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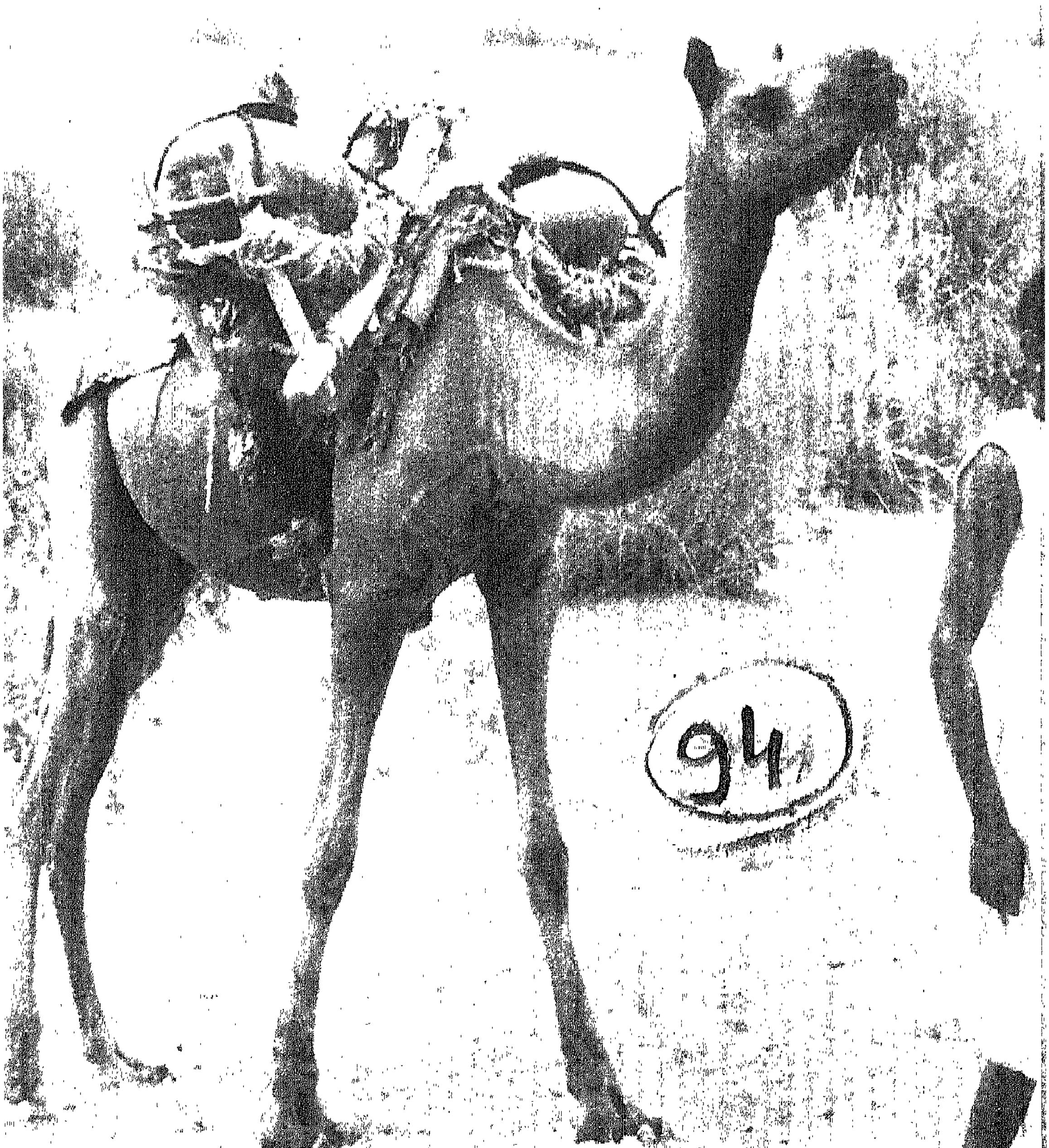
ICAR

Drought Management In Indian Arid Zone



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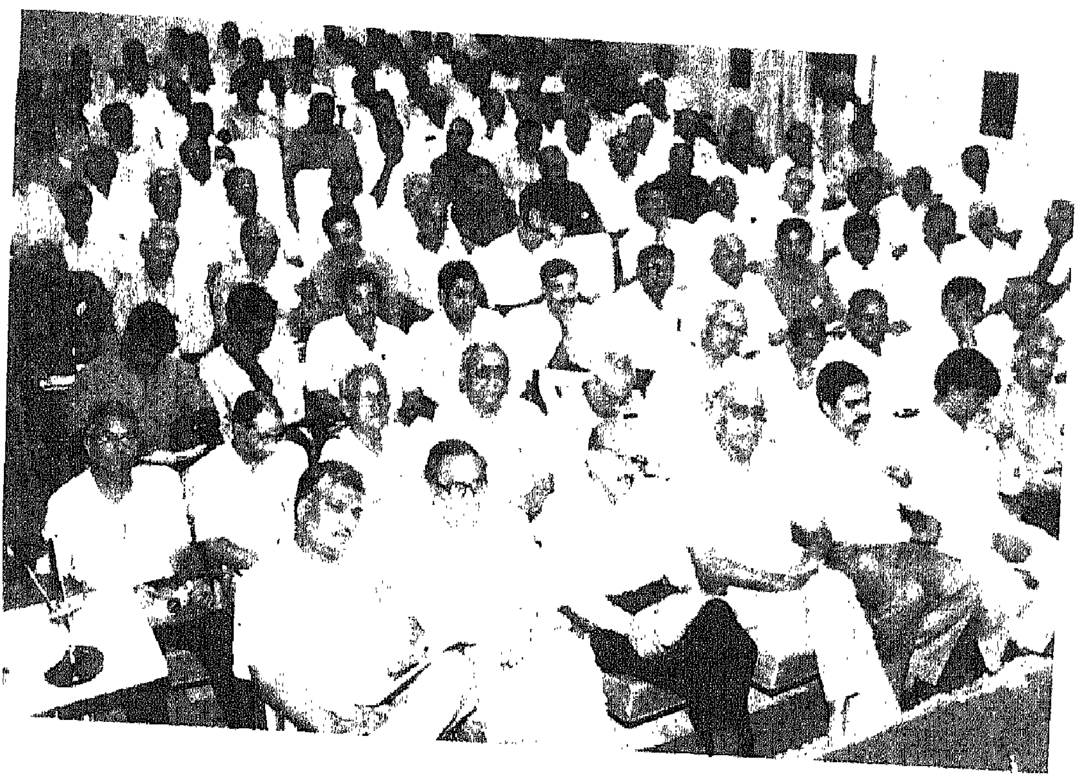

ICAR

Drought Management in Indian Arid Zone

Editors

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Foreword

Drought is a recurring feature in arid region of India. The drought of the year 2002 is unique and severest drought of the country in the sense that all the scientific and traditional predictions failed miserably. The region received only < 30 % of the mean annual rainfall in one or two spells of 10-20 mm each. This was insufficient for sowing of the *kharif* crops. Regeneration of grasses and has resulted in acute shortage of drinking water for human and livestock. Migration of livestock has started to the adjoining states, but the problem is compounded by insufficient or inordinate delayed rains in neighboring states. A contingency planning for *kharif* as well as for *rabi* crops was immediately rerquired particularly for arid region.

Since its inception, CAZRI has been engaged in developing technologies for drought proofing in the arid region. Techniques for wind erosion control, *in situ* moisture conservation, integrated nutrient and pest management, farming systems involving agro-forestry, agro-horticulture and silvi-pastoral have been evolved. Drought-tolerant genotypes of crops and perennial species have also been identified. The NATP programmes under Arid Agro-ecosystem is a forward step to strengthen the drought proofing of the arid region

In order to consider suitable short, medium and long-term strategies to combat droughts in the region, a brainstorming session on "Drought management: Contingency planning" was organised by CAZRI on August, 20 and 21, 2002. This volume is the outcome of that brainstorming session, and is a valuable document on the present drought scenario and possible interventions to overcome the effects of drought. I hope the recommendations of this brainstorming will be useful to all those concerned with the management of drought and contribute substantially to National Drought Policy.

(Panjab Singh)

Secretary, Department of Agricultural Research & Education, and

Director General, Indian Council of Agricultural Research,

Ministry of Agriculture, New Delhi-110 001.

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Welcome

Pratap Narain

Director
Central Arid Zone Research Institute, Jodhpur

Honourable Dr. Panjab Singh Sahib, Your Highness Shri Gaj Singh Sahib, Dr. J. S. Samra Sahib, Dr. S.L. Mehta Sahib, Dr. Gurbachan Singhji, Dr. I.P. Abrol Sahib, Distinguished Participants to the Brainstorming Session on Drought Management: Contingency Planning, Other Invited Guests, Members of the Press and other Media, Ladies and Gentlemen,

On behalf of all the staff members of Central Arid Zone Research Institute, and on my own behalf I extend to all of you a hearty welcome to our Institute. For delegates coming from outside of Jodhpur, I take this opportunity to welcome them to the Sun City of Jodhpur.

It is my proud privilege to formally welcome the luminaries gracing the dais. I have immense pleasure in welcoming here today, our Chief Guest, Dr. Panjab Singh, who is Secretary, Department of Agricultural Research & Education, Govt. of India, and Director General, Indian Council of Agricultural Research. CAZRI was waiting so long with bated breath to greet one of its dearest and most illustrious family members, a benevolent elder brother, and the second successive Director General of ICAR from this family. Dr. Singh almost started his illustrious career from here at CAZRI, and was an immensely sought after Scientist, whether for his research achievements, management of the Institute affairs, bringing scientific results to the farming communities, or social activities. Although he left the institute about 15 years ago to take up responsibilities as Director of different research institutes, Vice Chancellor of an agricultural university, and finally as Director General of ICAR, he was never mentally far off from people who worked with him here, or who had even the slightest acquaintance with him. Sir, we are most beholden to you for your advice, guidance and for kindly accepting our invitation, in spite of your extremely busy programmes.

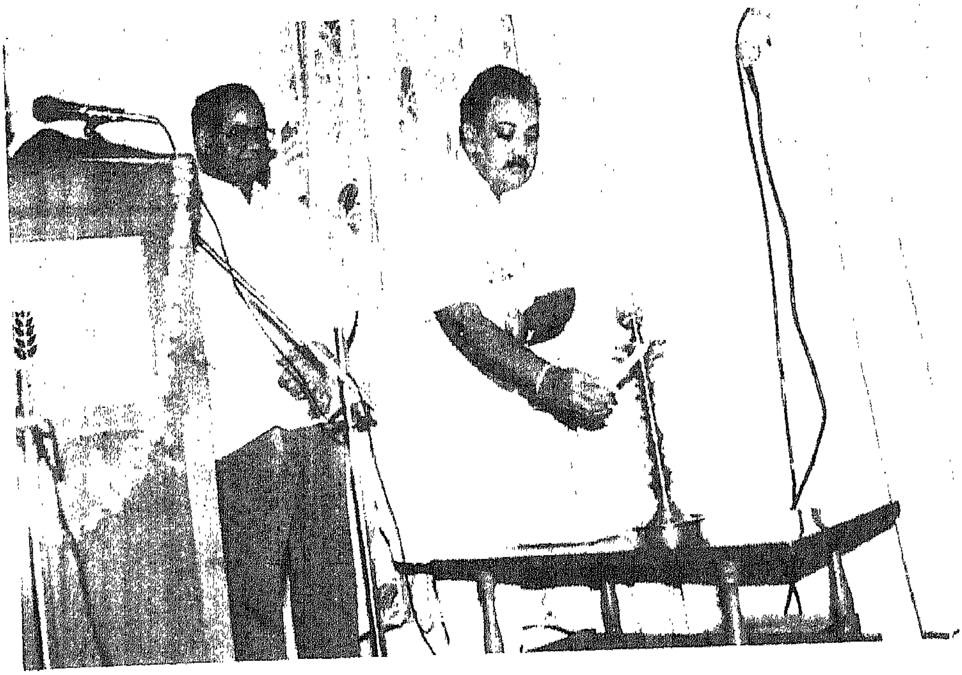
My head bows naturally in obeisance while welcoming the President of this inaugural function, His Highness, Maharaja Gaj Singhji of Marwar, Jodhpur. In many ways

Jodhpur and Maharaja Gaj Singh have become synonymous. So varied are his philanthropic activities for the region, be that for drought relief, universal education, especially women's education, medical care and desert development, and so effective are the charitable trusts run by him that the vast populace of Marwar continues to have the same sense of belonging and respect for the Eton and Oxford educated Maharaja that they had for his royal ancestors. He is also actively involved in renovation of traditional water harvesting structures and siting of new ones with the NGOs, as well as development of Common Property Resources through philanthropic and industrial houses. He is a great environmentalist, and is the most appropriate personality to preside over this function today. Sir, your gracious presence on this solemn occasion inspires us to rededicate ourselves to the cause of the society in its hour of need.

