions. Jowar irrigated area is higher in Rayalaseema, while maize area is more in Telangana region. The irrigated area in ragi is higher in Rayalaseema and Coastal Andhra and in Telangana it is negligible (Table 3).

Table 3: Crop wise area irrigated in Andhra Pradesh 2000-01 (ha)

Crops	Region			Total	Cropped area
	Coastal	Rayalaseema	Telangana		
Rice	2272816	303227	1464644	4040687 (95.2)	4243000
Jowar	710	16959	7543	25212 (37.2)	677000
Bajra	14476	8792	8809	32077 (24.7)	130000
Maize	30188	4465	126697	161350 (30.6)	527000
Ragi	10886	12423	1547	24856 (25.10)	99000
Small millets	-	254	-	254	55000
Total cereals	2329076	346528	1619782	4295386	

The area and productivity of major cereals indicate that productivity of rice is higher in Coastal Andhra Pradesh, Jowar in Rayalaseema, Bajra in Coastal Andhra particularly in North Coastal Andhra and Ragi in Rayalaseema. The Maize yields in three regions of Andhra Pradesh are almost similar (Table 4). This indicates that wherever considerable area is under irrigation, the yields are higher.

Table 4: Area, production and productivity of crops in different regions of Andhra Pradesh, 2000-01

Sl.No.	Crop	Region	Area ('000 ha)	Prod. '000t	Productivity t/ha
1	Rice	Coastal AP	2383	7158	3.00
		Rayalaseema	312	883	2.83
		Telangana	1548	4418	2.85
		AP	4243	12459	2.94
2	Jowar	Coastal AP	16	10	0.64
		Rayalaseema	129	169	1.31
		Telangana	532	827	0.44
		AP	677	914	0.62
3	Bajra	Coastal AP	61	82	1.35
		Rayalaseema	32	32	0.99
		Telangana	37	22	0.60
		AP	130	136	1.05
4	Ragi	Coastal AP	57	64	0.95
		Rayalaseema	22	34	1.62
		Telangana	20	22	1.03
		AP	99	120	1.11
5	Maize	Coastal AP	71	280	2.60
		Rayalaseema	7	21	2.60
		Telangana	449	1279	2.57
		AP	2572	527	1.58

Source:. Directorate of Economics and Statistics, A.P.

In Krishna-Godavari and North Coastal zone 52 and 33% of the cropped area is under rice and rice-rice is the common cropping system (Table 5). On the other hand, groundnut crop occupies 32 and 38% of the cropped area and rice occupies 27 and 11% respectively in scarce rainfall and southern zone of Rayalaseema. The predominant cropping system followed is rice-rice, groundnut, groundnut + redgram, fallow-jowar, cotton and sunflower. In North and Southern Telangana region, rice is the predominant crop followed by maize, jowar, castor, cotton and chillies. In High altitude zone, rice, ragi, pearlmillet are major crops and rice based cropping system is common.

Crop strategies

The crop strategies to be adopted for successful rainfed crop cultivation and improvement of income to the farmer are

- Encouraging traditional food crops
- Sowing the crops with early showers and irrigating whenever water is available
- Exploring medicinal and aromatic plants
- Adoption of farming systems approach (dairy, poultry, sheep and goat production) and
- Cropping systems approach in relation to soil and season.

Table 5: Cropping Systems in different zones of Andhra Pradesh (area '000 ha) 1999-2000

Zone (District)	Area ('000 ha)	Major crops	Cropping Systems
Krishna Godavari zone (Krishna, Guntur, East & West Godavari)	3037	Rice (52), Cotton (6), Chillies (2), Red gram (2), Tobacco (1) & Maize (1)	Rice (20), Rice (16) – Rice (16), Cotton (6)
North Coastal zone (Srikakulam, Vijayanagaram, Visakhapatnam)	3037	Rice (33), Groundnut (11), Ragi (4), Bajra (2), Til (2), Sugarcane (2), Cotton (1)	Rice (31), Rice (1) – Rice (1), Groundnut (11)
Southern zone (Cuddapah, Nellore, Chittoor)	1235	Rice (27), Groundnut (32), Sugar- Cane (2), Cotton (2), Bengalgram (2)	Rice (5), Rice (11) – Rice (11), Groundnut (32)
North Telangana Zone (Adilabad, Karimnagar, Nizamabad, Warangal and Medak)	3119	Rice (22), Maize (11), Greengram (5), Jowar (9), Chillies (2), Black-gram (2), Sugarcane (2)	Rice (4), Rice (9) – Rice (9), Greengram (5) – Maize (4), Maize+Redgram (2), Cotton + Redgram (2), Maize + Groundnut (4)
Southern Telangana zone (Mahaboobnagar, Nalgonda, Sangareddy)	1808	Rice (26), Jowar (15), Castor (13), Groundnut (10), Cotton (9), Redgram (7), Maize (2), Bajra (2), Chillies (1), Ragi (1)	Rice (8), Rice (9) – Rice (9), Jowar (10), Fallow Jowar (5), Castor (13), Groundnut (10), Cotton (9), Redgram (7)
Scarce rainfall zone (Kurnool, Ananthapur, Prakasam)	2523	Groundnut (38), Rice (11), Cotton (6), Jowar (6), Redgram (4), Sunflower (3), Bajra (1)	Groundnut (31), Groundnut + Redgram (4), Groundnut (3), Rice (5), Rice (3) – Rice (3), Cotton (6), Fallow jowar (5), Sunflower (3)
High altitude Tribal area (Srikakulam, Viajayanagaram, Visakhapatnam, East Godavari and Khammam)		Rice, Pearlmillet, Groundnut, Fingermillet, Til	Rice based

Figures in parenthesis indicate the percentage of total cropped area in the zone

Suggested crops and cropping systems for different zones / districts of Andhra Pradesh (Table 6 and 7)

Table 6: Crops and cropping systems for rainfed areas in Andhra Pradesh

S.No. Zone	Soil type	Kharif	Rabi
1. Krishna Godavari zone (Krishna, Guntur, East & West Godavari)	Light soils	Bajra, ragi, maize, redgram, cowpea, groundnut, castor, greengram, blackgram, fodder jowar	-
	Medium to heavy soils	Rainfed rice, Maize, ragi, vegetables, blackgram, soybean, redgram, chillies, greengram, sunflower, cotton, fodder jowar	Coriander, bengalgram, sunflower, jowar, vegetables, fodder jowar
2. North Coastal zone (Srikakulam, Vijayanagaram, Visakhapatnam)	Light soils	Bajra, ragi, maize, jowar, mesta, redgram, cowpea, greengram, blackgram, maize, vegetables, fodder jowar	-
	Medium to heavy soils	Rainfed rice, maize, bajra, ragi, vegetables, blackgram, soybean, redgram,greengram, chillies, cotton, mesta, fodder jowar	Greengram, blackgram, horsegram, tomato, sesame
3. Southern zone (Cuddapah, Nellore, Chittoor)	Light soils	Bajra, ragi, redgram, jowar, greengram, blackgram, groundnut, bajra + redgram, groundnut+redgram, castor, jowar, sunflower, fodder jowar	-
	Medium to heavy soils	Redgram, castor, sunflower, jowar, cotton, fodder jowar	Bengalgram, coriander
4. North Telangana Zone (Adilabad, Karimnagar, Nizamabad, Warangal and Medak)	Light soils	Maize, jowar, bajra, redgram, bajra + redgram, blackgram, greengram, sunflower, fodder jowar,	
	Medium to heavy soils	Maize, ragi, cotton, chillies, soybean, sunflower	Safflower, bengalgram, jowar, coriander
5. Southern Telangana zone (Mahaboobnagar, Nalgonda, Rangareddy, Medak)	Light soils	Jowar, bajra, ragi, maize, redgram, greengram, sunflower, groundnut, castor	-
	Medium to heavy soils	Bajra, ragi, maize, sunflower, castor, redgram, cotton, chillies	Bengalgram, safflower, jowar, coriander
6. Scarce rainfall zone (Kurnool, Ananthapur, Prakasam)	Light soils	Korra, bajra, jowar, castor, onion, sunflower, redgram, fodder jowar	-
	Medium to heavy soils	Bajra, maize, redgram, castor, soybean, gingelly, cotton	Coriander, bengalgram, sunflower, jowar.
7. High altitude Tribal area (Srikakulam, Viajayanagaram, Visakhapatnam, East Godavari and Khammam)	Light soils	Bajra, ragi, maize, redgram, blackgram, rainfed rice	

Table 7: Crops and cropping systems of eight districts in Andhra Pradesh having major area under rainfed conditions.

S.No.	District	Soil type	Kharif	Rabi
1.	Prakasam	Light soils	Bajra, castor, jowar, redgram, fodder jowar	-
		Medium to heavy soils	Maize, soybean, chillies, cotton, redgram, castor, bajra, fodder jowar	Coriander, bengalgram, sunflower, jowar.
2.	Ananthapur	Light soils	Bajra, redgram, groundnut, castor, fodder jowar, cowpea, sunflower	
		Medium to heavy soils	Bajra, korra, redgram, castor, fodder jowar, cotton	Coriander, horsegram
3.	Kadapa	Light soils	Bajra, redgram, groundnut, bajra+redgram, groundnut+redgram, fodder jowar	
		Medium to heavy soils	Redgram, castor, sunflower, jowar, fodder jowar, cotton	Coriander, bengalgram
4.	Mahaboobnagar	Light soils	Jowar, cotton, sunflower, bajra, ragi, redgram, groundnut, castor, maize, greengram	
		Medium to heavy soils	Maize, ragi, sunflower, cotton, chillies, greengram	Safflower, bengalgram, jowar
5.	Nalgonda	Light soils	Bajra, jowar, ragi, redgram, maize, groundnut, castor, greengram, sunflower	
		Medium to heavy soils	Bajra, ragi, maize, sunflower, castor, redgram, cotton, chillies	Safflower, bengalgram, jowar
6.	Medak	Light soils	Maize, bajra, jowar, blackgram, redgram, sunflower, castor	
		Medium to heavy soils	Ragi, maize, soybean, cotton, sunflower	Safflower, bengalgram, coriander
7.	Adilabad	Light soils	Maize, groundnut, blackgram, redgram, castor, fodder jowar	
		Medium to heavy soils	Maize, soybean, jowar, blackgram, soybean+redgram, sunflower, cotton, redgram, cotton+redgram, chillies	Bengalgram, safflower, blackgram, coriander
8.	Vizianagaram	Light soils	Bajra, mesta, blackgram, ragi, redgram, bajra+redgram, cowpea, blackgram, fodder jowar, greengram	
		Medium to heavy soils	Rainfed rice, maize, bajra, ragi, ragi+redgram, jowar, cowpea, fodder jowar, chillies, soybean	Blackgram, greengram, horsegram, tomato, sesame

Tankfed areas

The majority of the tanks in the state are not receiving water for last 8 to 10 years and the farmers are interested to grow paddy. Due to paucity of water, rice crop could not be grown as a result large areas under tanks are kept fallow. The concentration on groundwater has increased from 80's and a greater quantity of groundwater is used for cultivation of paddy, which is an unhealthy practice (Table 8). There are several reasons for non-filling of tanks which include lower runoff causing rains, increased cropped area, lack of catchments treatments, excessive ground water exploitation, indiscriminate watershed works in catchment areas and improper desilting works.

It has been observed that 23.12 lakh ha is under current fallows and this constitute 30% of the area of the food grain crops grown in the state (Table 8). There is every need to bring this land under cultivation as large number of people especially 17.5% of total population of the state are living on wages earned by working in agriculture (Table 9). It is advisable to grow rainfed crops in tankfed areas with onset up monsoon and if water is available these areas can be given supplementary irrigation, which increases the water productivity. The suggested crops and cropping systems are given in table 10.

Table 8: Source wise net area irrigated in Andhra Pradesh (lakh ha)

Year	Canals	Tanks	Dugwells	Tube wells	Others	Total
1955-56	12.92	10.68	2.84	-	1.03	27.47
2000-01	16.49	7.27	8.88	10.66	1.97	45.27

Source: Directorate of Economics and Statistics, A.P.

Table 9: Area under food grains and current fallow lands (lakh ha) – 2000-01 and population distribution in agriculture, 1991 (lakhs) in Andhra Pradesh

Region	Area (lakh ha)		Population distribution (lakhs)			
	Food grains	Current fallows	Total population	Main workers	Cultivators	Agril. Labourers
Coastal Andhra	35.43	3.24	287.3	121.6	28.4	55.7
Rayalaseema	7.92	4.30	116.9	50.4	16.2	20.6
Telangana	33.38	15.59	261.0	112.5	34.3	40.0
Andhra Pradesh	76.73	23.12	665.2	284.5	78.9 (12)	116.3 (17.5)

Source : Directorate of Economics and Statistics, A.P., Director of Census Operations, A.P.

Table 10: Suggested crops and cropping systems for tankfed areas of Andhra Pradesh

Region	Soil type	Kharif	Rabi
Coastal Andhra Pradesh	Light soil	Bajra, ragi, maize, jowar, greengram and mesta	-
	Medium to heavy soils	Rainfed rice, ragi, maize, bajra, mesta, greengram, fodder jowar	Greengram, blackgram, sesame, vegetables, fodder jowar
Rayalaseema	Light soil	Groundnut, greengram, bajra, redgram, castor, jowar, sunflower	-
	Medium to heavy soils	Jowar, castor, bajra, maize, cotton, sunflower	Coriander, chickpea, jowar, vegetables
Telangana	Light soil	Greengram, jowar, maize, castor, Redgram	-
	Medium to heavy soils	Maize, jowar, bajra, ragi, blackgram, soybean, sunflower, cotton,	Coriander, safflower, chickpea, jowar

Farming systems

Live stock position

Andhra Pradesh possesses 10.6 million cattle, 9.6 million buffaloes, 9.6 million sheep and 5.2 million goats (Table 11). The back yard poultry still play a vital role in rural areas. Salient features in livestock sector are: area under pastures/ fallows/ cultivable waste generally used for grazing has decreased by 30-50% (Viroji Rao and Bose, 2002). Nearly 60% of households in rural areas are keeping bovine with an average size of 4 per herd. Farmers with less than 2 ha of land maintain 70% of bovine; 20% landless farmers maintain bovine for milk production. Use of cattle for draft purpose is high in Telangana (52%) and Rayalaseema (21%). Buffaloes are predominant in coastal A.P. (52%) and Telangana. Male cattle registered negative trend, while female and young stock registered positive growth. Sheep registered a negative growth rate as goats are predominant in Telangana, North Coastal Andhra and Rayalaseema with a positive growth rate of 3.5, 1.4 and 3.1 per cent respectively.

Table 11: Percentage (to state population) of live stock population in different regions of the state

Animal	Region			Total population
	Coastal Andhra	Rayalaseema	Telangana	of AP (millions)
Cattle	26.7	20.9	52.4	10.6
Buffaloes	51.6	13.4	36.5	9.6
Sheep	25.5	26.0	48.5	9.6
Goats	29.7	21.3	49.0	5.2

Source: Viroji Rao and Bose, 2002

Centres of various crop / livestock production

The enterprises, which emerged as basic entities in farming system of different zones, are (1) Agriculture; (2) Cattle, Buffaloes for milk production; (3) Sheep production (4) Goat production; (5) Backyard poultry and (6) Fisheries. Of the above enterprises agriculture is the lead enterprise. Based on the type of crop, agriculture can be classified into – rice, millets, oil seed, pulse, sugarcane and cotton based farming systems.

Two broad categories of integrated farming systems involving livestock are identified: Systems combining animals and annual cropping and systems combining animals and perennial cropping.

Between the two systems, dairying, involving mainly cattle and buffalo is very much common in the first system involving annual cropping. These are the areas, which are usually irrigated where intensive cereal cropping is common, and a distinctive market pull exists because of the peri-urban demand for milk. Thus, dairy production is an expanding feature in these situations in which it is integrated with crop cultivation and provides an economic motivation for farming systems. Systems combining animals and perennial crops are more common in upland rainfed areas.

Remunerative farming systems

Diversified land uses including the adoption of farming systems based on the resource carrying capacity will ensure remunerative agro based farming system to flourish and lead to prosperity of the farmer in achieving the much needed food and nutrition security as well as social security.

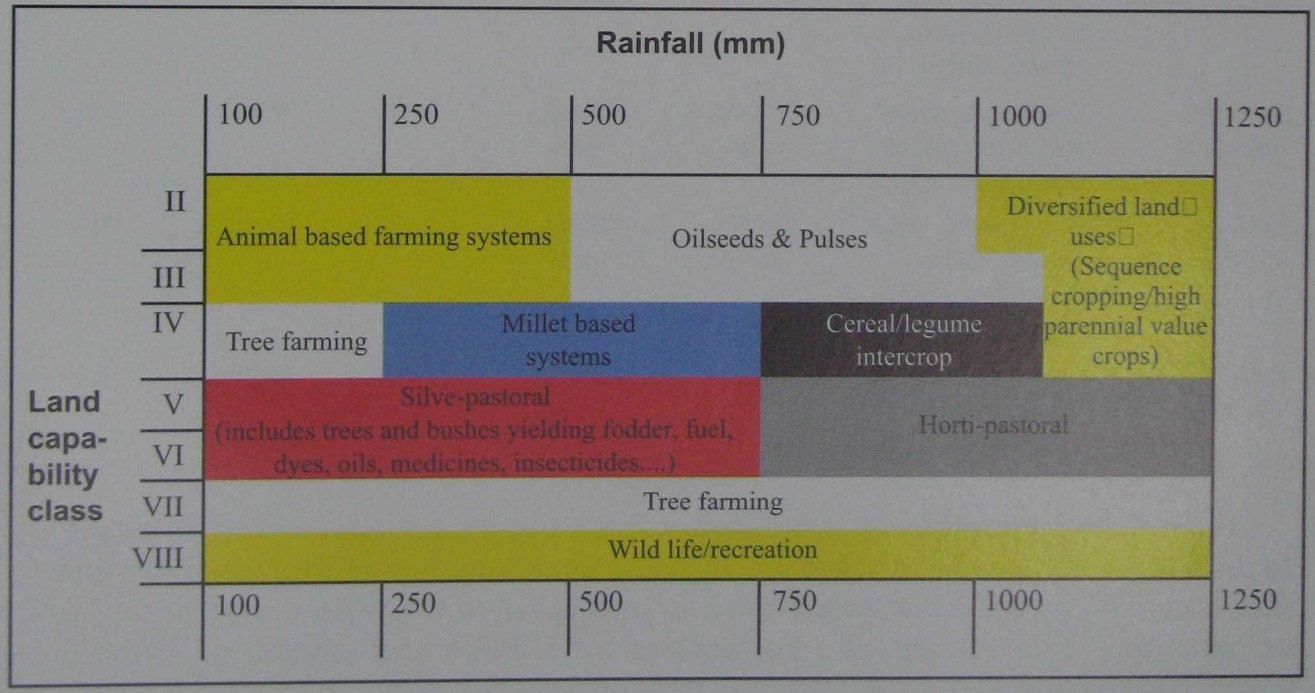


Fig. 1. Possible land uses based on resource carrying capacity

Source: CRIDA

Farming systems vary with location/crop/cropping pattern/livestock/farm family assets and priorities. However, data on major homogenous farming systems at micro level are not available. There is an immediate need to document major farming situations up to mandal level along with agro-based industry to prepare detailed micro level action plan.

The potential farming systems in different zones of Andhra Pradesh on agriculture + livestock / sericulture / apiculture / fisheries are given in Table 12. Forage crops are to be included in major cropping systems. Specific action is needed on production related factors for profitability and sustainability of farming system.

Table 12: Major food crops and various possible farming systems of different agro-climatic zones of the state

Agro climatic zone	Major food crops	Dairy	Sheep and goat	Backyard poultry	Fishery	Apiculture
North Coastal	Rice, pulse, ragi, sesame, sugarcane, cashewnut	Cattle, buffalo	Sheep, goat	Backyard poultry	Inland coastal	Apiculture
Krishna-Godavari	Rice, maize, pulse, sugarcane, coconut, cotton, chillies	-do-	Sheep in Prakasam	-do-	-do-	-do-
South	Groundnut, rice, ragi, jowar, pulses, cotton, sunflower	-do-	Sheep	-do-	Inland	-do-
Scarce rainfall	Groundnut, rice, safflower, jowar, pulses, cotton	-do-	Sheep	-do-	Inland	-do-
Southern Telangana	Groundnut, castor, sunflower, pulses, rice, jowar, cotton	Buffalo, cattle	Sheep, goat	-do-	Inland	-do-
Northern Telangana	Rice, maize, jowar, pulses, cotton, groundnut, chillies, sugarcane	Buffalo, cattle	Sheep, goat	-do-	Inland	-do-
High altitude and tribal zone	Rice, ragi, maize, bajra, Jowar, Sugarcane, pulse	Buffalo	Sheep, goat	-do-	Inland	-do-

The success of adoption of suggested crops, cropping systems and farming systems depends on price policy as there are regional variations in cost of cultivation and no intervention by agencies when the price of millets fall in the market, no support price for perishable commodities and no facilities for storage and marketing. Thus, more skillful management of natural resources through adoption of integrated forming systems and implementation of favourable pricing policies are very much needed in future.

Conclusions

- The crop strategies to be adopted for successful rainfed crop cultivation and improvement of income to the farmer are encouraging traditional food crops, sowing the crops with early showers, exploring medicinal and aromatic plants, adoption of farming systems and cropping systems approach in relation to soil and season.
- It is advisable to grow rainfed crops in tankfed areas with onset of monsoon and if water is available these areas are to be given supplementary irrigation, which increases the water productivity.
- The dairy production has to be integrated with crop cultivation, which provide an economic motivation for farming systems. Systems combining animals and perennial crops are to be encouraged in upland rainfed areas.

References

Directorate of Economics and Statistics, A.P., 1999-2000.

Directorate of Economics and Statistics, A.P., 2000-2001.

Viroji Rao, S.T and Bose, Ch.S.C. 2002, Integrated farming systems approach for sustainable Agriculture, presented at 32nd research and extension advisory council meeting of ANGR Agricultural University, Rajendranagar, Hyderabad. 26-27 Dec, 2002.

Integrated Nutrient Management for Efficient Crop Production in Andhra Pradesh

A. Sreenivasa Raju and K.P.R.Vittal

Abstract

The results of experiment carried out on crops and cropping systems have conclusively proven that substitution of 25 to 50 per cent inorganic fertilization is possible by applying organic manures. This benefit is more and will be highly economical in cropping systems as the residual effects of applied nutrient through organic and inorganic sources and also good effects of growing legumes which improve soil fertility through biological N fixation and showing positive effects on soil physical conditions can effectively be harnessed through crop rotations. However, the situation is different with dryland agriculture, where water is a limiting factor for successful crop production. It even alters the nutrient use efficiencies. Under conditions of growing single crop annually depending upon the quantum of rain received, the scope for extending INM to dryland agriculture may not be remunerative though direct benefit of different components of INM can be seen on individual crop. Hence, it is necessary to critically evaluate the research work so far carried out on INM in different situations and translate those results to suit dryland agriculture and make it more remunerative. A scanning of previous work also indicates that the dryland farmers also use FYM and sheep penning for improving the productivity of their fields. Growing cowpea and horse gram as green manures and utilizing sesbania, gliricidia, sunnhemp and Leucaena loppings as green leaf manures were found useful in dryland areas. Since mixed cropping or inter cropping are commonly practiced in dryland fields, it will be beneficial if these species are utilized appropriately as green manures. The best way would be through harvesting the first flush and then incorporating it into the soil. The green leaf manuring helps to achieve the benefits where time and space are problem for growing the green manure crops. However, more intensive studies are needed to understand the nutrient release pattern to assess their possible contribution to nutrient requirement of growing crops and also the substitution of inorganic fertilization possible under the limited moisture conditions.

Introduction

India is one of the most populous countries; the population being just over one billion mark with an increase by 14 to 15 million per annum. It was long back estimated that India needs to produce 235 to 240 million tonnes of food grain in its 210 million hectares of gross cropped area by 2000 A.D. consuming 20.5 million tonnes of N, P_2O_5 and K_2O. However, the food production touched only a maximum of 208.9 million tonnes in 1999-2000 while it slightly increased to 211.3 million tonnes in 2001-02.

In 2000-01 and 2002-03, the food production showed decline to 196.1 and 182.8 million tonnes, respectively. The maximum production of 211.3 million tonnes was achieved by consuming 17.54 million tonnes of NPK, which touched the peak consumption of 18.37 million tonnes in 1999-2000. These statistics indicate that we are reaching the long back-targeted fertilizer consumption of 20.5 million tonnes but are far away to produce the required quantum of food, which is highly fluctuating. The per hectare consumptions of NPK during 2001-02 and 2002-03 were 85 and 91 kg, respectively. At the present growth rate of population, India has the compulsive need to raise food grain output at a rate of more than 5 million tonnes per annum through sustainable agriculture. Although sustainable agriculture indicates the need for agricultural production to satisfy the changing human needs, it also lays emphasis on successful management of resources while maintaining or enhancing the quality of environment. The quality of environment is particularly under threat due to increased production of chemical fertilizers and their prolonged use for cultivating crops to produce enough food, fodder, fuel etc. At All India level, the present consumption ratio is 6.8: 2.5:1 in 2002-03 against the ideal ratio of 4:2:1 for N, P_2O_5 and K_2O, respectively. This indicates an imbalanced consumption of this costly input, which ultimately, if not properly used, will lead to pollution of land and water. Hence, efforts to decrease the consumption of chemical fertilizers through technologies developed for improving nutrient use efficiency and integration with other possible sources of nutrients are most welcoming. Such efforts will also lead to conserving lot of energy, which is being invested in manufacturing different fertilizers in our country.

Agricultural scenario in Andhra Pradesh

Andhra Pradesh comprises of 3 physiographic regions – Coastal plains, Eastern Ghats and Peninsular plateau. The state is divided into 7 agro-climatic zones based on rainfall pattern, irrigation, soil characteristics and cropping patterns (Fig. 1 & Table 1). The state receives about 70 per cent of its total rainfall through southwest monsoon and 20 per cent through northeast monsoon while the rest is received through non monsoonic rains.

Important soil types include red and laterite, black, alluvial and coastal soils occupying 66, 25, 5 and 3 per cent of total area, respectively (Fig. 2). Soils of the state are low to medium in organic carbon, low in available P and medium to high in available K. Deficiencies of P and Zn are widespread, particularly in the soils of Nagarjuna Sagar Project and Sriram Sagar Project areas. In Anantapur, accumulation of P in soils is being reported. The Zn deficient areas in the state (Venkata Subbaiah *et al.*, 2000) can be seen in Fig. 3. While Zn deficiency is prevalent in 54 per cent soils, deficiencies of Cu, Fe and Mn were reported in <1, 2 and 2 per cent of soils, respectively. High responses to applied nutrients, particularly P and Zn to cereals and S to groundnut were observed (Raman *et al.*, 1985). Of late, responses of crops including sunflower, castor, pulses etc. to applied sulphur have been reported.

Crops grown in Andhra Pradesh

In Andhra Pradesh, the farmers of coastal districts grow a variety of agricultural crops while millets, oilseeds and orchards are grown by most of the Telangana and Rayalaseema farmers (Fig. 4). Rice and sugarcane cultivation is taken up when assured irrigation is possible though some area is existing under rainfed conditions. The size of holdings, irrigated area and cropping intensity in the 7 agro-climatic zones are furnished in Fig. 5.

As shown in Table 1, cropping patterns differ with agro-climatic zones. Depending upon the soil depth and texture, a variety of crops like sorghum, maize, pearl millet, finger millet, red gram and other pulses, groundnut, tobacco etc. are grown in red soils during rainy season (*kharif*). Normally only one crop is raised on these soils during rainy season. However, in the *maghi* sorghum tracts and in heavy rainfall areas, two crops are taken up in these soils. In *maghi* tract, a pulse, generally greengram precedes early *rabi* or *maghi* sorghum. With improved technology, farmers are adopting intercropping and sequence cropping systems and sowing two crops even in black soils (*regurs*). Similarly, a variety of rainfed crops like sorghum, maize, pearl millet, finger millet, pulses, sesamum, groundnut, tobacco, chillies, coriander, safflower and gram are grown on black soils, mostly during *rabi* season. Rice, sugarcane, chillies, cotton and turmeric are grown both on red and black soils under irrigated conditions. Rice is the major crop in deltaic alluviums. Commercial crops like sugarcane, tobacco, cotton, turmeric and chillies are the other major crops grown on these soils. Rice and tobacco nurseries, flowers and vegetables are raised in small areas in coastal sands by means of pot watering from shallow dug out wells (*Doruvus*). The area and production of major crops in 2002-03 are presented in Table 2. (Directorate of Economics and Statistics, 2002-03).

Among the individual crops, rice occupied the largest area of 38.51 lakh ha followed by groundnut 20.84 lakh ha during 2002-03. Sorghum, maize and *bajra* occupied 8.45, 3.62 and 1.25 lakh ha, respectively. A total of 53.84 lakh ha was under total cereals and millets. Among pulses, blackgram, greengram, redgram and bengal gram were cultivated in 4.93, 4.76, 3.40 and 1.36 lakh ha, respectively out of total area of 16.01 lakh ha under pulses. Sugarcane and cotton were cultivated in 3.64 and 10.21 lakh ha, respectively during the year. The production of rice was 9.87 million tonnes out of total cereal production of 11.85 million tonnes. The average yield of rice was 2,609 $kgha^{-1}$.

Fertilizer consumption in Andhra Pradesh

The fertilizer consumption in the state is rated higher when compared with many states. The data on zonewise fertilizer consumption (lakh t) indicate that the consumption was highest in Krishna, Godavari zone followed by northern Telangana zone (Fig. 6). The N, P_2O_5 and K_2O consumption which was 23, 007 tonnes 1956-57 has increased to 16,72,678 tonnes during 2002-03. West Godavari in A.P. showed the maximum consumption of 1,67,271 tonnes of N, P_2O_5 and K_2O ranking second in the country.

This was followed by Krishna (1,40,639 tonnes) Guntur (1,31,982 tonnes), Kareemnagar (1,17,439 tonnes) and East Godavari (1,18,808 tonnes) ranking 4,7,10 and 12, respectively at All India level. The state of Andhra Pradesh showed a consumption ratio of 5.2: 2.3:1 and 5.0: 2.0:1 in 2001-02 and 2002-03, respectively indicating that balanced fertilizer use is being approached. The per hectare consumption of N, P_2O_5 and K_2O were 112.2, 49.7 and 17.2 kg (i.e. a total of 179.2 kg ha^{-1}) during 2001-02. Among the districts, Adilabad had the lowest consumption of 30,005 tonnes. The zonewise fertilizer (N, P and K) balance in use can be seen in Fig. 7. The relative consumption of fertilizers is more in scarce rainfall zone. Though there is no precise information on cropwise consumption of these nutrients, irrigated crops like rice, sugarcane, groundnut and commercial crops like chillies and cotton were found consuming higher quantities of fertilizers in the state. The dryland crops like millets, pulses and oilseeds consume lower quantum of fertilizers.

Some indicators related to agricultural development in the various districts of Andhra Pradesh as compiled by Rao and Rao (1999) for the year 1993 through district profiles are furnished in Table 3. The average response ratios at indicated levels of N, P_2O_5 and K_2O were 10.5, 4.5 and 4.5 at 120:60:60 for rice, 5.8, 3.0 and 3.4 at 90:60:30 for *jowar;* 3.0, 2.4 and 1.4 at 120:60:60 for *ragi;* 8.9, 5.1 and 4.9 at 120:60:60 for maize; 15.8, 1.5 and 0.6 at 20:40:30 for bengalgram, 3.4, 2.4 and 0.6 at 60:60:20 for redgram; 27.6, 7.1 and 3.8 at 20:60:40 for groundnut; 1.9, 1.8 and 1.8 at 60:40:40 for gingelly, and for N and P_2O_5 17.7 and 2.1 at 20:40 for blackgram; 12.1 and 2.7 at 20:40 for greengram; 19.8 and 1.4 at 20:40 for horsegram, respectively (Reddy and Raidu, 1995).

Types of fertilizers, manures and bio-fertilizers used

Fertilizers: Farmers of the state are using different chemical fertilizers for crop production purposes. These include straight fertilizers like urea, ammonium sulphate, calcium ammonium nitrate, single superphosphate and muriate of potash. Among the complexes, DAP, UAP (28-28-0), 20-20-0, 15-15-15, 17-17-17, 19-19-19 and 14-35-14 are used in agriculture and horticultural fields. Use of zinc sulphate to overcome the zinc deficiency problems in crops and other micro nutrient fertilizers (ferrous ammonium sulphate, copper sulphate, manganese sulphate, borax/boric acid and ammonium molybdate) depending upon the necessity has been noticed in different parts of the state. Chelated fertilizers and certain mixtures of micronutrients (approved by Govt. of A.P.) are also available in the state for use by farmers.

Manures: Among organic manures, farmers are applying FYM, compost, cakes (castor, neem etc.), poultry manure, pressmud, pig manure, green manure and green leaf manures to crops in different parts of the state. Cattle penning and sheep penning (besides pig penning) are also in practice. Application of *pati mannu* (old alluvium) and tank silt has also been observed.

Bio-fertilizers: Bio-fertilizers contain actively living cells of bacteria, fungi and actinomycetes. Bio-fertilizers form an integral part of integrated plant nutrient supply

system and organic farming, which constitute the present as well as future mandate of Indian agriculture. Commercial production of bio fertilizers is undertaken in ANGRAU at Agricultural Research Station, Amaravathi. During 2003-04, the quantities of bio fertilizers produced by the Station are given in Table 4 (Ramana Reddy, 2004). The success of a bio-fertilizer inoculation depends on the quality of inoculants used against a particular crop. Liquid inoculant formulations are favourable due to high cell count, zero contaminants, more shelf life and protection against abiotic stresses.

The successful establishment of introduced strains mainly depends on various factors like their ability to compete with native population and other soil factors. A successful microbial inoculant needs to be more competitive than that of the existing rhizosphere micro flora in forming effective colonization on the roots of a particular crop. Dual inoculations of N_2 fixers and phosphate solubilizers must be compatible to form favourable colonization in the rhizosphere of legumes. Hence, it is now considered necessary to develop efficient microbial consortia and test the performance of different crops to derive benefit from these living organisms. Positive findings with dual inoculation of Azospirillum and VAM and *Azospirillum* and *Pseudomonas striata* on crops like tomato, chilli and *bhendi* are reported in literature. In order to reduce fertilizer consumption and safeguard the soil environment, it is essential to identify and produce efficient *Azospirillum* and *Azotobacter* inoculants along with VAM and P solubilizers.

Integrated nutrient management

In order to emphasize the use of several sources of nutrients in crop production, technologies such as 'Integrated Plant Nutrient Supply System' (IPNSS), 'Integrated Plant Nutrition System' (IPNS) and 'Integrated Nutrient Management' (INM) have been coined and are used synonymously though there are slight differences among them. The INM is technical and managerial component of achieving the objective of IPNSS under farm situations. The INM aims at the maintenance and possibly increase the soil fertility for sustaining increased crop productivity through optimizing all possible sources (organic and inorganic) of plant nutrients required for crop growth and quality in an integrated manner, appropriate to each cropping system or farming situation in its social, ecological and economic possibilities. Thus, INM conceptually integrates all sources of plant nutrients and also all improved crop production technologies into a productive agricultural system. Integrated nutrient management encourages the use of inhouse organic waste: thus, it saves on cost of fertilizers for crop production.

In INM, the soil nutrient reserve, mineral fertilizers, organic manures and bio fertilizers form the important components which need to be efficiently managed in crop production.

i) *Soil nutrient reserve*

Soil is a store bin of several nutrients which are present in both available and reserve forms; both being in dynamic equilibrium with each other. When plant absorbs nutrients, a depletion occurs in available form, which is immediately replenished from reserve

pool, if supply is proper. However, soil is not an eternal supplier of nutrients. In order to produce more, soils are exploited very badly leading to deficiencies in supplies of N,P,K, S, Zn, Fe, Mn and B in recent years. It is estimated that there is an annual depletion of about 5.8 million tonnes of major nutrients due to agricultural production systems, mostly P and K since most farmers apply these nutrients in much lesser amounts than needed (Rajendra Prasad, 2002).