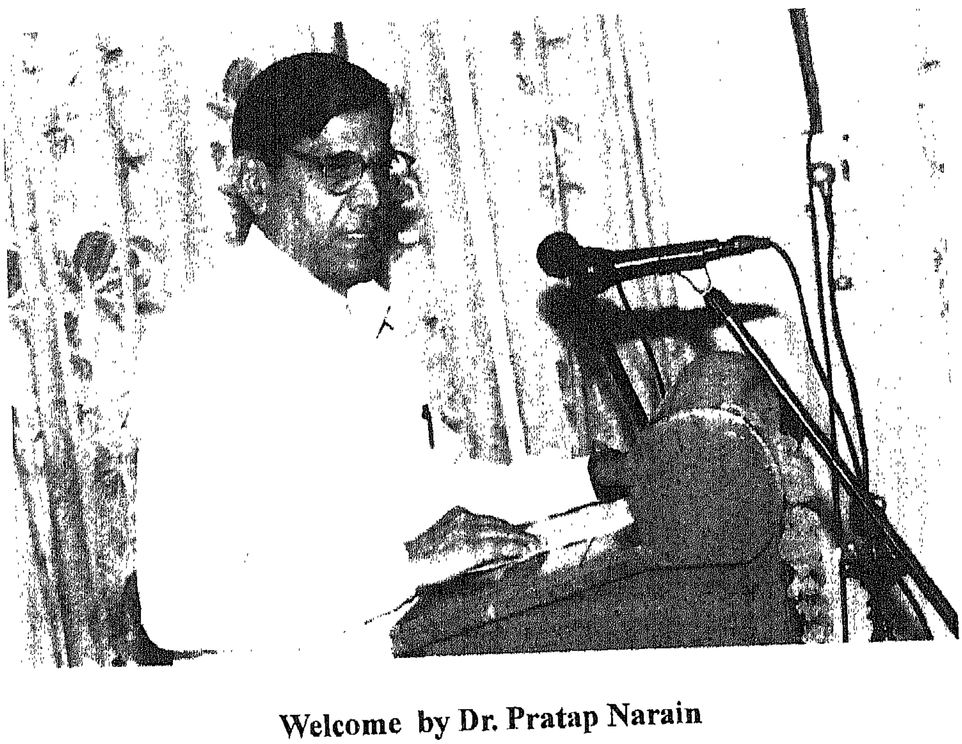
I also extend a warm welcome to Dr. J. S. Samra, Deputy Director General (NRM), ICAR, who also looks after our institute since taking over this onerous position two years back. A scientist of very high calibre and an able administrator, Dr. Samra was previously Director of Central Soil and Water Conservation & Training Institute, Dehra Dun, where I had the opportunity of working with him. He took keen interest in the holding of this Brain Storming Session, and guided us on every detail of its contingency planning for drought. We are sure, his deliberations during the session will provide us future directions in research on drought management.

In welcoming Dr. S. L. Mehta, National Director, National Agricultural Technology Programme (NATP), I feel more humbled before a renowned biochemist, who has a very bright academic record, and has contributed enormously to agricultural research. He was Head of Biochemistry Department, and then Dean and Joint Director of IARI, New Delhi. He was also Deputy Director General (Education), ICAR, before accepting his present position as National Director, NATP. Incidentally, this Brain Storming Session is being funded by NATP. Dr. Mehta took keen interest in holding of this session, and approved the needed funds forthwith.

I shall fail in my duty if I do not extend a special welcome to Dr. I.P. Abrol, our former Deputy Director General, and current Chairman of SAP (NATP), who was the chief initiator of this proposal to hold a session on drought. I also welcome Dr. Gurbachan Singh,



His Highness Gaj Singh ji lighting the wisdom lamp



Welcome by Dr. Pratap Narain

Assistant Director General (Agro-forestry), ICAR, who worked with us almost incessantly during the planning stage of this session.

This is, perhaps, not the best season to visit Jodhpur. For most researchers at CAZRI this is the busiest field season. Unfortunately, we have been struck by a very severe drought that may turn out to be the worst during the recorded history. Drought is no stranger to arid Rajasthan, but this time it has struck with a force that is rare. To give you some chilling figures, Jodhpur has received only 19.8 mm of rain from June to this day in August, this year. This value is far below the normal rainfall amount of 212.4 mm for the same period. During the worst droughts of 1911, 1955 and 1987 Jodhpur received slightly higher rainfall over the same period. If it does not rain within next two days, it will break the record of lowest rainfall for the period in 1918. A feeling of being struck by the most severe drought in recorded history is gradually getting embossed in the mind of the local people. Fortunately, scientists, administrators, management experts and people at large are now better equipped to face the challenge. Although scientists of our institute and elsewhere are working for decades to find cost-effective technological solutions to mitigate the effects of drought, it is now time that we take urgent stock of our regions-specific research efforts and think ahead for suggesting more efficient contingency plan, drought early warning and management, and a national drought policy. It is with these objectives in mind that we sought the guidance and advice of our Director General, Dr. Panjab Singh, and our Deputy Director General, Dr. J.S. Samra, and contacted the key personalities in different spheres of drought management. I sincerely wish that all these efforts culminate in a long-term policy direction of research on drought management in the arid region.

It is indeed very gracious of you participants, that, in spite of your extremely busy schedules, you chose to share your views on drought with us here, and that too at a very short notice. We are indeed very thankful to your kind gesture.

We are holding this Brainstorming Session in an austere and solemn manner, and have tried to make your stay as conformable as possible in our limited way. Please feel free to contact me in case you have any problem.

I welcome you once again.

Thank you.

Introductory Remarks

J.S. Samra

Deputy Director General (NRM)
Indian Council of Agricultural Research, New Delhi

His Excellency Shri Gaj Singhji, Panjab Singhji, my colleagues on the dias and distinguished participants.

It is very heartening that this meeting is being held in Jodhpur because of various reasons. People coming from outside Rajasthan will get an opportunity to have a feel of the drought and see how local people are reacting. In management of drought local mechanisms are very important, and it is in this scheme of things that we are meeting here. As Dr. Pratap Nartain has said, drought is some thing not new, and every year there is drought somewhere, while there is a flood somewhere else. Unfortunately we become active only when the drought has happened or the flood has occurred. Then we think of very short term measures to manage it, some thing like giving drip to a patient. All short term measures are very expensive. Therefore, if a drought has to be managed, it has to be managed in a previous normal year, or in the post-normal year. I hope when we have the deliberations we will debate on both the strategies, what is to be done this year, a small- scale, short surgical operation, and how to moderate the drought effects sustainably. That is the reason why we have tried to bring in lots of experts, participants from various disciplines from various regions, from various departments with different kind of experiences so that an integrated approach comes out. If we really utilize these two days very seriously to bring out strategy not only for this year but for the next couple of years, I think we will be doing great service.

Dr. Pratap Narain said His Excellency Shri Gaj Singhji is a great philanthropist in the field of education, health, and with his participation we hope he will also include drought management in his scheme of things. Since he belongs to this region we solicit his patronage, his participation, his input, and his motivation to bring out a very sustainable drought management program. With these few words I once again welcome you all and wish that we get very good deliberations. We hope to come out with a solution, which is not a very short range, but may be a for years, so that this recurring very serious problem is taken care of.

Address on behalf of NATP

S. L. Mehta
National Diector NATP
Project Implementation Unit, New Delhi

His Excellency Shri Gaj Singhji, our DG & Secretary, DARE, Dr. Panjab Singh, Dr. Samra, Dr. Pratap Narain, Dr. Gurbachan Singh, Dr. I.P. Abrol, Distinguished participants to this brainstorming session, Media Presonnel, Ladies & Gentlemen.

This is indeed a matter of privilege for me to join you for this very important Brainstorming session. In fact this year's drought is unprecedented. My brother made an analysis of the rainfall data for almost 100 years in the region. It is for the first time in 100 years that the region in July and August received less than 10% of the rainfall of entire Rajasthan. It never happened in the past. We had several droughts, but then some districts faced severe drought, while others received good rainfall and, therefore, our strategy will have to be little long term. I will like to compliment Dr. Pratap Narain, for very timely organising this brainstorm. Dr. Abrol also played an important role. He suggested long back that we organize this meeting. In fact, at ICAR level there had been tremendous push by our DG to organize such meetings in different parts of the country. ICAR itself is also coming out with a contingent plan and, therefore, the inputs from this brainstorm would help us tremendously.

As far as NATP is concerned, realising the importance of both rainfed ecosystem and arid ecosystem tremendous support has been provided. In fact, total support under these two ecosystems amounts to Rs.130 crore. In addition, we have projects which have been running under mission mode. Some aspects are also covered under teams of excellence. Total support is about Rs. 200 crore. This support, considering the entire NATP budget itself, is Rs. 992 crore, including the extension part, and I have not included whatever we are spending under extension efforts, especially IVLP and TAR program. From the council, major effort has been directed in studying some of the major problems of the rainfed and arid regions. As we all know, this region is characterized by low and erratic rainfall. In many years either there is late onset of monsoon or an early cessation of the rainfall, or there is long period of drought during the crop season. This is not very uncommon. However, if we look at our total rainfall that we receive and compare it with that of some other countries which get still less than ours, we find that despite getting much more rainfall we are not able to manage it properly. Therefore the focus of various research projects under NATP has been many-fold. The foremost has been, of course, watershed management, *in-situ* water conservation, development of varieties and production schedules, which can mitigate the effects of drought to some extent. In addition, a major emphasis is on starting, or at least assessing those programs which can generate employment and can also bring major economic benefits. We have started program on poultry, brackish fish, fish culture, and these are very popular. These can also generate additional employment. But most important part is if you look at the total occurrence of this drought, especially in this region, we find that out of 5 years one is a good monsoon year, two are really bad monsoon and two are average monsoon.

The life support system in this region is mainly based on perennial crops, perennial trees and perennial vegetation. Therefore, our major emphasis is on development of genotypes of shrubs that have commercial importance, like ker, guggal, isabgol and many other crop species. Therefore, we try to popularize them and try to bring additional income to farmers. That again is a major emphasis in arid ecosystem. The program also supports maximizing the water use efficiency. For example, as I said we are still getting higher rainfall compared to Israel, but yet we are not able to the get level of production which is comparable anywhere. Therefore, the efforts need to be made to popularize the sprinkler irrigation and drip irrigation. Diversification of agriculture is another major objective, so that at least when we diversify there is some assurance that some crops would still give you some return. If we depend on a system that has high water requirement then this would not be possible. Farmers would not get adequate return in time of drought and, therefore, there are certain issues which will have to be taken into consideration, which I find they are not being addressed to in sincerity. First issue is about the water recharge. In fact, during the period of good monsoon are we taking adequate care that groundwater is recharged, because everywhere the report is that the water table is going down. Earlier, water in many wells were at 80 to 100 feet depth, but has gone down to 200 feet depth in this region, and even 300-400 feet level. What are our efforts to look at water recharge? Even in those good years, when we have good rainfall, can we put measures which would make this water recharge possible?

In this region the survival depends on animal wealth. We have rich biodiversity and animal husbandry is an important occupation in the region. Therefore, can we think of long term planning, that fodder is available for the animal wealth of the region. Can we save fodder harvested during good rainfall period and to conserve this fodder for years to come. You know, at least for 1 or 2 years of drought that we get, normally farmers do store some fodder. It is not that they do not store, but that lasts for couple of months only. It is not possible for them to have fodder for longer duration of time and may be our efforts are needed not only to harvest more fodder, but also for conserving fodder. Fodder transport is another problem. It is bulky, costs money and, therefore, efforts done in this direction in arid region of developing feed block making machine will go a long way for easy transport of fodder. In making such blocks one-third compaction can be done and not only these blocks can be made, but you can also add vitamins and mineral supplements, which are good for animals. Such approaches are good and need to be taken further. Agri-horticulture is another issue. In fact, lot of support has been provided for agri-horticulture, which is a part of diversification process. When some of these horticultural plants or trees are established their water requirement is not that much. Once these survive and are established in two years' time, may be after third year, you do not have to worry for irrigation/watering. So why cannot we do that? Take Khejri, which is a life line of the region. Have we developed a protocol to make it grow faster? Today biotechnology offers lots of solution, in fact it helps in not only propagation of the material, but also their improvement. These are immediate issues that need to be focused.

With these words I would like to thank Dr. Pratap Narain for arranging this brainstorm and we are looking forward to the recommendations of this brainstorm so that both short term and long term contingent planning may be made.

Thank you very much.

Address by Chief Guest

Panjab Singh

Secretary, DARE & Director General
Indian Council of Agricultural Research, New Delhi

Most respected Shri Gaj Singhji, Dr. J.S. Samra, DDG, NRM, Dr. S.L. Mehta, DDG & ND, NATP, Dr. Pratap Narain, Director of this Institute, Dr. Gurbachan Singh, ADG, who is looking after these programs, my distinguished very old colleagues, Dr. S.D. Singh, Dr. M.B.L. Saxena, Dr. J.P. Gupta, Dr. R.P. Dhir, Dr. I.P. Abrol, who was in charge of this institute for a long time, Directors from different Institutes of the region, Dr. H.P. Singh, Dr. Mruthyunjaya, Divisional Commissioner of Jodhpur, Distinguished farmers, Jaisalmeriaji, Bhairon Singhji, Shakti Singhji, Heads of Division of this Institute, Scientist colleagues, Guests from various sections, Participants from various institutes, press and media, Ladies and Gentlemen,

At the outset I welcome you all at this very important meeting, particularly His Highness Shri Gaj Singhji, who has been monitoring and implementing various programs, which directly influence drought management in the region that you are strengthening here. It is right of Dr. Pratap Narain to have contacted him, so that we are not only able to project the problems that we have, but we are also able to steer the programs that we plan to do, and in doing that perhaps his association, guidance and his vision will help us. He is so dynamic that his presence is most important to us.

Drought, drought, drought all over the country. For the last two months we have been talking only about drought in every region that we go. This brainstorming meeting that you are organizing here is a part of that countrywide dialogue on the subject. We have had it at Hyderabad, we had it at Nagpur, we also had it at Rahuri, and we are also going to have it in the northeastern region. Day after tomorrow we shall meet in Delhi, where a large number of participants will come from different parts of the country, not only to plan for what we have now, but also to plan for the second season that follows kharif. It becomes more important for us to plan for both kharif and rabi seasons, and therefore, this brainstorming session is very important for us. We have to think about short term, medium term and long term planning because we have to find a permanent solution to this problem of drought, and provide the right kind of technical know-how to the people. If you look at this year's rainfall, almost all the districts of Rajasthan, except perhaps Dungarpur, have deficit rainfall that varies from -19 to -20% in some, and more than -60 to -80% in many, causing a serious drought problem. Jodhpur has received so far less than 20 mm rainfall, which is as good as no rainfall, because the moment it falls it gets evaporated. We are not able to make use of this rainfall for cropping under most situations. So, obviously you can see that you have gone rainless and, therefore, a good management strategy is necessary to tackle such situation. Of course we will never wish this kind of situation to be repeated, but you cannot leave aside these things arguing that this is a rare phenomenon, or that such severe conditions recur in the small driest part of the country. We have to face the situation. Now, managing the drought and famine has been in practice in this country for centuries, and some people may say that there is nothing new in contingency planning for drought and famine, that famine relief or drought relief in modern time was started about 200 years ago. I was reading somewhere that an English gentleman noted about 150 years back, that in the north-western part of the country, particularly in Rajasthan, famines were not famine for food, but for work, and therefore we have to look at it this way: where there is work there is money, and where there is money there is food. In other words, the whole strategy that is being designed and developed, is poverty alleviation through employment generation and enhancing the income of individual farmers. Water stress as well as excess of water are both real problems in our country.

I still remember the dual problem of drought and flood, which struck western Rajasthan in 1979. First there was drought in the whole state, and then subsequently it was found there was flood in the Luni river basin. Flood creates a problem in many states of India. Some states can be visited by floods in a particular year, like this year in West Bengal and parts of Bihar, or the north eastern states. On the contrary, you have drought in large parts of the country. If there is high rainfall in August-end or September, we may have to manage both flood and drought in some regions, and I want to repeat that it is every year's phenomenon. This year the drought has become very serious, as it has spread countrywide and that is why there is lot of hue and cry. It is time that we do something better to mitigate the effects of droughts and floods. We have to evolve some functional programs so that we are really able to address these issues effectively. Now, I was also reading a recent report from the Center for Monitoring Indian Economy that says that the production of this year's kharif crops is likely to decline by 11% than what we had last year. The report says that overall crop production in 2002-03 may decline by 4.9 to 5%. How far it comes true is a question to be seen. The poor rainfall has so far resulted in a 30% drop in the area sown under food crops all over the country, and it is a grim situation that you find in Rajasthan. There is an apprehension of having about 10-20% decline in the overall yield of kharif food crops, and more of oil seeds. Rice production may be seriously hit in many parts of the country. Some disturbing numbers are: UP -58%, Madhya Pradesh -65%, Chatisgarh -30%, and Haryana -42%. If it happens, then the country's rice production during kharif, 2002, is expected to be about 70 million tonnes, which is about 12% less than what we got last year and for 2002-03 as a whole 83 million tonnes, compared to 92 million tonnes in 2001-02. In Rajasthan, the major crop is bajra, and it has been very severely hit this year. However, the region is facing a larger fodder problem than a grain problem, and also a water problem, although there is shortfall in food grain production. Fortunately, India has attained some kind food security and you must have listened to the Prime Minister's speech on 15th August, when he said very categorically "Hum sukhe me bhuk se nahi marne denge". The idea behind was that we have about 60 million tonnes of food in reserve, we can move it from one place to another. But it is almost impossible to move large amounts of fodder from one area to another, or even water from one place to another. It is going to be a very serious problem, and that is why we attach more importance to the discussions that you will have on these issues, and suggest some activities that could be put in action, so that these problems are taken care of in a better way.

I have touched upon few issues on which we are going to have two days of deliberation. I am very happy that we have many good participants here, who understand the mechanism and management of drought, and are eager to discuss about what we should plan from everyone's angle. You are here from various states like Gujarat, Maharashtra, Rajasthan, Haryana, etc., and I am sure we will be able to come out with some good suggestions and strategies. Now, one very urgent thing that emerges is the insured supply of

Dr. Panjab Singh (Chief Guest) addressing the audience

Dr. J. S. Samra addressing the audience

food and drinking water that is being talked at the national level, both for human and livestock population, livestock particularly in the state of Rajasthan. Livestock is linked with the livelihood security here and, therefore, livestock becomes much more important. We cannot leave livestock. We have to design the techniques to manage and keep them productive for the time that we are keeping so that we can meet the livelihood security that we are talking about in the region. We have central and state governments' joint programs, more particularly on food security, which is being talked about now. It should be an open-ended food guarantee scheme on the model of employment guarantee, which was floated in MP, so that we are able to withstand this kind of situation that has come this year. Then, we have the universal and user-friendly public distribution system, which is being promoted by the government, and in the process we have integrated implementation of safety networks, under which many programs have come up, like Annapurna yojna, Antodaya yojna, etc. Even mid-day meal programs in schools and food for nutrition program are also being talked about. Some of these are being talked about at the national level, like the community food and water bank, which was talked about recently, and can be tested at selected places. Then, there are discussions like fodder bank, seed bank, food reserve, etc. As I said, in food we have made some headway, but we still have to make headway in areas that are left out, like fodder bank, or an integrated crop-livestock saving technology. That is a major thrust that we have to consider, and can we really think in terms of contingency planning in that context? Can we think in terms of alternative cropping development or systems that can support the production programs, and can we really have some kind of compensating mechanism in food production programs, or for the livestock production programs of the system? It is in this context also that we are trying to organise this kind of brain storming at different place s, so that we are able to screen out certain ideas and develop some useful programs in near-future.

It becomes more important that the economic and social impact of drought must be looked into. Also, the assessment of the existing approaches is necessary, and the policies concerning how we take the recommendations forward, how to project these, and how we implement these, so that we do not feel sorry that we had some strategies, but we were unable to implement those. I wish you will address these policy issues also in the sessions. Some of these could be state level policies, or the central government policies. Some of the developed programs could be labour-intensive and labour-oriented, so that people are able to get job and meet the demands of water, food, livestock, etc. Then we should have some medium term plan, which we should also discuss in detail. Finally, we must look into long term plan, since these are very important. I must also tell this house that we have models, which have been demonstrated, and which have been tested. There are experiments, which have been very well laid, whether you come to Rajasthan or you go to other parts of the country, which are facing drought. All perhaps you have to do is to test these models outside your region or state, and find its real potentials. Kindly then think of a plan where we involve ICAR, state agencies and other agencies, which are playing a role, the NGOs, the private sectors, and design a plan that cannot only normally be visualized, but also could be implemented. Right now I can say that there are good examples.

Even if you talk of the desert in Rajasthan, we had been saying that the region can meet the whole country's milk requirement. Can we think of an integrated plan through which it can be put to practice technical, policy framework, socio-cultural isssues, all integrated? Water is a problem here, but not that serious a problem if you manage it properly at the country level. The average annual rainfall of the country is so much that if you collect it properly it will cover the whole surface of the country by 1 m or so, allowing people to have 3-4 crops annually. Still, there are floods in Rajasthan and droughts in Cherrapunji. That obviously shows the mismanagement of the situation that we have. Given the kind of resources that the country has, including brain power, we should be able to plan and organize activities to scientifically manage water. What is needed is to integrate the programs of various agencies and their resources, and prepare a perspective plan, which can then be put to action. The time has come to act in this direction. We have excelled in food production, and we have shown the world that we can produce food and feed not only India, but also other countries around us, who need it. We should accept the challenge and come forward as scientists with good plans to manage the deserts, manage the droughts and manage water, not only for production of crops, but also for all other sectors, like livestock and industrial set up.

We have the technologies, which have proven merits, we have the successful models, and there are takers who are really able to do wonder with the technology. I still recall that once we promoted improved Ber in CAZRI during the 1970s, progressive farmers adopted the technology, multiplied those plants and generated huge income. Ber has now gone from Jodhpur to beyond the boundaries of Rajasthan and has become a success story in states like Haryana, Gujarat, Maharastra, and other parts of the country. As a matter of fact, the other day when I was in Rahuri, farmers were cutting ber trees. They said that there is so much of ber production now that the prices have gone down too much. There was a time when it was considered to be a very unliked and unwanted fruit. Now it is sold at Rs. 20 per kg, well packed, at the Connaught Place. We have produced it, but we have over- produced it, which is bad from economic point of view. To address such problems we need proper policies.

With these words, I once again welcome all of you. I hope that the session that you have organized here and elsewhere in the country will give us some new ideas on which we can really rest our foundation and march forward, so that we are able to say to the country that here are the technologies from the scientists, which can be relied upon, particularly under the situations like the one we face now. The meeting on drought that we are going to hold on the 25th August in Delhi will be presided by our honourable Minister, where we shall discuss our contingency or strategy for the next rabi season. Since kharif time has almost gone, we have now to plan for the rabi. In this particular session we can even think of what we can plan for fodder, because fodder is very important for Rajasthan. Can we think of some very short duration crop varieties, which can be grown here, and can be grown with little water or even canal water? Can we make suitable plans for survival of the animal, and make plans for fodder availability? Let us think jointly, come forward with some kind of program, some technology, and some action plan, which are adoptable. We can think of joint programs involving NGOs, farmers, private sector and public sector, so that we can execute a good program. I am very happy to be here and thank you very much for coming here to participate in this important brainstorming session.

Presidential Address

Shri Gaj Singhji
His Highness Maharaja of Jodhpur

Dr. Panjab Singh, Dr. J.S. Samra, Dr. S.L. Mehta, Dr. Gurbachan Singh, Dr. Pratap Narain, Divisionl Commissioner, Distinguished scientists, Agriculturists, Faculty of CAZRI, Citizens of Jodhpur, Members of the Press and friends, for me it is always a pleasure to come to this Institute. Ever since I returned after my education in England, I have taken the opportunity of attending various conferences, seminars and field visits with CAZRI scientists and have been enlightened by the experience. I had a very good rapport with some of your past Directors and scientists. It is, therefore, a matter of great pleasure to interact once again with Dr. Panjab Singh. I know him from those early days and I have seen him arisen to the top in the field of his specialty. I am grateful to organizers for inviting me and giving me the opportunity to share with you some thoughts during this brainstorming session. Of course, the learned speakers before me are specialists in their fields. I happen to be just a layman. But this is a topic of concern and it did interest me since I inherited it from my ancestors, who ruled this part of the country for several hundred years and had to face this problem of recurring droughts from time to time. So, drought management and plight of the people, the plight of the animals have always been uppermost in our minds. It is a part of my growing up and commissioning that I had and, hence, I greatly appreciate this drought management conference taking place at this very crucial time when we are passing through the worst drought that we have witnessed in 100 years. I certainly cannot remember anything like this in my life time, of course, 1987 was a bad year and whole of the mid-eighties were bad and I remember at that time taking a padyatra to Ramdeora for the rains. Fortunately rains did come subsequently, and we had in the nineties a good cycle, which seems to have run out in the end of nineties and in the last 4 years. We have now come to this crucial point that we face now.

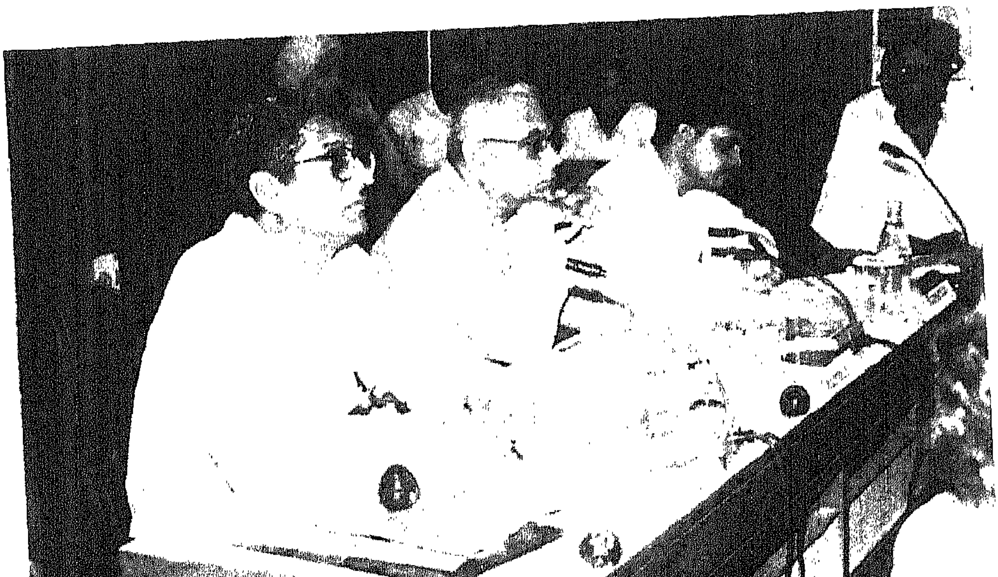
In Rajasthan there is an old saying and also we believe in certain cycles. There is a saying that in 100 years there are 7 acute years of drought, 27 years of scarcity, 63 years,

His Highness Gaj Singh ji delivering presidential address

Dr. Panjab Singh releasing the publication which are manageable average and 3 years that are exceptional. But, we have been unable to predict very accurately those cycles and the worst is that today we are facing the problem in most parts of the country. If only we had proper warning system we could have prepared ourselves for the season ahead. In these desert regions we know this is a recurring phenomenon and we have to be prepared for it. We do not react, we have to be proactive and think in the long term what needs to be done, and why it is to be done. Only yesterday I was with our Finance Minister and I asked him whether there was any immediate forecast. He said, we do not have really accurate long-range forecast and he was also consulting various international agencies for information.