Several physical, chemical and biological constraints also limit the use of nutrients by crops. To overcome these problems, adoption of soil management and conservation practices, amelioration of problem soils, improving soil physical conditions, achieving higher fertilizer use efficiency, choosing crop species to exploit reserve forms of nutrients, choosing appropriate cultural practices and cropping systems, growing legumes and intercrops etc. need greater attention. Crop specificities for soil phosphorus forms are presented in Table 5.

ii) *Mineral fertilizers*

Green revolution virtually transformed 'Soil dependent agriculture' into 'Fertilizer dependent agriculture'. The quantities of nutrient added, the level of depletion and balance left out in soil in different agro climatic zones depicted in Fig. 8 show that the removal is more in all the agro ecological systems leaving negative balance of this nutrient in soil. The quantity of N left out as balance is more in K-G zone followed by NT zone. While P balance is less in this zone, a negative balance was observed in High Altitude Tribal Area Zone. The addition and removal were the same in North Coastal Zone leaving behind no P as balance in soil. However, fertilizer use efficiencies (FUE) in soils are very low. The average use efficiency of N ranges from 40 (low land situation) to 60 per cent (upland situation), whereas phosphorus is utilized to an extent of 15 to 25 per cent by a single crop in a season. While K use efficiency is around 50 per cent, the Zn use efficiency hardly exceeds 2 per cent. This indicates that the added fertilizer is not fully utilized by the crops and a major portion of it is either lost by different ways or made unavailable for crop use. Increase in net returns from crops, saving energy, stretching fertilizer use to other needy areas etc. are chief advantages of achieving higher FUE, which is possible through scheduling of fertilizer recommendations, choosing appropriate sources depending on soil and crop, selecting appropriate times and methods of application, correction of deficiencies, improving water use efficiency and controlling pests and diseases. Some guidelines for efficient management of N in flooded rice using prilled urea are furnished in Table 6 (All India Coordinated Agronomic Research Project, 1971). The pattern of application of N at different phenological/ growth stages in splits to several ID crops can be seen in Table 7 (Das, 1993).

iii) *Organic manures*

Organic manures vary in their composition depending upon the source from which they originate (Table 8). They release nutrients contained in them by decomposition but at a slower rate giving scope for residual effects. They also improve soil physical conditions, which help proper growth of plants. The soil health care and environmental

safety are also ensured by application of organic wastes to soils. Several organic wastes are recycled through rural and urban composting. The available estimates show that about 875 million tonnes of organic wastes are generated annually in India out of which 30 per cent are only diverted for agricultural purposes. However, future agriculture is poised to make efficient use of these organic manures for crop production as it has been established that they cut down the expenditure on chemical fertilizers by 50 per cent. Organic farming activity is gaining momentum in recent years for improving the quality of environment. However, one should also keep in mind that organic manures are slow releasers of plant nutrients and will not be in a position to meet the crop requirement of nutrients to give high yields. Certain social problems in collection and usage also come in the way of their utilization for crop production purposes.

iv) *Bio-fertilizers*

Bio-fertilizers serve as microbial inoculants which would participate in nitrogen fixation, solubilize phosphate and other nutrients and mobilize nutrients like C and S. *Rhizobium*, a bio fertilizer is host specific in nature and maximum benefit is achieved only when respective cross inoculation groups of crops are considered. The amounts of N which can be fixed by different legumes in symbiotic association can be seen in Table 9.

Azotobacter and *Azospirillum* are useful for improving production of crops other than legumes. In rice fields, BGA is proving to be beneficial. Azolla, a water fern, serves as a green manure and supplies N to crops. Inoculation with *Rhizobium* could substitute 19-22 kg N ha^{-1} while *Azotobacter* and *Azospirillum* can substitute 20kg N ha^{-1}. Azolla applied at 6-12 t ha^{-1} has a N equivalent of 3-4 kg N per tonne. The fertilizer equivalent of some frequently used organic manures and biofertilizers can be seen in Table- 10 (Tandon, 1992). Other bio fertilizers such as phosphobacteria and VAM are useful for mobilizing P and nutrients in soils for utilization by annual and perennial crops, respectively. The saving in phosphate application due to inoculation with P solubilizing microorganisms was reported as 30 to 50 kg P_2O_5 ha^{-1}.

INM research on crops and cropping systems

Research work carried out on individual crops has established beyond doubt that all these components have their definite positive effects in improving production of particular crops. Research on cropping systems, specifically in Andhra Pradesh is meager. But the experiments conducted during the past 5 to 6 years indicated that considerable residual effects can be harnessed by subsequent crops grown in the sequence, specifically when organic manures are applied in conjunction with inorganic fertilizers. Research work carried out on cropping systems in ANGRAU helped to suggest options depending upon the availabilities of different materials locally. Attempts were also made to make options available based on economic conditions of farmers. A few findings on different crops on aspects related to integrated nutrient management are briefly given below:

Rice

- Combined application of organic amendments and nitrogenous fertilizers resulted in more production of ammoniacal nitrogen and also increased dry matter yields of BPT 1235 rice.
- The rice yields with the recommendation made by M/s PPIC, Gurgaon, i.e., 180kg N + 105kg P_2O_5 + 210 kg K_2O ha^{-1} were higher than with the state recommended dose of 120 kg N + 60 kg P_2O_5 +30 kg K_2O ha^{-1}. Highest grain yield (7.53 t ha^{-1}) was obtained with 50% N applied as poultry manure (PM) + 50% RD of PPIC and it was on par with the same doses of FYM and fertilizer. Hence, application of 180kg N + 105kg P_2O_5 + 210 kg K_2O ha^{-1} and PM/FYM in 50:50 combination was recommended.
- Under STCR Project, efforts are also being made to develop targeted yield equations when fertilizer N was applied in conjunction with paddy straw and poultry manure.

Sorghum

- Increase in dry matter production of sorghum with the application of P and Zn was less compared to that of mycorrhizal inoculation coupled with P and Zn application.
- Higher grain yield of 38.7 q ha^{-1} was recorded when *rabi* sorghum was grown after French bean and the lowest yield of 24.6 q ha^{-1} was observed when sorghum was sown after finger millet.
- Dry matter production by sorghum grown on a Isohyperthermic Typic Haplustalf of Central Research Institute for Dryland Agriculture, Hyderabad was higher with 100% N in the initial stages of crop growth. Later on with age, urea + glyricidia produced required or greater dry matter yield and grain yield. Application of sorghum straw caused reduction in dry matter production and grain yield. The N uptake also showed similar trend. Agronomic efficiency and apparent N recovery were more with glyricidia than with sorghum straw treatments.

Maize

- Conjunctive use of N, P_2O_5 and K_2O @ 120-60-60 kg ha^{-1} and poultry manure at 4.5 t ha^{-1} gave maximum yields of maize when grown on Alfisol. However, the yields obtained were on par with the N, P_2O_5 and K_2O applied at 60-30-30 + poultry manure at 4.5 t $ha^{-1}$and, hence, the latter is recommended.
- Application of sewage sludge @ 20 t ha^{-1} + 100% RDFN and 30 t sludge ha^{-1}+ 100% RDFN to maize grown on Alfisol and Vertisol, respectively were found to give maximum dry matter yield under pot culture conditions. However, the former was on par with 20 t sludge ha^{-1}+ 50% RDFN and hence, it was recommended with a view to reduce chemical load on soil.
- Seed inoculation with VAM and application of P at 30 kg P_2O_5 ha^{-1} was equally beneficial as that of 60 kg P_2O_5 ha^{-1} level applied to maize grown on Vertisols of Guntur district.

Sugarcane

- The yield, uptake and % juice sucrose values increased significantly with the application of 100% RDFN + 75% RDP + Phosphobacterin in both plant and ratoon crops. However, for economic application, the treatment 75% RDFN + 75% RDP + Azotobacter + Phosphobacterin was recommended for higher sugar yield.
- Irrespective of organic source (FYM or vermicompost), application of 75% and 100% fertilizer N significantly improved cane yields over other levels of fertilizer N application. Application of vermicompost significantly gave higher cane yields of both plant and ratoon crops than with FYM at corresponding level of fertilizer N. Highest sugar yield was obtained with 75% RDFN + vermicompost.
- At RARS, Anakapalli, it was observed that 25% NPK can be saved through the application of enriched pressmud cake @ 5 t ha^{-1} in integration with 75% RDF (NPK).

Bengal gram

- In medium P containing sandy clay soil, combined application of 50 kg P_2O_5 ha^{-1} and inoculating with PSB and VAM was found economical for bengal gram though 100 kg P_2O_5 ha^{-1} + PSB + VAM gave the highest yield.

Soybean

- Combined application of 5 t FYM ha^{-1} + 1 t PM ha^{-1} + 50% RDFN resulted in the highest dry matter production at flowering, grain and haulm yields of soybean besides high protein content of seed at maturity.

Green gram

- Application of N at 20kg ha^{-1} and inoculation with *Rhizobium* increased the yields of Pusa Baisakhi *moong* compared to PS-16 grown on Alfisol.

Black gram

- Inoculation of black gram with *Rhizobium* and application of phosphate significantly increased 1000 seed weight, harvest index, protein content and yield.
- Conjunctive application of organic manures and P increased the yield of LBG-20 black gram grown on a sandy loam soil. Biogas digest was found superior to FYM application in this regard.

Groundnut

- Nitrogen application at 20kg ha^{-1} combined with *Rhizobium* inoculation increased the yields, protein and oil contents of J-11 groundnut.
- In Anantapur, highest pod yield of groundnut was obtained with half of the recommended dose of fertilizer + groundnut shells @ 4 t ha^{-1}

Safflower

- *Azospirillum* inoculation to safflower can be recommended in combination with 20 kg N ha^{-1} as basal application since the yields obtained were on par with those recorded with 40 kg N ha^{-1}. Thus, a saving of 20 kg N ha^{-1} was observed due to conjunctive use of N and *Azospirillum* inoculation.

Sesamum

❖ Combined application of inorganic nitrogen through urea at 25 kg N ha^{-1} and organic manure through groundnut shells at 5 t ha^{-1} resulted in higher yields of sesamum grown on a black soil.

Sunflower

- ❖ Application of poultry manure @ 1 t ha^{-1} and 75% RDFN to sunflower grown on sandy clay loam soil and application of 50% N through vermi compost + 50% RDFN when grown on a sandy loam soil were found to increase seed yields of sunflower significantly over other combinations.
- ❖ In medium P sandy clay loam soils, similar P utilization of that of 100% RDP was obtained by reducing the dose by 20 to 30% and inoculating sunflower seed with PSB besides applying FYM.

Vegetables

- ❖ Application of 10kg N ha^{-1} + 15 t vermi compost ha^{-1} gave maximum yield of *bhendi.*
- ❖ Application of 50% RDFN + 50% N through vermi compost or 50% RDFN + 6 t castor cake ha^{-1} resulted in better performance of carrot. Maximum response of the crop was also noticed with 120 kg K_2O ha^{-1} + 15 t FYM ha^{-1} which, however, was on par with 80 kg K_2O ha^{-1} + 15 t FYM ha^{-1}.
- ❖ Application of 50% RDFN + 50% N through vermi compost gave maximum yield and N uptake by radish.
- ❖ Application of 100% NPK + 15 t vermi compost ha^{-1} gave highest yield of ridge gourd.
- ❖ The tuber yield of sweet potato obtained with Azospirillum +20kg N $ha^{-1}$was on par with 40kg N ha^{-1} indicating that 20kg N ha^{-1} was compensated by treating with Azospirillum. The use of Azospirillum was ineffective at higher levels of N application done to sweet potato crop.
- ❖ In onion, combined application of 25 t FYM ha^{-1} and 200 kg K_2O ha^{-1} was found to give maximum bulb yield, which however, was on par with the yield obtained with 12.5 t FYM ha^{-1} + 200 kg K_2O ha^{-1}. Hence, the latter treatment was only recommended.
- ❖ Application of FYM at 25 kg + pressmud at 2 kg + iron pyrites at 200 g $plant^{-1}$ was found suitable for obtaining optimum yield and improving soil fertility besides achieving maximum recovery from iron chlorosis in young acid lime orchards grown on calcareous red soils in Nellore district.
- ❖ At RARS, Jagtial, application of 75% RDF + 3.5 t vermicompost ha^{-1} along with green manuring with cowpea *in situ* gave significantly higher pod yield (41.76 q ha^{-1}) of chillies besides showing maximum uptake of nutrients. Highest pod yield of 3,858 kg ha^{-1} was obtained with 25 t vermi compost ha^{-1} along with RDF in 2001-02.

Though maximum yields were seen with the application of 15 t vermicompost in certain combinations with inorganic fertilizers, such applications are uneconomical).

The costs spent on purchase of manures (FYM) and fertilizers for application to certain cereal (Fig.9), oilseeds (Fig. 10), pulses (Fig.11) and some commercial crops (Fig.12) and cost of production of these crops in different agro-climatic zones indicate that the use of manures in general, more in cereal crops grown in all the zones of the State. The oilseed and pulse crops grown in High Altitude and Tribal area zone on a large extent in southern zone do not receive manure dressings. Cotton and sugarcane are usually applied manures in 5 out of 7 zones in the state.

Cropping systems

In order to attain maximum yields of crops by improving soil fertility and also to reduce the cost of cultivation by harnessing the residual effect, FAO gave a model in case of rice-grain legume-wheat system (Table 11). Several options are made available to farmers to achieve saving in chemical fertilizer usage besides achieving sustainability in production from crops involved in the cropping systems. A few trials on mono cropping and multiple cropping systems were conducted in different parts of the state. The results obtained are briefly given below:

Rice-rice system

- Application of FYM along with 100% optimum NPK resulted in higher build up of organic carbon, total N and total and available P in long term experiments conducted on rice-rice system.
- In alluvial soils of Godavari delta, application of FYM at 10 t ha^{-1} + poultry manure @ 1 t ha^{-1} + 25% RDFK resulted in the highest dry matter yields at flowering, and grain and straw yields at maturity with yields of 71.6, 52.3 and 56.3 q ha^{-1}, respectively in case of *kharif* rice. The *rabi* rice showed responses to the residual quantity of K: the responses being 19.3, 11.8 and 6.5 kg grain per kg of applied K_2O at no K, 50 and 75% RDK, respectively. Due to direct, residual and cumulative effects of added K; there was a net saving of 25% RDK in each season due to addition of FYM or PM with fertilizer K, while a net saving of 75 and 25% can be achieved by addition of combination of organic manures with fertilizer K. A saving of 17.5 to 32.5 kg K_2O ha^{-1} was obtained by application of organic manures along with residual doses of K in rice-rice system.
- At ARS, Marutur, highest mean grain yield of 5620 kg ha^{-1} was obtained with 100% NPK + 5 t FYM ha^{-1}. Soil fertility improvement was noticed under this treatment.

Sunflower-sunflower system

- Mixed feed vermi compost application resulted in superior stand and vigour of sunflower. The crop showed response upto 50 kg N ha^{-1} in both pot culture and field conditions. Application of vermi compost + urea (fertilizer) in 1:1 ratio to supply 50 kg N ha^{-1} resulted in seed yields of 1878 kg ha^{-1} and 2160 kg ha^{-1} in *kharif* and *rabi* seasons of 1994-95, respectively.

Rice-pulse

- In a rice-blackgram sequence taken up on a sandy clay loam soil utilizing BGA inoculation @ 10 kg ha^{-1}, the highest grain yield was obtained at 80 kg N ha^{-1}. However, the response was more pronounced at lower level of N i.e. 40 kg N ha^{-1} + BGA. Thus, BGA was found to substitute 40 kg fertilizer N ha^{-1}. The yield of succeeding blackgram was markedly improved with increase in level of N along with BGA applied to *kharif* rice and maximum was obtained at 80 kg N ha^{-1} applied along with BGA.

Rice-sunflower

- The dry matter yield at flowering, grain and straw yields at maturity of rice were highest with the application of 75% RDFN + 25% N as poultry manure (PM); the yields being 95.1, 55.0 and 73.3 q ha^{-1}, respectively. This treatment was followed by 75% RDFN + 10 t FYM ha^{-1}. The sunflower crop grown during *rabi* showed responses to residual quantity of inorganic N; the responses being 5.5, 4.5 and 3.3 kg seed $kg^{-1}$of applied N in no green manuring, cowpea and pillipesara green manured plots, respectively. The total N removal by rice-sunflower cropping system was highest in 75% RDFN + 2 t PM ha^{-1} in no green manure (212.9 kg ha^{-1}), cowpea green manured (236.7 kg ha^{-1}) and pillipesara green manured (232.9 kg ha^{-1}) plots. Highest net income from rice-sunflower cropping system was recorded in 75% RDFN + 2 t PM ha^{-1} treatment applied to rice followed by application of 40kg N ha^{-1} to sunflower.

Maize-soybean

- The maize-soybean system was taken up on a sandy loam soil. Integrated use of organic manures and inorganic fertilizers increased dry matter yield, grain and straw/ haulm yields of crops. The beneficial effects and net profit were more with 75% RDFN + 25% N as vermi compost followed by 50% RDFN + 50% N as vermi compost. The latter treatment was recommended due to cost prohibitive ness of vermi compost. The yield increase in both the crops and monetary returns were highest under vermi compost followed by PM, BGS and FYM in that order.

Tomato-onion

- The dry matter yields of fruits/bulbs, haulm yields of crops and nutrient uptake increased; the highest values being observed with vermi compost. The yields etc. were maximum at 50% RDFN + 50% N as vermi compost. Based on the results, the latter was found useful for obtaining optimum yields of crops.

Mesta based systems

- The total N removed by mesta-horse gram sequence was highest in the treatment 1 t PM ha^{-1} + 75% RDFN and same was the case with mesta-rice system; the values being 113.48 and 132.43 $kgha^{-1}$, respectively. The cost : benefit ratio was highest in case of treatments with Azospirillum as there was no much additional expenditure involved for purchase of the biofertilizer. Options were suggested to farmers based on their economic conditions to obtain economic yields from the crops (Table 12).

Nutrient gains in INM

Nitrogen gains through application of FYM to crops depend on the soils and crop growing environments. In case of low land rice, savings of 30 to 40 kg N ha^{-1} were reported when grown on sandy clay loams and loamy sand soils receiving applications of 10 and 12 t ha^{-1} respectively. Poultry manure, which is having a lower C:N ratio when compared with FYM, can substitute up to 75 kg N ha^{-1}. Maize crop grown on loamy sand soil under upland conditions showed a gain of fertilizer N equivalent up to 60 kg N ha^{-1} when FYM was applied at 10 t ha^{-1}. Results of long term fertilizer experiments conducted at several locations all over India with a treatment using FYM conclusively showed that application of 100% NPK (recommended) together with 10 t FYM ha^{-1} is as good or even better than application of 150% NPK to crops. Nitrogen gains through bio fertilizers are, however, highly variable. Results of research also indicated the possible reduction in doses of fertilizer K application, secondary and micronutrients when organic manures were applied in combination with inorganic fertilizers. While sole crops like sorghum and castor deplete soil nitrogen heavily when grown in cropping system, inclusion of leguminous plants in crop rotations was found to leave behind a saving of N in the soil (Table 13). The leguminous crop residues in mixtures were found to increase agronomic efficiency of sorghum crop grown under dryland conditions. While residues of *Gliricidia sepium* and *Leucaenia leucocephala* showed higher agronomic efficiency, the mixtures of *G. sepium* of *Cassia siamea* and *G. sepium* + castor showed much higher agronomic efficiencies of 10.63 and 11.11 kg grain kg^{-1} N with apparent N recover values of 28.40 and 29.95, respectively (Table 14).

Use of components of INM by farmers of Andhra Pradesh

Surveys have been carried out on fertilizer use in several parts of the state to understand the pattern of usage of fertilizers, manures and bio fertilizers by farmers for crop production purposes. The types of fertilizers and manures being used by farmers in different parts of the state are presented in Tables 13 and 14, respectively. Predominant use of urea and DAP by farmers is also reflected in the state wide survey carried out by ANGRAU recently (Sreenivasa Raju and Padma Raju, 2000). Ammonium sulphate and CAN are used by a few farmers of Nizamabad, Warangal and Nellore districts. Complex fertilizers such as 28-28-0, 20-20-0, 15-15-15, 19-19-19 and 14-35-14 are in use by very few farmers in different districts (Table 15). The complex fertilizer 14-35-14 is used in Cuddapah, Anantapur and Khammam districts only. Farmers are seen investing large amounts on purchase of fertilizers. However, indications are there that certain farmers of Vizianagaram and Visakhapatnam districts are not using any type of inorganic fertilizers for crop production even now. The survey further indicated that all these types of fertilizers were adequately available in markets in the state. As the micro nutrient deficiencies are cropping up in intensively cultivated areas, application of micronutrients along with the recommended doses of fertilizers was found to benefit crops like castor, groundnut, mungbean, maize and pigeonpea (Fig. 13).

Among the manures, FYM followed by sheep penning was followed by farmers of the state. Use of castor cake and neem cake was observed in Cuddapah, Anantapur and Nellore districts by a few farmers. Green leaf manuring is followed in Chittoor, Cuddapah, Anantapur, Khammam and Ranga Reddy districts while use of green manure crops for improving soil fertility was adopted by farmers in many districts. Use of poultry manure is seen in Cuddapah, Anantapur, Nizamabad and Nellore districts only by very few farmers. Tank silt is used in Karimnagar district. The survey indicated that some farmers in Kurnool, Cuddapah, Mahabubnagar and Ranga Reddy districts were not using organic manures at all for crop production purposes (Table 16).

Unfortunately use of bio fertilizers is not making any headway in utilization for crop production in Andhra Pradesh. Several farmers expressed that they were not aware of the beneficial effects of the bio fertilizers. Those that were aware were also not using them due to lack of information on places where the materials can be procured. However, in some districts (Anantapur, Adilabad, Chittoor and Nellore), very few farmers are using the *Rhizobium* for groundnut and *Azotobacter* and *Azospirillum* to cereal and commercial crops.

Madhava Swamy and Subba Rao (1995) observed that the farmers of scarce rainfall zone were applying more of nitrogen through chemical fertilizers to paddy, cotton, chillies and less in sorghum, *bajra*, setaria and tobacco. Similarly, use of phosphorus was more in paddy, cotton, chillies and onion and was less in *bajra*, *setaria*, irrigated sunflower and bengal gram crops. They further observed that farmers were using more of complex fertilizers than straight fertilizers, which was causing imbalance in fertilizer use. Lack of awareness about the recommended doses of fertilizers and lack of knowledge about conversion of different fertilizers into their nutrient forms were identified as reasons for the imbalanced use of fertilizers. More than half of the farmers surveyed indicated that they were using increased rates of fertilizers in spite of higher costs of these materials (Table 17).

Reddy *et al.* (1997) carried out a study to examine the fertilizer use deviations in case of three important crops viz., rice, sorghum and groundnut in Andhra Pradesh. In case of rice, the per hectare fertilizer use ranged from 80 kg in Penumantra to 366 kg in Mantralayam. In most places, excess use of nitrogen and phosphorus was observed. In contrast application of potash was meager. In case of sorghum, fertilizer use ranged from a mere 3 kg ha^{-1} in Mantralayam to as high as 100 kg ha^{-1} in Penugonda. No fertilizer was applied in tribal areas of Hukumpet and Rampachodavaram. The nitrogen deficiency in sorghum was attributed to reluctance or inability of farmers to top dress this nutrient. Regarding the fertilizer use in groundnut crop, greater degree of deviations from recommended doses were observed. It was emphasized that the fertilizer use is to be increased wherever found underused while excess use is to be discouraged (Table 18). Shaik Haffis *et al.* (1997) also observed greater degree of deviations in fertilizer use from recommended doses in production of different crops across different agro-climatic zones of Andhra Pradesh. While N was applied excessively, P and K were underused at most of the places surveyed whereas fertilizer use was considerably high in case of irrigated crops.

In another survey carried out by Sreelatha (1998) on 222 mesta farmers showed that 2, 5, 87, 56 and 22 farmers were using one, two, three, four and five types of fertilizers, respectively in crop production. While urea is the straight fertilizer predominantly used by all the farmers, among the complex fertilizers DAP was preferred. Here too, indications were there that the farmers were using fertilizers either in much excess or less quantities than recommended doses. Financial condition of the farmers is stated to be the main reason for low usage of chemical fertilizers as mesta farmers, in general, are poor in economic condition. Regarding usage of organic manures by these farmers, all of them were found using FYM in their fields. This was followed by sheep manure, paddy straw, green manure and neem cake in that order. Farmers were depending upon combination of sources too. While 41 farmers (18.7%) were using FYM alone, 93 (41.7%) farmers were using two sources out of which one was FYM. Three types of manures were found used by 33.2% (74) farmers. There were 9 and 5 farmers depending upon 4 and 5 types of organic sources of nutrients. The survey, thus, showed that the farmers are aware of use of manures for crop production. However, it was found that they were not applying the materials as per recommended doses. The quantities of FYM being used was ranging from 2 to 10 t ha^{-1} against the recommended doses of 10 to 15 t ha^{-1} for several of the crops grown in the district. In majority of the cases farmers are dependent upon the FYM generated in their cattle sheds while a few of them purchase either partly or wholly required quantity from others for use in their fields. In another survey carried out by Madhava Swamy and Subba Rao (1995) in the scarce rainfall zone, it was observed that only one third of the farmers were applying organic manures in lower quantities than recommended to all the crops.

Conclusions

Farmers in irrigated areas are aware of INM, balanced use of fertilizer etc., and recently the ideal N:P:K ratio of 4:2:1 in fertilizer use is being approached. However, a recent nutrient survey indicates that far more has to be done to increase awareness among farmers on components of INM etc. The awareness of farmers on use of biofertilizers, soil testing, INM, balanced use of fertilizers can be seen in Table 19. Intensive efforts are needed to make site specific recommendations to farmers of dryland areas to derive maximum benefit from such nutrient concept like INM.

For making the dryland farmer get remunerative price for his crops/produce by adopting INM package, the following aspects need to be looked into:

- Strengthening the extension network to educate the dryland farmer on the benefit of waste recycling, use of bio-fertilizer, balanced fertilization, etc.
- Research on studying the pattern of release of nutrients in different agro-ecological situations where dryland agriculture is practiced.
- Provision of alternate energy sources to rural poor to prevent burning the organic materials like stubbles, dung, etc. as a source of fuel.
- Imparting training on *in situ* moisture conservation for improving water use efficiency as well as nutrient use efficiency.

- Introducing drought tolerant nutrient response cultivars.
- Improving the delivery network to make the green manure seed, bio-fertilizers, vermi-compost, etc., available to farmers.
- Modernizing soil-testing facilities for early diagnosis of impending nutrient deficiencies.
- Giving special attention to areas where deviations are too much in fertilizer use against recommended dose and giving emphasis for substitution through use of organic manures.
- Efforts are also to be made to enable farmers get remunerative prices, specifically when they are utilizing nutrient exhaustive crops.

All the above will help to create awareness among farmers on INM, reducing cost of cultivation / production, betterment of soil health and sustaining the soil productivity in the long run.

Table 1: Description of Agro-climatic zones of Andhra Pradesh

S. No	Zones	Rainfall (mm)	Land form (with elevation)	Soils	Major crops grown	Predominant cropping systems
1.	Krishna-Godavari (Delta) Zone	800-1100	Delta plains and river valley hinter lands	River valley and delta alluvial soils, mixed red and black and deep black soils in sub coastal valley	Rice,cotton, blackgram/greengram, groundnut, fodder, tobacco, sugarcane, chillies, coconut, sesamum	Rice based
2.	North-Coastal zone	1000-1100	Coastal plain and isolated hill ranges, delta and several smaller rivers (0-300 m)	Coastal alluvium patches below lateritic and red sandy uplands	Rice,groundnut, pearlmillet,mesta, fingermillet, sugarcane, sesamum, horsegram, greengram, blackgram	Rice, sugarcane, groundnut, pearlmillet and fingermillet based
3.	Southern zone	750-1100	Coastal plain and southern part of central hill ranges, delta Pennar and catchment of smaller rivers (0-900 m)	Coastal alluvium belt below lateritic and red sandy hinterlands	Rice, groundnut, sorghum, pearlmillet, redgram, fingermillet, horsegram	Rice and groundnut based
4.	Northern Telangana zone	900-1200	Deccan plateau and valley low lands, Godavari catchment area (300-600 m)	Mixed red and black soils and medium black soils and plateau, deep black soils in valleys and red sandy soils in uplands	Sorghum, rice, maize, cotton, groundnut, redgram, and bengalgram	Sorghum, rice and maize based
5.	Southern Telangana zone	700-900	Deccan plateau and hill range catchment of Krishna river (300-600 m)	Red sandy soils and medium black and lateritic soils	Sorghum, rice, castor, groundnut, pearlmillet, redgram, horsegram, fingermillet, greengram, maize, safflower	Sorghum, rice and castor based

S. No	Zones	Rainfall (mm)	Land form (with elevation)	Soils	Major crops grown	Predominant cropping systems
6.	Scarce rainfall zone	500-700	Deccan plateau and hill ranges and valley low lands, catchment of Pennar river (150-600 m and ranges to >1000 m)	Red sandy soils in uplands and mixed red and black to deep black soils in lower areas	Groundnut, sorghum, setaria, rice, cotton, coriander, pearlmillet	Groundnut, sorghum, setaria, rice and cotton based
7.	High altitude tribal area zone	1000-1300	Mountains, isolated valleys and foothills, catchment of several smaller rivers (150-1500 m)		Rice, pearlmillet, groundnut, fingermillet, sesamum, tuber crops, forest trees and horticultural crops	Rice and pearlmillet based

Table 2: Normal area, production and yield of principal crops in Andhra Pradesh during 2002-03

S. No.	Food crops	Area (ha)	Production (tonnes)	Yield (kg ha^{-1})
1.	Rice	3851077	9873002	2609
2.	*Jowar*	845169	591076	699
3.	*Bajra*	125189	108469	863
4.	Maize	361744	1078226	2963
Total cereals and millets		5393820	11845296	-
5.	Bengalgram	135865	97056	715
6.	Greengram	476256	187571	393
7.	Redgram	340016	113290	327
8.	Blackgram	493175	275219	556
Total pulses		1600640	726552	-
Total food grains		6994460	12571848	-
9.	Onion	24853	372767	15024
10.	Sugarcane	363690	1545515	7500
11.	Chillies	209485	427424	2023
12.	Total cotton	1021099	1551293	262
13.	Groundnut	2084154	1930396	918
14.	Sesamum	173451	35841	202
15.	Sunflower	360074	229818	642
16.	Castor	229830	63436	271
17.	Total tobacco	164959	193360	1183
	Total non food crops	4540632		
	Total food crops	8458832		
	Total food and non food crops	12999164		

Normal: Average over 5 years (1994-95 to 1998-99)

Table 3: Some indicators related to agriculture development in the various districts of Andhra Pradesh

District	Relative development index	Gross irrigated &%of gross cropped area	Fertilizer consumption (kg ha^{-1})	Values of output of major crops (Rs.)		Per capita food grain production (kg)
				Per hectare	Per capita	
			A. Developed			
West Godavari	115	86.29	271	8088	1413	342
Krishna	119	59.28	202	5500	1081	265
Guntur	114	43.79	207	6595	1251	214
East Godavari	93	68.10	170	7338	938	219
Nellore	96	75.85	226	6250	924	230
Nizamabad	104	50.75	223	5005	819	208
Karimnagar	97	43.23	184	5040	731	196
Nalgonda	104	50.75	223	5005	819	208
			B. Moderately developed			
Srikakulam	56	50.11	89	3796	632	127
Vizianagaram	65	34.88	81	4149	692	107
Visakhapatnam	92	29.40	69	4420	456	60
Prakasam	66	27.83	120	3451	807	141
Chittoor	84	36.42	82	4778	768	66
Cuddapah	83	26.77	141	4360	1392	97
Anantapur	92	14.25	58	4695	1182	64
Warangal	80	40.10	180	4058	696	137
Khammam	76	29.20	109	3828	909	149
			C. Less developed			
Mahabubnagar	53	13.00	90	1464	461	95
Adilabad	66	9.68	29	1213	363	91
Ranga Reddy	95	15.64	159	2042	256	71
Medak	86	24.41	81	2713	537	144
Kurnool	83	13.89	92	2740	847	104
State average	99	35.85	131	4392	799	150

Table 4: Biofertilizers produced and supplied by ANGRAU in 2003-04

Inoculant and crop	No. of packets		Population count (cells/g)
	Produced	Supplied	
*Rhizobium** Groundnut	3570	3565	4.5×10^8 to 6.0×10^8
Soybean	29800	29754	5.4×10^8 to 4.8×10^9
Blackgram	2650	2622	6.8×10^8 to 5.4×10^9
Greengram	3525	3521	5.0×10^8 to 6.2×10^8
Redgram	11550	11524	5.6×10^8 to 6.3×10^8
Bengalgram	476	476	4.4×10^8 to 5.7×10^8
Subabul	250	250	5.8×10^8
Azospirillum Sorghum, maize, *bajra*, paddy, sugarcane etc.	1600 (200g) 2550 (1.0kg)	1568 2463	5.8×10^8 to 6.8×10^8
PSB	12580 (250g) 1150 (1.0kg)	12579 1127	4.8×10^8 to 5.4×10^9 5.6×10^8 to 6.2×10^8

- *Rhizobium* packets of 200 g each at a cost of Rs.7/-
- *Azospirillum* Rs.30/- per packet of 1kg
- PSB Rs.7/- for 250 g + Rs.25/- for 1 kg packet

(Source: Presentation at State Level Technical Programme Discussion meetings of ANGRAU held during May, 2004)

Table 5: Crop specificities for soil phosphorus fractions

Crop	Fractions of P taken in
Rice	Fe – P, Al – P
Wheat	Ca – P, Al – P
Sorghum	Adsorbed P
Maize, cowpea	Al – P, Fe – P
Pearlmillet, Jute	Fe – P
Redgram, blackgram, greengram, sunflower	Al – P
Groundnut	Ca – P

Table 6: Some guidelines for efficient management of N in flooded rice using prilled urea

Situation	Strategy
Assured water supply	N can be top dressed every 3 weeks upto panicle initiation stage. Drain the field before top dressing and reflood after 2 days
Soil very poor in N	Give relatively more N at planting
Permeable soils	Emphasis is to be on more number of splits
Short duration varieties	Prefer more N as basal; early top dressing is needed
Long duration varieties	More number of top dressings are required
Colder growing season	Less N as basal and more N as top dressing
Overage seedlings used	More N is to be applied at planting
Danger of bacterial leaf blight (BLB)	More number of smaller splits of N have to be applied

Table 7: Efficient management practices for N in ID crops grown in Andhra Pradesh

Crop	Management practice
Maize	Apply in 2 equal splits in heavy soils and in 3 splits in light soils (basal, knee high stage and flag leaf emergence)
Sorghum, pearlmillet and fingermillet	Apply N in 2 equal splits – 1/2 at sowing and 1/2 as top dressing at knee-high stage of the crop. For rainfed crops, apply 1/4 as basal and remaining 3/4 after about a month of crop growth
Pulses, groundnut and sesamum	Apply all N as basal at seeding
Castor	Apply in 2 splits – 1/2 at sowing and the rest at 35-45 DAS
Sunflower	Apply in 2 splits – 1/2 at sowing and the rest at 30-35 DAS
Hybrid cotton	Apply N in 3 equal splits at 30, 60 and 90 DAS. For other cottons in 2 equal splits at 30 and 60 DAS
Mesta	Apply in 2 splits – basal and at 20 DAS
Sugarcane – Eksali	Apply in 2 equal splits at 60 and 120 days after planting
Adsali	Apply in 3 equal splits at 60 and 120 and 180 days after planting
Tobacco	Apply in 3 splits viz., 1/4 at 10th day after planting, 1/2 at 3-4 weeks and the rest 1/4 at 40th day after planting
Safflower and other *rabi* crops	All N as basal at sowing by placing it deep

Table 8: Average chemical compositions of some organic manures

Manure	Content (%)		
	N	P_2O_5	K_2O
Cattle dung	0.3 to 0.4	0.10 to 0.15	0.15 to 0.20
Cattle urine	0.8	0.01 to 0.02	0.5 to 0.7
Town compost	1.5 to 2.0	1.0	1.5
FYM	0.5 to 0.6	0.15 to 0.20	0.5 to 0.6
Poultry litter	3.03	2.6	1.4
Leather waste	7.0	0.1	0.2
Hair and wool waste	12.3	0.1	0.3
Dried blood	10 to 12	1 to 2.6	0.8
Bone meal (raw)	3.0	20.0	-
Meat meal	10.5	2.5	0.5
Fish meal	4 to 5	3 to 9	0.3 to 0.4
Bird guano	7 to 8	11 to 14	2 to 3
Night soil	1.2 to 1.5	0.8	0.5
Human urine	1.0 to 1.2	0.1 to 0.2	0.2 to 0.3
Sewage	15 to 30 ppm	4 to 6 ppm	10 to 20 ppm
Oil cakes – edible			
Groundnut	7.29	1.65	1.33
Mustard	4.52	1.78	1.40
Rapeseed	5.21	1.84	1.19
Linseed	5.56	1.44	1.28
Sesame	6.22	2.09	1.26

Manure	Content (%)		
	N	P_2O_5	K_2O
Cotton seed	6.41	2.89	1.72
Safflower	7.88	2.20	1.92
Oil cakes – non edible			
Castor	4.37	1.85	1.39
Neem	5.22	1.08	1.48
Mahua	3.11	0.89	1.85
Karanj	3.97	0.94	1.27
Kusum	5.23	2.56	1.37
Khakan	4.32	2.45	1.24

Table 9: Nitrogen fixation by legumes

Legume		Quantity fixed (kg N $ha^{-1}year^{-1}$)
Forage legumes		
Clover	Temperate	23-620
Lucerne	Temperate	164-300
Stylo	Tropical	30-196
Tick clover	Tropical	700
Grain legumes		
Peas	Temperate	46
Lupins	Temperate	128
Lentil	Tropical	35-77
Pigeonpea	Tropical	41-150
Cowpea	Tropical	73-354
Soybean	Tropical	17-206
Clusterbean	Tropical	37-196
Groundnut	Tropical	33-111
Chickpea	Tropical	41-270
Mung bean	Tropical	224

Table 10: Some fertilizer equivalents of organic manures and bio-fertilizers

Component	Input level	Fertilizer equivalent of input in terms of crop yield
Organic manure (FYM)	Per tonne	3.6 kg N+ P_2O_5 + K_2O at 2:1:1 ratio
Green manure (Sesbania)	-do-	4.4 kg N
Cowpea intercropped with castor	Legume buried after 6 weeks	30 kg Fert. N to castor
Leucania loppings	88 kg N in Leucania	25 kg Fert. N to sorghum
Rhizobium	Inoculant	19-22 kg N
Azotobacter and *Azospirillum*	Inoculant	20 kg N
BGA	10 kg ha^{-1}	20-30 kg N
Azolla	6-12 t ha^{-1}	3-4 kg N t^{-1}
Sugarcane trash	5 t ha^{-1}	12 kg N t^{-1}
Rice straw + water hyacinth	5 t ha^{-1}	20 kg N t^{-1}

Table 11: FAO model of INM for wheat-rice rotation

Crop	Production ($t\ ha^{-1}$)	Nutrient ($N+ P_2O_5+ K_2O$) removal ($kg\ ha^{-1}$)	Fert. Dose required ($kg\ ha^{-1}$)	Fertilizer dose required under INM ($kg\ ha^{-1}$)
Wheat (any ID crop)	5.0	140+60+130	Soil available + 120+60+60 through fertilizers	Soil available + O.M @ 4 $t\ ha^{-1}$ (20+12+20) through fertilizers. Apply 85+40+35 only
Grain legume	1.5	160+35+80	Soil available (inherent + residues from crop and fert.) through fertilizers 40+30+30	Soil available (inherent + residues from crop, fert. & O.M) biological N fixation. Apply through fert. 20+25+25 only
Rice	6.0	140+60+190	Soil available (inherent + residues from crop, fert. etc.) through fert. 120+30+60	Soil available (inherent+residues from crop, fert. & O.M) residues from biological N fixation (20+0+0) O.M. @ 4 $t\ ha^{-1}$ (20+12+20) Apply through fert. 70+15+35 G.M/Azolla/BGA (25+0+0) through fert. 65+25+50 O.M. (20+12+20) & G.M./Azolla/BGA (25+0+0) Apply through fert. 45+15+35 only

(Source: Fertilizer in Agricultural Development. KRIBHCO)

Table 12: Quantities of components of INM suggested based on status of farmers for mesta based cropping systems

Status of farmers	Quantities suggested		Total N applied* ($kg\ ha^{-1}$)
	Mesta	Horsegram	
** Poor	Azospirillum + 12.5 kg N ha^{-1}	10 kg N ha^{-1}	22.5
# Medium	1 t PM ha^{-1} + 12.5 kg N ha^{-1}	–	20.0
	1 t PM ha^{-1} + 12.5 kg N ha^{-1}	10 kg N ha^{-1}	30.0
& Large	25 kg N ha^{-1}	20 kg N ha^{-1}	45.0
	1 t PM ha^{-1} + 19 kg N ha^{-1}	20 kg N ha^{-1}	46.5
	5 t FYM ha^{-1} + 19 kg N ha^{-1}	20 kg N ha^{-1}	48.0
	Mesta	**Rice**	
Poor	Azospirillum inoc.	Glyricidia @ 7.5 t ha^{-1}	16.0
	Azospirillum inoc. + 12.5 kg N ha^{-1}	Glyricidia @ 7.5 t ha^{-1}	28.5
Medium	1 t PM ha^{-1} + 12.5 kg N ha^{-1}	40 kg N ha^{-1}	60.0
	10 t FYM ha^{-1}	80 kg N ha^{-1}	98.0
Large	25 kg N ha^{-1}	80 kg N ha^{-1}	105.0
	1 t PM ha^{-1} + 19 kg N ha^{-1}	80 kg N ha^{-1}	106.5
	5 t FYM ha^{-1} + 19 kg N ha^{-1}	80 kg N ha^{-1}	108.0

** The contribution of N is taken as 1/3 of the applied quantity through organic source.*

*** Farmers who are not applying N to mesta crop.*

 # Farmers who are applying moderate dose of N to crops.

& Farmers who can afford to apply large quantities of N over and above recommended dose.