So let us also look into the rosy sides; invariably in such situations there are last minute downpour and you get unprecedented amount of rain. How do we cope during the interim period, and how are we going to cope with the rain when this does come and make most of it when it does come? Drought is not easy to predict. It is perceived in different ways by different people. The meteorologists perceive it in terms of rainfall, the hydrologists in terms of water levels and ground water, the agriculturists of course look at it in terms of their crops and the animals and the sociologists and economists look at it and assess its impact on the lives of people. You are in a forum such as this where we are looking not only at immediate out come and what can be done, but also at long term where we have eminent scientists, who are in touch with the latest technologies, for developing new crops, new varieties that are resistant to diseases, that require less fertilizer, less water. At the same time we also should not forget our traditional systems. In arid region like this we did depend on animal husbandry. We depended on mixed farming, vegetation, mixed cropping, mixed livestock and also on sturdy varieties of indigenous crops. These are the roots on which the agricultural development takes place and the foundation on which new scientific technology must be built and wed it to. Along with this we had our traditional methods of water harvesting. Rain water harvesting is well known to all of you, and you have seen the effects of perched water, under ground water, subsoil water and salinization. We have forgotten what was done by village communities to maintain and sustain various community systems like the talabs, and even the personal water harvesting, which took place in the tankas, the bawaris, and roof tops. We have abandoned the systems. As we see in Jodhpur also, Jodhpur had wonderful system of rain water harvesting. It is now felt, it is now required, because we are getting sufficient ample water from Indira Gandhi canal. Of course we know that was required because population grew at such a rapid rate we could not cope. During my grandfather's era, water was brought from Aravali's from Jawai, that kept us going for some time. But even that outlived. So requirements of people and industry have increased and population has also increased putting pressure on water resources. The increased population will take a big toll on fragile ecosystem and the natural resources that we have. These are the things that you have to take a note of and to see how best we can face them, and how best we can regulate our policies and our own life style in order to minimize the impact of drought and to minimize the sufferings of people and to see that people are well fed, happy and have sufficient work to do. I have been involved recently in these water harvesting projects. Thanks to my interaction with Rajendra Singhji, the Magsaysay Award winner who has worked in Alwar district. Some of the members of our trust visited there recently to see the impact of work done there. The areas are badly suffering there. But in areas where harvesting structures have been put up, it has changed the whole vision of the people and the whole scenario of the villages and there is still activity. Three is water and people are able to meet the water needs. Water levels in the region are dropping at an alarming rate, in a frightening manner. These water systems, the small community-based water systems, I think are very important things, they lead to community participation and they lead to capacity building. It is to be done with the community participation. It is to be done with empowerment of the lower classes, depressed classes, farmers, women, everybody in the field and also the environment around. Be it livestock development, catchment area protection, all these have to be brought in our thinking, to our policy making and to our public representatives to put across to our people. We have to think in the long term. We have to think together. As Panjab Singhji just said, it is not for any individual, any institution to take up, but this is an issue we all have to get together and work together as specialists, scientists and as NGOs as administrators and policy makers. You, in this forum, over the next few days be deliberating on a number of issues, and we hope and we look forward to these deliberations and you

Dr. S. L. Mehta releasing NATP-Research Highlights



Dr. I. P. Abrol chairing on contingency planning session

findings, but at the same time we hope these findings are put in a way that are, I suggest three-fold or even four-fold, most importantly for the common man, for the farmer, that are simplistic, understandable, implementable and they achieve results within a short period of time. Then, of course, there are scientific decisions that you have to take, scientific approach that is required. Third is what the administrators can do, along with the NGOs, to help implement what you are recommending. And finally and most importantly, I think it is important to have policy, correct policy, and you as a scientist I hope, will be able to influence some of those policies that would lead to proper land use, proper development pattern, proper industrial and educational development pattern in different states which have bearing on what those areas, those states are able to produce. The land use and cropping pattern have to be very different in different areas of arid zone, in hilly areas, in different places, looking to the concentration of the population, and out of these most vital and important thing that needs to be addressed is to have some kind of sustainable growth and involve our communities and all people in a rational approach to land use. I think there is also a need to consider land policies for long time. We have to prepare the distribution of land to be of vital importance so that every individual has an opportunity to possess land, but we have come a long way in that some of the land distribution policies have not gone well either, but at the same time green revolution has been a success. Our godowns are over-flowing to the extent that the major beneficiaries are the rats. We have on the other hand overtaken China and Thailand in export of food grains in this region. This is a major achievement, which should not be looked down. We have sufficient food as Prime Minister said, but we have to adopt an improved distribution system. It would be better that those areas which face economic crunch need better management and do not rely on these emergency stocks. In that I feel that some time the investments required to make these line productive are of high nature and, therefore, the land policies also need to be looked at very carefully as they are in Egypt, Israel and other places where they have put in a lot of investment, but in the long run the yields are far better and of greater value to the country and they are able to sustain themselves in export of fruit and other vegetables to Europe and other places despite being extreme desert areas. These are some stray thoughts that I shared with you. Other areas include development of pasture land. I think in development of green revolution and the white revolution we have forgotten about the development of pasture land. We have this very magical quality grass, the sevan grass, which is being either over-exploited or being flooded or being dug out by tractors and the land is used for other types of cropping patterns which may not be suited to those regions in the long run. Again the advent of Indira Gandi Canal has been a blessing in many ways, but are we making best use of these waters or are we making the best use of land around? These are the things that need to be thought of, so that we get much more and maximum returns of the investments that we have already made. And we can ill-afford to make heavy investments in large projects and not get the returns that are required. Hence the approach referred to earlier to involve people in the projects in village areas is an approach that is of vital importance. Once again my thanks to you in asking me to be here and giving me this opportunity to speak to you, to hear your deliberations. I regret, due to other schedules, I will not be able to participate in your deliberations for the next few days, but I can assure you that mentally I am with you and I look forward hearing some of the outcomes and hope to assist in their implementation and propagating some of the knowledge down to the level of people.

Thank you once again very much,

Vote of Thanks

Gurbachan Singh

Assistant Director General
Indian Council of Agricultural Research, New Delhi

His Excellency Shri Gaj Singhji, Dr. Panjab Singh, Secretary, DARE and DG, ICAR, Dr. J.S. Samra, DDG (NRM), Dr. S.L. Mehta, ND (NATP), Dr. Pratap Narain, Director, CAZRI and distinguished participants.

It is my proud privilege to propose a vote of thanks on behalf of the organisers and on my own behalf. We are highly grateful to His Highness Maharaja Shri Gaj Singhji who has spared his valuable time to grace the occasion and delivered the presidential address. Presence of Dr. Panjab Singh on this occasion indicates the concern of Council to meet the challenges of the serious drought. Sir, I express sincere gratitude to you for being with us on this occasion. Dr. Samra has been a guiding force all along in the organization of this programme. Sincere gratitude is due to him for extending all the needed support. Sincere thanks are also due to Dr. Mehta for extending financial support through NATP and for his presence on the occasion. It was Dr. Abrol, Chairman, Scientific Advisory Panel of the Arid Agro- Ecosystem of NATP, who not only perceived the holding of this programme, but also pursued and planned the activities. All appreciations and thanks are due to him. We are very grateful to Dr. A. S. Faroda, Vice Chancellor, MPUA&T, Udaipur, and Dr. C. P. S. Yadav, Vice Chancellor, RAU, Bikaner as well as to all the Directors of the ICAR institutes for their presence. Grateful thanks are also extended to various Central and State Government. officers, from different departments including DST, New Delhi; CCS HAU, Hisar; RAU, Bikaner; CGWB, Jaipur; MOA, New Delhi; NCAP, New Delhi; RRSSC, Jodhpur; SRSAC, Jodhpur; PIU, NATP, New Delhi; GUIDE, Bhuj; Gujarat Ecological Commission, Vadodara; AFRI, Jodhpur and Defence Laboratory, Jodhpur, for participation. At last, but not the least, thanks are also due to Dr. Pratap Narain and his team members for making excellent arrangements.

I Thank you once again.

Medium Range Weather Forecasting for Drought Prediction

L.S. Rathore

National Centre for Medium Range Weather Forecasting, DST, New Delhi

Drought is considered by many to be the most complex, but least understood natural hazard, affecting more people than any other hazard (Hagman, 1984). For example in sub-Saharan Africa, the drought of early to mid-1980s was reported to have adversely affected more than 40 million people. The 1991-92 drought in Southern Africa affected 20 million people and resulted in a deficit of over 6.7 Mt in cereal supplies (SADCC, 1992). Lessons from developed and developing countries demonstrate that drought results in significant impacts, although the character of these impacts will differ profoundly (Subbiah, 1993; Benson and Clay, 1998, 2000; Wilhite, 2000; Wilhite and Vanyarkho, 2000). Being normal feature of climate, its recurrence is inevitable. However, there remains much confusion within the scientific community about its characteristics. It is perhaps this confusion that results in poor drought management in most parts of the globe.

Predicting Drought

It is difficult to predict drought well in advance for most locations. Predicting drought depends on the ability to predict two fundamental meteorological surface parameters, precipitation and temperature. From the historical records it is evident that the climate is inherently variable and that the anomalies of precipitation and temperature may last for several months to several decades. How long they last depends on air-sea interactions, soil moisture and land surface processes, topography, internal dynamics, and the accumulated influences of dynamically unstable synoptic weather system at the global scale. The potential for improved drought predictions in the near future differs by region, season and climatic regime.

Empirical studies conducted over the past century have shown that meteorological drought is never the result of a single cause. It is a result of many causes, often synergistic in nature. A great deal of research has been conducted in recent years on the role of interacting systems, or teleconnections, in explaining regional and even global patterns of climate variability. These patterns tend to recur periodically with enough frequency and with similar characteristics over a sufficient length of time that they offer opportunities to improve our ability for long-range climate prediction, particularly in the tropics. One such teleconnection is the El Nino/Southern Oscillation (ENSO).

The immediate cause of drought is the predominant sinking motion of air (subsidence) that results in compressional warming or high pressure, which inhibits cloud formation and results in lower relative humidity and less precipitation. Regions under the influence of semi-permanent high-pressure during all or major portion of the year are usually deserts, such as Sahara and Kalahari deserts of Africa and Gobi desert of Asia. Even Thar Desert of India falls under the subsidence zone.

Most climatic regions experience varying degree of dominance by high pressure, often depending on the season. Prolonged drought occurs when large-scale anomalies in atmospheric circulation patterns persist for months or seasons or still longer.

In the tropics, meteorologists have made significant advances in understanding the climate system. Specifically, it is now known that a major portion of atmospheric variability that occurs at time scales of months to several years is associated with variations in tropical sea surface temperatures. The recently completed Tropical Ocean Global Atmosphere (TOGA) project has produced results that suggest that it may now be possible to predict certain climatic conditions associated with ENSO events more than a year in advance. For those regions whose climate is greatly influenced by ENSO events, TOGA project results may help produce more reliable meteorological forecasts that can reduce risk in those economic sectors most sensitive to climate variability and, particularly, extreme events such as droughts. However, in extra-tropical regions, current long-range forecasts are of very limited reliability. In the tropics, empirical relationships have been demonstrated to exist between precipitation and ENSO events, but few such relationships have been confirmed north of 30-degree north latitude. Meteorologists believe that reliable forecasts are attainable for all regions a season or more in advance.

Medium Range Weather Forecasting

The National Centre for Medium Range Weather Forecasting (NCMRWF) is currently involved in the preparation of five-day location-specific forecast by running a

Numerical Weather Prediction Model [18-layer Global Spectral Model (T-80) with roughly 160 km x 160 km horizontal resolution] on operational basis (Fig. 1 & 2). Computational requirements till recently were being met by CRAY X-MP. A new high end computer CRAY-SV 1 has been installed recently and the forecast will soon commence to be produced from T-170 model.

Anomalies During Monsoon 2002

Monsoon 2002 witnessed certain anomalous features in the wind and pressure fields. Tropospheric level-wise significant features are listed in Table 1. Based on the interpretation of these and other phenomena, NCMRWF issued weekly advisories on monsoon scenario in the country. Table 2 contains verification of the medium range forecast issued to Ministry of Agriculture. The forecast can be viewed in the light of actual performance of the monsoon over India from 1 June, as shown in Figs. 5 to 7.

Table 1. Wind and pressure anomalies during monsoon, 2002

850 hPa level (Fig. 3)	Easterly anomaly over Arabian Sea Anticyclonic flow over Arabian Sea Cyclonic circulation close to equator over Indian sea Cyclonic circulation over Afganistan-Pakistan region Cyclonic circulation over NW Pacific.
700 hPa level	Strong anticyclonic circulation over NW India with a ridge extending upto Central India Westerly anomaly over Gangetic Plains of north India Anticyclonic flow over Arabian Sea Cyclonic circulation over Afganistan-Pakistan region Cyclonic circulation over NW Pacific.
500 hPa level	Anticyclonic flow over Arabian Sea Cyclonic circulation over Afganistan-Pakistan region Cyclonic circulation over NW Pacific
200 hPa level (Fig. 4)	Prominent cyclonic circulations over Afganistan and China.

GLOBAL DATA ASSIMILATION-FORECAST SYSTEM

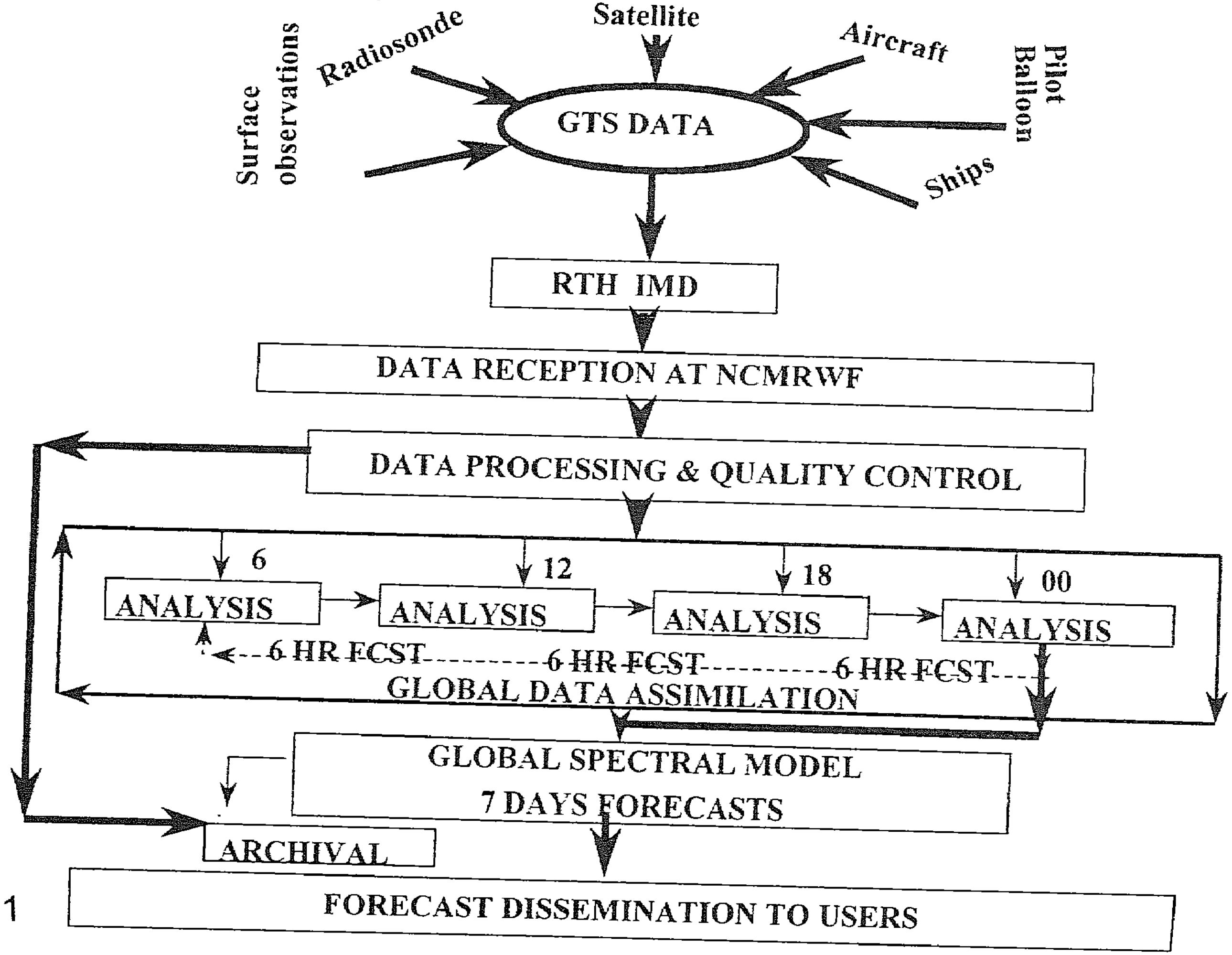


Fig.1

120HR FORECAST VALID FOR00Z20AUG2002
TOTAL PRECIPITATION (Land); Contours in cm
NCMRWF T 80 ANALYSIS-FORECAST SYSTEM

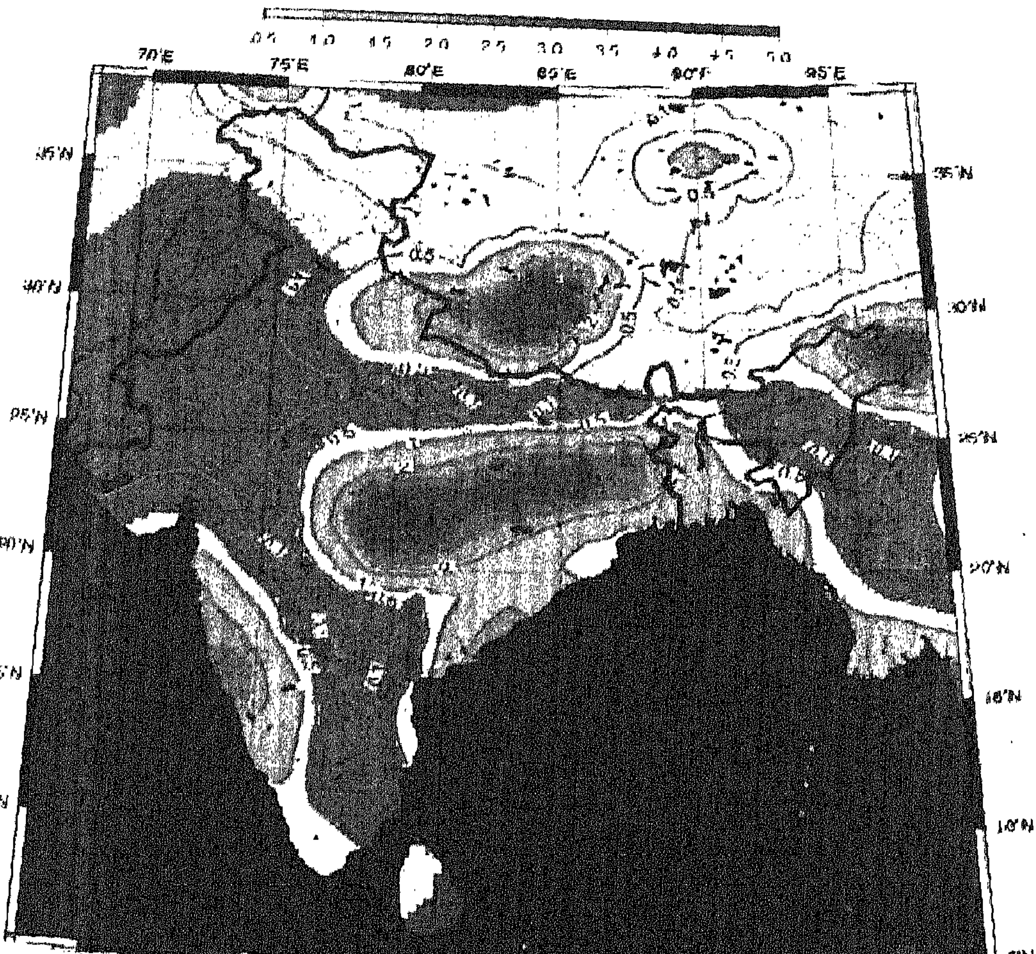


Fig. 2

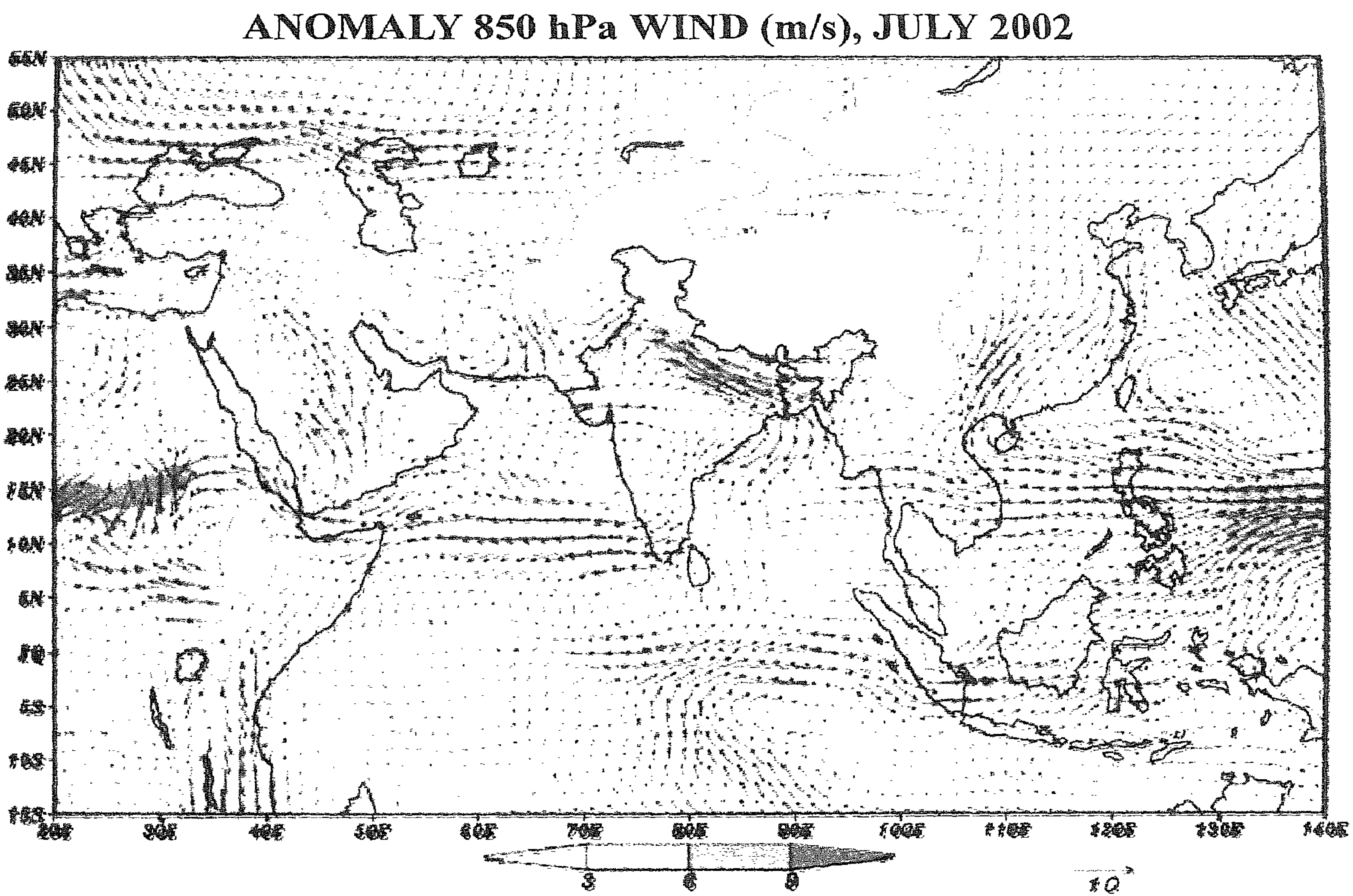

ANOMALY 850 hPa WIND (m/s), JULY 2002
65N
60N
45N
40N
35N
30N
25N
20N
15N
10N
5N
EQ
5S
10S
15S
20E
30E
40E
50E
60E
70E
80E
90E
100E
110E
120E
130E
140E
3
6
9
10

Fig. 3

ANOMALY 200 hPa WIND (m/s), JULY 2002

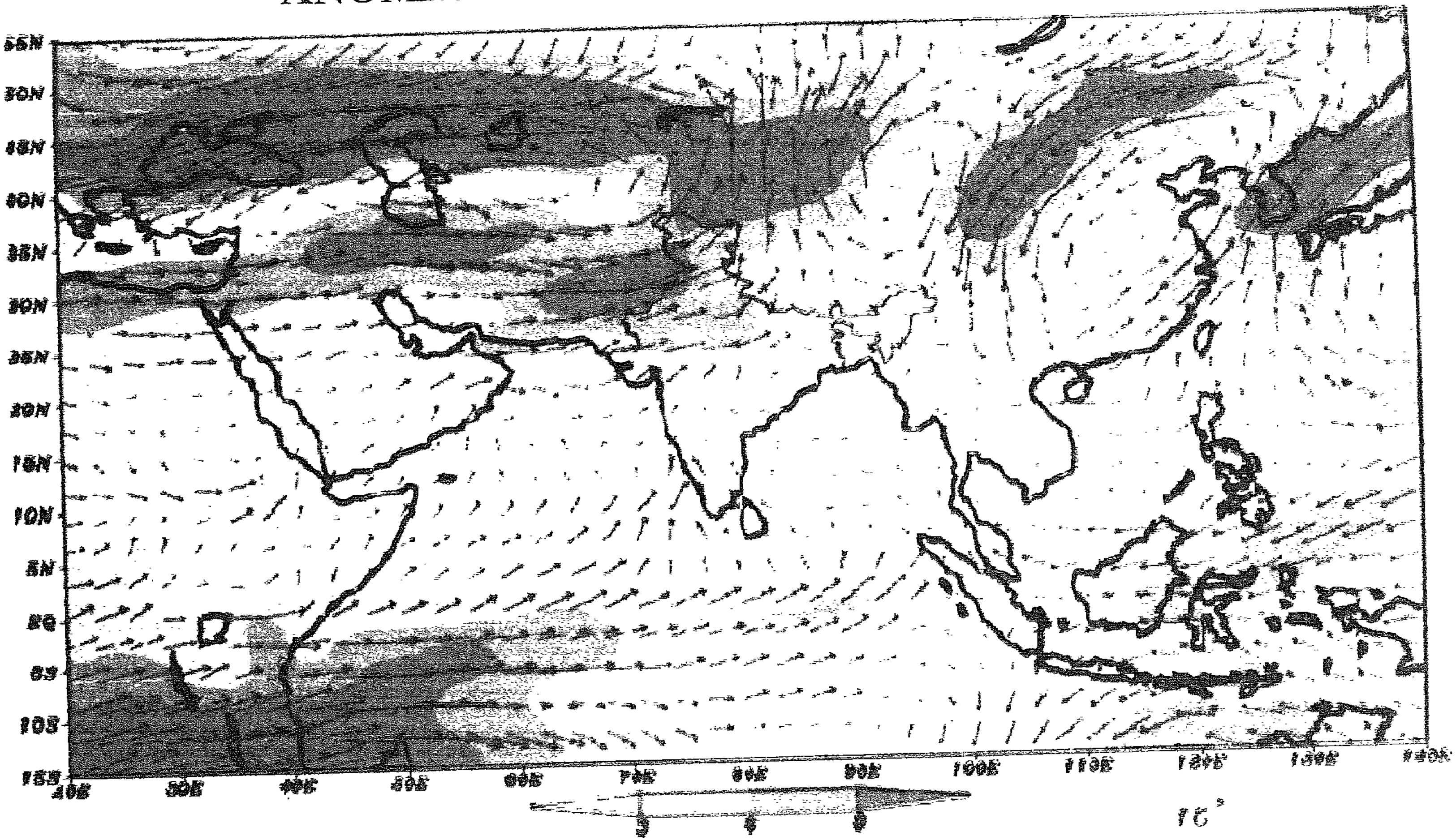


Fig. 4

MONSOON 2002:
Cumultive Performance of Monsoon Over the Country
For the Period Beginning from 1 June (Weeks)