Table. 13: N Balance in Different Crop Rotations in an Alfisol (Hyderabad)

Cropping pattern	Initial total N in 0-30 cm depth (A)	Fert. N added (kg ha^{-1}) in the system (B)	Total N (kg ha^{-1}) after 3 crops (C)	N uptake by 3 crops (kg ha^{-1}) (D)	Net gain/ loss by the system (kg ha^{-1}) (C+D)–(A+B)
Sole sorghum-castor-sole–sorghum	1870	110	1770	99	- 111
Sorghum+pigeonpea, Castor–sorghum+pigeonpea	1830	110	1836	160	+ 56
Greengram+pigeonpea – castor–greengram+pigeonpea	1418	50	1800	161	+ 97

Table 14: Effect of residues and residue mixtures on grain yield, apparent N recovery and agronomic efficiency of sorghum

Treatment	N added (kg ha^{-1})	Grain yield (kg ha^{-1})	Agronomic efficiency (kg grain kg^{-1} N)	Apparent N recovery (%)
Control	0	1224	-	-
G. sepium	61.1	1755	8.70	21.47
L. leucocephala	107.7	2125	8.61	20.53
C. siamea	65.2	1563	5.20	17.97
Castor	82.8	1601	4.55	13.55
G. sepium + C. siamea	63.1	1895	10.63	28.40
G. sepium + castor	71.9	2023	11.11	29.95
L. leucocephala + *C. siamea*	86.5	1930	8.16	23.27
L. leucocephala + castor	95.3	2079	8.98	24.21
LSD (p=0.05)		417.8		

Table 15: Trends in use of fertilizers by farmers of Andhra Pradesh

S. No	District	No.of farmers surveyed	No.of farmers using													
			U	SSP	MOP	AS	CAN	DAP	28-28	20-20	15-15-15	17-17-17	19-19-19	14-35-14	$ZnSO_4$	Not using
1.	Kurnool	15	14	-	5	-	-	15	4	-	-	1	-	-	-	-
2.	Chittoor	13	7	8	3	-	-	7	-	-	-	10	2	-	-	-
3.	Cuddapah	21	16	11	10	-	-	9	2	2	-	9	4	2	-	-
4	Anantapur	20	14	14	13	-	-	13	3	2	-	4	4	2	-	-
5a	Khammam-I	12	11	10	7	-	-	10	-	-	-	-	-	-	-	-
b	Khammam-II	9	9	-	7	-	-	9	-	4	-	2	1	1	-	-
6	Medak	14	14	-	-	-	-	14	-	-	-	-	-	-	-	-
7a	Nizamabad-I	11	11	-	9	-	-	8	-	5	-	3	-	-	-	-
b	Nizamabad-II	12	12	2	11	1	-	8	-	8	-	3	-	-	1	-
8	Adilabad	12	10	2	9	-	-	10	-	1	-	-	-	-	-	-
9	Karimnagar	13	13	3	9	-	-	12	2	5	3	9	-	-	3	-
10	Warangal	12	12	1	12	1	1	11	1	2	-	1	-	-	-	-
11	Vizianagaram	14	13	9	10	-	-	13	1	2	-	-	-	-	-	1
12	Visakhapatnam	10	7	2	-	-	-	8	-	-	-	-	-	-	-	2
13	Srikakulam	10	10	-	10	-	-	8	5	-	-	-	-	-	-	-
14	Nellore	19	17	9	13	-	1	13	-	5	-	7	-	-	1	-
15	East Godavari	16	16	-	6	-	-	11	-	-	-	-	-	-	-	-
16	Guntur	10	10	6	8	-	-	2	-	8	-	2	-	-	1	-
17	Mahabubnagar	12	12	8	2	-	-	11	-	-	-	3	-	-	-	-
18	Ranga Reddy	12	11	7	5+2 SOP	-	-	6	6	-	-	-	-	1	-	-

Table 16: Trends in use of manures by farmers of Andhra Pradesh

S. No	District	No.of farmers surveyed	No.of farmers using										
			FYM	Com-post	SP	CP	Castor cake	Neem cake	PM	GM	GLM	Pig manure	Not using
1	Kurnool	15	14	11	7	5	-	-	-	-	-	-	1
2.	Chittoor	13	13	3	-	2	-	-	-	-	1	-	-
3.	Cuddapah	21	19	-	2	-	4	3	1	5	1	-	1
4	Anantapur	20	20	3	1	-	1	1	1	-	1	-	-
5	Khammam I	12	12	-	-	-	-	-	-	-	-	-	-
	Khammam II	9	8	-	1	-	-	-	-	3	2	-	-
6	Medak	14	14	2	-	-	1	1	-	-	-	-	-
7	Nizamabad I	11	11	-	3	1	-	-	-	3	-	-	-
	Nizamabad II	12	11	-	-	-	-	-	2	-	-	2(PP)	-
8	Adilabad	12	12	-	1	-	-	-	-	-	-	-	-
9	Karimnagar	13	10	1	6	2	-	-	-	2	-	-	1 (TS)
10	Warangal	12	12	-	2	4	-	-	-	1	-	-	-
11	Vizianagaram	14	14	-	1	11	-	-	-	-	-	-	-
12	Visakhapat-nam	10	10	1	1	1	-	-	-	-	-	-	-
13	Srikakulam	10	10	-	2	-	-	-	1	-	-	-	-
14	Nellore	19	19	-	2	-	1	1	-	3	-	-	-
15	East Godavari	16	16	-	2	5	-	-	-	-	-	-	-
16	Guntur	10	10	2	-	-	-	-	-	3	-	-	-
17	Mahabubnagar	12	8	-	-	-	-	-	-	-	-	-	4
18	Ranga Reddy	12	9	-	3	-	1	1	-	2	1	-	1

SP = Sheep penning

CP= Cattle penning

TS = Tank silt PP = Pig penning

PM = Poultry manure

GM = Green manure

GLM = Green leaf manure

Table 17: Fertilizers applied by farmers under different situations during 1993-94 in scarce rainfall zone

Crop/ situation	No. of farmers surveyed	Yield (q ha^{-1})	Nutrients through fertilizers (kg ha^{-1})			Recommended dose of nutrients (kg ha^{-1})		
			N	P	K	N	P	K
1. Paddy								
a. Irri. black soil	123	52.3	190	126	33	160	60	60
Irri. red soil	59	49.0	152	83	21	160	60	60
Overall	182	51.2	178	112	29	160	60	60
2. Sorghum								
a) Rainfed – black	25	12.3	33	33	2	60	30	30
b) Rainfed – red	13	10.0	14	16	1	60	30	30
c) Irri. black soil	6	33.4	121	87	18	90	45	45
d) Irri. red soil	3	45.3	102	49	0	90	45	45
Overall	47	16.5	43	36	3	-	-	-
3. *Bajra*								
Rainfed – red soils	15	14.9	41	1	1	40	20	20
4. Setaria								
a. Rainfed – black	12	13.0	5	1	1	40	20	20
b. Rainfed – red	7	11.2	9	5	0	40	20	20
Overall	19	12.4	6	2	0.3	40	20	20
5. Cotton								
a. Rainfed-black-Mungari	24	6.3	14	17	2	20	20	0
Rainfed-black-Hybrid	20	16.7	120	86	20	60	40	0
b. Rainfed-red-Mungari	11	4.3	28	25	5	20	20	0
Rainfed-red-Hybrid	6	18.0	142	105	16	60	40	0
c. Irri. black-Hybrid	15	25.0	137	114	42	120	60	60
d. Irri. red – Hybrids	18	22.1	161	130	13	120	60	60
Overall	94	15.1	94	75	16	-	-	-
6. Groundnut								
a. Rainfed – black soil	41	12.4	34	47	12	20	40	20
b. Rainfed red soil	72	8.7	24	35	7	20	40	20
c. Irri.black soil	52	16.2	65	64	15	40	60	30
d. Irri.red soil	80	15.7	71	57	19	40	60	30
Overall	245	13.2	50	50	13	-	-	-
7. Sunflower								
a. Rainfed – black soil	31	2.8	31	39	5	60	30	30
b. Rainfed red soil	11	3.0	20	35	7	60	30	30
c. Irri.black soil	31	10.6	67	66	19	80	90	30
d. Irri.red soil	21	13.1	59	26	9	80	90	30
Overall	94	7.7	49	41	11	-	-	-
8. Castor								
Rainfed red soil	12	11.5	38	36	0	40	20	-
9. Bengal gram								
Rainfed black & red	22	11.9	32	36	0	20	50	0

Crop/ situation	No. of farmers surveyed	Yield (q ha^{-1})	Nutrients through fertilizers (kg ha^{-1})			Recommended dose of nutrients (kg ha^{-1})		
			N	P	K	N	P	K
10. Coriander								
Rainfed – black soil	17	7.5	35	36	0	30	-	-
Rainfed red soil	8	7.8	44	42	11	30	-	-
Overall	25	7.6	38	38	3	30	-	-
11. Tobacco								
Rainfed black soil	11	9.5	43	55	10	60	60	50
12. Chillies								
Irrigated – black & red	9	142.7	249	178	56	150	60	50
13. Onion								
Irrigated – black & red	15	152.0	107	133	18	120	60	60
14. Tomato irrigated – black & red	15	83.7	65	71	6	100	60	60
15. Oranges (Santra)	15	95.4	137	81	35	-	-	-

Tabel 18 Deviations in fertilizer use in rice, sorghum and groundnut crops by farmers of A.P.

Zone	Place	Rice Deviation from Rec. dose %			Sorghum Deviation from Rec. dose %			Groundnut Deviation from Rec. dose %		
		N	P	K	N	P	K	N	P	K
KG. Zone	Penumantra	40	-63	-82	-	-	-	-	-	-
	Parchur	253	-	-	-	-	-	-	-	-
	Madhira	175	80	-	-	-	-	120	100	-100
	Proddutur	-	80	-	-70	-67	-	-	-	-
North coastal zone	Atchutapuram	98	100	-100	-	-	-	-	-	-
	Amudalavalasa	40	-23	-73	-	-	-	-55	-43	-100
	Tekkali	45	45	-87	-	-	-	-55	-80	-100
Southern zone	Madanapalle	3	-100	-50	-	-	-	-65	-80	-100
	Kodur	49	18	-97	-	-	-	195	45	-100
	Proddutur	40	-25	-100	-	-	-	-	-	-
Northern Telangana Zone	Nirmal	35	80	-100	-95	-87	-	225	3	-100
	Verni	53	138	-93	-87	-37	-	275	33	-100
	peddapalli	75	68	-30	-	-	-	90	-45	-20
Southern Telangana Zone	Achampet	25	145	-100	-83	-38	-	5	13	-100
	Wardhannapet	8	20	-100	-53	60	-	120	20	-100
	Mantralayam	98	318	-70	-95	-97	-	-	-	
Scarce rainfall zone	Nandyal	43	128	-100	-28	+13	-	5	13	-100
	Gooty	27	60	-100	-	-	-	120	20	-100
	Penugonda	17	5	-97	-30	+140	-	-	-	-
High altitude Tribal area	Parvatipuram	60	73	-100	-	-	-	435	93	-100
	Hukumpet	74	-80	-100	-	-100	-	-	-	-
	Rampachodavaram	27	-23	-98	-100	-100	-	15	45	-100

(Reddy et al., *1997)*

Table 19: Awareness among farmers of Andhra Pradesh about certain components of INM in Crops

S. No.	Place/district	No. of Farmers surveyed	Biofertilizers		Soil testing		INM		Balanced fertilization	
			Yes	No	Yes	No	Yes	No	Yes	No
1	Kurnool	15	1	14	13	2	7	8	6	2
2	Chittoor	13	8	4	8	3	2	2	5	3
3	Cuddapah	21	6	11	6	4	5	5	5	7
4	Anantapur	20	-	20	9	11	1	19	5	9
5	Khammam I	12	2	10	-	12	4	-	-	-
6	Medak	14	-	-	6	7	-	-	-	12
7	Nizamabad I	11	-	11	3	8	5	-	1	9
8	Adilabad	12	2	7	3	3	1	1	4	1
9	Karimnagar	13	2	6	5	2	1	-	2	3
10	Warangal	12	3	8	8	-	2	3	4	2
11	Khammam-II (Madhira)	9	6	3	6	3	-	3	2	2
12	Nizamabad-2	12	1	10	6	2	-	1	1	4
13	Rastakuntabai (Vizianagaram)	14	-	14	4	10	-	-	-	2
14	Visakhapatnam	10	3	7	5	-	-	-	-	8
15	Naira (Srikakulam)	10	-	8	9	-	10	-	6	2
16	Nellore	19	7	9	2	9	8	2	11	-
17	Pandinimamidi (East Godavari)	16	1	-	-	-	-	1	-	1
Total		233								

- Krishna-Godavari zone: East Godavari part, Krishna, Guntur and contiguous areas of Khammam, Nalgonda and Prakasam and West Godavari.
- North coastal zone: Srikakulam, Vizianagarm, Vishakapatnam and uplands of East Godavari Dist.
- Southern zone: Nellore, Chittoor, Southern parts of Prakasam and Cuddapah and Eastern parts of Anantapur.
- Northern Telangana zone: Adilabad, Karimnagar, Nizamabad, Medak (northern part), Warangal (except N.W part), Eastern tips of Nalgonda and Khammam.
- Southern Telangana zone: Hyderabad, Ranga Reddy, Mahbubnagar (except southern border), Nalgonda (except north eastern border) Medak (southern parts), Warangal (north western part).
- Scarce rainfall zone: Kurnool, Anantapur, Prakasam (western parts), Cuddapah (northern part) and Mahbubnagar (southern border)
- High altitude & Tribal areas: Vizianagaram, Vishakapatnam, East Godavari, Khammam and Northern borders of Srikakulam

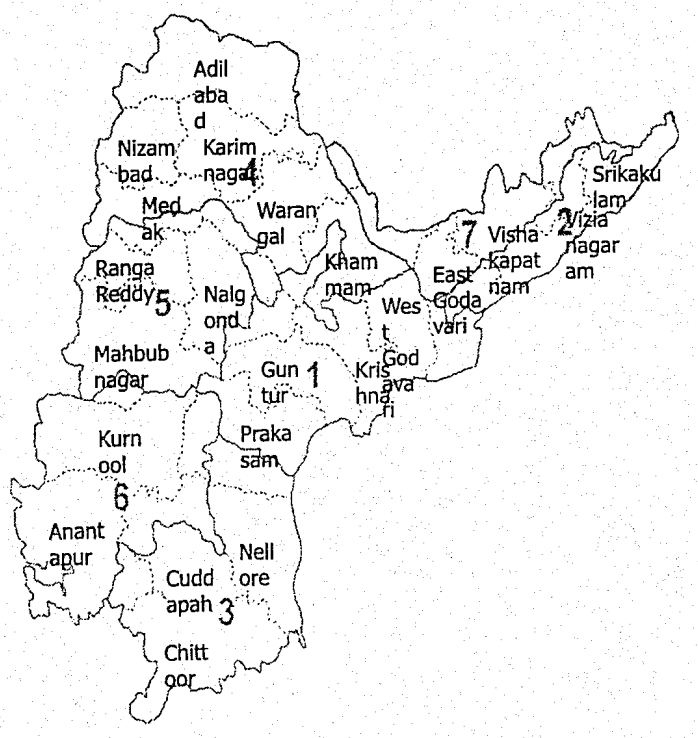


Fig. 1 Agro-eco Zones in Andhra Pradesh

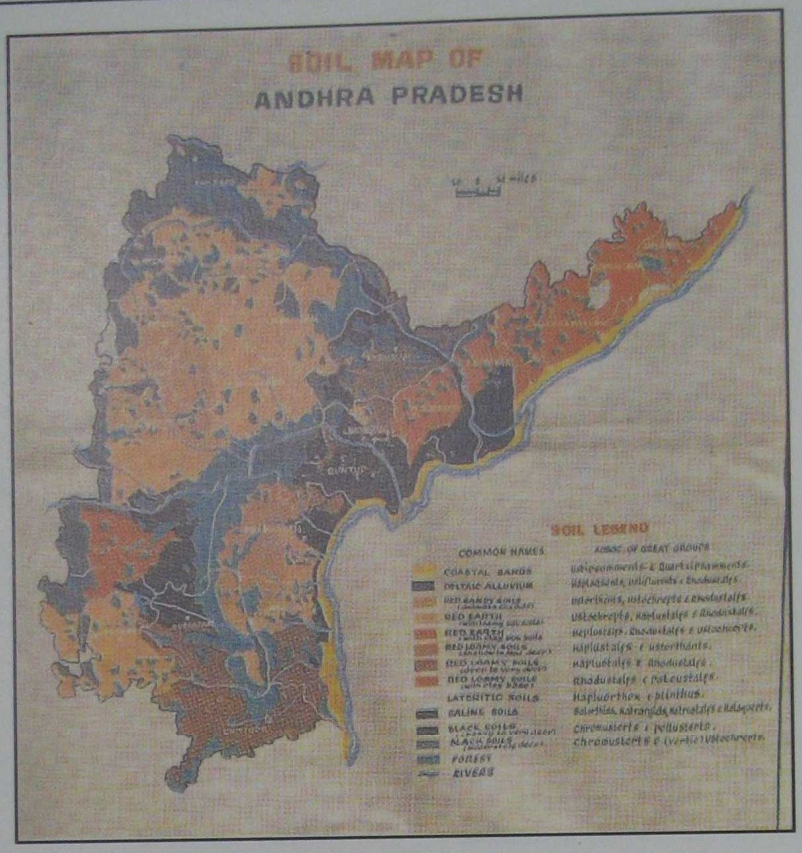


Fig. 2. Soil Map of Andhra Pradesh

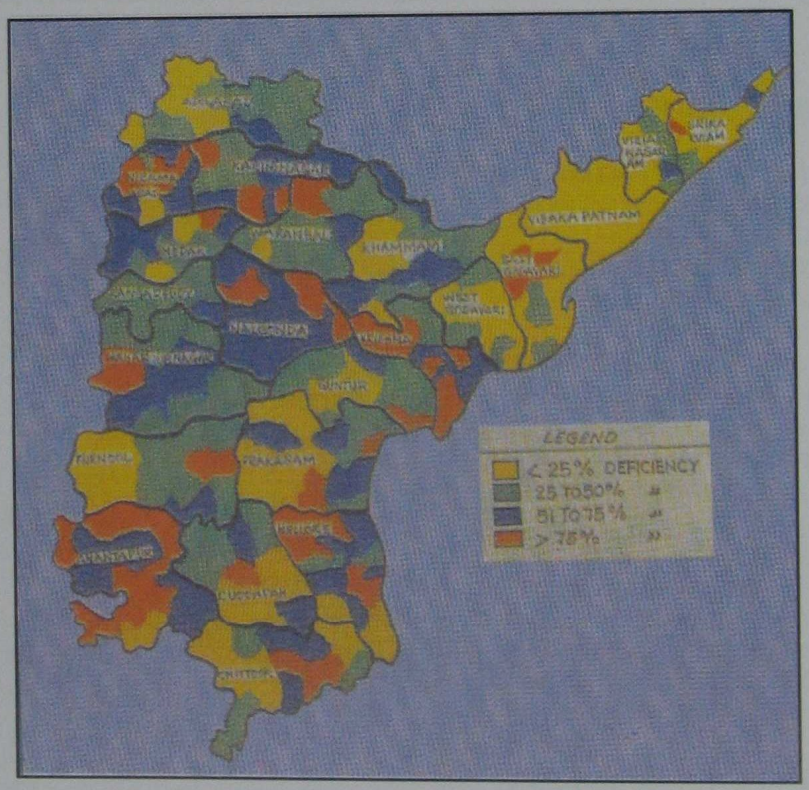


Fig. 3. Zinc deficient areas in Andhra Pradesh

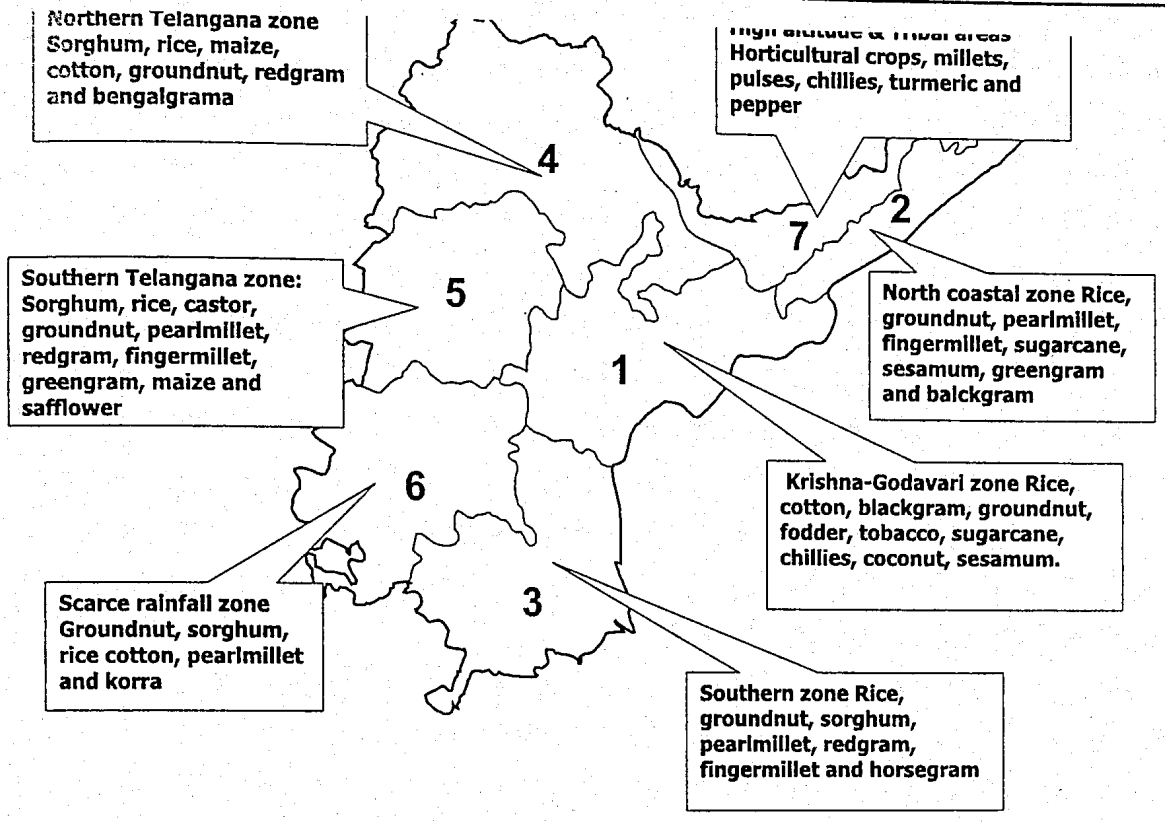


Fig. 4. Crops grown in different agro-climatic zones of Andhra Pradesh

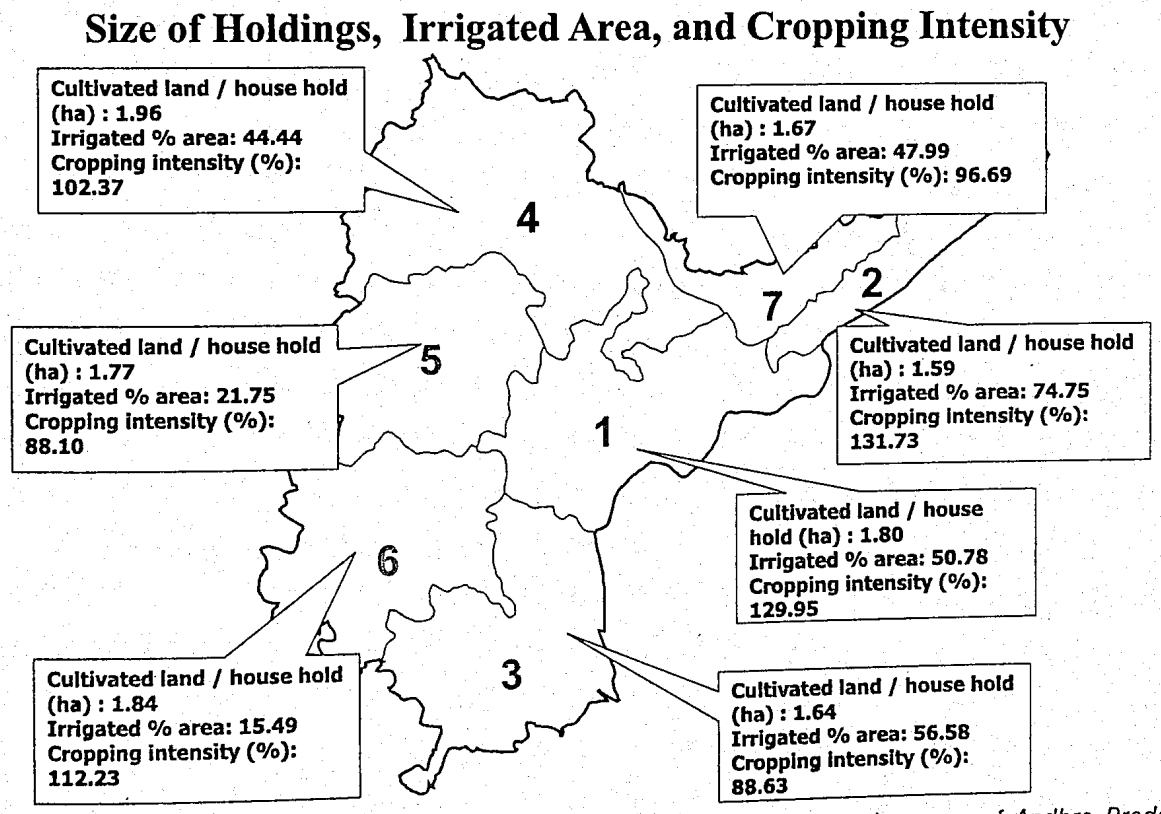


Fig. 5. Size of holdings, irrigated area and cropping intensity in agro-climatic zones of Andhra Pradesh

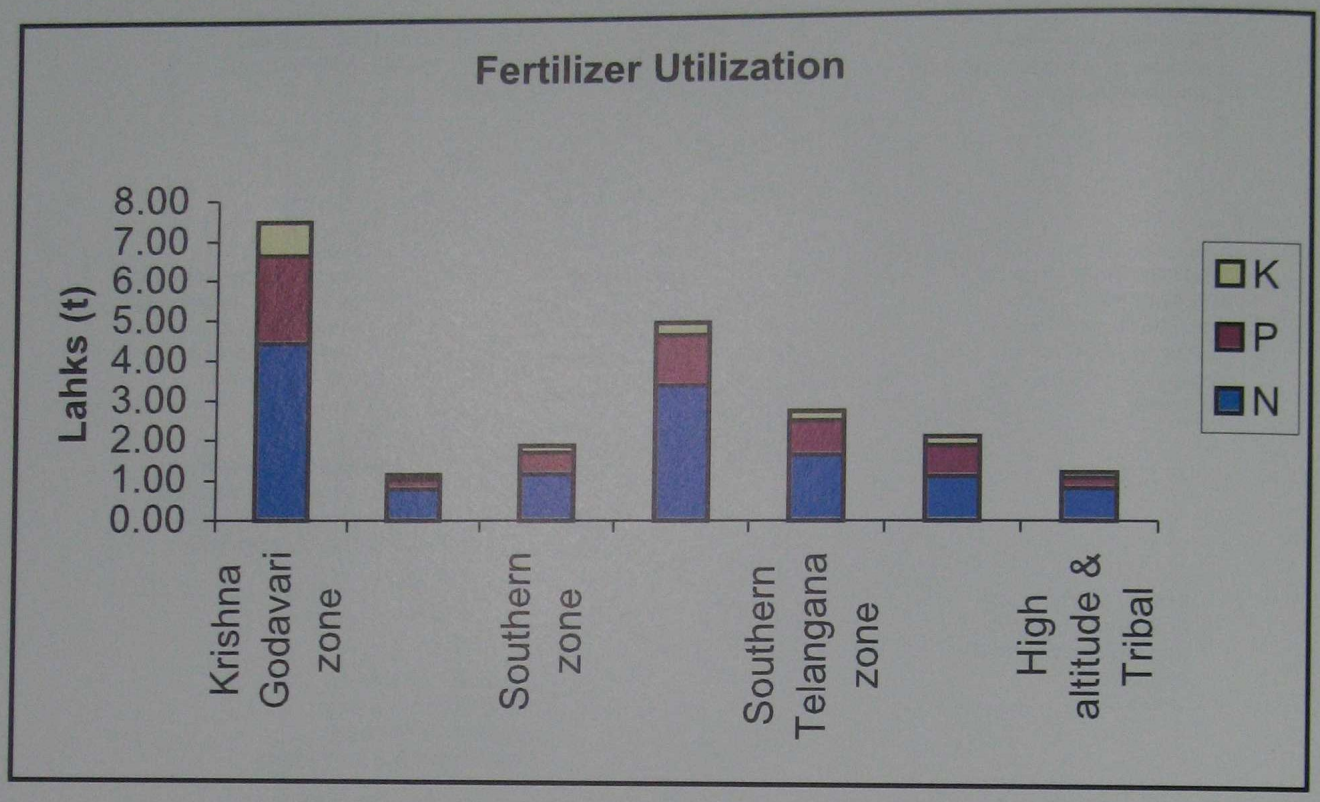


Fig. 6. Zone wise fertilizer consumption in Andhra Pradesh

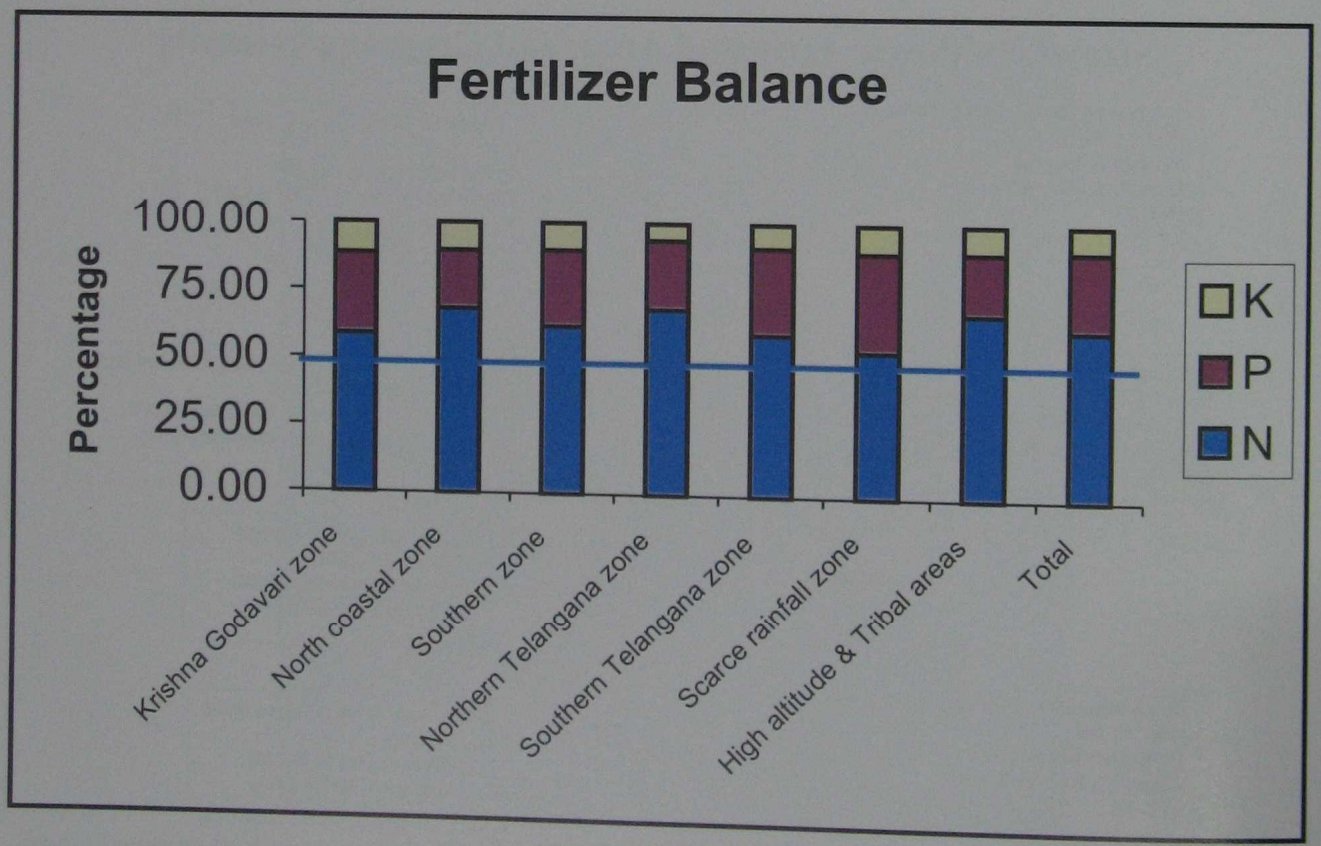


Fig. 7. N,P & K fertilizer ratio use in Andhra Pradesh

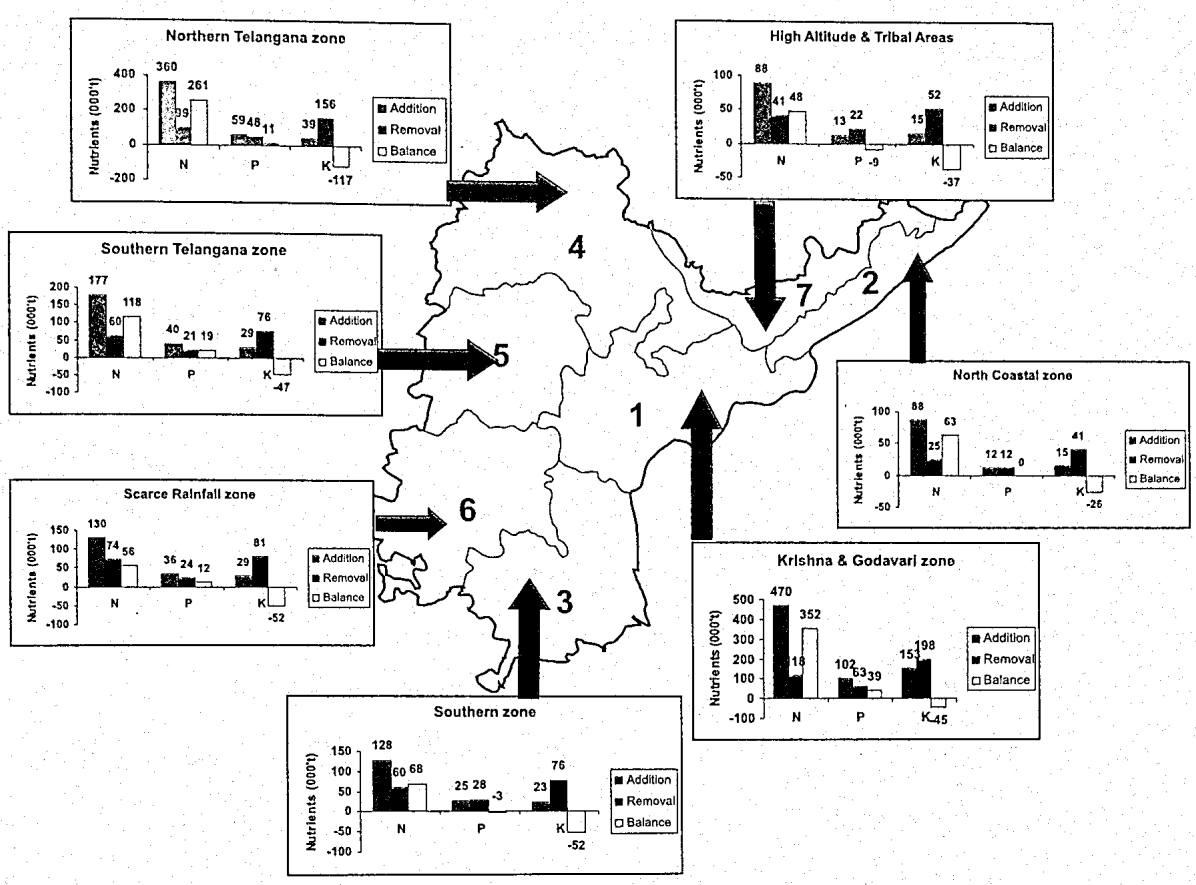


Fig. 8. Additions, removal and balance N, P & K left out in soils in different agro-climatic zones of Andhra Pradesh