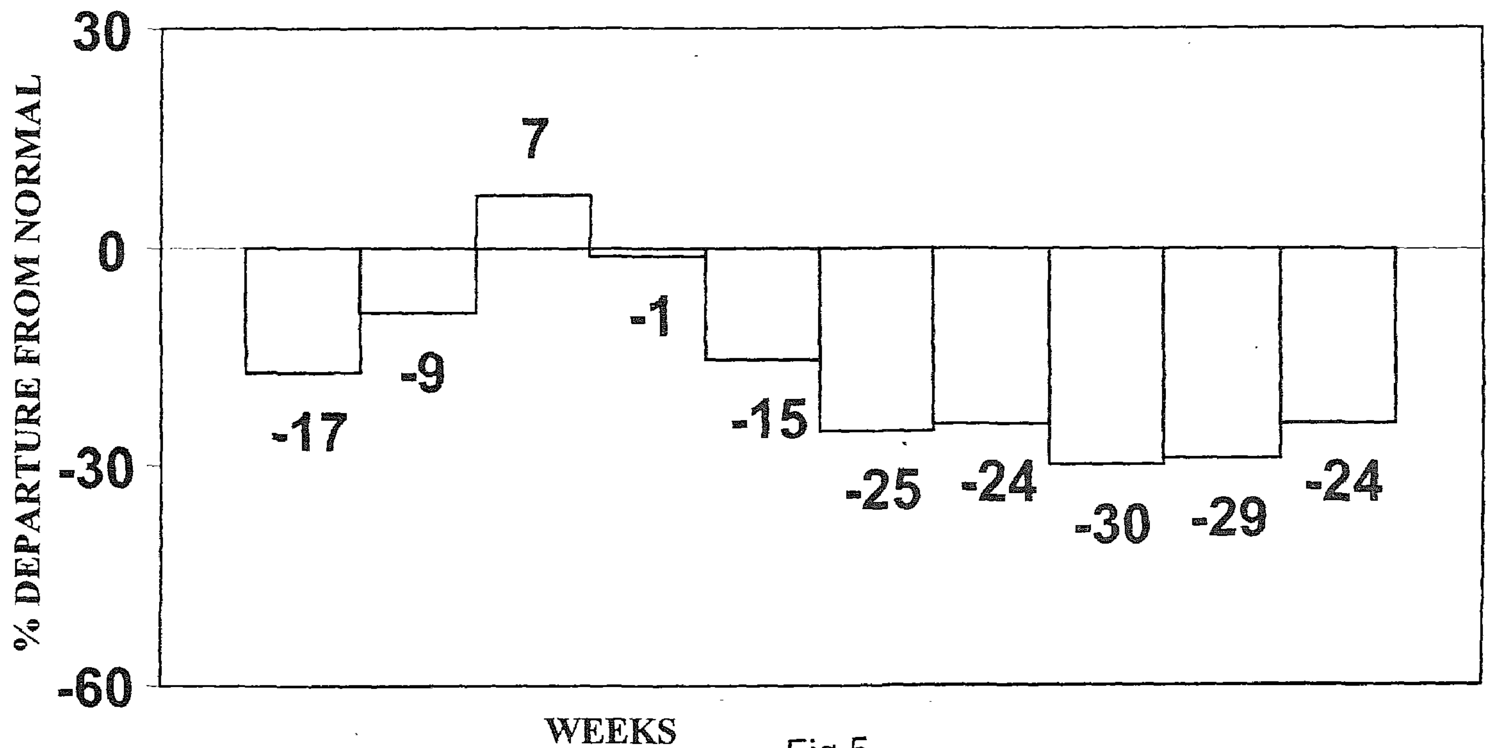


Fig.5

RAINFALL % DEPARTURE IN DEFICIENT METEOROLOGICAL SUB-DIVISIONS
(as on 14 August, 2002)

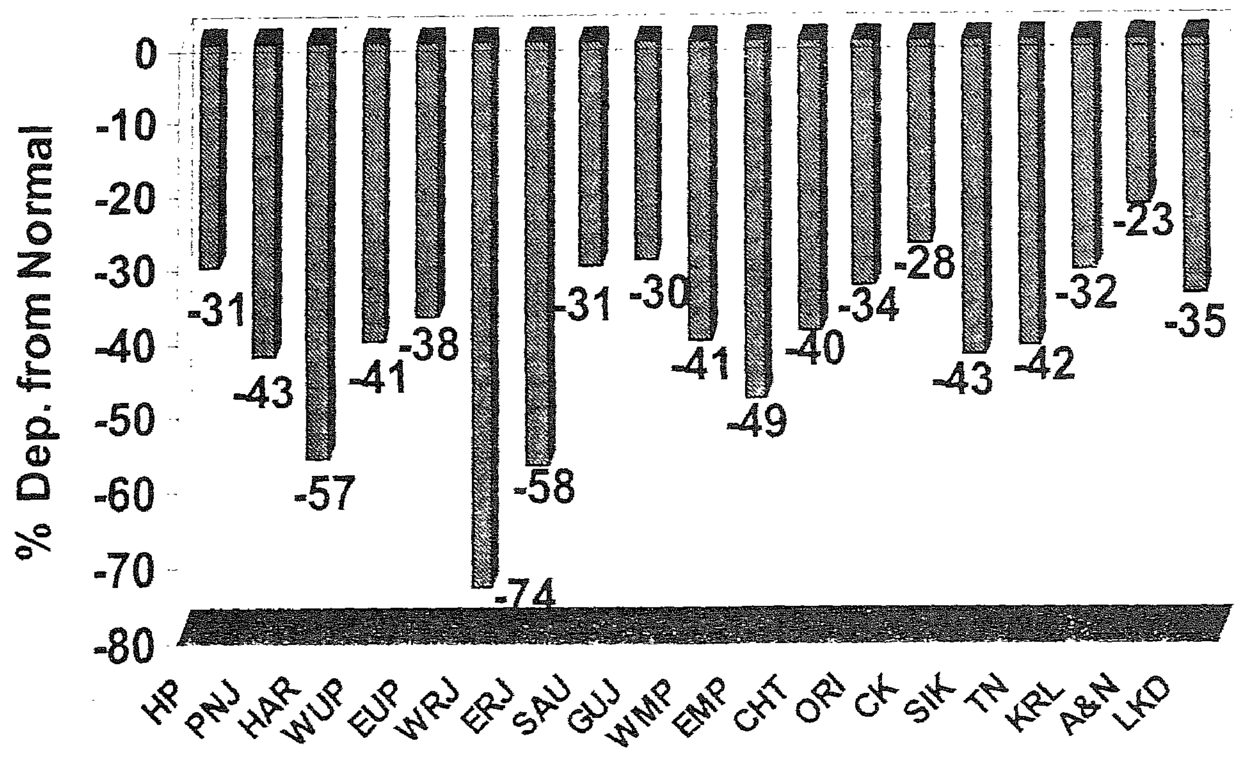


Fig.6 **Sub-Division**

MONSOON DEFICIENT YEARS: JULY *vs.* SEASONAL RAINFALL

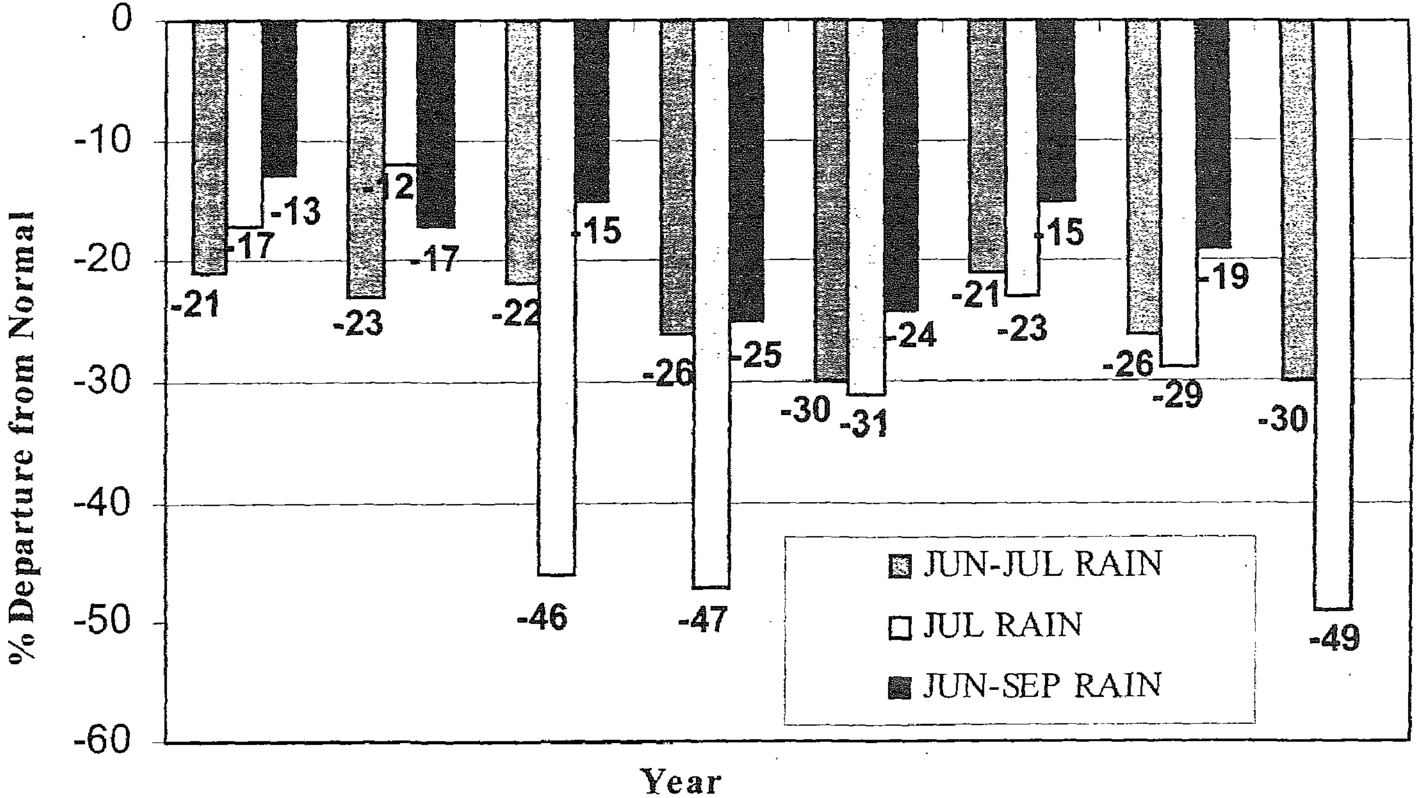


Fig.7

Table 2. Verification of prediction/advisories issued by NCMRWF to Ministry of Agriculture (Crop Weather watch Group) on drought condition over the country during Monsoon-2002

Date of issue	Period of validity	Advisory issued by NCMRWF	Verification based on IMD's weekly report
8-7-2002	8-14 July, 2002	No significant weather system persists over the Indian region. Hence, weak monsoon condition prevails over the country with major activity confining to eastern and northeastern regions.	
		Under the present circumstances, further advancement of south west monsoon is not likely during next 4-5 days. Rainfall activity over the country will remain subdued except over Eastern and NE India during next 4-5 days.	No advancement of monsoon observed till 14 July, 2002.
		Model prediction suggests formation of a low pressure system over Bay of Bengal and adjoining Orissa around 12 July 2002. This would enable reviving the monsoon flow over the country in subsequent days.	A trough formed over the east central Bay of Bengal on 12 July2002, which became a low pressure area on15 July 2002.
15-7 -2002	15-21 July, 2002	South-west Monsoon continues to be in weak phase over the country as it is so for past 2 weeks, with major rainfall activity confining to eastern and northeastern States.	
		Model prediction suggests no perceptible change in the situation during next 3-4 days and hence further advancement of monsoon is not likely till 19 July, 2002.	No change in the situation observed till 18 July 2002. No advancement of monsoon till 18 July 2002.
		Fairly widespread rains with isolated heavy to very heavy falls are expected over northeastern and eastern parts of the country	Widespread rains occurred over eastern and northeastern states

		during next 3-4 days.	
17-7 -2002	17-23 July, 2002	Based on analysis of 16 July, 2002, NCMRWF's model prediction suggests that the low pressure area which is currently seen over north Bay of Bengal & adjoining areas, is expected to move in a west-north-westerly direction, leading to revival of the southwest monsoon.	The low pressure area moved west-north-westwards and has revived the monsoon over Peninisular and central India.
		Under its influence, monsoon activity is expected to enhance over central and Peninsular India to start with. The regions which are likely to receive fairly widespread to widespread rains include: Andhra Pradesh, Chattisgarh, Madhya Pradesh, Uttar Pradesh, Bihar, Jharkhand, Maharashtra, Karnataka, Kerala, West Bengal, North-eastern States and sub-Himalayan regions of NW India during next 4-5 days.	Fairly widespread rains occurred in central and Peninsular India during 17-20 July, 2002.
		Conditions are becoming favourable for further advancement of Monsoon in next 2-3 days.	Monsoon advanced into most parts of NW India, including Delhi on 19 and 20th July, 2002, leaving a small portion of NW India.
22-7 -2002	22-28 July, 2002	The western end of the Monsoon axis has once again shifted to foothills of Himalayas (indicative of weak monsoon phase). Model prediction suggests no improvement in the situa tion till 25 July, 2002. However, it does indicate formation of a monsoon system over North Bay of Bengal on 26 July, 2002.	The monsoon trough continues to lie close to foothills and no improvement in this situation was observed till 26 July, 2002.
		Under the circumstances, eastern parts of the country will receive copious rains, causing flood situation particula-	A cyclonic circulation formed in the middle tropospheric levels (between 3 and 5 km above mean sea level) on 25 July, 2002.