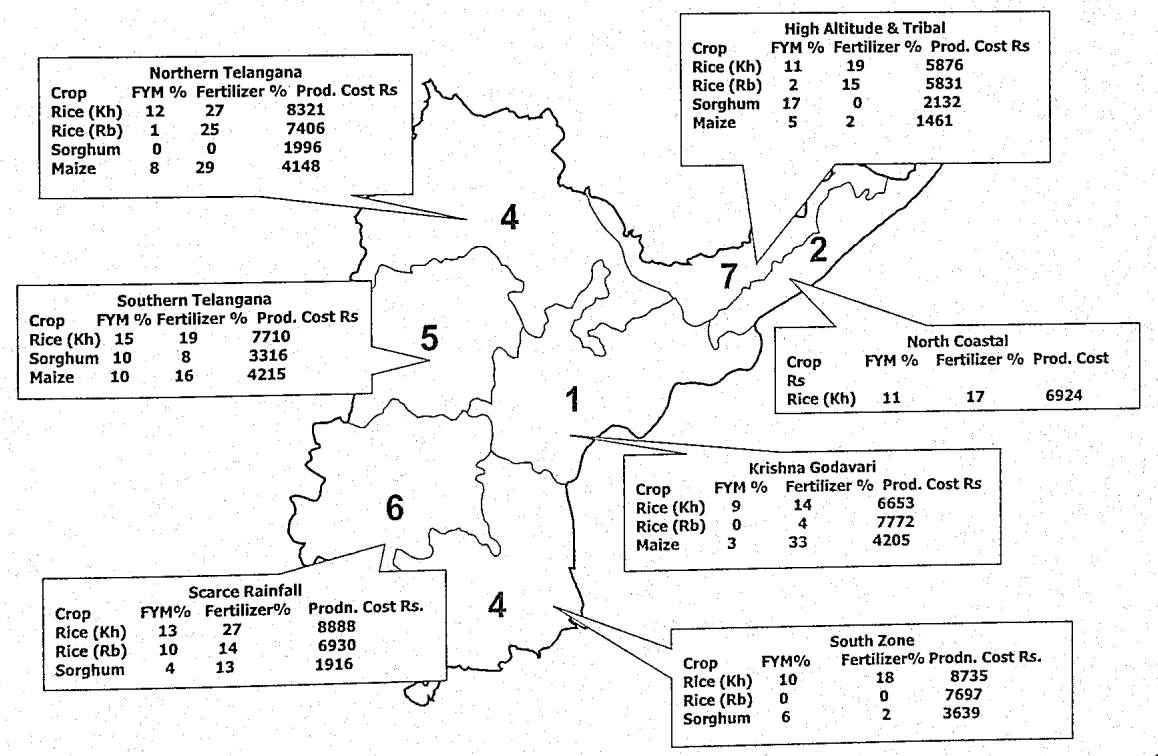


Fig. 9. Cost spent on FYM & Fertilizer and cost of production of some cereals & coarse cereals

Crops, cost spent on FYM & Fertilizer and Cost of Production of some Oilseeds

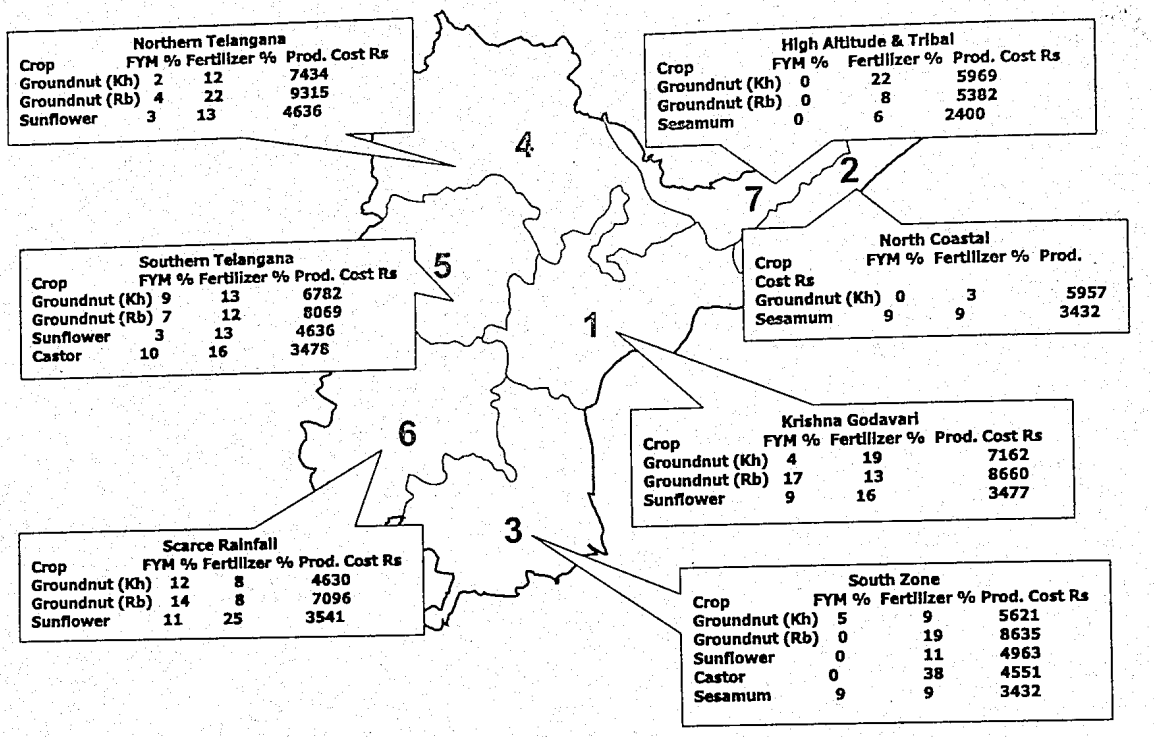


Fig. 10. Cost spent of FYM & Fertilizer and Cost of production of some Oilseeds

Crops, cost spent on FYM & Fertilizer and Cost of Production of some Pulses

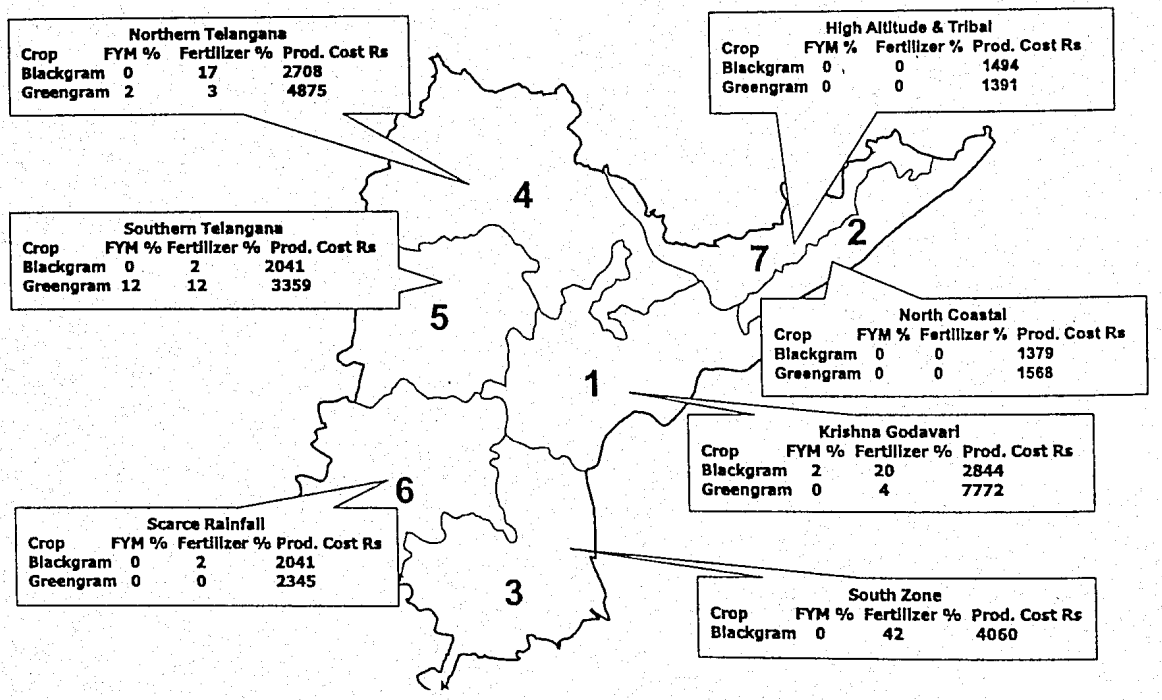


Fig. 11 Cost spent on FYM & Fertilizer and cost of production of some Pulses

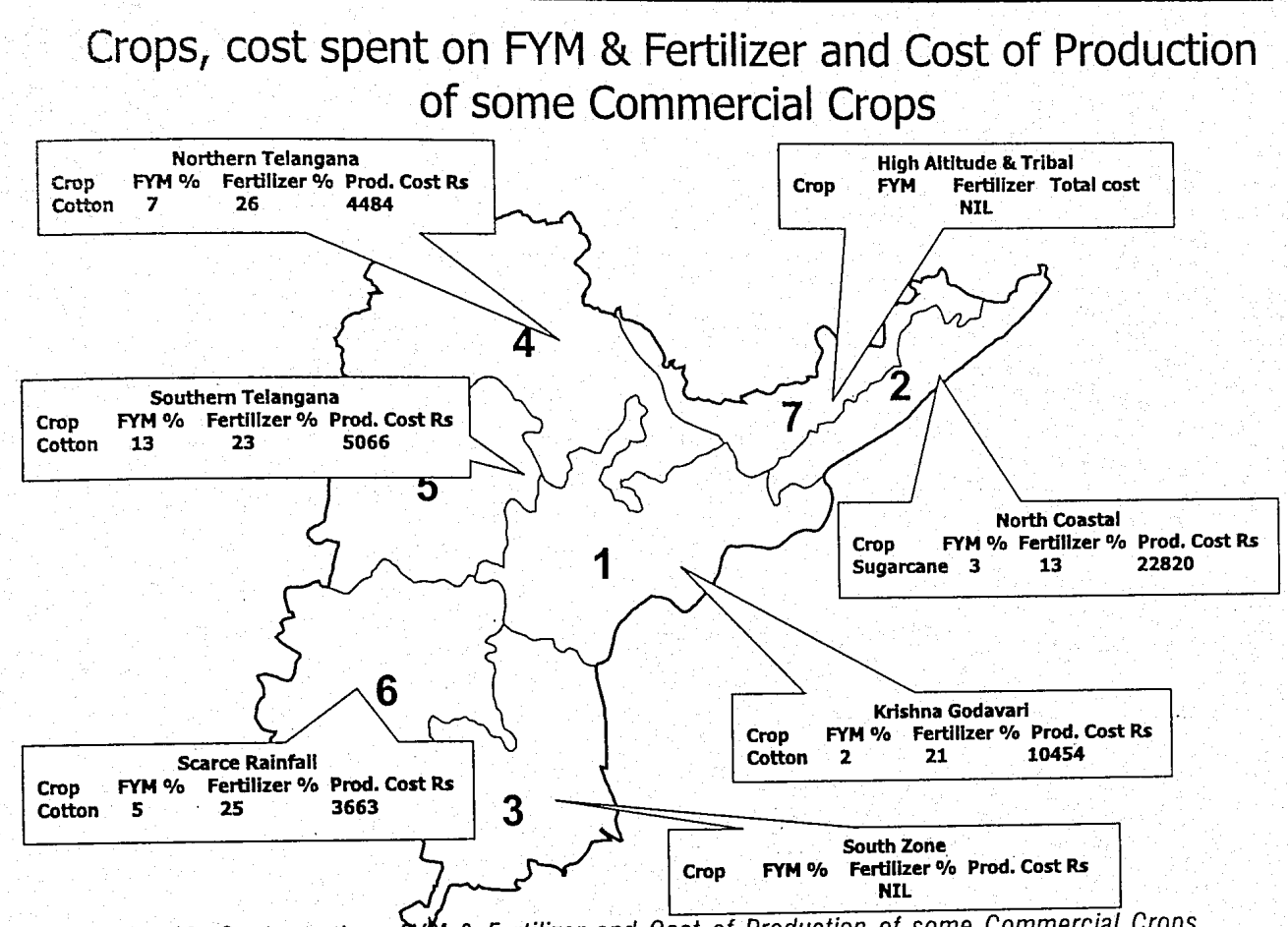


Fig. 12. Cost spent on FYM & Fertilizer and Cost of Production of some Commercial Crops

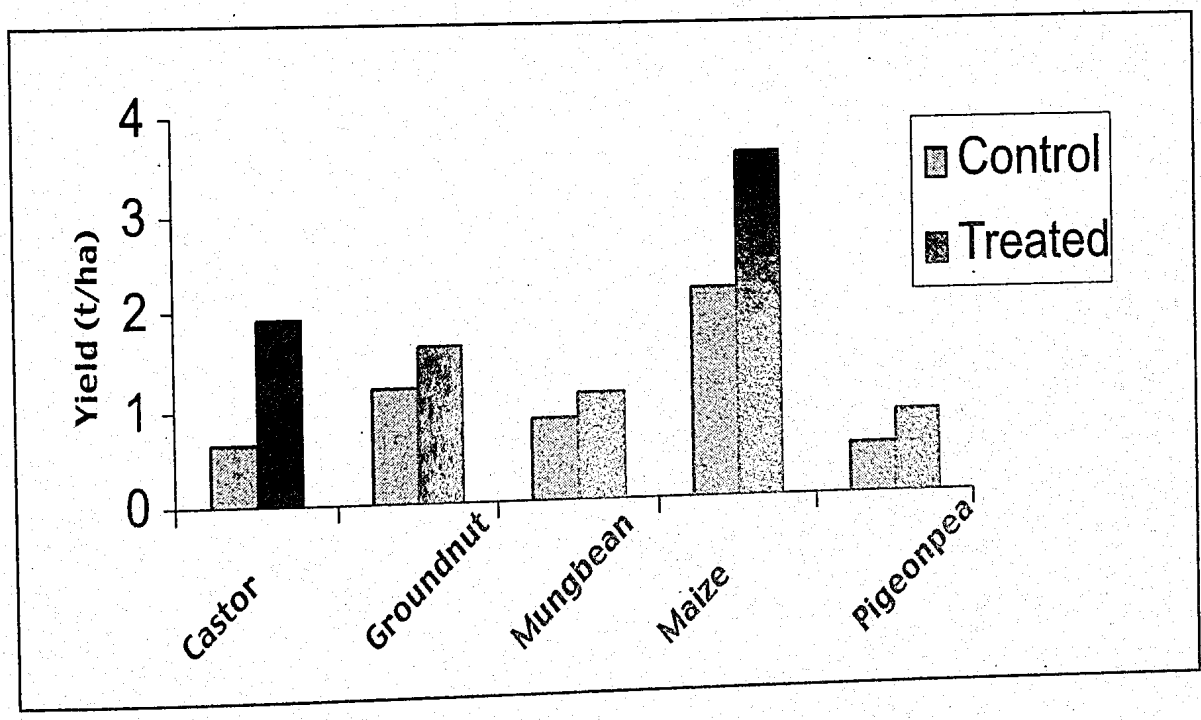


Fig. 13. Application of Micronutrients along with Recommended Fertilizers

References

All India Coordinated Agronomic Research Project 1971. Annual Report Indian Council of Agricultural Research, New Delhi.

Das, S.K. 1993. Fertilizer recommendations for crops in Andhra Pradesh, Paper presented at the meeting of State Level Committee on Fertilizers, CRIDA, Santoshnagar and State Department of Agriculture, Government of A.P.

Directorate of Economics and Statistics 2002-03. Government of Andhra Pradesh

Madhava Swamy, G. and Subba Rao, D.R. 1995. Fertilizer use in different crops of scarce rainfall zone. Report No.17. Regional Agricultural Research Station, Nandyal.

Rajendra Prasad, 2002. Sustainable agricultural production and integrated nutrient management. Souvenir: 2nd Intl. Agronomy Congress, November 26-30, 2002. held at New Delhi, India. pp: 57-66.

Raman, K.V. Sreenivasa Raju, A. and Krishna Murthy, P. 1985. Soils of Andhra Pradesh and their management in Soils of India and their management. The Fertilizer Association of India, New Delhi. pp:19-45 .

Ramana Reddy, D.V. 2004. Production of bio-fertilizers in ANGRAU. Paper presented in State Level Technical Programme discussions held in May, 2004 at ANGRAU

Rao, N.G.P. and Rao, K.V. 1999. Policies and strategies for crop research and development in Andhra Pradesh in the context of vision 2020. Paper presented in the Seminar on 'Towards Vision 2020 – A.P. Agriculture' held on 31st July 1999 at MANAGE, Hyderabad.

Reddy, K.C.K. and Raidu, D.V. 1995. Fertilizers in 'Soils of Andhra Pradesh – A monograph' (Ed.Subba Rao, I.V.) A.P. Agricultural University and Hyderabad Chapter of Indian Society of Soil Science, Hyderabad. pp:245-258.

Reddy, Y.V.R., Rama Rao, C.A. and Katyal, J.C. 1997. Fertilizer use derivations in Andhra Pradesh. Fertilizer News 42(3):33-36.

Roy, R.N. 1988. FAO fertilizer programme with special reference to Integrated Plant Nutrition System. In Fertilizer in Agricultural Development. Krishak Bharati Cooparative Limtied. New Delhi. pp: 149-169.

Sreelatha, T. 1999. Integrated nutrient management in mesta based cropping systems on Alfisols in Srikakulam district. Ph.D. thesis submitted to ANGRAU, Hyderabad.

Sreenivasa Raju, A. and Padma Raju, A. 2000. Nutrient management technologies and patterns adopted by farmers in Andhra Pradesh (Personal communication).

Tandon, H.L.S. 1992. Fertilizers and their integration with organic and biofertilizers. In Tandon, H.L.S. (Ed.) Fertilizer Development Corporation, New Delhi. pp: 12-35.

Venkata Subbaiah, V. Bhupal Raj, G. Patnaik, M.C. 2000. Micro and secondary nutrients and pollutant elements in soils and crops of Andhra Pradesh. Research Report on ICAR Scheme. Indian Council of Agricultural Research, New Delhi and Acharya N.G. Ranga Agricultural University, Hyderabad.

Rainfed Horticulture in Different AESRs of Andhra Pradesh

J.V.Rao and V.S.Rao

Abstract

Rainfed horticulture has been found to be a very viable and sustainable alternate land use system for different AESRs of Andhra Pradesh. In a systems approach the fruit crops when intercropped either with annual crops or fodders give high B/C ratio besides helping in soil and water conservation in degraded lands. Establishment of fruit plants in a fragile semi-arid ecosystem is the biggest challenge. The suggested techniques are live/community fences, micro-site improvement *'in-situ'* grafting, micro catchment, mulching, supplemental watering, etc. The success depends on right combination of fruit crop and inter/fodder for different AESRs and promotion of farm level processing of perishables for value addition.

Introduction

The soils of rainfed areas are shallow, marginal in fertility, low in water holding capacity and associated with the deficiency of several plant nutrients. The rainfall distribution is also erratic both in quantity and spread, coupled with intermittent droughts of longer duration during the crop season. In most of the areas nearly 70% of the rains occur from June-September. Due to short growing season (less than 120 days), short duration crops are generally cultivated in monocropping in Alfisols. The marginal and small farmers (<2.0 ha) represent nearly 75 per cent of land holdings. The income generated from such holdings through arable cropping is inadequate to sustain the family. In addition to the above constraints and the poor socio-economic conditions of the farmers, rainfed agriculture has not been paying the expected dividends through traditional methods. In this direction, it becomes essential to explore other technologies, which can boost the productivity of the scarce resources and act as insurance against vagaries of monsoon.

In rainfed areas, alternate land uses involving agroforestry systems particularly rainfed horticulture have proved to be more stable and sustainable compared to the traditional crops/cropping systems. These systems can effectively utilize off-season rainfall for their establishment and production. Integration of tree with agricultural crop is known to withstand the vagaries of climate and conserve natural resources efficiently and enhance productivity of the land. Such systems not only fulfill the demands of people but also elevate their socio-economic status.

Agro-techniques for establishing tree saplings in rainfed areas

Most of the fruit crops can grow well in rainfed areas. However, these can be mounted successfully on deep soils with well-distributed rainfall pattern or provision for supplemental irrigation at active crop growth period coinciding with flowering and fruiting.

Microsite improvement

This involves preparation of pits of suitable size (1m x1m x1m) in summer at specified spacings depending upon the canopy size of a grown-up tree. Dried leaves should be burnt in the pit to kill the germs, if any. In Alfisols, the pits should be filled with equal proportions of good soil from the pit + well decomposed FYM + tank silt or black soil along with 100 g of DAP, 50 g of a systemic insecticide and 250 g of castor cake or neem cake. In Vertisols, red soil or sand should replace black soil/ tank silt while filling pits. Addition of clay minerals like Illite or Vermiculite or other materials like Bentonite @ 10 kg/pit at its bottom helps in retaining more soil moisture at least upto 18-24 months after planting. In a recent study use of *fullas earth*, a locally available clay mineral which is a mixture of Montmorillonite and attapulgite was found to improve the soil physico-chemical conditions, survival and growth of plants when applied @ 4.8 kg/pit of 45 cm^3 in custard apple and 11.2 kg/pit of 60 cm^3 in guava. The same clay mineral also improved the yield and quality of fruits when applied @ 8 kg/plant to 8 year old guava and @ 32 kg + FYM @ 20 kg/plot (5x4 m) to tomato (unpublished). Planting of grafts of selected fruit species or other saplings should be done soon after onset of monsoon on a rainy day preferably in July for better survival. Once the plants establish well, they would strike deep root system and draw moisture from deeper layers of soil profile.

In-situ grafting

Mango grafts and *Aonla* budded plants purchased from reputed nurseries cost around Rs.20-25 each and custard apple Rs.10-15 each. The mortality of grafts in rainfed Alfisols is around 40% in first year. These are quite delicate and hence need acute care for their establishment. On the other hand, for aiming at better survival and growth of saplings it is desirable to sow the seeds of fruit plants in main field and graft the desired scion material on 9-12 months old seedlings (*in situ* grafting). This has been successful in fruit plants like custard apple and mango. The custard apple hybrid 'Arka sahan' when *in-situ* grafted on Balanagar seedlings, has shown better scion growth compared to other varieties. This technique can be advantageously adopted incase of mango also. The drought hardiness can be improved with *in situ* grafting (mango, custard apple) and budding (*aonla)* over the seedlings in main field under rainfed conditions. Since the seedling has already established by then, the success rate of grafting will be much more, say upto 80% in first year. However, grafting / budding needs skill and must be done by a trained person.

Micro-catchment

The soils of rainfed Alfisols are degraded, sloppy and shallow. In these areas micro catchment plays an important role to check erosion and reduce evapo-transpiration. Depending upon the topography of the site and canopy size, basins of different shapes (crescent, horse shoe, saucer, rectangular, 'V' shape, etc.) and sizes should be made to capture maximum possible rainwater for its prolonged use. Small trenches of 90 cm length, 30 cm width and 30 cm depth across the slope above the plant basin increased yield, size and quality of custard apple in slopy lands. Regular de-silting of the trench and using it in the basin is desirable for holding more rainwater. This is more useful particularly to utilize the off-season rainfall, for better survival and development of young plants. This system will increase the survival percentage of fruit plants under rainfed conditions and help in boosting the production and employment to an extent of at least 60%.

Mulching

Mulching of the basins of fruit plants in the initial 2-3 years of establishment especially during post rainy season is an important aspect in rainfed areas for reducing surface evaporation, moisture stress, canopy temperature and weed menace. Use of any locally available materials like paddy husk, used paddy straw, gravel, coco pith, etc., spread up to 5 cm height are equally effective.

Irrigation

In rainfed areas water is the critical and scarce resource, hence needs to be used judiciously. The young plants need to be protected from the extremes of hot weather and resultant moisture stress through life saving irrigation. Establish an earthen pitcher of 8 litre capacity (with a small hole at 1/3 height from bottom and a wick) in the upper side of the slope of the plant. Water filled in it can keep the root zone of young fruit plants like mango, guava, custard apple, and pomegranate in moist condition for 4 to 6 days from February to May depending upon day temperatures. This practice coupled with mulching gives better results in terms of growth and survival of plants. Irrigation must be given during rainless period if drought occurs for longer time and also during summer to protect the plants from the adverse effects of higher temperature. This will boost the growth, survival and help in striking deep roots soon, so as to get moisture from deeper layers of profile. The encouragement given by the governments motivates the farmers to go in for drip/sprinkler irrigation to boost up survival percentage.

After care

In the initial years of plantation, the vegetation needs to be protected from cattle tresspass or grazing so as to get better survival of saplings. Fencing with posts and barbed wire is effective but quite expensive. Small and marginal farmers cannot afford

this. Therefore, alternative live fencing materials must be promoted all along the boundary. Some of these also result in valuable economic products through their leaves, fruits, fibre, seeds, repellant properties, etc. Eg. *Lawsonia inermis* (Henna), *Carissa carandes* (Karonda), *Agave sisalana*, *Jatropha curcas* (Rattanjyoti), *Vitex negundo,* Bougainvillea, etc.Thus establishment of live fence is precursor for establishment of any vegetation. Young plants also need to be tied to a support (staff) so that the plant can grow erect. Likewise, unwanted side branches also need to be removed now and then. Adoption of these simple techniques help in better establishment of fruit plants in rainfed areas and it is possible to establish 100 per cent population over a period of 5 years with protective watering and gap filling. These technologies will help in reaping full potential from the plantations, unlike only 50-70% from without these techniques.

Rainfed horticulture

A large variety of fruits are grown in about 7 % of cultivated area. Suitable fruit crops and varieties have been identified for rainfed areas in different districts/AESRs of A.P. as given in Tables 1 and 2.

Table-1: Rainfed fruit crops grown in different Agro-ecoregions of Andhra Pradesh

Agro-eco sub- region	Districts	Rainfall(mm)	Fruit crops
3.0	Anantapur	400-500	Ber, custard apple, *aonla*, pomegranate
6.2	Nizamabad, Adilabad	700-1000	Custard apple, mango, guava, sapota, papaya
7.1	Kadapa, Kurnool	700-750	Citrus fruits, guava, mango, sapota
7.2	Karimnagar, Ranga Reddy, Warangal, Khammam, Mahabubnagar, Nalgonda, Medak	700-1000	Mango, custard apple, guava, sapota

Table-2: Suitable fruit crops and varieties for rainfed regions

Crop	Botanical Name	Cultivars
Ber	*Zizyphus mauritiana*	Gola, Umran, Banarasi, Karaka, Kaithili, Seb (for Anantapur)
Custard apple	*Annona squamosa*	Bala Nagar, Arka Sahan, Tirupati-1, Chance seedling
Guava	*Psidium guajava*	Allahabad Safeda, Arka Mridula (selection-8), Sardar (Lucknow-49), Kohir Safeda, Safed jam
Aonla	*Emblica officinalis*	Kanchan, Krishna, Banarasi, Chakkaiya, NA-6, NA-7, NA-10
Jamun	*Syzygium cuminii*	-
Bael	*Aegle marmelos*	Narendra Bael-5, Narendra Bael-9
Tamarind	*Tamarindus indica*	PKM-1, Pratisthan, Local selection
Karonda	*Carissa carandes*	American red and green
Sapota	*Achras zapota*	Cricket Ball, Kalipatti, Pala sapota, PKM-3, Keerthi Bharati
Pomegranate	*Punica granatum*	Ganesh-137, Arakta, Be-dana, Ruby, Mrudula

Crop	Botanical Name	Cultivars
Mango	*Mangifera indica*	Benishan, Totapuri, Amrapali, Kesar, Suvarna Rekha, Mallika, Himayat, Rasalu, Manjeera, Arka Puneet, Neelum, Dashehari
Drumstick	*Moringa oleifera*	PKM-1
Wood apple	*Feronia elephantum*	-
Chironji	*Buchanania lanzan*	Grown in Adilabad and Northern Coastal AP.
Soapnut	*Sapindus emarginatus*	-
Citrus fruits:		
Sweet orange group Acid lime		Sathgudi, Batavian (Battayi), Mosambi (grown in all AESRs of AP) Kagzilime, Balaji
Cashewnut		BPP-5, BPP-6, BPP-8 and BPP-9 grown in coastal areas from Srikakulam to Nellore (export quality) BPP-2 and BPP-4 medium size kernels, high yielding

Mango is the most important fruit crop of AP grown under rainfed/protective irrigated conditions. The varieties, Banganpalli, Totapuri and Rasalu are grown in all the Agro-eco sub-regions. In addition, the following varieties are recommended by ANGRAU for different regions (Table-3).

Table-3: Mango varieties preferred in different AESRs of Andhra Pradesh

Agro-eco sub region	Districts	Mango varieties
3.0	Anantapur	Mallika
6.2	Nizamabad, Adilabad	Kesar, Manjeera, Amrapali, Mallika, Suvarnarekha, Dashehari, Himayat
7.1	Kadapa, Kurnool	Manjeera, Mallika, Suvarnarekha
7.2	Karimnagar, Ranga Reddy, Warangal, Khammam, Mahabubnagar, Nalgonda, Medak	Suvarnarekha, Kesar, Manjeera, Amrapali, Mallika, Dashehari, Himayat
7.3 & 18.3	Warangal, Krishna, Guntur, Prakasam, Nellore	Kesar, Himayat Suvarnarekha
8.3	Chittoor	Suvarnarekha, Mallika
12.2	Visakhapatnam	Suvarnarekha, Kesar
18.3	Coastal plains of Krishna and Warangal	Kesar, Suvarnarekha, Mallika, Himayat
18.4	Srikakulam, East Godavari, Visakhapatnam, Vijayanagaram	Suvarnarekha

Source: Vyavasaya Panchangam, 2004, ANGRAU, Rajendranagar, Hyderabad-500 030 and Annadata Diary, 2004.

In the initial years of growth of an orchard, several cereal/leguminous food crops/ forages can be intercropped for various purposes. These help in production of nutritious food and fodder, helpful in soil and water conservation and also meet part of the expenditure incurred in establishing an orchard. Several such systems prevalent in rainfed regions are described.

Horti-pasture system

In slightly slopy and marginal lands fruit species like custard apple, guava and *ber* can be promoted with suitable agro-techniques as suggested earlier. In these orchards, semi perennial/annual fodders can be encouraged from the point of soil and water conservation besides generation of nutritious fodder for use during off-season. Examples of such fodders are *S.hamata/scabra* (semi perennial legume), *C.ciliaris/setigerus* (semi perennial grass) and annual fodders like cowpea, horsegram, fodder sorghum and fodder maize. The potential of *cenchrus* (buffel, Anjan) is 3-5 t/ha of dry forage while stylo legume gives about 2.5 to 4.0 t/ha. The annual fodder crops give about 2 to 3 tonnes of dry matter/ha. In this system care needs to be taken to protect the fruit plants by cleaning the basins atleast 3 to 4 times in a year. Otherwise the semi-perennial forages smother the young fruit plant and might result in its death. Annual fodders like sorghum can also be cultivated successfully upto 8 years. The yield potential of fresh fodder of sorghum and cowpea can be 3-5 t/ha/year. Intercrops are more desirable in widely spaced guava while per tree yield and weight of single fruit were higher in closer planting.

In **guava based** horti-pasture system, the yield reduction in stylo was less under widely spaced trees (8 x 5 m) compared to closer spacing (5 x 5 m), indicating the necessity of wider spacing of fruit trees when grown with stylo (Osman and Rao, 1999). The fruit yield of guava is not influenced by fodder inter crop and hence these can be profitably grown in orchards. Crops like guava respond to closer spacing (5x5m) even in rainfed conditions giving scope for high-density plantations, yielding at least 50 kg fruits / tree after 6 years of age. Semi perennials like stylo legume and cenchrus can be intercropped upto 8-10 years of establishment without any adverse effect on the plantation under good management. These intercrops also have improved the physico-chemical properties of the soil considerably (Rao, 2004).