		rly in Bihar, West Bengal and north-eastern States whereas Gangetic plains in NW India (U.P., Haryana and Punjab) may continue to experience only isolated rainfall activity during next 4-5 days.	Eastern parts particularly Bihar has received good rainfall with isolated heavy fall. Northwest India experienced subdued rainfall till 26 July, 2002 with only isolated rainfall activity.
25-7 -2002	25-31 July, 2002	Weak monsoon condition continues to prevail over the country with monsoon trough running close to foothills. A cyclonic circulation exists in the middle tropospheric levels over North-east Bay of Bengal. Model prediction suggests that this may descend down to lower levels by 28 July, 2002 and thence move inland in a west-north-westward direction. This may help reviving the monsoonal flow over the country. With the revival of monsoon, the areas which are likely to receive fairly widespread to widespread rainfall activity include: Orissa, Chattisgarh, East Madhya Pradesh, Coastal Andhra Pradesh, Telangana, Vidarbha and West coast of India.	Weak monsoon condition prevailed till 29th July, 2002. Monsoon revived on 30 July, 2002 with the formation of a low pressure area in the Bay of Bengal. Good rainfall activity occurred in the central India.
29-7 -2002	29 July-4 August, 2002	The monsoon is expected to remain in weak phase for next 2-3 days as the model continues to give a weak signal of formation of a low pressure area in the bay of Bengal. A weak trough in middle and upper tropospheric westerlies lies over Pakistan and adjoining area, which	A low pressure area formed in the Bay of Bengal on 30 July, 2002. NW India received isolated rainfall activity 30 July 2002 onwards.

		may provide isolated rainfall activity over NW India during 1-3 August 2002.	
1-8-2002	1-4August, 2002	Monsoon has revived, although, as weak current, with the formation of a low pressure area in the Bay of Bengal. It presently lies over Chattisgarh and adjoining area. It is likely to move north-westward and weaken gradually. Under its influence scattered to fairly widespread rainfall is likely over Orissa, Chattisgarh, Jharkhand, M.P. and U.P. Monsoon trough is likely to remain in the normal position over gangetic plains of north India for next 3 days. An east-west wind shear zone (indicative of renewed monsoon activity) has formed across the south peninsular India. Model suggests its northward movement. Under its influence the rainfall activity over West coast and South peninsula is likely to enhance during next 2-3 days.	The low pressure area moved west-north-westwards and provided fairly widespread rains in Central India during 1-4 August 2002. Monsoon trough remained over Gangetic plains of North India during 1-4 August 2002. East-west shear zone moved northwards and enhanced rainfall activity over Peninsular and Central India.
5-8-2002	5-11 August, 2002	Monsoon trough is at the normal position. Other components of the monsoon are also favourable. Model prediction suggests that such a situation may continue for next 5 days thus indicating good prospects of monsoon rains over different parts of the country However, parts of West Rajasthan, Punjab and Haryana may continue to receive subdued rainfall as the model forecast indicates prevalence of anticyclonic wind flow in the lower-middle tropospheric levels over the region.	Monsoon trough remained at the normal position throughout the period. Fairly widespread rains occurred over Peninsular and Central India. Northwest India continues to receive subdued rain.

Extended Range Prediction System and Outlook for August, 2002

Components of the NCMRWF Extended Range Prediction (ERP) System:

Model climate

The NCMRWF global model at T80L18 resolution has been modified to update SSTs during model integration. The model has been integrated for 45 (46)-days, starting from observed initial conditions (with data for the middle of a month) and with observed SSTs (with different initial conditions and SST for 15 years) and model output for last 30 (31) days are considered to be prediction for the next month. For example, to prepare the model climate for June, the model has been integrated for 45 days starting with initial data for May 16 of several years with SSTs of 1986 to 2000. The mean of results for last 30 days corresponds to the model climate for June. It may be noted that the model climate thus prepared has taken into account the inter-annual variability of SSTs from 1986 to 2000. Observed SSTs used for this simulation were monthly NCEP analyzed SST (Reynolds and Smith, 1994).

The model climatology for rainfall has been compared with the GPCP rainfall climatology for the corresponding period (GPCP Version-2 Combined Precipitation Data Set). The model's rainfall climate is reasonably good and all the essential features of rainfall pattern over the Indian region are simulated well by the model. It is noticed that the circulation features obtained from the model simulations (climate) are reasonably good. Therefore, it can be said that the model simulates a realistic climate, and the model can be used for extended range prediction.

Predicted SST fields

On a real-time basis, the experimental predictions started with the preparation of ERP in June 2002. So far, for June, July and August 2002, three different procedures have been adopted for getting SST fields. These are as follows:

- *Persistent SST anomalies*: NCMRWF routinely downloads NCEP SST analyses. From these data (for last 2 weeks), SST anomalies were computed. These SST anomalies were added to the SST climatology and model simulations were carried out.
- *SAC Analog SST anomalies*: SAC, Ahemdabad prepares SST anomalies based on

analog method. Though the quality of these SSTs are not known yet, due to a collaboration that exists between NCMRWF and SAC, SAC provided the SST forecasts to be used for ERP.

IRI SST anomalies: IRI, USA, prepares SST forecasts on a regular basis. They also use these SST data for seasonal prediction purposes. As per IRI, the SST forecasts over the Indian Ocean may not be very accurate. However, on request, IRI provided the SST forecasts to NCMRWF and these data have been used for ERP in July and August, 2002.

Ensemble members

Several extended range runs have been made for June, July and August 2002. For June forecasts, a 10-member ensemble was chosen. For July, the number of runs was increased to 13. Out of these, 5 runs were made with persistent SST anomalies, 5 were with SAC analog SST anomalies and 3 were with IRI SST anomalies.

For August, the number of ensemble members was increased to 15. Out of these, 10 runs were made using persistent SST anomalies and IRI predicted SST anomalies. Forecast based on these 10 runs was made on July 17. With updated initial conditions and SAC-predicted SST, 5 more runs were made, and forecasts were updated on July 29.

Ensemble averages for various predicted fields were computed and analysed. Predicted anomalies were computed as a deviation from the model climate. In addition to the above, predicted anomalies of rainfall were computed for each of the ensemble member. For rainfall prediction, area-weighted averages for the meteorological sub-divisions were computed. Area-weighted averages of rainfall anomalies for 6 homogenous regions were also computed. Probability of rainfall anomaly being either excess, normal or deficient were computed based on how many runs from these ensemble fell in which category (Fig. 8).

Use of MRWF in Drought Monitoring

Frequent and prolonged drought in marginal areas leads to excessive pressure on land, water and vegetative resources, which result in land degradation and desertification. Establishing systematic monitoring systems, especially for drought and other extreme events in dryland areas, can greatly assist in avoiding land degradation in the future by developing suitable drought response plan and management schemes, and by promoting public awareness for the control and management of drought. There are several indices that measure drought but none is inherently superior to the rest in all circumstances. Palmer drought severity index is widely used by US Department of Agriculture, but it is better only when working with large areas of uniform topography.

India Meteorological Department (IMD) prepares rainfall maps (actual rainfall received during the week) on meteorological sub-division scale (total 36) every week, and also the corresponding departure from the normal rainfall for the concerned week. During rainy seasons, these maps show the development of drought condition and its termination. State Agricultural Departments take ground observations of agricultural conditions to delineate drought-affected areas. Such a system involves a significant amount of subjective judgment at various stages and is often based on sparse observations.

For effective drought monitoring medium range weather forecasting coupled with monthly weather outlook, are vital. This in association with past weather (total precipitation map, temperature departure and maximum/minimum temperature maps, growing degree day maps, pan evaporation maps, etc.), current weather, crop moisture maps, Palmer drought maps and agriculture summary with crop progress condition, pasture condition, etc., for different districts, states and regions provide useful information to monitor the drought.

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REGION-WISE RAINFALL FORECAST
(1 MONTH IN ADVANCE) FOR AUGUST 2002

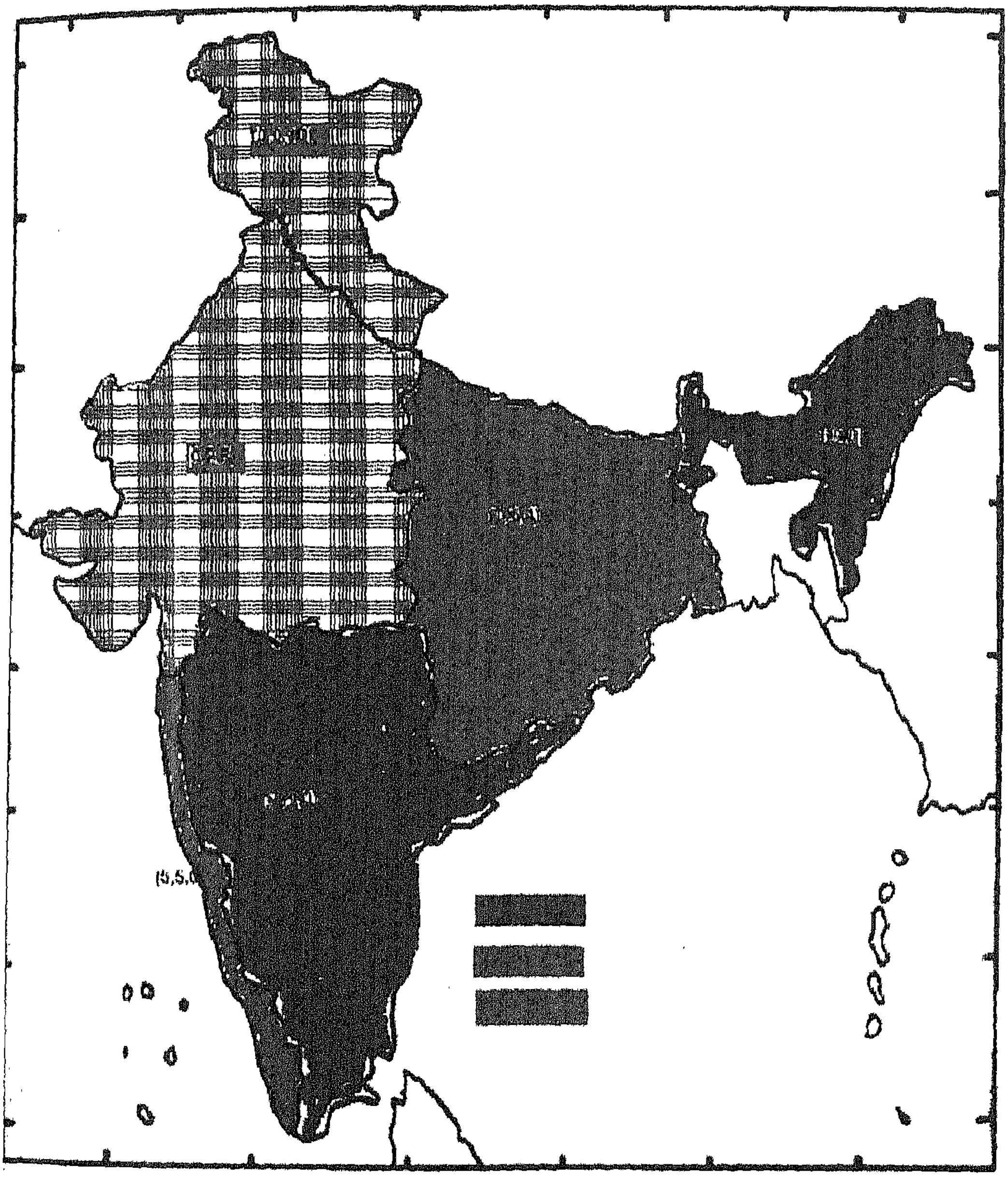

Fig. 8

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Drought Scenario in Arid Western Rajasthan

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Indian agriculture is a gamble, and depends on the vagaries of monsoon. About 70% of our net sown area is still unirrigated. Aberrant behaviour of monsoon, such as delayed onset, poor rainfall, ill distribution and early cessation have caused a dip of 9-22 million tons in food grain production during the years 1965, 1979 and 2000 over the respective preceding years. A widespread drought due to 50% less rain all over India during 2002 is a matter of great concern. The major food grain producing northern states of Punjab, Haryana, Rajasthan, MP, UP, Gujarat and many southern and eastern states, namely Karnataka, Kerala, Orissa and Chhatishgarh are in the grip of drought. Hence, the country faces one of the worst droughts in 2002. The situation in the drought-affected 12 districts of western Rajasthan is serious, and the condition in five severely affected districts is precarious.