Horti-silvi-pasture

Timber yielding species can be encouraged in marginal and slopy lands along with horticultural crops with proper agro-techniques. Generally the timber trees are planted along the field boundary or sparcely distributed between the fruit plants in the main field. The examples of fruit plants are guava, ber, custard apple grown along with *Tectona grandis* (teak), *Azadirachta indica* (neem), *Hardwickia binata* (Anjan, Yepi), Acacias, *Dalbergia sissoo* (shisham), etc. The pasture management is similar to the one described above incorporating *S.hamata/scabra, C.ciliaris/setigerus*, *D.annulatum, Pennisetum pedicillatum.* The trees like neem, Acacias, shisham, anjan also provide top- feed (fodder) during off season for the farm animals. Such systems are already popular with the rainfed farmers.

Agri-horticultural systems

In this system, short duration arable crops are raised in the interspaces of fruit trees. The system works best in medium to deep soil with good water holding capacity or

supplemental irrigation. In the initial years of establishment of an orchard (say upto 8-10 years of age), arable crops can be grown successfully to meet the domestic needs of the farmers as well as part of establishment expenditure. Short duration legumes like cowpea, greengram, blackgram, groundnut, mothbean, horsegram are promising intercrops. These also act as erosion resistant crops and check run-off in sloppy lands. Among vegetables, clusterbean, dolichos, okra and others can be promoted. In fully grown orchards intercropping should be discouraged. Agri-horticultural systems are observed to increase land use efficiency and generate employment opportunities. Promising agri-horti. systems for different regions are given here under:

Ber, custard apple, pomegranate and Aonla based

Clusterbean is preferred as an intercrop in ber orchard at Hyderabad (Tomer *et al.,* 1988). The yields of sorghum, groundnut and mungbean intercropped with pomegranate and custard apple decreased by 23-26 per cent over sole crops (CRIDA,1999). Yield reduction was higher in association with custard apple compared to pomegranate. Groundnut with pomegranate or custard apple gave highest gross income (Rs.19,540–19,770/ha) while custard apple + mungbean recorded highest yield advantage (54%). Custard apple can tolerate drought as well as high rainfall conditions. In states like A.P., it has minimum risk.

Guava based

The yield of guava was significantly influenced by application of even 8 litres water/ day from Feb-May coinciding with dry period over rainfed control. The fruit yield of guava was significantly higher over farmers' practice (12.5 kg FYM /ha) when 100% NPK (860g urea, 2.2 kg SSP, 650 g MoP/tree) or 100% NPK + 50 kg FYM/tree or 100% NPK+ 25 kg FYM/tree were applied.

Mango based

Among different intercrops (groundnut, greengram and cowpea) tried under mango at Hyderabad, groundnut was proved to be a successful one (Rao *et al.*, 2003). The crop yield of groundnut in a 9-year-old agri-horticultural system with mango was reduced by 29 percent in JL 24 as against 42 percent in K 134 over sole cropping (768 and 776 kg/ha, respectively). The cv. JL 24 was comparatively more shade tolerant than K 134. The leguminous intercrops can be taken in mango orchard upto at least 10 years after planting with minimum reduction in yields of annual crops. Application of 100% NPK+5t FYM/ha gave significantly higher pod yield over other nutrition levels. Drip irrigation in mango at 0.75, 0.5, 0.25 Ep. gave 86, 85 and 136 % higher fruit yield over rainfed control (18.4 kg/tree). 100% NPK + 75 kg FYM/tree gave significantly higher fruit yield of mango (55.2 kg/tree) over other nutrition treatments in a 10 year old plantation. Pruning 25% of over-lapping branches in over 6-7 year old mango trees either on eastern or western direction during July-August increased light intensity and resulted in more number of fruits and yield / tree.

Alternate land use systems in *Kharif* sorghum area decreasing regions

The productivity of sorghum and other nutritious cereals in rainfed regions is decreasing rapidly and uneconomical due to erratic rainfall thus, leading to a declining trend in its area (Reddy *et al.,* 2003).

The surveys conducted in A.P have indicated that - there is a substantial shift towards fruit trees viz., mango, custard apple, tamarind, sapota, *ber*, guava, pomegranate, *aonla* etc. apart from growing vegetables, timber yielding and multipurpose trees in place of coarse cereals. Farmers preferred teak, neem, leucaena, *Acacia*, *Dalbergia*, *Hardwickia* and *Gmelina arborea* on their farm bunds. Higher mango yields were realized in 5-7 year old and in 10 year old and above orchards by following the interventions like *in situ* moisture conservation, preparation of crescent shaped basins, making ridges and furrows across the slope, mulching the tree basins and application of recommended doses of nutrients. With farmers' own practices the average mango yields were very low in Mahaboobnagar district.

In a study on selection of suitable tree and crop species for land capability class VI in arid Alfisols at Anantapur during 2002, soapnut was found to perform better with a plant height of 3.68 m and girth of 32 cm with drip irrigation, and a height of 3.22 m and girth of 23.4 cm without irrigation (Table-4). This was followed by tamarind, custard apple and *ber* (AICRPDA, 2003).

Table-4: Suitable tree species for land capability class VI at Anantapur

Species / spacing	Plant height (m)		Girth (cm)	
	With drip irrigation	Without drip irrigation	With drip irrigation	Without drip irrigation
Custard apple (4.5 x 4.5 m)	2.56	1.72	24.0	18.6
Ber (6.0 x 6.0 m)	1.91	1.78	15.5	15.0
Soapnut (6.0 x 6.0 m)	3.68	3.22	32.0	23.4
Tamarind (9.0 x 9.0 m)	2.95	2.73	27.5	20.1

A five year study in 6 villages of Nalgonda and Mahaboobnagar districts of A.P. mounted with agroforestry programme on 50 ha of land/village as per farmers' preference with (Korwar *et al,* 2003) tamarind, mango, *aonla*, custard apple, leucaena, teak, along with predominant arable crops (groundnut, pulses, castor, sorghum) indicated that:

- Agroforestry alone cannot improve the degraded lands unless integrated with soil and water conservation measures.
- The agroforestry programmes should begin with exposure visit, boundary plantation in the first year, followed by main field plantation in the second year and *in-situ* grafting.
- Protection from cattle through social fencing is essential.
- The farm size has to be large to support farmer's family and to arrest migration.

Plant protection

Control of pests and diseases is required mainly in mango, as described in Table-5.

Table-5: Plant protection measures in mango

Pests/Diseases	Control measures
Pests	
Hopper	Spray carbaryl (3g)/Dimethoate (2.0 ml)/monocrotophos (1.6 ml)/litre just before the emergence of the inflorescence immediately after emergence, and after fruit set
Stone weevil	Spray 1.6 ml/litre of monocrotophos immediately after fruit set (pea stage)
Bark eating Caterpillar	Prune the infected shoots after harvest during July, followed by a spray of chlorpyriphos (2.5 ml/l)
Fruit fly	When the fruit attains marble size, spray 2 ml/l of endosulphon + 0.5 ml/l of teepol
Stem borer	Remove caterpillar with a wire and destroy, followed by filling the hole with petrol or metacid (0.5 ml/l) + plugging the hole with clay. Spray carbaryl (3g/l) on foliage during rainy season on a rainless day.
Diseases	
Powdery mildew	Spray wettable Sulphur (4 g/l) or Carathane (1 ml/l). This can be clubbed with the spray for hoppers
Anthracnose	Remove the affected branches and spray Bavistin (1g/l) at flower emergence, and after fruit set, spray Indofil M-45 (2g/l).

Rehabilitation of degraded lands

In rainfed areas the problems of desertification are continuously increasing due to over exploitation of natural resources resulting in minespoils, degraded lands, etc. This is also seen in common property lands. Most of these problems are location specific needing appropriate solutions. Such areas have to be thoroughly surveyed utilizing remote sensing techniques for arriving at suitable options. Horti-pastoral systems are the best options in such areas. Technologies already evolved must be made available to the farmers. A close interaction and dedicated effort on the part of researchers – development agencies - NGOs - farmers is essential to develop a sustainable technology and give a clean environment to the people.

Value addition to farm products

Most of the times the dryland products face glut in the market as similar produce comes from many places during short time, resulting in very low prices and losses to the producers. Post harvest processing and conversion into various products will result in not only higher income to the farmer but also promotion of cottage industry, more employment opportunities during off-season and better nutrition.

Custard apple: A simple technique has been developed for manual extraction of custard apple pulp by rotatory motion of a round hair comb in the scooped fruit held in stainless steel sieve. This pulp can be used for manufacture of ice cream.

***Aonla*:** Technique has been developed for separation of segments of *Aonla* and do away with nut by steaming. These segments were used for preparation of *Aonla* pickle and *murabba*. The initial organoleptic scores for both pickle and *murabba* were: colour (8.6 out of ten), flavour (8.5) and texture (8.5), and were well above the acceptable limits.

Roselle: The calyces of Roselle (*Hibiscus sabdarifa. L*) which grows well even when sown in September under rainfed conditions in Alfisols can be utilized for processing into different products. It can also be a very good source for coloring fruit products, which do not have attractive colour.

Jellies with Guava – Roselle blends: Calyces of Roselle can be used as a source of colorant for guava jelly, since there is a problem of browning in guava jelly during storage. Organoleptic evaluation of jellies prepared from different proportions of guava – Roselle (calyces) revealed the preference of tasters for blending at 85 – 15 proportion to get a jelly with attractive colour. Roselle calyce can be used with guava for jelly making without significant change in guava flavour.

Roselle sauces: After extraction of colour, acids and pectin for jelly making, the calyces mass could be further processed to a sauce which was also organoleptically highly acceptable.

Curry leaf essence: Traditionally, curry leaf as such is being used widely for culinary purpose in South Indian preparations as a source of flavour. The availability of fresh leaf during summer is less. The essence product can provide the aroma of fresh curry leaf where it is not available or expensive. Leaf essence extract can be used as a flavoring agent in fast food items, pharmaceuticals and perfumeries. There is a possibility of exporting this essence to USA and Gulf countries.

The post harvest processing of curry leaf thus can help in fetching better prices to the farmers. The technology on adoption will generate employment and develop home/small scale industry using fresh leaves when there is excess production and glut in the market.

Economic evaluation of agri-horticultural systems

Survey carried out in 100 randomly selected guava and mango orchards (of average 1.5 ha size) in semi-arid conditions with rainfed groundnut, sorghum, vegetables in Shadnagar and sugarcane and turmeric in Zaheerabad area (A.P.) indicated that agri-horticulture was more viable and profitable compared to horticultural system alone (Reddy and Sudha, 1988). The time lag between cash inflows and outflows could be minimized by adopting agri-horticultural system with arable crop like rainfed groundnut in mango orchard and agri-horticultural system can substantially enhance the income of rainfed farmers (Rao, 1999). Alternative land use systems were observed to perform better than cultivation of arable crops as given below (Table-6). However, establishment of such systems demands heavy investments and proper marketing and probably not possible in small holdings (Reddy and Rao, 1999).

Table-6: Economics of alternative land use systems

Alternative land use systems	B/C ratio
Agri-horticulture with ber	5.00
Agri-silviculture	2.00
Arable crops	1.20-1.75
Dryland horticulture	
Mango	3.21
Acid lime	3.04
Sweet lime	2.89
Guava	2.18

Adoption of identified agri-horti. systems in marginal rainfed Alfisol areas help in generation of higher biomass, fruits, fodders, promote dairy, improve nutritional standards of farmers' families/livestock, increase employment potential by at least 60% mandays and socio-economic conditions besides conserving the natural resources and enhancing environmental quality.

Recommendations

- Selection of right combination of fruit sp./varieties and intercrop/fodder for different AESRs of A.P.
- Encouraging live/community fencing.
- Micro-site improvement according to the situation.
- *'In-situ'* grafting for better survival of plants and reducing the cost of the planting material.
- Supplemental watering with pitchers during rain less period in the initial years of establishment.
- Micro-catchments for efficient utilization of rainwater.
- Timely plant protection.
- Promotion of farm scale/home scale processing for value addition of perishables.

Acknowledgements

The authors are grateful to the Director, CRIDA and all the scientists whose work has been reported in this paper.

References

AICRPDA, 2003. Annual Report of All India Coordinated Research Project on Dryland Agriculture, CRIDA, Hyderabad.

CRIDA, 1999. Annual Report of Central Research Institute for Dryland Agriculture, Hyderabad, 1998-99. pp: 49-51.

Korwar, G.R. Pratibha, G., Srinivas, K. and. Ramesh, V. 2003. Influence of different agroforestry models on soil fertility and resource conservation under rainfed conditions in SAT. Annual Report of CRIDA, 2002-2003. pp.35.

Osman, M. and Rao, J.V. 1999. Alternate land use: Horti-pastoral systems. *In* Fifty years of Dryland Agricultural Research in India (Eds. H.P.Singh, Y.S.Ramakrishna, K.L.Sharma and B.Venkateswarlu) pp: 485-495.

Rao, J.V. 1999. Agri-horticultural systems in rainfed Alfisol watershed. Annual Report of CRIDA, Hyderabad 1998-99.

Rao, J.V. 2004. Agri-horticultural and Horti-pasture systems in rainfed Alfisol watershed. Annual Report of CRIDA, Hyderabad 2003-04.

Rao, J.V.,.Rao, V.S.,.Reddy, N.N. and Jyothi Lakshmi, N. 2003. Agri-Horticultural Systems in rainfed areas. Annual Report of CRIDA for 2002-2003. pp.19.

Reddy, N.N., Rao, J.V. Rao, G.R. and Mishra, A.K. 2003. Develop agri-horticulture and agroforestry systems in kharif sorghum area decreasing regions for overall sustainability of the production system. Annual Report of CRIDA, 2002-03. pp:36-37.

Reddy, Y.V.R. and Rama Rao, C.A. 1999. Economic analysis of dryland agricultural technologies. In Fifty years of Dryland Agril. Research in India. H.P. Singh *et al.*, (Eds.) 1999. CRIDA. pp:559-564.

Reddy, Y.V.R and Sudha, M. 1988. Economics of different land use systems in dryland farming. Annual Report of CRIDA Hyderabad: pp: 62-63.

Tomer, D.S., Saharan, N and Singh, R.P.1988. Agri-horticultural system for drylands of semi-arid tropics. Annual Report of CRIDA, Hyderabad. pp: 42-58.

Identification of Efficient / Appropriate Fodder Crops and Trees for Different AESRs in Andhra Pradesh

G R Korwar and V Satyanarayana Rao

Abstract

The gap in demand and supply of fodders in Andhra Pradesh is large and would increase further. There is urgent need to improve forage supply, both in quantity and quality. Suitable fodder crops and tree fodders have been identified for different AESRs of Andhra Pradesh. Intensive forage crop sequences and / or intercropping systems also have been identified. Inclusion of perennials both among grasses and legumes; and tree components improves the fodder supply and availability throughout the year. The efficient fodder crops, fodder trees and systems for introduction of fodder trees and discussed in this paper.

Introduction

In Andhra Pradesh, only 2% of cultivable area is used for fodder production. The livestock depend on direct feeding on pastures in uncultivable lands in the monsoon season and crop residues in winter and summer seasons. There is large-scale shortage in the fodder supply. The recent crop shift from duel purpose sorghum to cash crops like sunflower is further adding to the fodder shortage. Supporting large livestock population with meagre and ever dwindling fodder resources are causing a crisis in animal husbandry sector.

Studies have been conducted on growth and yield attributes of different fodder crops and trees; based on these findings recommended ones are given in following paras.

I. Description of Agro climatic Zones in AP

S. No	Agro-Climatic Zone, Districts (AESRs)	Mean annual rainfall (mm)	Major soil Types	Major crops
I	**Krishna Godavari Zone** East Godavari, West Godavari, Krishna, Guntur, parts of Khammam, Nalgonda and Prakasam (18.3, 7.3)	900-1150 SW:550-750 NE:200-260 Off-season (OS) :80-110	Alluvial, Black cotton and Coastal sands, Deep Red loams and saline soils	Paddy, Sugarcane, Cotton, Chilli, Rabi Jowar, Groundnut, Sesame
II	**North Coastal Zone** Srikakulam, Vizianagaram, Vishakapatnam, Upland regions of East Godavari. (18.4)	1000-1100 SW:650-750 NE:260-310 OS:110-160	Deep red soils with P^H 4-5	Paddy, Bajra, Ragi, Green gram, Black gram, Horse gram Sesame and Sugarcane

S. No	Agro-Climatic Zone, Districts (AESRs)	Mean annual rainfall (mm)	Major soil Types	Major crops
III	**Southern Zone** Nellore, Chittoor, Southern parts of Prakasam and Cuddapah and Eastern part of Anantapur (8.3)	720-1025 SW:310-425 NE:250-600 OS:90-140	Red loams, Red loams with clay base, Black soils, Coastal sandy soils	Groundnut Rice, Sorghum Pearl millet, Foxtail millet, Red gram and Horse gram
IV	**Northern Telengana Zone** Adilabad, Karimnagar, Nizamabad, Warangal and Parts of Nalgonda, Medak and Khammam (6.2)	900-1150 SW:775-950 NE:70-120 OS:60-90	Shallow medium to deep black cotton soils, red sandy loams, red loamy sands	Rice, Jowar, wheat, Red gram, green gram, oilseeds, Maghi Jowar
V	**Southern Telengana Zone** Ranga Reddy, Mahabubnagar, parts of Nalgonda, Warangal and Medak (7.2)	700-850 SW:550-700 NE:90-120 OS:55-90	Light red soils, Black soils, problem soils	Jowar, Bajra, ragi, wheat, groundnut safflower, castor, red gram
VI	**Scarce Rainfall Zone** Kurnool, Anantapur, parts of Prakasam and Cuddapah (3.0, 7.1)	540-720 SW: 300-420 NE:150-240 OS:65-85	Black cotton (BC) soils, red earths with clayey sub -soils, red loamy soils, red sandy soils (Dubbas and Chalkas)	Groundnut, sorghum, fox tail millet, rice, cotton, and pearl millet
VII	**High Altitude and Tribal Zone** Parts of Srikakulam, Vizianagaram, Visakhapatnam, East Govadari and Khammam (12.2)	1400 and above SW: 765 NE:210 OS:220	Red soils, alluvial soils, coastal sands (medium, high and very high elevations)	Millets, red gram, cotton, paddy and other forest produce

II Total Livestock, Demand and Supply gap in fodders

No	District	Total Livestock (Lakhs)	Fodder Requirement (Lakh Tons)	Fodder Availability (Lakh Tons)	Fodder Deficit (Lakh Tons)
1	Srikalulam	11.19	20.94	6.19	14.75
2	Viziznagaram	10.23	20.23	4.98	15.25
3	Visakhapatnam	13.04	27.67	3.25	24.42
4	East Godavari	9.76	24.62	17.15	7.47
5	West Godavari	8.48	22.82	18.60	4.22
6	Krishna	11.06	30.96	16.22	14.74
7	Guntur	13.53	36.40	15.21	21.19
8	Prakasham	16.92	39.00	7.85	31.14
9	Nellore	13.72	31.19	9.17	22.02
10	Kurnool	15.57	29.04	6.89	22.15
11	Ananthapoor	20.62	32.07	3.36	28.71
12	Cuddapah	12.55	24.91	3.36	21.55
13	Chittoor	16.27	26.59	5.39	21.20
14	Rangareddy	9.35	17.52	3.13	14.12
15	Hyderabad	0.26	0.64	-	0.64
16	Nizamabad	9.94	19.60	6.40	13.20

No	District	Total Livestock (Lakhs)	Fodder Requirement (Lakh Tons)	Fodder Availability (Lakh Tons)	Fodder Deficit (Lakh Tons)
17	Medak.	12.83	24.63	6.52	18.11
18	Mahabubnagar	28.21	44.10	4.77	39.33
19	Nalgonda	22.55	44.33	10.98	33.35
20	Warangal	18.42	23.92	5.40	18.52
21	Khammam	15.21	33.39	6.64	25.75
22	Karimnagar	18.82	34.85	8.67	26.18
23	Adilabad	12.96	23.38	5.59	17.79
	Total	321.58	632.53	170.58	461.95

III Efficient Fodder Crops for Different Zones

S. No.	Agro-Climatic Zone/ Soil Type / Situation	Irrigated	Rainfed
I and II	Krishna Godavari/ North coastal zone Black soils	**Perennials:** Bajra Napier (BN) Hybrid + Lucerne (2:2), Para grass **Early Kharif:** Guinea, Jowar + Cowpeas, Bajra **Mid-Kharif:** Jowar + Cowpeas, Teosinte **Late Kharif:** Sunnhemp, amaranth **Rabi:** Maize, Sunnhemp, pilipesera **Summer:** Bajra (multi-cut), Guinea	Cluster beans
	Red Soils	Fodder Jowar + Cowpeas, Pillipesara	Cenchrus, Guinea
	Problem soils	Para grass	Rhodes grass
	Orchards	Stylo, Diacanthium, Cenchrus	
	Field bunds	Pilipesara, hedge Lucerne, Sesbania	
III	Southern Zone	**Perennials:** Bajra Napier (BN) Hybrid + Lucerne (2:2), Para grass, Berseem **Early Kharif:** sorghum / Bajra (Dual purpose) + cowpea/ pilipesara **Mid-Kharif:** Jowar/ maize + Cowpeas **Late Kharif:** Horse gram, amaranth **Rabi:** Maize, Lucerne, berseem **Summer:** Bajra (multi-cut)	Green panic/ Cenchrus, colonial guinea, Chrysopogan, Sehima, Stylo, Dicanthium as pasture grasses in wastelands
IV, V and VI	Northern / Southern Telengana; and scarce rainfall Zone	**Perennials:** Bajra Napier (BN) Hybrid + Lucerne (2:2), Para grass, Berseem **Early Kharif:** sorghum / Bajra (Dual purpose) + cowpea/ pilipesara **Mid-Kharif:** Jowar/ maize + Cowpeas **Late Kharif:** Horse gram, amaranth for uplands; sorghum and pilipesara for lowlands **Rabi:** Maize, Lucerne, berseem, oats **Summer:** Bajra (multi-cut)+ pilipesara/ cowpea	Green / blue panic, stylo, Cenchrus, Andropogon, hedge lucerne
VII	High Altitude and Tribal Zone	**Perennials:** Bajra Napier (BN) Hybrid + Lucerne (2:2), Para grass, Berseem **Early Kharif:** Maize, sorghum / Bajra (Dual purpose) + cowpea/ pilipesara **Mid-Kharif:** Jowar + Cowpeas **Early Rabi:** Jowar, Maize, Lucerne, berseem, oats **Summer:** Bajra (multi-cut)+ pilipesara/ cowpea	Green / blue panic, stylo, Cenchrus, Andropogon, hedge Lucerne, Napier, lemon grass, Urochloa, stylo

IV. Fodder Tree species for different Zones

S.No.	Agro-climatic Zone (AESR)	Species	Systems
I	Krishna-Godavari (18.3, 7.3)	*Ailanthus malabarica*	Silvi-agri
		Erythryna variegata	Silvi-agri
		E poppigiana	Silvi-agri
		Leucaena leucocephala	Hedgerows, Pollarding
II	North Coastal (18.4)	*Ailanthus malabarica*	Agri.-Silvi
		Erythryna variegata	Silvi-agri
		E poppigiana	Silvi-agri
III	Southern (8.3)	*Leucaena leucocephala*	Hedgerows, Pollarding
		Albizzia lebbeck	Silvi-pasture
		Dalbergia sissoo	Silvi-pasture
		Sesbania	Hedgerows
		Azadirachta indica	Silvi-pasture
IV	North Telangana (6.2)	*Albizzia lebbeck*	Silvi-pasture
		Hardwickia binata	Agri-silvi
		Dalbergia sissoo	Silvi-pasture
		Anogeissus pendula	Silvi-pasture
		Sesbania	Hedgerows
		Leucaena leucocephala	Hedgerows, Pollarding
V	Southern Telangana (7.2)	*Acacia nilotica*	Silvi-pasture
		Albizzia lebbeck	Silvi-pasture
		Leucaena leucocephala	Alley cropping, Contour hedgerows, Pollarded trees
		Dalbergia sissoo	Silvi-pasture
		Faidherbia albida,	Agri.-silvi
		Hardwickia binata	Agri.-silvi
		Acacia leucophloa	Silvipastoral
		Gliricidia sepium	Contour hedgerows
VI	Scarce rainfall (3.0, 7.1)	*Acacia nilotica*	Silvi-pasture
		Albizzia lebbeck	Silvi-pasture
		Hardwickia binata	Agri.-silvi
		Faidherbia albida,	Agri.-silvi
		Ailanthus excelsa	Agri.-silvi
		Dalbergia sissoo	Agri.-silvi
		Azadirachta indica	Silvipastoral
		Gliricidia sepium	Contour hedgerows
VII	High Altitude and Tribal (12.2)	*Albizzia chinensis*	Agri.-silvi
		Bauhinia variegata	
		Cordia dichotoma	
		Hardwickia binata	Agri.-silvi
		Moringa oleifera	Agri-silvi
		Erythryna	Agri-silvi
		Azadirachta indica	Silvipastoral
		Sesbania	Agri-silvi

Summary

The use of efficient fodder crops in different seasons and situations, with adequate fertilizer application would solve the fodder shortage problem to a great extent in AP. The tree fodders also should be used to supplement the regular fodders especially in the lean season and in the predominantly dry areas. Many fodder grasses and trees can e raised in proper conjunction with soil and water conservation measures in farmers fields.

Policy implications and recommendations

Improved fodder crops and the improved management of these crops have to go hand in hand. These should form the recommendations and extension activities of the agriculture Department. Promotion of these crops through, subsidies and incentives should be taken up. Training of farmers on the importance of feeding quality fodders rather than depending on "free-good" from the denuded forests has to be taken up.

References

AICRPDA 2003. Bio-Diverse farming System Models for Dryland Agriculture. AICRPDA, CRIDA, Hyderabad p. 58.

AP Forest Dept. 1991. Forest map of Andhra Pradesh. AP Forest Dept., Hyderabad

Gupta, R.K. 1993. Multipurpose trees for agroforestry and wasteland utilization. Oxford and IBH, New Delhi, p. 562

Hocking, D. 1993. Trees for drylands Oxford and IBH, New Delhi, p. 370

Panjab Singh and Roy M.M. 1998. Agroforestry and rangeland development In Yadav RL, Panjab Singh, Rajendra Prasad and Ahlawat IPS Eds Fifty years of agronomic research in India. Indian Society of Agronomy, New Delhi 221-254.

Tree-based Farming Systems for Different Agro-Eco-Sub Regions of Andhra Pradesh

Mohammed Osman and L.G. Giri Rao

Abstract

The State of Andhra Pradesh is well endowed with natural resources and is divided into nine agro-eco-sub regions. There is a need to develop land use as per the bio-physical and socio-economic characteristics. The paradigm shift in dryland agriculture calls for land use diversification to overcome recurring droughts. An attempt is made in this direction to plan tree-based land uses for different agro-eco-sub regions. Tree-based farming systems have proven to be a good option for drought proofing. Tree-based farming systems include agri-horticulture, silvi-pastoral system, bunding planting, horti-pastoral system, contour vegetative hedges, etc., Need-based, agro-eco-sub region based and tree-based farming systems are discussed in this paper.

Introduction

A necessity has arisen to make the best use of land based on its carrying capacity in view of the short term and long-term goals of sustainability. The short-term focuses on market demand and profitability, where as the long term covers the soil health and amelioration of microclimate, besides protection and improvement of ecosystem at large. Alternative land use aims at diversification of land use and is different from the conventional or the existing land use and may be defined as "*effective, appropriate and economic utilization of land without harming the natural resource base*" (Singh and Osman, 1995). Alternative land use systems/practices (ALUS) essentially involve a perennial component to impart stability in production from farmlands. Perennials are known for drought tolerance or avoidance characteristics and can withstand late onset or early withdrawal of monsoon and prolonged dry spells that are frequent in drylands.

Network research carried out in India revealed that alternative land use involving perennials (tree/crop, grass shrub or a combination of both) has advantages and can conserve natural resources and increase productivity (Osman, 2003). Some of the advantages of perennials are:

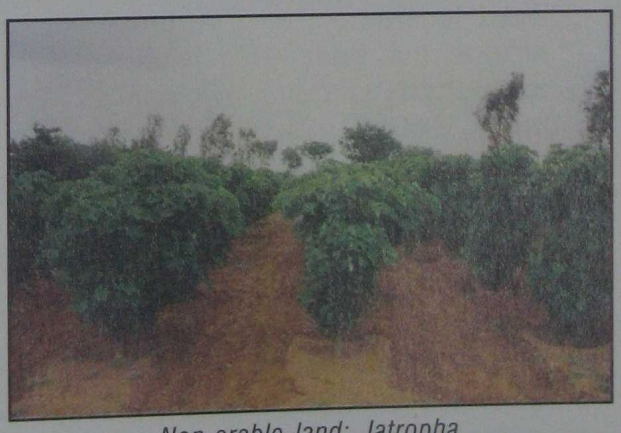
- They can thrive in relatively resource-poor soils.
- Provide continuous vegetative cover to the soil and thus substantially control erosion caused by both runoff and wind.
- Amelioration of microclimate.
- Provide good quality green fodder, which is in short supply to support livestock.

- Protect the environment and upgrade soil quality through their deep root system.
- Enhance organic matter through litter fall and root turnover.
- Reduce surface evaporation and weed growth, and improve water use efficiency and add nutrients to the soil when pruned material is applied as surface mulch.
- Ensure rational utilization of soil moisture stored in deeper soil layers and substrata through tree component.
- Effective nutrient cycling from deeper soil layers.
- Provide fuel, timber and minor forest products (e.g. gum, honey) and thus lessen the farmers' dependence on forest reserves.
- Supplement the diet of poor farm families by giving the necessary vitamins and minerals, and thus contribute to their nutritional security.
- Generate much needed cash when aromatic and industrial value plants are grown.
- Support development of soil microbe and earthworm activity.
- Generate employment throughout the year, which substantially increases the income level and cash flow.

Central Research Institute for Dryland Agriculture (CRIDA) and ANGRAU in the past two decades have focused on devising simple land use practices based on sound scientific principles and rural scenario. From the past experience, we could identify some basic principles that govern the success of any alternative land use systems (Osman *et al.*, 1997).

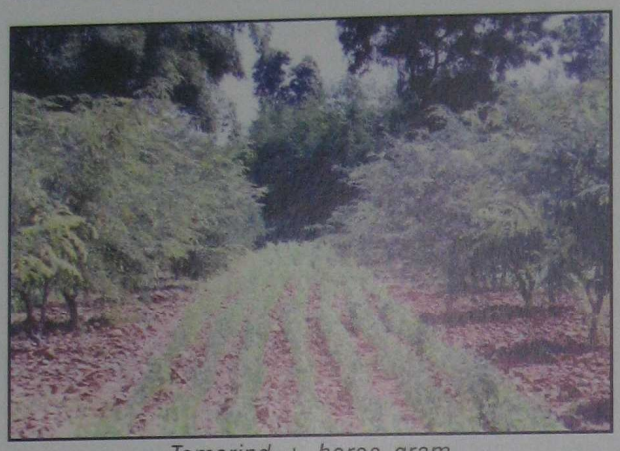
- Selection of suitable land use system from various models like agri-horticulture, agrisilviculture, alley cropping, silvipasture, ley farming, tree farming, etc. This essentially involves sound farmer participatory planning, based on various components like soil, climate, native vegetation, and socio-economic aspects.
- Shrubs or trees that are not palatable to livestock can be successfully grown compared to palatable ones because of high stocking rate and uncontrolled open grazing system. Shrubs have been found to be more compatible with crops (**Fig. 1**).

Arable land: Curry leaf + Black gram

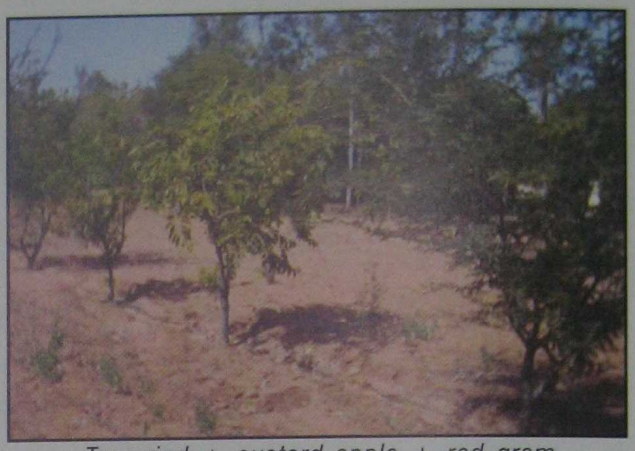


Non-arable land: Jatropha

Fig. 1 : Bush farming in arable and non-arable land



Tamarind + horse gram



Tamarind + custard apple + red gram

Fig. 2. Agri-horticulture system for non-arable land

- The acceptability of farming community is more for fruit plants compared to fodder or fuel wood trees. Horticulture in drylands has wide scope, provided selection of right fruit plants and elite planting material having short gestation is made. Selection has to be based on flowering and fruiting stages coinciding with rainy and post-rainy season, respectively. Fruit trees like guava, custard apple, ber, tamarind that flower during rainy season are highly compatible and bear fruit during post-monsoon period. Agri-horticulture system is highly suitable for drylands, both for arable and non-arable lands (**Fig. 2**).
- Improvement of planting spot (microsite) is a pre-requisite for success of any perennial plants on drylands. This should be coupled with timely planting (with onset of monsoon), so that the saplings establish well before cessation of rains and becomes hardy enough to pass through the first summer. The cost of restructuring microsite ranges from Rs.10 to Rs.12 per spot and may depend upon the number of spots on hectare basis.
- *In situ* water harvesting: Water is always a critical factor in drylands. Plant survival can be greatly enhanced by shaping the land surface in the immediate vicinity of the trees so that runoff is concentrated in the root zone. Various methods can be used to shape the ground surface so that water can concentrate in one area, around the base of a newly planted plant. The principle is to construct mini-watershed that collects sheet flow near the plant even if light rain occurs. On sloping lands, construction of half moon terraces may be appropriate. A provision of supplemental watering during establishment phase is a must for the success of plantation.

Alternate land use systems based on agro-ecological sub-regions of A. P.

Different ALU systems suiting to varying AESR of A.P. are discussed below along with photographs of some promising systems.

AESR 3.0 Anantapur

Agroforestry systems – arable land

Agri-horti system:

- Ber, Tamarind with crops (rainfed)
- Mango, Sapota, Guava with crops (irrigated)

Silvi-pastoral system:

- Neem, Ailanthus, Gliricidia with *Cenchrus ciliaris*, Stylo (rainfed)
- Subabul with hybrid napier (irrigated)

Agroforestry system – Non arable land

- Boundary planting: *Acacia nilotica*, *Prosopis cineraria*, Subabul, Pongamia, Jatropha (**Fig. 3**)

Tectona grandis (Teak)

Cassia siamia

Pongamia pinnata (Kanugu)

Fig. 3. Some of the suitable species for boundary planting

Guava + Cenchrus ciliaris (Anjan grass)

Mango + Grass

Fig. 4. Horti-pastoral system for non-arable land
Note: Stylo may be preferred over grass as it is less competitive

- Contour + Vegetated hedges – Gliricidia, Stylo
- Hortipastoral system: Dryland fruit trees like mango, ber with stylo, cenchrus (**Fig. 4**)

AESR 6.2 Adilabad, Nizamabad

- Intensive agriculture: irrigated (paddy, sugarcane), rainfed (cotton, maize, sorghum)
- Seed production as an enterprise eg. Armoor
- Alternate enterprises e.g. apiculture
- CFM for NTFP: e.g. chironji, beedi leaf, gum karaya, honey, marking nut, etc.

Agroforestry system – Arable land

- Boundary planting Teak, Gliricidia, Jatropha, Pongamia, Bamboo
- Contour vegetated hedges (CVHs): Stylo & Gliricidia (**Fig. 5**)
- Agri-horticulture: Mango/Sapota + crops

Agroforestry system - Non-arable land

- Tree farming: Chironji (*Buchanania lanzon*), beedi leaves, gum karaya, custard apple, wood apple, etc.
- Pasture management

Fig. 5: Contour vegetative hedge green capped with stylo and gliricidia on either side of the bund

AESR 7.1 Cuddapah / Kurnool

Agroforestry system – Arable land

- Boundary planting: Babul, Anjan (Hardwickia binata), Bamboo, Neem, Jatorpha, Pongamia
- Contour vegetative hedges (CVHs): Stylo / Gliricidia
- Agri – horticultural system: Citrus sp. + crops
  Mango + crops

Fig. 6: Guinea grass, more promising than Anjan grass

Agroforestry – Non-arable land

- Silvi-pastoral system – Subabul + Stylo, Anjan + Stylo
- Pasture Management (**Fig. 6**)
- Tree / Bush farming: Jatropha, Annato, Curry leaf, Lawsonia, etc.

AESR 7.2 Karimnagar, Khammam, Warangal, Medak

Agroforestry system – Arable land

- Boundary planting: Teak, Jatropha, Pongamia, Bamboo
- Contour vegetative hedges (CVHs) – Gliricidia, Stylo
- Agri – silvi – horticulture
  - Horti: Mango,Guava, Sapota
  - Crop: Cotton, Jowar, Maize, Chillies
  - Silvi: Teak, *Gmelina arborea* (Gummadi teak)

Agroforestry system – Non-arable land

- Silvi-pastoral system: Subabul / Babul / Anjan + Cenchrus / Guinea
- Bush-farming: Lawsonia, Jatropha

AESR 7.3 Agency Area of E & W Godavari Districts

Agroforestry system – Arable land

- Boundary planting: Cashew nut, Coconut, Jackfruit, Casuarina, Bamboo, Pongamia, Jatropha, etc.
- Terracing for steep slopes: Grasses on risers
- Contour vegetative hedges for mild slopes, bigger size bunds (0.5 m^2 section) : Green cap with stylo + staggered planting of Gliricidia on either side of bund
- Agri-horti system: *Citrus* sp. + crops
  Mango + crops

Agroforestry system – Non-arable land

- Silvipastoral System: Cashew nut / Jackfruit + Stylo legume/ Guinea grass
- Tree farming: Casuarina, Bamboo, Pongamia, Jatropha

AESR 8.3 Chittoor

Agroforestry system – Arable land

- Agri-horticulture system: Citrus sp. + crops, Mango + crops
- Horti-pastoral system: Mango + stylo

Agroforestry system - Non-arable land

- Silvi-pastoral System: Tamarind + Stylo / Guinea

Casuarina

Eucalyptus

Subabul

Fig. 7. Raising of crops with fast growing tree species (Agri-silviculture)

AESR 12.2 High Lands of Visakhapatnam

Agroforestry system - Arable land

- Silver oak (*Grevillea robusta*) + Cocoa/ Coffee + Pepper

Agroforestry system – Non arable land

- Silvi-pastoral system: Teak (*Tectona grandis*) + Guinea (*Panicum maximum*)
- Tree farming: Silver oak, Jatropha, Pongamia

AESR 18.3 Coastal Areas (W. Godavari, Krishna, Guntur, Prakasam, Nellore)

Agroforestry system – Arable land

- Agri – silviculture - rainfed areas (**Fig. 7**)
  - First preference: Subabul + crops
  - Second preference: Casuarina + crops
  - Third preference: Eucalyptus + crops
- Agri-horticulture – irrigated areas
  - Coconut + Paddy
  - Coconut + Banana + Ginger

Agroforestry system - Non-arable land

- Tree farming: Subabul, Casuarina (**Fig. 8**)
- Pasture management: Guinea grass, Napier
- Horti – pastoral system: Cashew nut + Stylo in the early stage and Guinea grass or Cenchrus at later stage when canopy spreads

Subabul

Subabul fodder

Fig. 8: Tree farming for paper pulp and fodder production from coppice

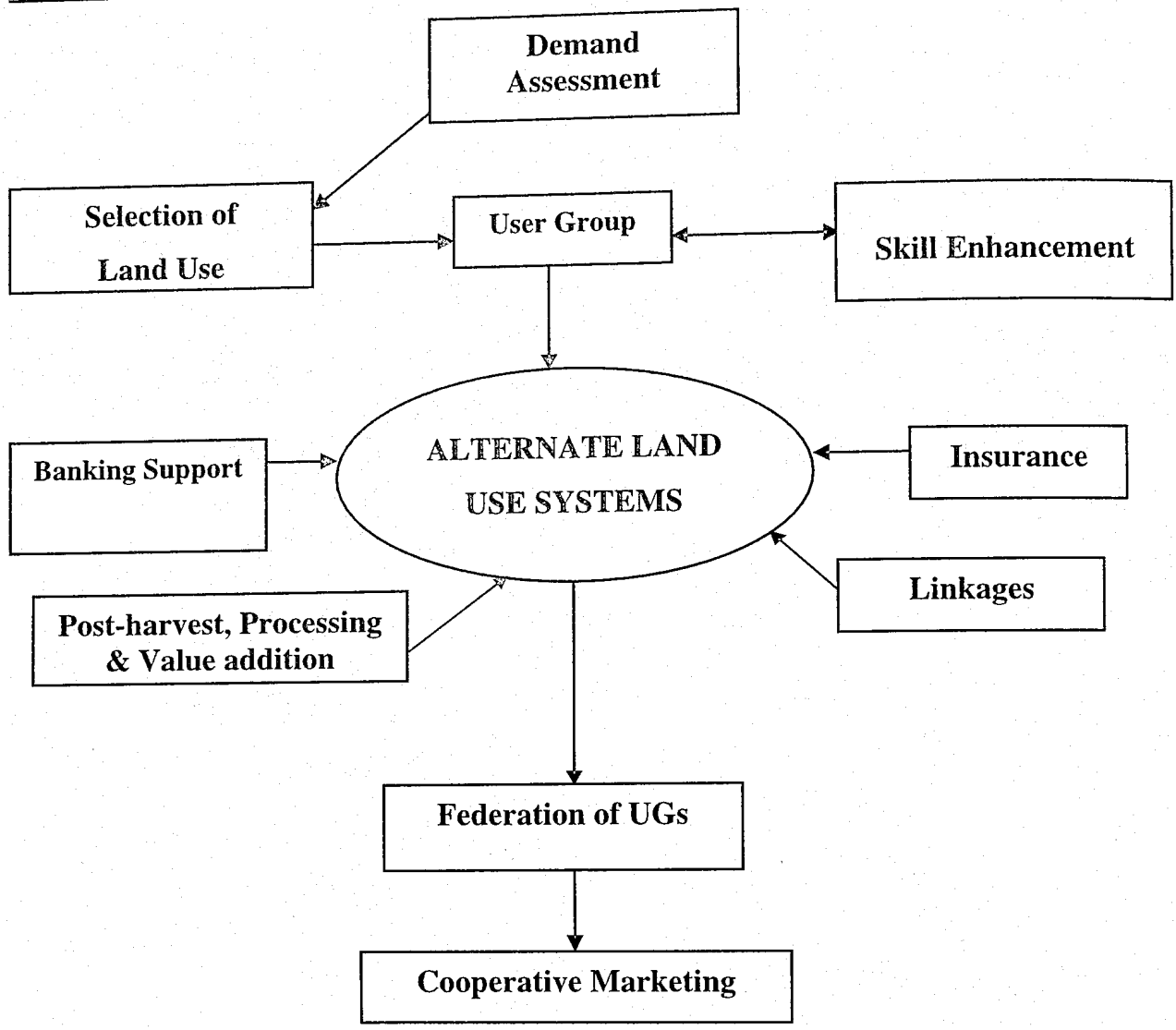


Fig. 9. Strategy for popularizing alternate land use systems (ALUs)

AESR 18.4 Srikakulam, Coastal Plains of E. Godavari

Agroforestry system - Arable land

- Agri-horticultural system: Coconut + crops
  Cashew nut + crops

Agroforestry system - Non-arable land

- Tree-farming: Casuarina, Teak, Bamboo, Jatropha
- Pasture Management: Grasses: Napier/ Guinea
  Legumes: Stylo / Desmanthus (hedge lucern)

The most important component of the strategy for popularizing ALUS is to assess the demand for the product in the market followed by formation of user groups (UGs), skills enhancement, banking support, insurance and linkages with other subsidiary enterprises and market (**Fig. 9**). Exposure visit of the potential farmers to successful on-farm agroforestry / alternate models and hands-on training on different aspects is desirable to convince them to adopt the new models. Since farmers of dryland areas are used to single cropping season, the protection of perennials from stray (and their own) cattle during the non-cropping season is crucial. CRIDA's experience of on-farm popularization of ALUS models shows that, social fencing facilitated by Self Help Groups (SHG / Sangha) is very effective.

References

Osman M., Korwar, G.R., and Katyal, J.C. 1997. Composite Land Use Systems. In Resource Management in Rainfed Drylands, MYRADA, Bangalore, India and International Institute of Rural Reconstruction (IIRR), Silang, Cavite, Phillipines, pp: 195-198.

Osman, M. 2003. Alternate Land Use Systems for Sustainable Production in Rainfed Areas. In. Agroforestry Potentials and Opportunities (eds. P.S. Pathak and Ram Nevaj), Agrobios (India) pp: 171-182.

Singh, R.P. and Osman, M. 1995. Alternate Land Use Systems for Drylands. In. Sustainable Development of Dryland Agriculture in India (ed. R.P. Singh), Scientific Publishers, Jodhpur, India, pp: 375-398.

Selective Mechanization of Rainfed Agriculture in Andhra Pradesh

V.M. Mayande and Aum Sharma

Abstract

Andhra Pradesh has 69 lakh hectare area under rainfed crops like groundnut, pulses, cotton, maize, pearlmillet etc. Telangana and Rayalaseema are major rainfed regions whereas costal Andhra Pradesh has only 20% rainfed area. In this region, animal power has reduced during last 13 years whereas tractor power has tremendous growth of 700 times during this period with overall increase in farm power was 18%. Present power density in rainfed areas is 1.16 kw/ha which is still much short of 3.75 kw/ha demand for timely operation. The power density and productivity are highly correlated within optimum range. There is a need to further enhance power density in Andhra Pradesh. Power mechanization and implement options are suggested for major rainfed crops. A case study of groundnut mechanization in Anantapur district clearly indicate that during 2003-2004 drought year, mechanization translated losses into profit by reducing operation cost in spite of low yield. Selective mechanization of rainfed agriculture is recommended in Andhra Pradesh.

Introduction

Andhra Pradesh with total geographical area of 274.4 lakh ha has about 110 lakh ha as net sown area. Out of this, about 59% area is rainfed, which comes to roughly 69 lakh ha. Major rainfed crops are Groundnut (22 lakh ha), Pulses (16 lakh ha), Cotton (10 lakh ha), Jowar (8.5 lakh ha), Maize (3.61 lakh ha) and Bajra (1.3 lakh ha). The area under different rainfed crops keeps on shifting from year to year depending upon the rainfall and other conditions.

Crops grown on rainfed lands produce low yields due to erratic rainfall and poor use efficiency of nutrients and moisture. Further, improper management of resources due to inadequate power and equipment is one of the major constraints of farmers in rainfed areas. Farmers continue to follow traditional methods using indigenous equipment by which it becomes difficult to complete timely operations with desired precision. This leads to inefficient utilization of natural resources (soil, water, nutrients) resulting in poor crop yields. Although the traditional field operations practiced by dryland farmers are time consuming, they persist because they are less sensitive to poor management than improved systems. In other words, the solution to growth in future production in drylands through improved technology depends on improved management of input resources by mechanization. Status and strategies for mechanization of rainfed agriculture in Andhra Pradesh are discussed in this paper.

Andhra Pradesh is divided in three distinct regions i.e. Coastal Andhra Pradesh, Rayalseema and Telengana. Region wise rainfed area is given in Table 1:

Table 1: Region wise rainfed area in Andhra Pradesh

Region	Net Sown Area (lakh ha)	Rainfed Area (lakh ha)
Coastal Andhra	39	17
Rayalseema	28	22
Telangana	40	26

Source: Reddy S.J.

Groundnut is a major rainfed crop grown on 22 lakh ha area in the state followed by Pulses, Cotton and Jowar. The region wise distribution of these crops is given in Table 2.

Table 2: Region wise distribution of major rainfed crops

Region	Area under major Rainfed Crops (lakh ha)		
	Groundnut	Cotton	Jowar
Coastal Andhra	2.6	3.0	0.3
Rayalseema	16.0	1.6	1.9
Telangana	3.4	6.0	6.8

It is seen from above data that major rainfed area is in Telangana and Rayalseema region and also major crops that need mechanization focus are groundnut in Rayalseema and cotton and jowar in Telengana. Major rainfed districts in Andhra Pradesh under groundnut, cotton and jowar are shown in Table 3.

Table 3: Major rainfed districts in Andhra Pradesh

Crop	Districts
Groundnut	Anantpur, Kurnool, Chittoor, Cuddapah, Mahboobnagar, Vijayanagaram, Warangal, Nalgonda, Karimnagar, Prakasham & Srikakulam
Cotton	Guntur, Kurnool & Adilabad
Jowar	Adilabad, Mahboobnagar, Medak & Kurnool

It is imperative to emphasize that crop based location specific selective mechanization is the best approach in rainfed areas. Large variations in crop and soil specific needs also change the requirement for mechanization. Therefore, micro level assessment of needs will be more realistic than macro level state planning for mechanization.

Agricultural implements used in different parts of the state are quite different based on traditional agricultural needs and farm power available. With large migration of human labour and reduction in draught animals, a necessity of mechanical power has become an essential component in planning mechanization strategy for improvement of rainfed agriculture. Status of farm power available in Andhra Pradesh (Table 4) shows that there

is drastic reduction in availability of human and animal power during last 14 years whereas there is significant jump of 700% increase in tractor population in the state during the same period. This indicates that there is a strong under-current in favour of tractorization taking place obviously to supplement the power deficit created by human and animal. This period also show about 18% increase in total farm power density because of tractorization.

Table 4: Changes of farm power density in Andhra Pradesh

Year	Farm Power Density (KW/ha)			
	Human	Animal	Tractor	Total
1990	0.23	0.56	0.10	0.90
2003	0.15	0.18	0.83	1.16
Increase (+) / Decrease (-), %	(-) 34	(-) 73	(+) 700	(+) 18

Source: CRIDA Annual Report, 2003-04

This indicates a strategic change required in approach of mechanization, which goes in favour of tractors and power operated machines. There is virtually a farm power crisis in Andhra Pradesh due to decrease in conventional power sources and relatively slow adoption of tractor and other mechanical devices. The total power density currently available from all sources (1.16 kW/ha) is much shorter than timeliness demand (3.75 kW/ha) for different operations in rainfed agriculture (Mayande and Katyal, 1996). Faster growth of tractors and power machinery needs to be emphasized for next 5 year period till the power density reaches minimum timeliness demand plateau. This is possible only through systematic approach in preparation of district wise and region wise mechanization policy frame work for next 5-10 years.

Adequate farm power available has direct co-relation with crop productivity (Table 5). Increasing power density in various districts has shown proportionate increase in the crop productivity index till the adequate value of power density (3.75 kW/ha). Mirzapur district has close to adequate farm power and gave a highest productivity. Subsequently it is seen that significant jump in power density of 8.27 kW/ha at Indore in Malwa region of Madhya Pradesh has not increased proportionately the crop productivity index. This is a clear-cut case of over-tractorization in the region due to several factors including easy credit availability.

Table 5: Farm power and crop productivity

District (State)	Power density (Kw/ha)	Crop Productivity Index
Raichur (Karnataka)	0.32	0.48
Visakhapatnam (A.P)	0.78	0.52
Rajkot(Gujrat)	1.10	0.65
Rewa (Madhya Pradesh)	2.40	0.89
Mirzapur (Uttar Pradesh)	3.49	0.98
Indore (Madhya Pradesh)	8.27	1.0

Source: Mayande et al. 1996

Since the excessive power density beyond adequacy level is undesirable, the co-relation between power density and crop productivity hold good within the limit of adequate farm power density of 3.75 kW/ha for timeliness of operation. Malwa region in Madhya Pradesh is a glaring example of wastage of excessive farm power and capital investment made by the farmers and financial agencies. Therefore, state should workout regional /district /mandal level saturation limits for tractor power and develop suitable norms for restricting flow of credit for tractor and power units beyond saturation limits fixed for the unit area.

Mechanization strategies for rainfed agriculture in Andhra Pradesh

Rainfed agriculture in Andhra Pradesh by and large continues to be poor in adoption of mechanization for different crops. Most traditional tools and equipments with some local improvements continue to be used for various operations. Andhra Pradesh is passing through a transition phase in improving the living standards of farmers in rainfed areas. Therefore, this is a right time to improve the comfort of farmers, overcome crisis of deficit farm labours and animals, reduce operation costs, improve productivity through timely and precision operations and increase the profitability of rainfed agriculture through large scale adoption of selective mechanization in the state.

Crop based approaches for development of mechanization strategy appears to be most appropriate with focused attention on a major dryland crops like groundnut, pulses, cotton, sorghum, maize etc (Table 6). Since groundnut is the major rainfed crop, a case study on groundnut mechanization in Rayalseema region will be most appropriate to discuss here.

Groundnut mechanization in Andhra Pradesh: A case study

Anantapur district is major rainfed groundnut producing district with 7.5 lakh ha area. Soils are light textured with low water holding capacity and annual rainfall of 400-500 mm. A joint study by CRIDA and ANGRAU scientists in Anantapur district indicated that reduction in cost of cultivation is most crucial factor in increasing profitability of groundnut crop. The cost of production of groundnut crop is presently Rs. 8750/- per ha out of which Rs. 3200 is a seed cost. This is a very high cost. Presently indigenous equipment are used. Sowing period available is only 3-4 days during kharif due to typical rainfall behaviour, hence with indigenous tools, it is not possible to complete sowing on all the area during this period.

Table 6: Suggested mechanization for major rainfed crops in Andhra Pradesh

Major crops (area in lakh ha)	Region (% area)	Indigenous equipments	Improved power implements for adoption
Groundnut (22)	Rayalseema (72) Telengana(16) Coastal Andhra (12)	Local drill, Rayal gorru, Asha guntaka, Sickle	Rotavator, Inclined plate planter, Herbicides sprayer, Combination weeder, digger shaker, stripper, thresher, sheller
Pulses (16)	All regions	Country plough, Manual drill, Guntaka, Knapsack sprayer, Sickle	Rotavator, Disc harrow, Inclined plate planter, Combination weeder, Pulse thresher, Cleaner/grader and Mini dal mill
Cotton (10)	Telengana (54) Coastal Andhra (30) Rayalseema (16)	Country plough, M.B. plough, Guntaka, drilling/ dibbling,Knapsack/ power sprayer, Sickle	Rotavator, Disc harrow, Inclined plate planter, Combination weeder, Tractor mounted boom sprayer, Cotton picker and Cotton stock puller
Sorghum (9)	Telengana (80) Rayalseema (20)	Country plough, Manual drill, Guntaka, Knapsack sprayer, Power thresher, Sickle	Rotavator, Inclined plate planter, Combination weeder, Power sprayers and power threshers
Maize (4)	All regions	Country plough, Local drill, Local guntaka, Sickle	Rotavator, Disc harrow, Inclined plate planter, Combination weeder, Maize sheller
Other crops Sunflower, Castor, Pearlmillet etc	All regions	Country plough, Local drill, Local guntaka, Sickle	Rotavator, Disc harrow, Inclined plate planter, Combination weeder, Sunflower thresher and Multicrop thresher
Rainfed horticulture	All regions	Country plough, Local guntaka, Manual sprayers	Rotavator, Disc harrow, Tree hole digger, Power basin maker, Orchard sprayer, Fruit harvestor, Fruit and vegetable preservator.

Source: Mayande V.M. (2003)

A mechanization package was introduced in the Venkatapuram village in Anantpur district where a nine tyne cultivator for tillage, CRIDA 9-row inclined plate planter for seeding cum fertilizer application, combination weeder with iron wheels for interculture, digger shaker for harvesting, power thresher and shellers were put into use for studying the feasibility of mechanization. Complete mechanization package and its economic advantage are given in Table 7.

Table 7: **Techno-economic performance of groundnut mechanization in Venkatapuram village of Anantapur district (2003-04)**

Implements/ Inputs	Initial Cost (Rs.)	Cost of operation (Rs/ha)		Savings as compared to local tools (%)
		Indigenous tools	Improved tools	
Operation				
Cultivator (TD)	9500	750	600	06
CRIDA 9-Row Planter	29500	600	200	67
Weeding attachment with Iron Wheel (TD)	10000	1650	920	44
Boom Sprayer (TD)	11000	500	200	60
Digger Shaker (TD)	22000	1500	975	35
Thresher (power)	21000	700	200	71
Sheller (power)	14000	1000	200	80
Sub total	**1,17,000**	**6700**	**3295**	**51**
Inputs				
Seed cost (Rs/ha)	-	3000	2100	30
Fertilizer cost (Rs/ha)	-	500	300	40
Total cost (Rs/ha)	-	**10,200**	**5695**	**44**
Pod Yield (kg/ha)	-	330	390	18
Receipts (Rs/ha)*	-	6600	7800	**18**
(-) Deficit (loss)				
(+) Surplus (profit)	-	(-) 3600	(+) 2105	-

** Sale price of pod is assumed as Rs.20/kg.*
Source: John Wesley and T. Yellamanda Reddy (2003)

Assuming time available for sowing is about 4 days, the command area for mechanization systems is about 15 ha/year. Even considering this minimum use of mechanization a net profit on 15 ha area will be Rs. 31,575/-. Hence, the payback period of investment made in mechanization is about 3-4 years. If a farmer owning complete mechanization package offers use of implements by others on custom hiring basis, then the payback period can be brought down to one season.

The results obtained from Anantapur district clearly show a significant savings (51%) in cost of cultivation and overall savings of 44% were achieved. Further there was 18% higher yield of groundnut as compared to indigenous method, which contribute additional receipts of Rs. 1200/ha. This case study very clearly brings out that overall cost savings and higher yield receipts together turn the table in favour of mechanization by converting huge losses into profit. This lead us to conclude that "Mechanization alone can improve the profitability and sustainability of rainfed agriculture in Andhra Pradesh".

Mechanization strategies and policy issues for rainfed agriculture in Andhra Pradesh

- Identification for suitable of farm machinery for adoption on selective basis for major agro-eco zones in three regions of the state is pre-requisite for planning mechanization strategies in rainfed agriculture.
- Promotion of tractor is an important issue to improve power density in rainfed agriculture.
- Development of norms to restrict over-tractorization by fixing a saturation limit for each mandal/district in collaboration with financial agencies is essential to avoid wastage of power, capital and resources.
- Expanding the use of costly agricultural machines through custom hiring to small farmers at reasonable cost will improve economics of use.
- Farm Machinery Custom Hiring Centres (FMCHC) should be promoted in the state on the line of one opened by Hon'ble Chief Minister of Andhra Pradesh at Nallapureddypalli, Pulivendala Mandal in Cuddapah district on August 16, 2004 with the conceptual support from CRIDA and financial support from NABARD and Rayalseema Grameena Bank.
- Training centres for farmers and entrepreneurs in operation, repair and maintenance of equipment, running an agri-business of FMCHC must be opened at least one in each district.
- Promotion of local implement industry and service centres are required for each mandal to improve farmers accessibility to mechanization.
- Appropriate subsidization and initial credit availability at reasonable interest rate for purchase of tractors and implements is a key factor in promotion of mechanization in rainfed areas.
- Task force on mechanization of rainfed agriculture should be created to oversee the process of transformation of rainfed agriculture into profit making enterprise through farm mechanization.

Conclusions

1. Loss making rainfed agriculture in Andhra Pradesh can be translated into a profit making sustainable agriculture through adoption of selective mechanization.
2. Task force on mechanization of rainfed agriculture will boost the prospectus of resource poor agriculture in the state.
3. Mechanization of rainfed agriculture is a key to bring about agricultural revolution in Andhra Pradesh.

References

Anonymous, 2003. CRIDA Annual Report 2003-04, Central Research Institute for Dryland Agriculture, Santoshnagar, Hyderabad- 59 pp: 49-50.

John Wesley and T. Yellamanda Reddy 2003. Mechanization of Groundnut Crop in Anantpur District. Report of NATP-Mission Mode Project, Anantapur Centre, Acharya N.G. Ranga Agricultural University, Agricultural Research System, Anantapur.

Mayande, V.M. 2003. Use of Improved Tools for Mechanization of Dryland Agriculture, Report on NATP-Mission Mode Project, Central Research Institute for Dryland Agriculture, Santoshnagar, Hyderabad –500 059.

Mayande, V.M., and Katyal, J.C. 1996. Farm Power Deficit: A major factor Inhibiting Dryland Agriculture. Proceeding of the International Agricultural Engineering Conference organized by Asian Association of Agricultural Engineers at Pune, India December 9-12, 1996, pp:9-32.

Mayande, V.M and Katyal, J.C. 1996. Low Cost Improved Seeding Implements for Rainfed Agriculture. Technical Bulleting No. 3, Central Research Institute for Dryland Agriculture, Santoshnagar, Hyderabad –500 059, A.P. India.

Reddy, S.J. 2000. Andhra Pradesh Agricultural Scenario of Last Four Decades, Published by Jeevan Charitable Trust, Plot No.6, ICRISAT Colony, Phase-I, Secunderabad – 500009, A.P., India.

Annexure-I

Agricultural Implements and Machinery of some Manufacturers in Andhra Pradesh

1. M/s.Manager (Implements),
   AP Agro Industries Development
   Corporation, Agro Bhavan,
   10-2-3, A.C.Guards,
   Hyderabad – 500 004

2. M/s.Viswakarma Industries
   Plot No.5, Road No.6,
   Industrial Estate, Kattedan,
   Hyderabad – 500 077

3. M/s.Viswakarma Engineering
   Company
   Plot No.138, Road No.26,
   Industrial Estate, Kattedan,
   Hyderabad – 500 077

4. M/s.Aruna Industries
   118 – B, Industrial Estate,
   Kattedan, Hyderabad – 500 077

5. M/s.Karshak Industries,
   No.18-3014, Chatrinaka,
   Laldarwaja, Hyderabad – 500 253

6. M/s.Karshak & Sons,
   Shop No.42, All Karim
   Trade Centre, M.G.Road,
   Secunderabad – 500 003

7. M/s.Mekins Agro Products Pvt.Ltd
   Plot No.30, IDA, Gandhinagar,
   Balanagar, Hyderabad – 500 037

8. M/s.Incon Engineers Limited,
   B-6/3, IDA Uppal,
   Hyderabad – 500 039

9. M/s.Boys Town
   Jahanuma
   (Only Cono weeder & Marker)
   Hyderabad

10. M/s.Riteset Industries
    Gudivada, Krishna District

11. M/s. Ganesh Agro Machinery
    Enterprises,
    Tadepallygudem
    West Godavari district

12. M/s. Navya Agro Industries
    1-3/12 Pammarru Road,
    Near Railay Gate,
    Gudivada – 521301,
    Krishna District

13. M/s.Navya Industries
    Plot A3 Industrail Estate
    Gudivada- 521301,
    Krishna District

14. M/s.Standard Trailer
    Bus Stand Road,
    Gudivada- 521301,
    Krishna District

15. M/s.Sri Srinivasa Auto
    Engg. works, Flat No.C2, C3,
    Gudivada- 521301,
    Krishna District

16. M/s.Modern ARC Welding Works
    16-256-7/1, S.N.Puram
    Gudivada- 521301,
    Krishna District

17. M/s.Mahaboob Auto Agency
    Near Sanjeeva Nagar
    Nandyal, Kurnool district

18. M/s.Ravi Engineering Works
    R.S Road, Nandyal,
    Kurnool District

19. M/s.Bhasker Engineering Works
    R.S Road, 25432,
    Nandyal, Kurnool District

20. M/s.Kumar Engineering Works
Banaganpally Road,
Opp. Petrol Bunk,
Koilkuntla, Kurnool

21. M/s.Mahboob General Engg.
Work, SRBC Road, Near Bus
Stand, Nandyal, Kurnool District

22. M/s.Mahaboob Engg. Work
NH-6, Nandyal Road,
Tadipatri, Kurnool District

23. M/s.Rasool Engg. Work
Guntakal, Ananthapur

24. Indira General Engg. Workshop
Tapovanam, Bypass Road,
Ananthapur

25. M/s.Balaji Engg. Work
Near RTC Bus Stand,
Ananthapur

26. M/s.Jeelani Industries
Atmakur, Ananthapur

27. M/s.Abdulla Trally & Engg Work
NH-6, Nandyal Road,
Tadipatri, Ananthapur

28. M/s.Bhart Trally Works &
alternation,
Work, NH-6, Compound,
Nandyal Road, Tadipatri

29. M/s.Vali Chand Trally Works
NH-6, Nandyal Works,
Tadipatri, Ananthapur

30. M/s.Eslam Automobile & Engg
Works, Nandyal Road,
Tadipatri, Ananthapur

31. M/s.Mahaboob Welding Workshop
& Industries, Rayanpally,
Nerametta,
Urvakonda, Ananthapur

32. M/s.Bhaskar Engg. Works
R.S. Road, 25/432,
Sanjeeva nagar, Nandyal

33. M/s.Kumar Engineering Works
Opp. Petrol Bunk,
Koilkuntla, Kurnool

34. M/s.Srinivasa Engg. Works
Ballary Road, Kurnool

35. M/s.Esdeoar Enterprises
9/21, P.N. Road,
Chandragiri – 511001.

36. M/s.Jyothi Industries
Chittoor, Palamner Road,
Chittoor.

37. M/s. Slesser & Tom Electronics
Pvt. Ltd., 205, Ganga Vihar,
Chaitanyapuri,
Dilsukhnagar, Hyderabad.

38. M/s. Nirmala Industries
Plot No. 61, IIIrd Phase,
Autonagar, Guntur – 522001.

39. M/s. Paru Engineers Pvt. Ltd.
plot No. 161/B, IDA Phase II,
Cherlapally,
Hyderabad – 500 051.

40. M/s. Sri Lakshmi Narsimha
Swamy Industries, Korrapadu
Village, Tadipatri Road, B.K.
Samudram Mandal,
Anantpur District-515001.

Low External Input Sustainable Agriculture (LEISA) in the Context of Andhra Pradesh

B. Venkateswarlu and Y.G. Prasad

Abstract

Sustainable agriculture involves the integrated use of a variety of pest, nutrient, soil and water management technologies and practices. These are usually combined on farms to give practices tuned to the local biophysical and socio-economic conditions of individual farmers. Most represent low-external input options. Integrated nutrient and pest management are undoubtedly the most important components of LEISA. Various alternate options available for farmers of Andhra Pradesh including the constraints in the adoption of IPM and INM are summarized.

Introduction

During the past 50 years, agricultural development policies have been remarkably successful at emphasizing external inputs as the means to increase food production. This resulted in high growth in consumption of pesticides, inorganic fertilizers, animal feedstuffs, tractors and other machinery. These external inputs have, however, substituted natural control processes and resources, rendering them more vulnerable. Pesticides have replaced biological, cultural and mechanical methods of controlling pests, weeds and diseases; inorganic fertilizers have substituted for livestock manures, composts and nitrogen-fixing crops; information for management decisions comes from input suppliers, researchers and extensionists rather than from local sources; and fossil fuels have substituted for locally generated energy sources. The specialization of agricultural production and associated decline of the mixed farm has also contributed to this situation (Pretty, 1996). What were once valued internal resources have now become waste products. The basic challenge for sustainable agriculture is to make better use of these internal resources. This can be done by minimizing the external inputs used, by regenerating internal resources more effectively or by combinations of both. Low external inputs sustainable agriculture (LEISA) has come under focus against this background.

The most common characterization of sustainable agriculture as a return to some form of low technology, 'backward' or 'traditional' agricultural practices is a misconception. It does not imply rejection of conventional practices, but an incorporation of recent innovations either by the scientist or farmer or both. Sustainable agriculture is more a process of learning rather than viewed as a simple model or package to be imposed as sustainability as a concept is open to change and adaptation with time and place. It is common for sustainable agriculture farmers to use recently developed equipment and technology, complex rotation patterns, the latest innovations in reducing input

strategies, and detailed ecological knowledge for pest and predator management. The most accepted defination as defined by FAO (1989) is:

Sustainable agriculture involves the successful management of resources for agriculture to satisfy changing human needs while maintaining or enhancing the quality of the environment and conserving natural resources.

Sustainable agriculture involves the integrated use of a variety of pest, nutrient, soil and water management technologies and practices. These are usually combined on farms to give practices tuned to the local biophysical and socio-economic conditions of individual farmers. Most represent low-external input options. Most such farms are diverse rather than specialized enterprises. Natural processes are favored over external inputs and by-products or wastes from one component of the farm become inputs to another. In this way, farms remain productive as well as reduce the impact on the environment.

This article attempts to list some of the proven and promising technologies for practicing LEISA or at least reduce the dependence on off farm inputs and decrease the cost of cultivation in Andhra Pradesh.

LEISA is defined as

- LEISA is about optimal use of local resources and natural processes, if necessary safe and efficient use of external inputs
- LEISA is about empowering farmers and communities to improve their skills and knowledge
- LEISA is about adapting agriculture to changing environment
- LEISA is a ***concept*** and ***approach*** but not a ***technology***

The cardinal principles of LEISA are

- Conserving soil and water and protection of catchments
- Rehabilitation of waste lands
- Efficient use of rain water
- Mulching, cover cropping, agro forestry with mixed species
- Feeding the soil rather than plant
- Relying on natural nutrient cycling
- Encouraging natural ecosystem and maintaining equilibrium between pests and natural enemies
- Crop –animal integration

Integrated nutrient and pest management are undoubtedly the most important components of LEISA. Various alternate options available for farmers of Andhra Pradesh including the constraints in the adoption of IPM and INM are summarized below.

Integrated pest management

Although pests, weeds and pathogens are thought to destroy some 10-40% of the world's gross agricultural production, pesticides are not the perfect answer to controlling pests and pathogens. Many of the newer pesticides are more selective, less damaging to natural enemies and less persistent in the environment. One consequence of greater regulation is the development of a number of chemicals that are highly targeted in their effect. But the problem is that many of these are more expensive to farmers than broad-spectrum products. What farmers need is a wide range of possible technologies that can make use of the agro-ecological pressures of predators, competition and parasitism to control pests more effectively than pesticides alone. Most pests species are naturally regulated by a variety of ecological processes and if these regulations work in harmony, the damage caused is relatively insignificant in most cases.

Integrated pest management (IPM) is the integrated use of a range of pest (insect, weed or disease) control strategies in a way that not only reduces pest populations to satisfactory levels but is sustainable and non-polluting. Inevitably IPM is a more complex process than, say, relying on regular calendar spraying of pesticides. It requires a level of analytical skill and basic training in crop monitoring and ecological principles. In recent years IPM has become widely adopted in many countries focusing mainly on better scouting for pests, rotation, cultural practices and selective use of pesticides.

Resistant varieties: A major unit of defense is to have crops that are resistant to pests and diseases. For low external input farmers, resistant crops represent an important alternative to pesticides. A list of important resistant varieties of major rainfed crops grown in Andhra Pradesh is given below.

S.No.	Location	Crop	Resistance to Pest / disease	Cultivar
1	Anantapur Kurnool Cuddapah	Groundnut	Bud necrosis	Vemana, K 134, TAG 24, Tirupathi 3, ICGS 11, ICGS 86325, ICGS 10,
			Leaf spots	Vemana, Kadiri 3, Naveen, K 134, ICGS 10
			Kalahasty malady	Tirupathi 2
			Multiple resistance to pests and diseases	ICGV 86325
2	Anantapur	Sunflower	Helicoverpa	KBSH-6, BRS-3 (line)
3	Mahabubnagar & Nalgonda	Castor	*Wilt* *Jassid* *Whitefly* *Capsule borer*	GCH-4, 48-1, DCS-9 Tripple bloom cultivars Zero bloom cultivars JI-144

S.No.	Location	Crop	Resistance to Pest / disease	Cultivar
4	Mahabubnagar, Nalgonda Adilabad Kurnool & Khammam	Sorghum	*Shootfly* *Stem borer* *Midge* *Grain mold* *Charcoal rot*	ICSV 705 and 717 IS – 2205 and IS – 2376 ICSV 197, ICSV 743, ICSV 745 and ICSV 88013 CSH-16 & CSV-15 M 35-1 & CRR 12
5	Mahabubnagar Rangareddy Warangal Khammam Nalgonda	Redgram	Helicoverpa *pod borer*	ICPL 332 (Abhaya)
6	Warangal Adilabad	Cotton	*Bollworms*	MECH 12 (Bt cotton) RCH-2 (Bt cotton)

(Anonymous, 2004)

IPM modules for important rainfed crops

Castor

- Use resistant variety in endemic areas for wilt (GCH-4, DCS-9, 48-1)
- Seed treatment with *Trichoderma viridae* @ 10 g /kg seed or carbendazim 1 g / kg seed
- Two to three releases of *Trichogramma chilonis* egg parasitoid @ 50000 / ha coinciding with semilooper and capsule borer incidence
- Adopt community approach for management of RHC with light traps/bon fires and vegetative barriers (cucumber, Ipomea twigs)
- Prohylactic sprays with local extracts of neem seed 5% starting 25 days after sowing
- For managing semilooper, sprays of locally produced baculovirus (200 LE/ac) or Bt (150 g/ac) could be used either alone or in combination. This practice is ecofriendly and conserves the good natural regulation of field populations of semilooper; In case of heavy attack apply Quinalphos @ 2 ml /l
- Erect bird perches @ 20 /ha between 45 and 80 days after sowing
- Collecting and destroying leaves infested by gregarious mass of larvae can successfully manage *Spodoptera* infestation. Chemical sprays are can be avoided by this method
- In case continuous wet weather conditions coincide with capsule development stage in September/October, apply carbendazim @ 0.1% to save the crop from Botrytis grey rot disease

(Vimaladevi & Prasad 1999; Vimala devi et al *1996; Prabhakar* et al *2003; Chattopadhyay & Varaprasad, 2001)*

Groundnut

- The major pests/diseases affecting groundnut production in AP are: leafminer, *Spodoptera*, white grub, red hairy caterpillar, *Helicoverpa*, aphids, jassid, bud necrosis disease, leaf spots and peanut stem necrosis. Strategies to minimize pest damage are:
- Summer ploughing
- Use of resistant varieties
- Adopting required seed rate (40 kg/acre) for closer spacing. Sowing should be done at optimum soil moisture level to maintain adequate plant stand (33 plants /m2)
- Seed treatment with chloropyriphos @ 6 ml/l, carbendazim @ 1 g or mancozeb @ 3g / kg seed
- Intercropping groundnut with pearl millet or sorghum or castor or redgram @ 7:1
- Sowing four rows of border crop with pearl millet or sorghum
- Timely weeding to remove alternate hosts (Parthenium, Azeratum, Acanthospermum, Achiranthus and Commelina) for peanut stem necrosis
- Community approach with light traps for management of red hairy caterpillar
- Monitoring of *Spodoptera* and *Helicoverpa* through pheromone traps (1 per hectare)
- For the management of Thrips (vector for viral diseases) apply Imidacloprid 0.5 ml/l
- In case of heavy attack by *Spodoptera* within 50 days after sowing, adopt poison baiting (rice bran 5 Kg + 500 g jaggery + 400-500 ml quinalphos)
- If necessary spray Mancozeb (0.3%) and carbendazim (0.1%) for control of leaf spots at 60-70 days after sowing

(Jayanthi et al, *2000)*

Redgram

- Summer ploughing
- Follow crop rotation
- Avoid staggered sowing
- Cultivate tolerant / recouping varieties such as ICPL 332, ICPL 84060, LRG 30 and MRG 66
- Grow intercrops (kharif: sorghum, soybean, gingelly, green gram, black gram, bajra)
- Grow short duration varieties in Telangana
- Monitor pod borer with pheromone traps
- Apply neem seed extract 5% at 10-25% flowering to reduce oviposition by pod borer, apply NPV @ 500 LE/Ha (locally produced HaNPV) at 25%-50% flowering targeting

early instar larvae; If necessary apply insecticide at pod development stage to control the pod borer complex.

- Ensure thorough coverage of plants while spraying (>700 liters per hectare)
- Dislodge and collect larvae by shaking the plants at pod development stage (2-3 times at intervals)

(Das et al, *2000; Prasad & Singh, 1992; Rao & Reddy, 2003)*

Cotton

The major pests on cotton in A.P. are bollworms, jassids and whiteflies. Thrips and spider mites are sporadic in nature. The following options are available under IPM basket for managing insect pests on cotton:

- Intercropping with short duration legumes, sunflower, short to medium duration pigeonpea, marigold, maize or sorghum.
- Border crops like sorghum or maize, okra, sesamum, short duration pigeonpea and castor.
- Own seed to be acid delimited.
- Seed treatment with Cruiser or Gaucho.
- Pheromone traps for monitoring *Helicoverpa*, *Spodoptera* and Pink bollworm.
- Installation of bird perches more than 10 / acre.

Early season pest management (up to 50 days):

- None unless absolutely necessary.

Mid-season pest management (40 – 80 days):

- Neem products or other proven natural interventions.
- Actra, Polo, Confidor for whitefly and jassid but only if heavy infestation.
- Avoid strong generics. Spinosad, Karate or Curacron for early *Helicoverpa* attack but only if needed.

End of season pest management:

- Ignore sucking pests unless well over the threshold.
- For *Helicoverpa* hand picking of larvae and nipping terminal shoots.
- Apply ovicide (Curacron) 3rd day after heavy egg lay – on no more than three occasions.
- If there are 'escapes' apply proprietary OP/SP cocktail, such as Polytrin C or Spark.
- As a final resort apply a synthetic pyrethroid of guaranteed quality.
- For Pink bollworm:

- Monitor with PBW pheromone trap.
- In PBW prone areas: Sow okra (bhendi) around field. When okra pods with PBW larvae are found destroy them by hand.
- If cotton crop has passed the first flower stage apply Karate if pheromone trap catches are increasing. Repeat in 25 days if less than 14 days before final harvest.
- Destroy (burn in field) all crop trash immediately after harvest.
- Do not extend the season by ratooning.
- Post-harvest: Burn the crop in PW-prone areas; Plough in all crop trash in non-PBW areas.

(Anonymous, 2003)

Integrated nutrient management

Extensive work has been done all over the country on the benefits of INM in sustaining soil fertility over chemical fertilizers alone. Some of the key strategies augmenting nutrient supply through natural methods are:

1. Recycling farm urban wastes (vermicomposting, phospho composting and mechanical (aerobic) composting)
2. Green manuring and green leaf manuring.
3. Restoring the importance of legumes as a part of cropping systems
4. Use of bio fertilizers and bioorganic manures.
5. Cover cropping with legumes and incorporation

In recent years, vermicomposting as a practice has gained considerable importance all over the state and there is good scope to further improve its production and availability. However, more and more emphasis on technology development is needed where dung is not available and places where water is a shortage and opportunities for solubilising insoluble forms of mineral like rock phosphate. Although the technology of phospo composting has been there for several years, it has not picked up due to the poor crop response due to N deficiency. Nitrogen enriched phospho compost can now be produced which can give better crop response. Similarly, a renewed emphasis is needed on production and use of quality bio fertilizers (Venkateswarlu and Wani, 1995). Particularly in case of paddy, the potential of Azolla and Blue Green Algae has not been exploited as in case of Veitnam and China.

Green leaf manuring has also proved to be very sustainable source of nutrients both in irrigated and rainfed areas (Subba Reddy *et al.*, 1991). In view of the shortage of water for traditional green manuring in irrigated areas, we can promote species like Glyricidia, which can come up successfully in rainfed areas and not grazed by cattle. A plantation of Glyricidia on bunds around one hectare can yield 300, 720, 1500, 5000 kg fresh leaf biomass during first, second, third and fifth years after planting respectively. One tonne of leaf material can contribute 10kg N/ha besides acting as a mulch for

moisture conservation. Cover cropping is another possibility in areas where second crop can be taken during post rainy season. Horse gram is an ideal choice for raising as a post rainy crop and incorporation in many areas in Andhra Pradesh.

Organic farming: With growth rates of 5-10% every year for organically grown food in many developed countries, we need to identify crops and areas in the state where successful organic farming can be done by groups of farmers and market it collectively (Venkateswarlu and Srinivasa Rao, 2003). There are ample opportunities for promoting neem products in Andhra Pradesh for creating employment opportunities and also meet the IPM/INM requirements.

Constraints

Due to the stagnant / falling growth rates in all major crops in the state, there is no option but to move towards sustainable agriculture with focus on enhancing input use efficiency and greater reliance on recycled inputs. However the major bottleneck in all these options is the high labour dependency and sometimes higher water requirement. Therefore, ways and means have to be found for mechanization of some of these practices in order to make them more feasible and viable. Suitable policy option also needs to be framed to encourage these approaches in the state in the interest of long term sustainability of dryland farming.

References

Anonymous. 2003. Proceedings of the fifth roundtable on cotton IPM. APCOT, Barkatpura, Hyderabad, pp: 28-30.

Anonymous. 2004. Andhra Pradesh – Crop strategies and contingency plans 2004-05. Acharya N.G. Ranga Agricultural University, Rajendranagar, Hyderabad, 1-82

Chattopadhyay,C. and Varaprasad, K.S. 2001 Potential of bioagents in castor wilt management. Indian Journal of Plant Protection. 2001, 29: 1-2, 1-7

Das, N.D., Sankar, G.R.M., Biswas,K.K. 2000. Field evaluation of botanical and biopesticides against pod borer, *Helicoverpa armigera* on pigeonpea. Annals of Plant Protection Sciences. 8 (2), 233-234.

Jayanthi, M., Singh, KM. Singh, R.N. 2000. Insecticidal schedule against groundnut pests. Indian Journal of Entomology, 62 (2):109-126.

Prabhakar, M., Rao,M.S., Prasad, Y.G. 2003. Evaluation of bio-intensive integrated pest management modules against castor semilooper, *Achaea janata* Linn. Indian Journal of Plant Protection. 31(1): 56-58.

Prasad, Y.G. and Singh, Y. 1992. Chemical control of insect pests of pigeonpea, *Cajanus cajan* (L.) Mill sp. Indian J. Ent. 54 (3), 312-320.

Pretty, J.N. 1996. Regenerating agriculture – policies and practice for sustaining and self-reliance. Vikas Publishing House, New Delhi, 1-320.

Rao, M.S., Reddy, K.D. 2003. IPM of pod borers in long duration pigeonpea. Annals of Plant Protection Sciences, 11 (1) 26-30.

Subba Reddy, G., Venkateswarlu, B. and Vittal, K.P.R. 1991. Green leaf manuring as an alternative nitrogen for castor bean on marginal soils of India. American J. Alternative Agriculture. Vol. 6(3), 132-138.

Venkateswarlu, B. and Srinivasa Rao, Ch. 2003. Limitations in adoption of Organic Farming. In: Proceedings of National Seminar on Organic Farming; Present status and future prospects held on March 19, 2003 at MAU, Parbhani (MS), pp:101-105.

Venkateswarlu, B. and Wani, S.P. 1999. Biofertilisers: An important component of Integrated Plant Nutrient Supply (IPNS) in drylands. Fifty Years of Dryland Agricultural Research in India (Ed. H. P. Singh, Y.S. Ramakrishna, K.L. Sharma and B. Venkateswarlu), CRIDA, Hyderabad, pp: 379-394.

Vimala Devi, P.S. and Prasad, Y.G. 1999. Efficacy of *Bacillus thuringiensis* against castor semilooper *Achaea janata* Linn. (Lepidoptera: Noctuidae). J. Oilseeds Res, 16 (2): 299-302.

Vimala Devi, P.S., Prasad, Y.G. and Rajeswari, B. 1996. Effect of *Bacillus thuringiensis* var. *kurstaki* and neem on castor defoliators-*Achaea janata* (Linnaeus) and *Spodoptera litura* (Fabricius). J. Biol. Control, (10): 67-71.

On going Efforts on NRM Related Livelihood Issues

K.V. Subrahmanyam & Y.S. Ramakrishna

Abstract

"Enabling Rural Poor for Better Livelihoods through Improved Natural Resource Management in SAT India" funded by the DFID – NRSP, UK is the on-going project implemented by CRIDA, Hyderabad in collaboration with two SAUs ANGRAU, UAS and ICRISAT and NGO, BIRD-K since 2002. The purpose of this project is establishing an enabling environment and appropriate social mechanism that enables poor people who are largely dependent on natural resources base to improve their livelihoods. The project is implementing both social and technological interventions for achieving its goal.

The programme is functioning in 2-3 cluster of selected villages in three districts Viz., Anantapur and Mahabubnagar in Andhra Pradesh and Tumkur in Karnataka. The rain water management through farm ponds, trench-cum-bunds, diversion channels and check dams were found to be very useful and accepted by people. Awareness creation and capacity building through participatory ground water measurement, formation of salaha samithis, SHG's, training and exposure visits helped in changing the mind set of people. Enterprise diversification through agro-forestry, livestock, training of youth in AI, nursery for women, custom hiring centres for agril. Implements and development of CPRs were found to be very effective for improving the livelihoods of landless.

The project learnings revealed that people contribution is more important for sustainability of the project interventions and these should be designed based on local resources availability, investment choices, access to natural resource base in addition to human capabilities.

Introduction

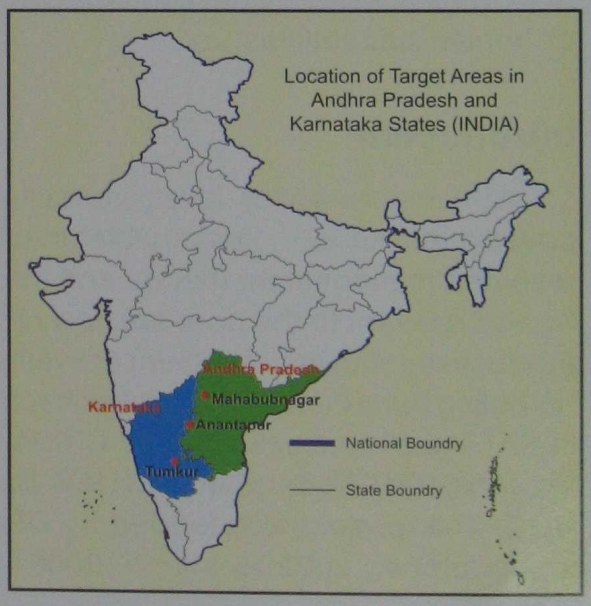
At a macro-policy level, agricultural growth continues to be viewed as a key to poverty alleviation. Sustainable mechanisms and institutions for improving natural resource management (NRM), and the associated service provision, that are accessible by and relevant to the poor are now recognized as integral to linking greater agricultural productivity with improvement of livelihoods of the poor. In this context, a project entitled "Enabling Rural Poor for Better Livelihoods Through Improved Natural Resource Management in SAT India" was executed by CRIDA in collaboration with two State Agril. Universities Viz., ANGRAU, Hyderabad and UAS, Bangalore and also with ICRISAT and BAIF a leading NGO. This project was funded by DFID-NRSP, UK and is for a duration of 30 months from October, 2002 to March, 2005. (Ramakrishna & Subrahmanyam, 2004).

Project aims: The project aims at improving the livelihoods of rural poor who are largely dependent on natural resources. This is being achieved through integrated management of natural resources and also by ensuring better access to and control of specific natural resources by the poor. The project envisages adoption of integrated nutrient management, soil and water conservation, improved cropping systems, implements and tools/techniques, by the poor farmers. Broadly, the project aims to answer the central question "whether and how can NRM lead to better livelihood opportunities for the poor?" In answering this key question, the project is trying to document the various processes that enable the rural poor towards improved livelihoods through better management of natural resources.

Objectives of the project: The main objectives are

- Improving the capacity and strengthen the rural institutions to provide the poor better access to specified natural resources.
- Conserving and sustainable use of NR (soil, water, vegetation and organic residues) in CPR's and PPR's with focus on specific target groups.
- Introduction of diversified farming systems/enterprises identified and promoted for improved livelihoods of various target groups through the use of appropriate participatory methods.
- Promotion of improved tools, implements and techniques for reducing drudgery and increasing outputs.
- Understanding the enabling processes for both rural community motivation and service provision, which are inclusive of various target groups of the poor and to communicate to the policy makers.

Project sites: The project is implemented in four villages Viz. Dharmapur, Chowderpally, Zamistpur and Bukkalonpally in Mahabubnagar dist (AP) three villages Pampanur, Pampanur Thanda and Kothapalli in Anantapur dist (AP) and in two villages Shankanhalli and Dodennagiri in Tumkur districts (Karnataka). The three districts have contrasting characteristics in terms of rainfall (semi arid in Mahabubnagar and Tumkur and (arid in Anantapur).



Methodology followed: The multi-institutional, multi-disciplinary project adopted a flexible action research framework to address issues relating to rural livelihoods and is building on the learnings. The project carefully chosen the NRM interventions based on local situations and the capacity of the target group to benefit from them. Further, the outcomes are being constantly reviewed and revised to suit the local needs.

Brief achievements:

In the selected clusters both technical and social interventions are being executed in this project, which will help improving the livelihoods of both cultivators and landless poor.

Capacity building of rural institutions: The PRA exercise was conducted to know the existing situations and formulate the action plans with the participation of the villagers.

As a first step Gramasabhas and Focus Group interactions were held and new Self Help Groups were formed besides existing ones. Advisory Committees for the cluster of villages Viz., Salaha Samithis/Central Project Management Committees were formed for each cluster consisting of representative from the selected villages. The Salaha Samithis played a major role in smooth implementation of the project interventions.

Chaff cutter at Chowderpalli in Mahaboobnagar

The capacity building of the group of farmers from the selected cluster of villages was taken up by training them on employment generation activities like nursery raising, repair of implements, artificial insemination, vermicomposting etc,.

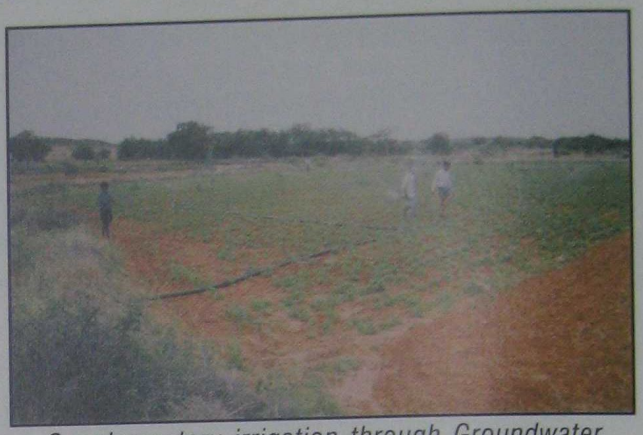
Besides this, a group of farmers were also taken on exposure visits to watersheds in Tumkur, research farms at CRIDA, Agril. Research Station, Anantapur, Livestock Research Station of Mahabubnagar etc.

Technical interventions

Soil and Water Conservation Measures

Farm pond technology for harvesting rain water: The erratic, uneven and highly skewed rainfall distribution in these rainfed areas results in some times heavy runoff which goes of as a waste and results in soil erosion. Hence, there is an urgent need to educate the cultivators regarding the proper harvesting and using the rainwater. The cultivators were first exposed to concept of rainwater runoff and soil erosion through portable rainfall simulator which shows the loss of soil and water with and without vegetative barriers. They were also taken to Research Station at Anantapur and were exposed to the use of water harvested from farm ponds for supplementary irrigation to Groundnut crops (Anonymous, 2004b). Based on this, the farmers have taken up the farm pond technology and a number of farm ponds were dug up especially in Anantapur and Tumkur clusters. The May rains in Anantapur have resulted in filling of all farm ponds and some of the cultivators used the stored water from farm ponds for supplementary irrigation for their groundnut crops during long dry spell following the May 2004 rains.

Farm pond filled with runoff water used for supplementary irrigation



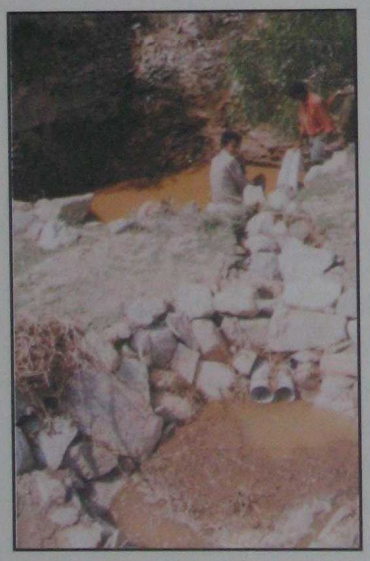
Supplementary irrigation through Groundwater

This has resulted in the change in mindset of the farmers and they started feeling that the farm pond technology is useful in dry areas like Anantapur with low rainfall also. More farmers have come forward to have farm ponds in their fields and the farm pond technology is accepted by some of the cultivators. Further work is in progress regarding this farm pond technology in the selected clusters regarding cheap lining material to be used etc,.

Trench-cum-bunds: Trench-cum-bunds were dug in the farmers fields based on the contour and plantation of agro-forestry trees were taken up.

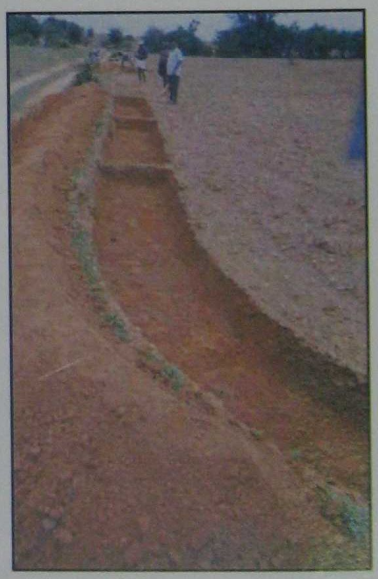
Diversion channels: Diversion channels were executed in the farmers fields which has resulted in recharging of the old and dried up open wells.

Check dams: Check dams were constructed in some of the selected villages in Anantapur and Mahabubnagar for collection of the excess runoff coming from tanks, etc.



Recharging defunt wells through Diversion Channels

Check Dam at Chowderpalli in Mahaboobnagar



Trench-cum-bund in Tiptur cluster

Ground Water usage

The over-exploitation has resulted in depreciation of ground water table and made the dryland areas more vulnerable to drought. To overcome the above situation there is a need to create awareness about the ill effects of over exploitation of ground water by educating the farmers about the same. This type of awareness programme has been carried out under the project (Anonymous, 2004a).

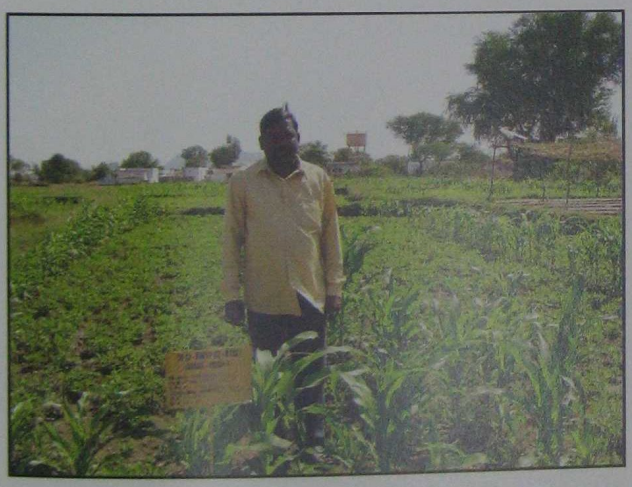
Farmer Measuring Water Level in the Bore-well Using the Device

People's Participation: Three types of people's participation was successfully implemented.

i) Farmers themselves were initiated to monitor the ground water levels in different locations in the villages through a measuring device so that they can be made aware how fast the ground water is being depleted in various seasons by over exploiting the use of Borewells

ii) The farmers were educated regarding the benefits of switch over from high water consuming crops like paddy to irrigated dry crops like groundnut, chickpea, maize, etc., so by using less of ground water more area can be irrigated resulting in high income.

iii) The third type followed was creating diversion channels for run off to dried up wells and making a series of ponds from ridge to valleys besides construction of check dams with the contribution and help of the villages themselves to recharge the ground water.



Maize as intercrop in groundnut

Efficient use of ground water: For the efficient use of the ground water alternate crops to paddy which are remunerative and uses less water like chickpea, maize and ragi in rabi season were promoted in the selected cluster of villages.

Agro-forestry

About 6000 saplings consisting of Glyricidia, Silver oak, Casuarina, Teak, Sesbania etc. were planted in an area of 30 ha on the occasion of green festival in Tumkur cluster. This has helped to promote agro-forestry with the cultivators and for creating awareness about the need for green cover for protecting the natural resources (Annual Progress Report, 2004). To create awareness

Co-1+ Teak on bunds - Ramulu's field at Zamistapur

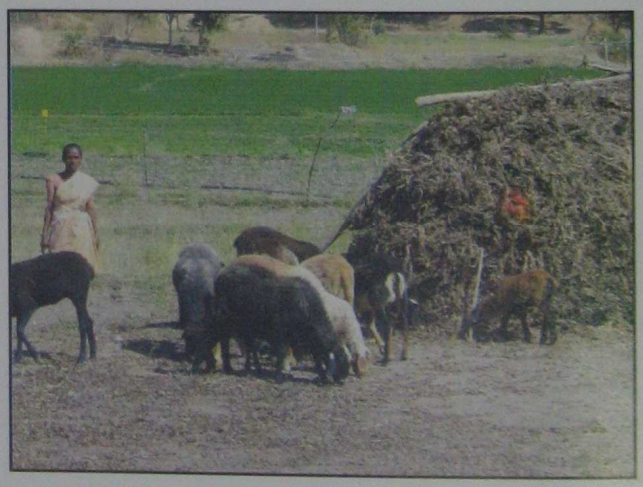
about the importance of planting trees to protect environment and preserve the natural biodiversity, a programme was organized in Anantapur cluster. In this programme school teachers and children have participated and planted forest trees neem, custard apple, jamun, casuarina, eucalyptus, etc. on Govt. lands around the school, veterinary hospital and on nearby forest land .In a CPR consisting of forestry land in Anantapur cluster 24 banyan plants were planted to help re-establishment of green cover in the barren and rocky forestry land. Besides this, dry sowing of Neem seeds was also taken up in the same forestry land through shramdaan by local school children and youth. The farmers were also encouraged to grow trees and fodder crops in their waste lands which are not at present used for crop cultivation

Livestock Development Programmes: Besides conducting the animal health camps, the cultivation of fodder crops was also promoted by giving exposure visit to live stock farms and supply of fodder seeds like stylo, leucerne, etc. An Artificial Insemination Centre was also started in Mahabubnagar cluster for improving the local breeds. The Chaff cutters were also provided for better feeding and preventing of wastages of straw fed to animals

Besides these, technological interventions the following livelihood interventions, for landless and marginal farmers were also taken up under the project.

Livelihood interventions for landless and marginal farmers

Sheep Rearing: There was a great demand for this avocation. A list of families was prepared in consultation with *Salaha Samithi* and each family was provided with three lambs at 40% contribution. Sheep rearing was perceived in the villages as a feasible livelihood option as the families can earn about Rs 3000 within six months. Lambs/ Sheep were selected by the families that were chosen to take up the avocation. *Salaha Samithi* entered into an informal agreement with the participant to ensure proper utilisation of assets.



The animals so procured were duly insured. The participants have agreed for following conditions

- Lambs/Sheep shall not be sold for the next six months
- In case of early death of lamb they should inform to *Salaha Samithi*
- Part of the sale proceeding shall be invested into this activity
- Violators of the conditions will be penalised as deemed fit by the Salaha *Samithi*

Vermi-composting: As an income generation activity vermicomposting was promoted. Each selected family contributed 30% in the form of labour. This has been initiated as a livelihood activity for small and landless cattle owning farmers. Ten units have been constructed in Anantapur and Mahaboobnagar cluster and they have started producing vermi compost.

Artificial Insemination(AI): An unemployed youth is trained in artificial insemination technique to take up breed improvement in the Project area to provide door-to-door service in Mahbubnagar cluster. He has performed nearly 85 inseminations during last two months out of which it is expected to get 60% conception.

Trained Village youth performing AI

The reaction of the farmers about the Center is very good. The liquid nitrogen and semen are supplied from BIRD-K once every of 40 to 50 days.

Use of Groundnut stripper at custom hiring centre

Custom hiring Centre: Selected enthusiastic youth two from each village in the Mahabubnagar cluster are trained for operating Agril. implements designed by CRIDA Scientists.

The idea behind the introduction of custom hiring centre is to provide gainful employment to rural youth as they charge nominally for supply of implements to small and marginal farmers besides reducing drudgery

Livelihood Interventions for women

Kitchen Gardens: With the help of women SHGs (Self Help Groups) a kitchen garden programme was taken up in the backyards to supplement the income and making available nutritious fresh vegetables for the families. Sixty women members from three SHGs groups have taken up the kitchen gardening with crops like *Cucumber, Brinjal, Tomato, Bhendi, Clusterbean* in their back yards.

Nurseries: Two nurseries with a capacity to raise 4000 seedlings every year are promoted. The women were trained in nursery raising techniques and were provided with the initial capital for seed and polythene bags etc,.

Backyard Poultry: Improved breed of poultry Vanaraja bird is given to rural women as off farm livelihood option, as these breeds weigh more in short time which is remunerative in providing income

Woman nursery in Chowderpally, Mahabubnagar

Implications of the project results

Finally the immediate change resulted due to intervention is encouraging. Some of the implications are given below

1. Livelihood interventions planning should be based on the analysis of village situation (through PRA) and people priorities.
2. Capacity development of target groups in terms of knowledge and skills is to be done before the implementation of the intervention to understand potential of intervention goals.
3. Livelihood intervention should be designed based on local resources availability, investment choices and access to natural resource base in addition to human capabilities
4. People contribution is more important for sustainability of the project interventions
5. It is difficult to run the project only for selected families neglecting others
6. Frequent visit of project staff enhanced the confidence levels of the villagers.

References

Anonymous, 2004a. Ground water management: Decision support system with peoples' participation, Policy Brief1, DFID-NRSP R8192, Improved NRM for Better Livelihoods, CRIDA, Hyderabad & BAIF, Tiptur.

Anonymous, 2004b. Rain water Management for Drought Proofing: Farm Pond Technology for sustaining groundnut production in Anantapur, Case study 2, DFID-NRSP R8192, Improved NRM for Better Livelihoods, CRIDA, Hyderabad, ARS, Anantapur & BAIF, Tiptur.

Annual Progress Report, 2004. Enabling Rural Poor for Better Livelihoods through Improved Natural Resource Management in SAT India, DFID-NRSP R8192, Improved NRM for Better Livelihoods, CRIDA, Hyderabad (Unpublished)

Ramakrishna, Y.S. & Subrahmanyam, K.V. 2004: DFID-NRSP Project R8192 Improved NRM for Better Livelihoods (Flier), CRIDA, Hyderabad.

Economic Viability and Acceptability of Dry Farming Technologies – Emerging Issues

Y.V.R. Reddy

Abstract

CRIDA, Hyderabad and its 22 centres in India developed suitable technologies – graded vs. package for drylands so as to improve the productivity of crops and thereby profitability to farmers. Technologies on watershed development programme, intercropping, sequence cropping, agroforestry system, suitable farm implements, bio-pesticides, and fertilizer application were discussed in addition to explaining the problems in adoption of dryland technologies. All technologies established their superiority and profitability over traditional technologies. However, dryland farmer is at disadvantage position compared to irrigated farmers due to delayed monsoon / prolonged droughts, non-availability of certified seed, genuine supply of plant products, lack of risk aversion mechanism during monsoon failure / droughts. Need based and productivity based mechanism are required to be developed for the benefit of farmers in drylands.

Introduction

Dryland farming constitutes about 64 per cent of arable area of about 143 m ha in India. Though food production has increased from 51 million tones in 1951 to 211 m tones today, the percentage of contribution of food production in drylands to national food basket has declined from 80 per cent in 1951 to less than 40 per cent today. This is due to increased irrigation facilities created in India through Five Year Plan periods. Thus the irrigated area has increased from 8 per cent in 1951 to about 35 per cent today. The food production increase is the result of use of improved / hybrid varieties, fertilizer application and spraying / dusting of pesticides / insecticides in addition to increase of irrigated area.

It is learnt that the cultivated area in India remains 50 per cent as dryland farming even after full utilization of all available resources and irrigation facilities. Hence importance of drylands will continue to play even in future. Dryland agriculture has set back during the past four years due to delayed monsoon / prolonged drought spells. In places of Anantapur and Chittoor districts, the area under drylands declined due to rainfall and its distribution, which are erratic and unpredictable. Hence seasonal migration of people from villages to towns / cities increased in search of employment and income generation to satisfy their hunger. Hence the problem of preventing crop failures becomes extremely important and calls for an adequate solution. One of the ways of solving this problem is to adopt dry farming methods in regions of low and uncertain rainfall. These methods include techniques of soil and crop management as well as improved system of cultivation in which maximum

amount of moisture can be conserved in the soil. Government of India initiated research work in 1935 through the Indian Council of Agricultural Research, which had five regional centers at Rohtak, Sholapur, Bijapur, Raichur and Hagari in collaboration with the respective state governments. Thus research work was done in relation to the agricultural conditions and methods of cultivation in vogue in various dry tracts in the country, rainfall and other climatic factors which affect crop production, disposal of rain water and soil erosion, cultural and manorial methods of preventing runoff and conserving soil moisture, physico-chemical characters of the soil in the dry tracts, physiological studies of important millets grown in arid regions and agronomy or soil management.

Government of India / Indian Council of Agricultural Research established All India Coordinated Research Project for Dryland Project, Hyderabad in 1971 with 24 centres under different agro-climatic conditions and it became a full-fledged research institute – Central Research Institute for Dryland Agriculture in 1985. It conducted research programmes on crop geometry, crop–inputs and its management, soil and water conservation techniques, intercropping, sequence cropping, drainage problem in vertisols, *in-situ* moisture conservation techniques, soil management, integrated nutrient management, integrated pest management, sowing / planting techniques, agroforestry system, watershed management, livestock management etc. A lot of data has been generated and farmer has a choice to choose technological components of his choice based on his financial and resource status. Nevertheless, farmers in dryland tracts have been facing many problems in relation to vagaries of monsoon, crop management, marketing etc. The dryland farmer is at disadvantage position today compared to farmer having irrigation facilities at highly subsidized rates in all aspects. However the position of dryland farmer today is better than earlier periods during normal rainfall years due to availability of seeds, fertilizers, pesticides and improved agronomic practices. Some of the results have been presented in this paper under different heads as explained below.

Watershed development programme: The economic indicators like Additional Benefit-Cost Ratio (ABCR), Additional Annuity Value (AAV), Additional Employment Days / Worker Per Year (AEWY), Reduction in Migration of labour (RML), Per Capita Expenditure / Year (PCEY) in watershed villages over non-watershed area villages are presented in Table-1 (Sastry *et al.*, 2003).

Table 1: Comparative study of socio-economic indicators in watershed villages over non-watershed villages in Andhra Pradesh

S. No.	Watershed location	ABCR	AAV (Rs)	AEWY	RML	PCEY	Soil type	Remarks
1	Kalakada (Chittoor Dist)	1.15	234	15	20	36	Alfisols	NWDPRA Watershed
2	Utnoor (Adilabad Dist)	1.70	615	19	25	45	Alfisols	International Agency Watershed Supported
3	Maheswaram (Rangareddy Dist)	1.34	496	18	10	32	Vertisols	International Funded project
4	P.Yaleru (Anatapur)	1.72	628	26	40	49	Alfisols	NGO, Watershed

When survey was carried out 'with' and 'without' in Watershed Development Programme area and its adjacent villages respectively, and additional benefits worked out for locations in Andhra Pradesh, the ABCR varied from 1.15 to 1.72; AAV varied from Rs.234 to Rs.628; Reduction in Migration of labour varied from 40 per cent to 10 per cent. The expenditure per person per year increased but it varied from Rs.32 to Rs.49 only. However the expenditure incurred in watershed by government was not included while working out ABCR, AAV and PCEY. If government expenditure is taken into consideration, the income generated was found to be abysmally low.

Acceptability: Farmers in all watersheds felt the necessity of diversion channels, bunding, ponds, checkdams, percolation tanks, water channels, gabion structures etc., but they expect support from government for their execution, as these are beneficial to entire area / part of the area covered by different farmers. However they reported that the existing irrigation tanks have not been receiving water due to soil and water conservation measures on upper reaches leading to no crop under such irrigated tanks. It is clearly visible in Kalikiri, Piler and Vayalpad mandals in Chittoor district. However it is not a regular and continuous practice. Thus, the problem needs to be examined in detail.

In-situ moisture conservation techniques like deep ploughing, dead furrow, broad bed & furrow, ridging due to intercultivation, ridge and furrow, scooping, leveling, smoothening, contour sowing with intercrops with pulses like greengram, blackgram, cowpea, horsegram etc. are useful in increasing the productivity to the tune of 10-30 per cent during normal rainfall years which was spelled out during survey period. More than average rainfall may also adversely affect the productivity of crops. Though farmers accept and agree on the profitability of different techniques, they have not been taking up due to their different avocations and the profits in real terms are not encouraging to the extent to their suffering mentally. However a few farmers are adopting periodically deep ploughing in Chittoor / Anantapur districts.

Intercropping

Groundnut + pigeonpea / cowpea / pulses is common practice in Chittoor and Anantapur districts. Row ratios varying from 6:1 to 1:1 in Sorghum + Pigeonpea, Maize + Pigeonpea are common in Rangareddy district and row ratios vary from 3:1 to 6:1. However the additional benefit due to intercropping per ha was worked out to be Rs.726 in case of groundnut + pigeonpea and Rs.878/ha in case of sorghum + pigeonpea. The percentage of profitability in sole crop of groundnut is worked out to be 28 as against 69 in case of groundnut + pigeonpea. Similarly the percentage of profitability is 24 in sole sorghum as against 72 in case of sorghum + pigeonpea. Though additional profitability was worked out to be Rs.590 in case of maize + pigeonpea but the percentage of profitability was 110 in sole maize as against 115 in maize + pigeonpea. Farmers accepted the recommended intercropping systems. The row ratios vary depending upon the prices of respective commodities in the market, family requirement etc.

However agriculture farming is dynamic and continuous move for increased productivity. Even cropping systems are changing. Sunflower has been spreading in Vertisols. Soybean has also entered in the system in Andhra Pradesh (Reddy and Singh, 1987).

Sequence cropping

Sorghum was grown during rainy season and chickpea was grown in rabi season on same piece of land in Medak district. The profitability was worked out to be Rs.1400 in case of sorghum in kharif and Rs.1550 in case of chickpea in rabi season in Chevella, Medak district. Thus farmer got Rs.2950 per year. It is observed in Chittoor district that a very few farmers had grown coriander after harvest of groundnut. The average net profit per ha was found to be Rs.2115 from second crop. However majority of farmers did not grow due to watch and ward problem or even otherwise farmers were busy with other agricultural operations or fear of loosing coriander crop if cyclone did not occur. Sequence cropping is accepted by Majority of farmer in Vertisols as farmers could grow rabi crops (rabi sorghum, chickpea, and safflower) on residual moisture. The sequence crops identified by farmers are sorghum – chickpea / safflower; greengram / blackgram – rabi sorghum / safflower etc. in Medak district (Reddy and Rastogi, 1985).

Agroforerstry systems

Agroforestry systems include agro-horticulture, silvo-agriculture, silvi-pasture, silvo-agro-pastural system etc. Dryland horticulture has become a popular in dryland tracts. Dryland horticulture includes – ber, guava, mango, sapota, amla, etc. The benefit cost ratios were worked out and found to be 3.50 in ber, 3.75 in guava, 3.62 in mango, 4.85 in amla, 1.15 in cashew and 3.15 in sapota. Eucalyptus and Casuarina were also profitable with annuity value of Rs.4250/ha and benefit-cost ratio of 7.52. In case of dryland agricultural crops it is less than 2 in many crops. Medium and large farmers prefer dryland horticulture due to labour and marketing problems to dryland crops. Thus area under agroforestry / dryland horticulture has been increasing in dryland tracts as per the crop and seasons of Andhra Pradesh (Sudha *et al.*, 1993).

Weeders and farm implements

Farmers in KVK villages have been using weeders viz., manual weeders, bullock drawn weeders, and castor weeder in drylands. These implements have replaced human labour. The the cost reduction in weeding was estimated to be 30-60 per cent in all dryland crops. Farm implements like 'Seed-cum-fertilizer drills' available are either bullock drawn or tractor drawn. Farmers in KVK adopted villages in Rangareddy district accepted them as more economical due to completion of sowings timely and seed – fertilizer application properly for better crop stand / growth. However availability of equipments was reported to be a major problem during the season. Even harvesting / threshing equipments were also available. Farmers accept but cash is required for

payment. Hence it is not yet fully followed by marginal and small farmers. However medium and large farmers reported that 'timeliness and precision' can be maintained in dryland operations. It saves 20-30% of cost of cultivation of each operation as maintenance of bullocks has posed a serious problem due to non-availability of permanent labourers based on government orders, subsidies, education, family planning etc (Prasad *et al.*, 2004).

Bio-pesticides

Bio-pesticides like neem seed, pongamia seed, neem / pongamia / castor cake can also be applied to dryland crops to control pests and diseases. It was successful in initial stages of pests / diseases attack in case of sorghum, castor, and vegetables crops in KVK adopted villages. Though it was found to be a problem to estimate 'with' and 'without' use of bio-pesticides in dryland crops. However two plots were studied which are at 1.5 km distance. The cost saving due to bio-pesticides was about Rs.230 per ha in case of castor (Kranti). Farmers accepted for application in vegetable crops (Prasad *et al.*, 2004).

Fertilizer application

Fertilizers are used in all dryland crops. Hybrids / commercial crops receive more attention and doses of fertilizers than in case of food crops. Most of the farmers have not been applying recommended doses to most of the dryland crops. Precision is also important in application of fertilizers for higher productivity. Farmers still practice broadcasting, application in furrows etc. But the productivity has increased to the tune of 25 per cent through use of seed-cum-fertilizer drill in case of castor, 30% in maize and 33 per cent in sorghum. Hence proper application of fertilizer through suitable equipments and proper placement of fertilizer would increase the productivity and thereby income from dryland crops (Reddy *et al.*, 1987).

Though minimum tillage methods, square planting, proper maintenance of population during rainy period / drought periods, use of drought resistant varieties, application of organic manure coupled with fertilizers, mulch influence, mid-season corrections, soil manipulation, recycling of collected water in ponds, in-situ moisture conservation techniques etc. play a role in increasing the productivity of crops in drylands. However complete data were not available to know economic viability during normal rainfall years, deficit rainfall years and high rainfall years. These are to be assessed in cyclical period of 11 years or so / meteorological calendars years to decide the efficacy of these technologies in dryland agriculture. Farmers who use complete package of dryland technologies harvest higher returns than the farmers who follow graded technologies based on resources at their disposal. In frontline demonstrations - castor, pigeonpea and maize, 40-60% increase in productivity was noticed compared to productivity average of farmers' fields.

Problems in adoption of dryland technologies

The question of superiority / profitability of technology would not decide its application in drylands. Any viable technology having self replicating ability spreads faster in drylands. The technologies are highly 'location specific' and 'farmer specific' as soil, rainfall and its distribution, climatic conditions, socio-economic conditions vary from place to place and economic conditions may vary even within the same location. As on today farmers are encountered with several problems – certified seed availability, genuine supply of plant protection chemicals, high prices for inputs, low prices of agricultural products, marketing of products, rainfall and its distribution which are uncertain, lack of risk aversion mechanism, low economic activity, poor resource base, unequal distribution of subsidies, lack of proper insurance policy, lack of punishment to dealers who supply dubious seed / plant protection chemicals, lack of proper policies for dryland agriculture development and so on. Thus farmer has to face many problems and miseries in dryland tracts. Dryland farmer cannot compete with irrigated farmers whose resource base is much better and sound compared to dryland farmer in India. Hence dairy, sheep / goatry, piggary, vegetable cultivation etc. are found to be constantly remunerative and profitable. The crop stand, intercrop, fertilizer and plant protection use in case of hybrids / commercial crops, agro-horticulture, strengthening of existing bunds, use of improved farm implements, tracterization etc. are widely accepted technologies.

Recommendations

- As drylands and farmers are neglected due to many, varied and complex reasons, there is an urgent need to improve the socio-economic conditions of the farmers in drylands through Dryland farmers oriented policies, and paper cropping / farming systems.
- As felling trees and denuding vegetation in private / community lands / government lands, deforestation and such other destroying the vegetation has reached an alarming stage in our country, government should take necessary steps to curb such techniques so as to improve the vegetation in general and tree development in wastelands, forest lands etc. through proper policies, action and punishments so as to improve the suitable micro-climatic conditions
- Dryland farmer needs financial support / subsidy to raise crops so as to compete with irrigated farmers. Suitable policies are to be developed and implemented effectively

Conclusion

There are number of dryland technologies under different agro-climatic conditions. Farmers have many choices, but externalities are beyond his capacity to control. Thus even sound technologies cannot be adopted during delayed monsoon / prolonged droughts which accrued during the past four years. Price of products has its impact

on choosing crops of his choice ignoring technologies. Hence it is necessary to develop need-based and high productivity based technologies for faster adoption in drylands.

Need-based: Drought resistant / tolerance and short duration varieties without affecting yield

Productivity based: Judicious methods of supply of seeds, fertilizers, plant protection chemicals, farm implements, biofertilizers use etc.

References

Prasad, M.S., Rama Rao, C.A., Nirmala, G., Ramakrishna, Y.S. and Reddy, Y.V.R (Eds.). 2004. Technologies for farm and household development (unpublished). Krishi Vigyan Kendra, CRIDA, Hyderabad, p.158

Reddy, Y.V.R. and Singh, S.P. 1987. Economics of intercropping systems in dryland areas. Indian J. dryland agric. res. and dev. 1(2): 41-56.

Reddy, Y.V.R., Rastogi, B.K., Annamalai, V. and Sudha, M. 1987. Dryland farming constraints to improve technology. Margin 19 (3): 48-54.

Reddy, Y.V.R. and Rastogi, B.K. 1985. Economics of recommended technology in dryland agriculture. Res. Bull. No: (2), 1-28. CRIDA, Hyderabad.

Sastry, G., Reddy, Y.V.R., Prakash, Om., Mishra, P.K. and Rama Rao, C.A. 2003. Preliminary Survey Report on Impact of Watershed Management Practices on Sustainability of Land Productivity and Socio-Economic Status (ROPS-14&14A), Report No. 1, NATP, CRIDA, p.154

Sudha, M., Reddy, Y.V.R. and Ramanatha Chetty, C.K. 1993. Economic Evaluation of dryland horticultural crops. Recent Advances in Dryland Agriculture, Part-(2), 615.

Viability of Dryland Farming in Andhra Pradesh

K.P.C. Rao

Abstract

Over the last three and a half decades, many technologies were developed by the research institutions for conserving soil and water and for improving the productivity of crops, livestock and trees in the dryland areas of Andhra Pradesh State. But these technologies were adopted by the farmers only selectively. While technologies appear promising at the research station level, they have so far not made a big impact on the farmers to alter the viability of dryland farming in Andhra Pradesh. Part of the problem lies with the poor resource base of the dryland farmers in terms of soil quality, rainfall and limited availability of ground water. The policies of the governments with respect to investments and subsidies have also not benefited the dryland farmers as they did in case of the farmers with irrigation facilities. The cumulative impacts of adverse policies, deteriorating soil fertility and declining ground water levels have rendered dryland farming non-viable in many parts of the state. This paper provides micro-level evidence from the Village Level Studies of ICRISAT to conclude that crop and livestock rearing activities in dryland areas of Andhra Pradesh are non-remunerative. It also highlights the infructuous investments in water exploration and migration of labour force, which are the responses of agricultural population to the deepening crisis in dryland agriculture. It argues for greater public investments for land and water development and for development of relevant technologies to benefit the dryland farmers. It also pleads for several policy initiatives to correct the bias that has inadvertently crept into the government policies while pursuing the objectives of self-sufficiency and quick development.

Introduction

Andhra Pradesh is an important agricultural state of the country. It is important because it still employs 62.3 per cent of the labour force in the state (Directorate of Economics and Statistics, Government of Andhra Pradesh, 2001). Its share in the Net State Domestic product however was only 28.6 per cent during the period 1997-2000.The average annual growth rate in the agricultural sector was only 2.1 per cent during 1991-2001 as against 5.0 per cent growth rate in the net state domestic product. Recent estimates put its share in the net state domestic product only at 20 per cent (personal communication, Principal Secretary, Planning, Government of Andhra Pradesh). But the labour force depending on it is still around 60 per cent. Stagnant output prices and spiraling input costs have rendered farming in the state a losing proposition, throwing the farmers into debt, destitution and desperation. A few thousands of farmers have already committed suicides and many more are on the verge of bankruptcy. The state,

which earned the fame as 'the granary of South India' only a few decades ago, is now facing a massive agricultural crisis.

Handicaps

The average rainfall in Andhra Pradesh is only 930mm as against the all-India average of 1150mm. The state has 65% red (less fertile) soils, 25% black (medium fertile) soils and 10% alluvial (highly fertile) soils. At all India level, 40% of the area is covered by alluvial soils, another 40% by black soils and the remaining 20% by red soils. Historically, it was able to make use of river waters early with the help of low cost irrigation projects because of favorable geographical features. But in the recent years, states in the upper reaches have completed high cost irrigation projects and are able to impound water in a big way. Being a tail-end state, it is getting very meagre flows in the rivers, particularly in the drought years. Due to low water availability and poor soils, the productivity levels are lower in the state, pushing up the unit costs of production. While drought has become the usual status of agriculture in the state, it is also frequently visited by cyclones and floods. To compound the natural disadvantages, the policy makers have grossly neglected the sector. The average capital expenditure per year per hectare of net sown area (at constant 1980-81 prices) during 1974-75 to 1996-97 was only Rs 160 in the state as against Rs 239 at all-India level. The new government in the state is giving priority to agriculture but it is guided more by populist measures rather than by a strong will to solve the root causes of the long-term problems.

Dryland farming

The Dryland farming in the state has always been risky and uncertain to provide any reliable source of income to the farmers. Much of the rainfed areas in the state fall in the Deccan plateau, which is a notorious rain shadow region. Communities and Governments (Kings and Nawabs) have invested in tank irrigation over many centuries to provide assured production environment, at least to a small part of land in the village. A few rich farmers could initially invest in open dug wells and gain access to ground water. After the green revolution, the returns to water have increased and motivated many farmers to invest in groundwater exploration. Innovations in drilling technology and supply of power have accelerated the investments in bore wells and caused a depletion in the groundwater levels. In the recent years, farmers are making infructuous investments by resorting to competitive drilling in the hope of getting a better share in the limited and declining groundwater sources. As the number of bore wells multiplied, the tanks were neglected and were allowed to decay and disappear.

Last five years period has been particularly bad for the low rainfall regions of the state. Besides a decline in rainfall, the distribution has been quite erratic with delayed onsets and long dry spells. The cumulative impacts of droughts and frequent crop failures have shattered the faith of farmers in dryland farming and induced large-scale seasonal and, even permanent, migration. Some evidence is presented below to substantiate the above generalizations.

Changes in the cropping pattern

Table 1 presents the cropping patterns of Aurepalle and Dokur (ICRISAT VLS Villages) in Mahaboobnagar district during 2001-02. In Aurepalle village, cash crops occupied nearly three-fourths of the gross cropped area. In Dokur village, they covered two-thirds of the cropped area. Sorghum and Sorghum-based cropping systems covered only about 10 per cent of the gross cropped area in these villages. In 1975-76, Sorghum based cropping systems covered 44 per cent of the gross sown area in Aurepalle and 21 per cent of the gross sown area in Dokur (Jodha, N.S, 1977). Farmers are shifting away areas from the coarse grains due to decline in their relative prices and changes in the consumption habits of rural people caused by public distribution system, which supplies rice and wheat at subsidized prices.

Table 1: Cropping patterns of Aurepalle and Dokur (ICRISAT VLS Villages) in Mahaboobnagar district, 2001-02

S. No	Crop	Aurepalle			Dokur		
		Kharif	Rabi	Total	Kharif	Rabi	Total
1	Cotton	71.36	0.00	71.36	1.11	0.00	1.11
2	Cotton + pigeonpea	3.44	0.00	3.44	0.00	0.00	0.00
3	Castor	17.40	0.00	17.40	14.57	0.00	14.57
4	Castor + pigeonpea	14.27	0.00	14.27	22.56	0.00	22.56
5	Sorghum	8.50	0.00	8.50	0.40	3.88	4.28
6	Sorghum + pigeonpea	5.48	0.00	5.48	2.02	0.00	2.02
7	Paddy	12.30	10.72	23.02	8.90	5.06	13.96
8	Finger millet	0.00	0.00	0.00	0.00	1.42	1.42
9	Others	1.62	1.21	2.83	4.65	1.17	5.82
	Total area	**134.37**	**11.94**	**146.31**	**54.22**	**11.53**	**65.75**

Crop economics

The costs and returns of important crop enterprises were worked out for the cropping year 2001-02 in some dryland villages of Mahaboobnagar, Kurnool and Nalgonda districts. The results are presented in Table 2.

Farmers were found to be incurring losses in case of most of the rainfed crops. In some cases, the returns were not adequate enough even to cover the variable costs. But in case of paddy grown under irrigation, farmers were either earning small profits or were incurring small losses. Overall, farmers were found to be incurring losses in 71 per cent of the plots they were cultivating (Table 3). In 37 per cent of the plots, they were not recovering even the variable costs. In the remaining 34 per cent of the plots, the gross returns were higher than the variable costs, but were able to recover only a part of the fixed costs. The returns were higher than the total costs in only 29 per cent of the plots. Most of these plots received irrigation support.

Table2: Economics of crop enterprises during 2001-02 in some predominantly Dryland villages of Andhra Pradesh (Rs/ha)

Village (District)	Crop	Variable Cost	Fixed Cost	Total Cost	Gross Returns	Net Returns
Aurepalle (Mahaboobnagar)	Cotton	12062	6168	18229	12238	-599
	Castor	5040	4304	9344	4755	-4589
	Paddy	19535	9084	28619	33145	4526
Dokur (Mahaboobnagar)	Castor	3782	7687	11469	3087	-8382
	Paddy	18544	11150	29694	25471	-4223
	Sorghum	3924	9261	13185	4121	-9064
Sripuram (Mahaboobnagar)	Maize	8697	6358	15055	12315	-2739
	Paddy	15316	9408	24724	24831	107
	Castor	5641	4053	9695	5758	-3937
Karivemula (Kurnool)	Setaria	3046	3095	6140	2727	-3414
	Groundnut	7990	4046	12036	8756	-3280
	Paddy	14131	7025	21156	21417	264
Nemmikal (Nalgonda)	Cotton	17478	5968	23446	18755	-469
	Greengram	3478	5443	8921	5489	-343
	Paddy	12460	7590	20050	19081	-969

Table 3: Summary of Crop economics of sample households in VLS villages of Andhra Pradesh, 2001-02

S. No	Name of Village (district)	Number (Percentage) of plots		
		Whose returns are less than variable costs	Whose returns are more than variable costs but less than total costs	Whose returns are more than total costs
1.	Aurepalle (Mahaboobnagar)	81 (46)	50 (29)	43 (25)
2.	Dokur(Mahaboobnagar)	26 (38)	31 (46)	11 (16)
3.	Sripuram (Mahaboobnagar)	51 (25)	77 (38)	76 (37)
4.	Karivemula (Kurnool)	99 (46)	61 (28)	55 (26)
5.	Nemmikal (Nalgonda)	91 (36)	83 (33)	76 (31)
6.	Isthalapuram (Nalgonda)	23 (27)	32 (37)	31 (36)
	Total of AP Villages	**371 (37)**	**334 (34)**	**292 (29)**

Neither were the farmers doing better in case of rearing milch animals. The incomes from cows did not cover even the variable costs, while those from the buffaloes were high enough to cover variable costs but were inadequate to cover the fixed costs like interest on fixed capital and depreciation on cattlesheds and other equipment (Table 4).

Table 4: Returns over variable costs of milch animals of sample households in VLS villages of Andhra Pradesh, 2001-02

S. No	Village	Buffaloes			Cows		
		No.	Returns over variable costs/ year (Rs)	Returns per animal (Rs)	No.	Returns over variable costs/ year (Rs)	Returns per animal(Rs)
1.	Aurepalle	36	105305	2925	17	5290	311
2.	Dokur	57	291348	5111	1	-485	-485
3.	Sripuram	54	83665	1549	22	1999	91
4.	Karivemula	36	22057	613	89	-31185	-350
5.	Nemmikal	95	110150	1159	30	-16836	-561
6.	Isthalapuram	35	35310	1009	9	-1282	-142
Total of AP villages		**313**	**647835**	**2070**	**168**	**-42499**	**-253**

Income levels and consumption standards

The average annual household income of the sample households amounted to Rs 31024, which works out to an income level of $0.35 per day per person (Table 5). Planning commission of India fixed an income level of Rs 11,000 per family as a cut-off for the poverty line at 1993-94 prices. At 2001-02 prices, the poverty line roughly approximates to Rs 20,000 per family. About 42 per cent of the households were having net household incomes below Rs 20,000 per year and can therefore be categorized as households below the poverty line. The per capita consumption levels correspond to the recommended levels of calorie and protein consumption. But nearly 36 per cent of the households received inadequate calories and 33 per cent of the households faced protein deficiency.

Table 5: Income levels and consumption standards of sample households in VLS villages of Andhra Pradesh, 2001-02

S. No	Name of Village	Average annual household income (Rs)	Percentage of households with annual income less than Rs 20,000	Average levels of per capita consumption		Percentage of households consuming per day	
				Calories	Proteins	< 2000 calories	<50 gm of protein
1	Aurepalle	31561	33	2380	68	25	16
2.	Dokur	36757	28	1957	52	56	48
3.	Sripuram	36084	35	2251	55	33	40
4.	Karivemula	26081	55	2214	57	45	38
5.	Nemmikal	31796	45	2481	66	26	27
6.	Isthalapuram	23864	56	2254	60	30	27
Average of AP Villages		**31024**	**42**	**2256**	**60**	**36**	**33**

The Sample households made substantial investments for exploring ground water over the sixteen-year period for which data were collected on a recall basis (Table 6). 646 attempts were made by 395 farmers to gain access to groundwater. Only 26 per cent of the open wells dug and 43 per cent of the bore wells drilled are presently in use. The average investment per a working open well worked out to Rs 51898 and that of a working bore well amounted to Rs 42,411. The average depth of the bore wells drilled by the sample households was 127 feet. While the depth of the bore wells and the investment per bore well are increasing over the years, the amount of water discharged and the area commanded per bore well are decreasing, making water exploration a costly and risky gamble.

Migration of labour force

Uncertain rainfall, growing water scarcity, rising input costs and stagnant output prices have rendered many of the crop and livestock enterprises non-remunerative. As the labour force is not finding enough work in the villages, they are migrating to long distances in search of work. Table 7 presents the details of migration by the labour force. 22 per cent of the labour force in the study villages migrated for work. In Dokur village where water scarcity was the greatest, one-third of the labour force migrated to long distances in Gujarat and Rajasthan for work. On an average, the labour force from the study villages migrated to a distance of 243km and found work for 158 days. The average earnings per migrant worker amounted to Rs 7026. Those who migrate a to long distances were able to repay the debts incurred by them in their villages.

Table 6: Investments in Groundwater exploration by the sample households of VLS villages in Andhra Pradesh, 1985-86 to 2001-02

Village	Open Wells				Bore wells				Average Benefits
	No .of Attempts	Amount invested (Rs)	% of wells presently in use	Cost per working well (Rs)	No. of Attempts	Amount invested (Rs)	% of wells presently in use	Cost per working well (Rs)	
Aurepalle	11	145000	36	36250	43	840400	72	27110	121
Dokur	10	71000	10	71000	36	839000	50	46611	119
Sripuram	34	792000	29	79200	166	1947500	20	49015	165
Karivemula	4	64000	0	∞	13	295000	69	32778	157
Nemmikal	84	495000	31	19039	156	1955250	28	44449	108
Isthalapuram	23	594000	48	54000	66	623000	21	44500	93
Total of all villages	**166**	**2161000**	**26**	**51898**	**480**	**6500650**	**43**	**42411**	**127**

Table7: Migration particulars of sample households in VLS villages of A.P, 2001-02

S. No.	Village	No. of workers per household	No. of workers migrating per household	Average of days of employment/ person	Average amount earned (Rs) per person per year	Average distance of migration (km)
1	Aurepalle	2.40	0.52	230	12264	85
2.	Dokur	2.85	0.95	226	10635	940
3.	Sripuram	2.35	0.39	226	12932	150
4.	Karivemula	2.72	0.85	62	1979	200
5.	Nemmikal	2.61	0.46	103	2344	68
6.	Isthalapuram	2.30	0.13	100	2000	16
	Average	**2.54**	**0.55**	**458**	**7026**	**243**

Adoption of improved dryland technologies

During the last thirty years, Dryland farmers of Andhra Pradesh were introduced to several crop and soil and water technologies developed by Agricultural University, CRIDA, ICRISAT and other research institutes. Some of them were tried and discontinued, while some others were adopted and continued. Depending on the agro-climatic conditions and their resource endowments, farmers picked and chose the technologies, which made sense to them. High yielding varieties, chemical fertilizers, plant protection chemicals and some improved farm implements are not new to them any more. The soil and water technologies, which they usually adopt, are strengthening of field bunds and land leveling. Wherever watershed programmes were implemented, they made some investments on contour or graded bunds to complement the community level investments made to arrest soil erosion and to improve water conservation. But the adoption of some of these technologies did not make a qualitative difference to the viability of dryland farming in the state. The inherent risks are so high that they do not bank upon it much. None of the research or development organizations could demonstrate on a sufficiently big scale that the investments on dryland technologies can give handsome returns. The policy makers doubt the viability of dryland farming even with the adoption of new technologies. The state government is advancing either provision of irrigation facility or planting of trees of economic importance as the alternatives. But both these alternatives are neither feasible nor appropriate to all the dryland areas in the state.

Policy initiatives

Since Dryland farming cannot be ruled out in the prevailing circumstances, many policy initiatives are needed to improve its viability. In fact, dryland farming suffered policy neglect and discrimination for many years. While the development policies of the government might have solved some problems, they have also widened the gulf between the predominantly irrigated and predominantly rainfed areas. It was because only farmers with irrigation facilities could harness much of the subsidies given to agriculture by the governments.

Two policy initiatives mentioned in the Budget speech of the Finance Minister are helpful to dryland farming. The first one is on weather insurance, which the government seeks to promote eventually in place of crop insurance. Crop (loan) insurance was mainly helpful to those who borrow from the financial institutions. Farmers generally borrow for irrigated crops and not for the cultivation of rainfed crops. But weather insurance could be purchased by the dryland farmers as well irrespective of the fact whether they borrowed or not. The other policy initiative talked about was the introduction of food stamps in place of the public distribution system. Since the present public distribution system subsidizes only rice and wheat, its replacement by food stamps should benefit the producers of coarse grains. But both these measures need to gain public acceptance. These policy initiatives are only in the experimental phase and it may take a long time before they can create an impact on dryland farming.

Watershed development programmes were the main vehicles through which resource development investments were made in dryland areas. Although substantial investments were made on these programmes, the investment per hectare is quite low and pales into insignificance, when compared with the investments on surface irrigation. But policy makers are already expressing concerns that the returns from the investments in watershed development programmes are quite low. The research organizations and development agencies have to prove the viability of the investments that are being made for resource development in the dryland areas. Otherwise, it will be difficult to get continued support and investment for these programmes.

Whatever may be technologies and investments available to dryland farming, it will always remain to be a poorer cousin of irrigated agriculture. But in the absence of support of technologies, investments and policies, the crisis in dryland agriculture may worsen further. It is hoped that the policy makers will continue to bestow attention on dryland farming for reducing horizontal inequalities and for mitigating poverty.

References

Directorate of Economics and Statistics – Different issues of Statistical abstracts, Department of planning, Government of A.P

Jodha, N.S. 1977. Resource base as a determinant of cropping patterns, occasional paper 14, Economics program, ICRISAT, p.58

Walker, T.S. and Ryan, J.G.1990. Village and Household economies in India's Semi-Arid Tropics, The John Jopking University press, Baltimore.

A.P. Water Vision – Objectives and Implementation

K.V.G.K. Rao and V.V.N. Murthy

The A.P. Water vision developed by the Water Conservation Mission of A.P. was released in the year 2003. The Andhra Pradesh Water Vision reviews the water availability in the State and describes the steps needed for better management of the available resources. The Andhra Pradesh Water Vision is based on consultations in all districts and with important stakeholders at State level. Subsequently, the Government of AP constituted the A.P. Water Vision Task Force to assist the different Govt. Departments to implement the necessary steps for achieving the goals of the water vision. The goals of the AP Water Vision are stated as follows:

- Clean and secure drinking water supplies for the entire population
- Sustainable levels of water extraction from rivers, tanks and groundwater – without jeopardizing their future use or vital ecosystem functions.
- Conservation of rainwater and its efficient use for agriculture, plantations, livestock and groundwater recharge.
- An efficient, well-managed and sustainable irrigated agriculture sector-enhancing value and ensuring farming livelihoods, but also avoiding wasteful use of water.
- Mitigation of the effects of droughts, with short-term emergency responses and long-term planning.
- Prevention of the pollution of water resources.
- Integrated governance of water-reflected legislation, efficient Government services that work in a coordinated manner, sound water information and data sets, adequate monitoring and applied research.
- Participatory water management through effective institutional arrangements. Greater concern for water management at every level – individual, community and Government. Special emphasis on the participation of women and landless persons in decision-making.

Strategic framework for implementation:

The Strategic Framework outlined in the Water Vision recognizes the need for a sustainable and integrated approach to water resources development and management. The following components comprise the core of a Strategic Water Framework:

- Acceptance of a Shared Water Vision as stated in the Water Vision document.
- Assessment of the current water resources stock and use in terms of spatial and temporal availability and quality.
- Development of a State Water Policy in consultation with the main parties – Government and non-government – and congruent with the National Water Policy, which outlines goals and objectives for sustainable water development and management, and the measures required to implement those goals and objectives.

- Preparation of plans for water resources development and management at the river-basin scale.
- Specification of the water management roles and responsibilities of the State Government and its agencies, local Water Conservation and Utilization Committees, Watershed Committees, local Government organizations and other organizations.
- Development and implementation of an auditing programme for water management, which measures progress towards sustainable water management goals and objectives.

The responsibility for implementing the strategic framework will eventually lie with the relevant Government departments who would develop respective agendas for concrete action. The elements of the vision are identified and all the departments in the water sector will make efforts for implementing the same.

Rainfed agriculture

Management of rainfed agriculture is one of the elements to be considered in the water vision.

At present, more than 50% of the cultivated area in the State of Andhra Pradesh has no provision for irrigation, and substantial areas in the State will continue to remain under rainfed agriculture. Rainfed agriculture in the high-rainfall and low-rainfall zones should be considered separately. The control of soil erosion is important in the tribal areas of the northern, high-rainfall districts. In the traditionally low – and uncertain rainfall zones of the State, 'dry farming' technologies should be adopted, integrating soil, land and crop management. Extension, demonstration/farmer-to-farmer approach and advisory services to men and women farmers must be intensified based on the technologies that the State. Central and International research institutions in the State develop in close cooperation with these farmer groups. Watershed development is important for the conservation of rainwater and enhancing recharge to groundwater. By the year 2007, the State proposes to develop more than 10 million ha of watersheds. At present work is in progress in more than 3 million ha. Practices for managing rainfed agriculture form an important component in the watershed development programs as watershed programs are implemented for the purpose of managing the rainfall received on the land surface.

In the State of Andhra Pradesh, research in the rainfed agriculture aspects, or dryland agriculture is being carried out by three principal research organizations viz., The Central Research Institution for Dryland Agriculture (CRIDA), Acharya N.G. Ranga Agricultural University (ANGRAU) and the International Crop Research Institute for the semi-Arid Tropics (ICRISAT). The practices developed by these three principal organizations will be useful for the farmers of the State and these practices need to be implemented at the field level.

Reference

Government of Andhra Pradesh 2003. Andhra Pradesh Water Vision – a Shared Water Vision. Volume I. Government Insurance Building, Tilak Road, Hyderabad, Andhra Pradesh: Water Conservation Mission. 148 pp.

List of Participants

1 **A.S. Raju**
Prof.& Head,
Department of S.S. & A.L. C.A.,
Rajendranagar, Hyderabad-30

2 **Aum Sharma**
Agril Engineer,
FIMSC, ARI Rajendra Nagar
Hyderabad

3 **B. Vaman Goud**
ADA (SC)
RR District

4 **B. Venkateswarulu**
Principal Scientist
CRIDA, Santoshnagar,
Hyderabad–500 059

5 **B. Vidya Sagar Reddy**
ADA (SC)
Kalwakurthy, Mahabubnagar

6 **D. Raji Reddy**
Agromet cell, ARI,
Rajendra Nagar, Hyderabad

7 **D. Thirumula Rao**
Andhra Jyothi (Press)

8 **G. Subba Reddy**
Head, DCS
CRIDA, Santoshnagar,
Hyderabad–500 059

9 **G.G.S.N. Rao**
Principal Scientist
CRIDA, Santoshnagar,
Hyderabad–500 059

10 **G.R. Korwar**
Head, DRM
CRIDA, Santoshnagar,
Hyderabad–500 059

11 **I.A. Khan**
Head, RCMU,
CRIDA, Santoshnagar,
Hyderabad–500 059

12 **J. Chandra Sagar**
Andhra Prabha (Press)

13 **J.V. Rao**
Principal Scientist, Agronomy
CRIDA, Santoshnagar,
Hyderabad–500 059

14 **K. Bhaskar Reddy**
ADA (SC)
Deverakonda, Nalgonda

15 **K. Raju, IAS**
Commissioner RD & Chief Executive
Officer, WCM, Tilak Road

16 **K. Suresh Kumar**
Eenadu (Press)

17 **K. Venkata Rao**
PMU-APRLP
O/o. CRD
Insurance Building, Hyderabad

18 **K.P.C. Rao**
Principal Scientist, ICRISAT,
Patancheruvu

19 **K.P.R. Vittal**
Project Coordinator, AICRPDA
CRIDA, Santoshnagar,
Hyderabad–500 059

20 **K.V. Narsing Rao**
C/o. Youth Employment
Service Network,
Dept. of Youth Services, Parishram
Bhavan Basheerbagh, Hyderabad

21 **K.V. Subrahmanyam**
Head, TOT
CRIDA, Santoshnagar,
Hyderabad–500 059

22 **KVGK. Rao**
Member, APWV,
MSU, Tilak Road, Hyderabad

23 **L. G. Giri Rao**
Professor, (Agro Forestry),
AICRPAF, ANGRAU

24 **Lex Cogle**
ACAIR, Mareeba,
Queensland, Australia

25 **M. Devendar Reddy**
Asst. Professor, Agronomy
AICRP on cropping system,
College of Agriculture,
Rajendranagar, Hyderabad-30.

26 **M. Kamalakar**
Asst. Director of Agriculture.
O/o. Director, Sameti,
Old Malakpet, Hyderabad

27 **M. Osman**
Senior Scientist, Agronomy
CRIDA, Santoshnagar,
Hyderabad–500 059

28 **M. Raman**
ADA (SC), Siddipet

29 **M. Singa Rao**
Professor, Soil physics
College of Agriculture, ANGRAU,
Hyderabad-30

30 **M.A. Saleem**
Farmer,
H.No. 405, SPL'C'
Agapura, Hyderabad

31 **Md. Manzoor Ahmed**
D.D.A. (SC)
Anantapur

32 **P. Srinivas Prasad**
Joint Director (GW),
BRK Bhavan, SFI, BRKR Bhavan,
Hyderabad

33 **P. Sriramulu**
Addl. Director,
Animal Husbandry,
Shantinagar, Hyderabad

34 **P. Subhodini**
Agricultural Officer
O/o. Director, Sameti,
Old Malakpet, Hyderabad

35 **P.K. Mishra**
Principal Scientist, S&WCE
CRIDA, Santoshnagar,
Hyderabad–500 059

36 **Papa Rao**
ADA (SC)
Anantapur

37 **Prabis G. Garain**
AFPRO FV VI, Tarnaka,
Hyderabad

38 **R.C. Sachan**
Senior Scientist,
ICRISAT, Patancheruvu

39 **Ramanjaneyulu**
WASSAN
Centre for Sustainable
Agriculture (CWS),
12-13-445, Street No.1
Taranaka, Hyderabad

40 **S. Bhargav**
Member, ICAR

41 **S. Eswaraiah**
ADA (SC)
Rayachoty, Kuddapah

42 **S. Kishan Das**
Joint Commissioner,
O/o. Commissioner, Rural Development
Government of Andhra Pradesh
5th floor, Insurance Building,
Tilak Road, Abids,
Hyderabad – 500 001

43 **S. Reddy**
Farmer, Nalgonda

44 **S.K. Anwar**
CWS,
12-13-438, Street No. 1
Taranaka, Hyderabad

45 **S.P. Wani**
Principal Scientist (Watershed),
ICRISAT

46 **S.R. Yadav**
PRO, CRIDA, Santoshnagar,
Hyderabad–500 059

47 **Srinivas Reddy**
Vaartha (Press)

48 **T. Koteswara Rao**
ADA (SC)
Bobbili, Vizianagaram

49 **T. Peddi Reddy**
Addl. Director, Agriculture,
Gunfoundry, Hyderabad

50 **T.S. Anjaneya Raju**
JDA (SC)
Ongole, Prakasam-523001

51 **V. Kasi Viswanath**
ADA (IWS), O/o. C&DA,
Hyderabad

52 **V. Satyanarayana Rao**
Asst. Professor, Plant Breeding,
AICRP on Forage crops, LRI

53 **V.M. Mayande**
Principal Scientist, FMP
CRIDA, Santoshnagar,
Hyderabad–500 059

54 **V.S. Rao**
Principal Scientist
CRIDA, Santoshnagar,
Hyderabad–500 059

55 **V.V. Bhaskar Rao**
ADA (SC)
Utnoor, Adilabad

56 **Vasu**
Chief of Bureau,
Businessline (Press)

57 **VVN Murthy**
Member, APWV, MSU,
Tilak Road, Hyderabad

58 **Y.G. Prasad**
Senior Scientist
CRIDA, Santoshnagar,
Hyderabad–500 059

59 **Y.S. Ramakrishna**
Director
CRIDA, Santoshnagar,
Hyderabad–500 059

60 **Y.V.R. Reddy**
Head, SDA
CRIDA, Santoshnagar,
Hyderabad–500 059