Drought refers to a temporary reduction in the water availability below the normal quantum in a region. It represents an adverse moisture index or deficient water balance for meeting the local normal crop requirements in the context of prevailing agro-climatic conditions. Agricultural drought implies inadequacy of rainfall during the growing season to support a healthy crop, and also a decline in crop production. Meteorological drought is due to >25% decrease in the precipitation from the normal rainfall over an area, while hydrological drought is a result of prolonged meteorological drought, causing marked depletion in surface water bodies like ponds, lakes, rivers and reservoirs, and also a fall in groundwater level. This kind of drought affects power generation and irrigation potential. Impact of drought further magnifies when it occurs in a succession as it happened in the near-past in western Rajasthan during 1984-87 and 1998-2000.

Drought-prone Regions of India

Arid and semi-arid regions of India are more prone to drought than the other climatic zones, the probability of drought being >20% of the years (Table 1;). The hot arid regions, covering 32.7 m ha of western Rajasthan, Gujarat, Haryana and a part of Karnataka and A.P, are chronically drought-prone, the probability of experiencing a drought being 30-40% of the recorded years.

Table 1. Probability of occurrence of drought in different meteorological sub-divisions

Meteorological sub-division	Frequency of deficient rainfall (75% of normal or less)
Assam	Very rare, once in 15 years
West Bengal, Madhya Pradesh, Konkan, Bihar and Orissa	Once in 5 years
South Interior Karnataka, eastern Uttar Pradesh and Vidarbha	Once in 4 years
Gujarat, east Rajasthan, western Uttar Pradesh, Tamil Nadu, Jammu & Kashmir and Telangana	Once in 3 years
Western Rajasthan	Once in 2.5 years

Source: Apparao *et al.* (1991)

Archives of severe droughts and famines in the Indian arid zone (1792-1900) reveal the occurrence of fifteen severe droughts, out of which nine were serious triple droughts (Table 2).

With improved instrumentation and documentation, Indian arid zone recorded 43-68 droughts of varying intensity during 1901-2001 (Table 3). The decreasing order of drought intensity in Jaisalmer > Barmer > Bikaner > Jodhpur matches with the proverbial description of drought/famine as having legs in Bikaner, head in Barmer, stomach in Jodhpur and stay for ever in Jaisalmer.

During the twentieth century, a disastrous drought was recorded in the second decade (Subrahmanyam, 1967), while a number of severe droughts have been recorded in post-independence era, especially during the sixties, seventies and eighties (Fig. 1). Often the drought persists continuously for 3 to 6 years at different intensities, as was experienced during 1903-05, 1957-60, 1966-71,1984-87 and 1998-2000, causing multiplier effects on

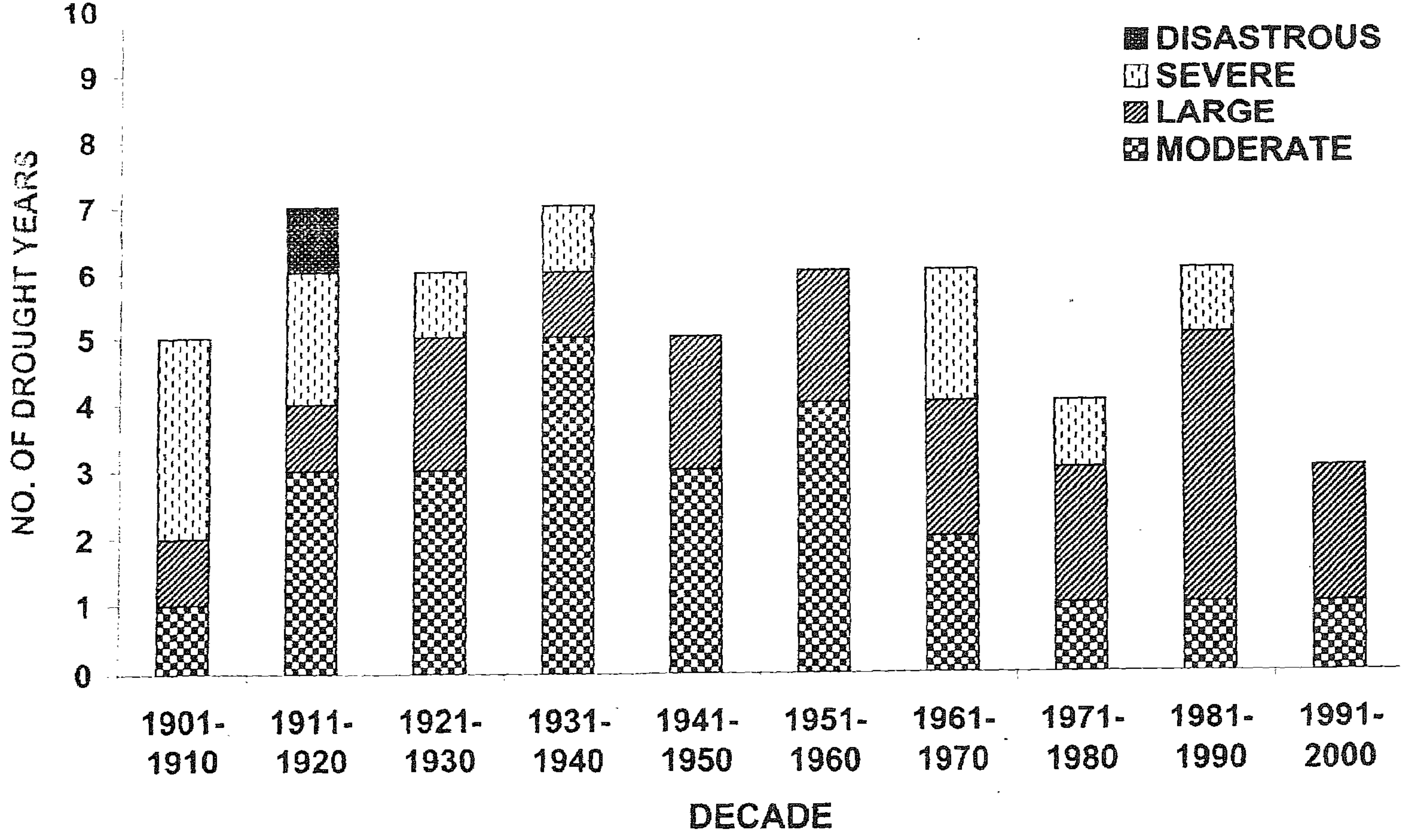


Fig.1 DECENNIAL FREQUENCY OF DROUGHT YEARS IN WESTERN RAJASTHAN

Table 2. Historical droughts and famines in the Indian arid zone (1792-1900)

Year	Severe drought
1792	Agricultural, Hydrological, and Meteorological
1804	Agricultural and Meteorological
1812-13	Agricultural, Hydrological, and Meteorological
1833-34	Agricultural, Hydrological, and Meteorological
1838-39	Agricultural and Meteorological
1848-49	Agricultural, Hydrological, and Meteorological
1850-51	Agricultural and Meteorological
1853-54	Agricultural and Meteorological .
1868	Agricultural, Hydrological, and Meteorological
1869	Agricultural and Meteorological
1877	Agricultural, Hydrological, and Meteorological
1891-92	Agricultural, Hydrological, and Meteorological
1895-96	Agricultural and Meteorological
1898-99	Agricultural, Hydrological, and Meteorological
1899-1900	Agricultural, Hydrological, and Meteorological

crop and fodder production, groundwater and availability of drinking water in the region.

Table 3. Frequency of droughts in the western part of arid Rajasthan (1901-2001)

District	Moderate drought	Severe drought	Total number of drought
Barmer	18	30	48
Bikaner	23	23	46
Jaisalmer	25	43	68
Jodhpur	26	17	43

Rainfall Pattern and Water Balance of Western Rajasthan

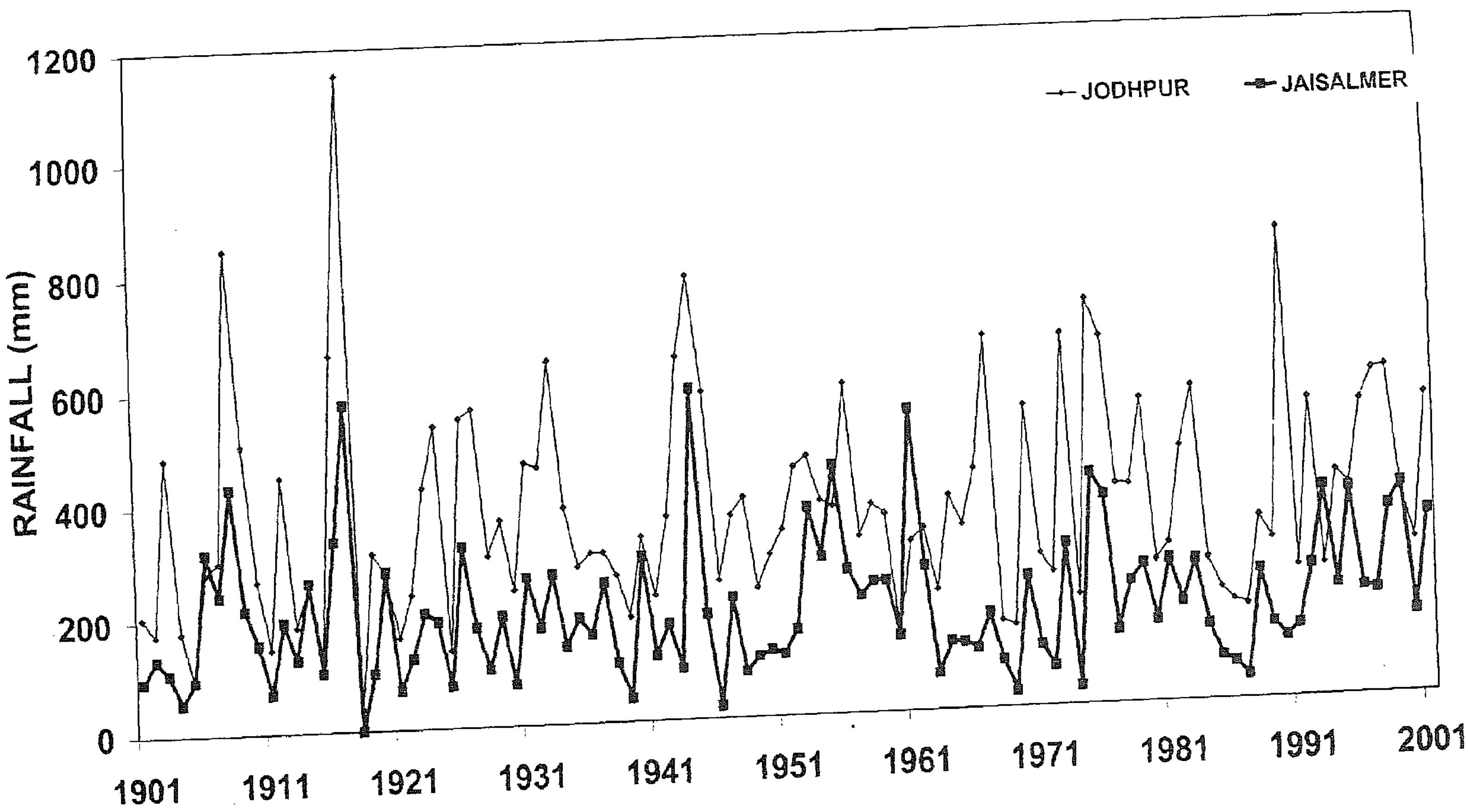
Western Rajasthan is located in NW India between latitudes 24^0 30'N and 30^0N, and longitudes 69^0E and 76^0 12'E. The region does not have any major river system. The annual rainfall is 450 to 100 mm. The coefficient of variation increases from 45 to >60% with decreasing rainfall, causing a very high year-to-year fluctuation in annual rainfall (Fig. 2), uncertainty in agricultural production and vulnerability to drought.

Climatic water balance (Thornthwaite and Mather, 1955) of western Rajasthan reveals that 13 week growing period during above-normal rainfall years reduces to 10 weeks during normal and merely 7 weeks in below-normal rainfall years (Fig 3), which is hardly sufficient to raise a good crop in less than 50 days.

Jodhpur region receives about 330.0 mm average rainfall during monsoon months from June to September. A weekly rainfall distribution model for 101 years (1901-2001) describes four kinds of monsoon rainfall situations, namely above-average rainfall (> 20% of normal), which happened in 30 years, average monsoon rainfall (± 20% of normal) occurred in 25 years, below-average rainfall (< -20% of normal) occurred in 32 years and poor rainfall (< -50% of normal) took place in 14 years (Fig. 4). This year's rainfall is worse than poor rainfall with only two showers of 7.7 mm and 12.1 mm in June and August, respectively. A comparison of the weekly rain distribution model with water balance would show that in above-normal monsoon years a good harvest of pearl millet and *kharif* legumes is possible. However, during average monsoon year only short duration pearl millet as well as legume crops can be grown. Below-normal monsoon year rainfall is only adequate for short duration *kharif* pulses like moth bean and mung bean and pearl millet for fodder. Probability of rainfall in chronically drought-prone districts also confirms that an average crop of pearl millet can be harvested at Jodhpur once in three years, at Bikaner and Barmar once in four years, and at Jaisalmer once in ten years, suggesting susceptibility of Jaisalmer for pearl millet. An average crop of *kharif* pulses can be obtained at Jodhpur twice in three years, at Bikaner and Barmer in alternate year and at Jaisalmer once in five years (Fig. 5). An extremely poor rainfall like this year's cannot support any crop excepting some fodder crops, pastures and perennial shrubs /trees or grasses as recommended by CAZRI for this region.

Spatial and Temporal Spread of Drought in Western Rajasthan During 2002

The SW monsoon normally enters western Rajasthan in the last week of June and covers the entire region by the middle of July. This year's rainfall analysis reveals that during 16 to 30 June western Rajasthan received normal pre-monsoon showers, excepting Bikaner



Variation in annual rainfall at Jodhpur and Jaisalmer

Fig.2

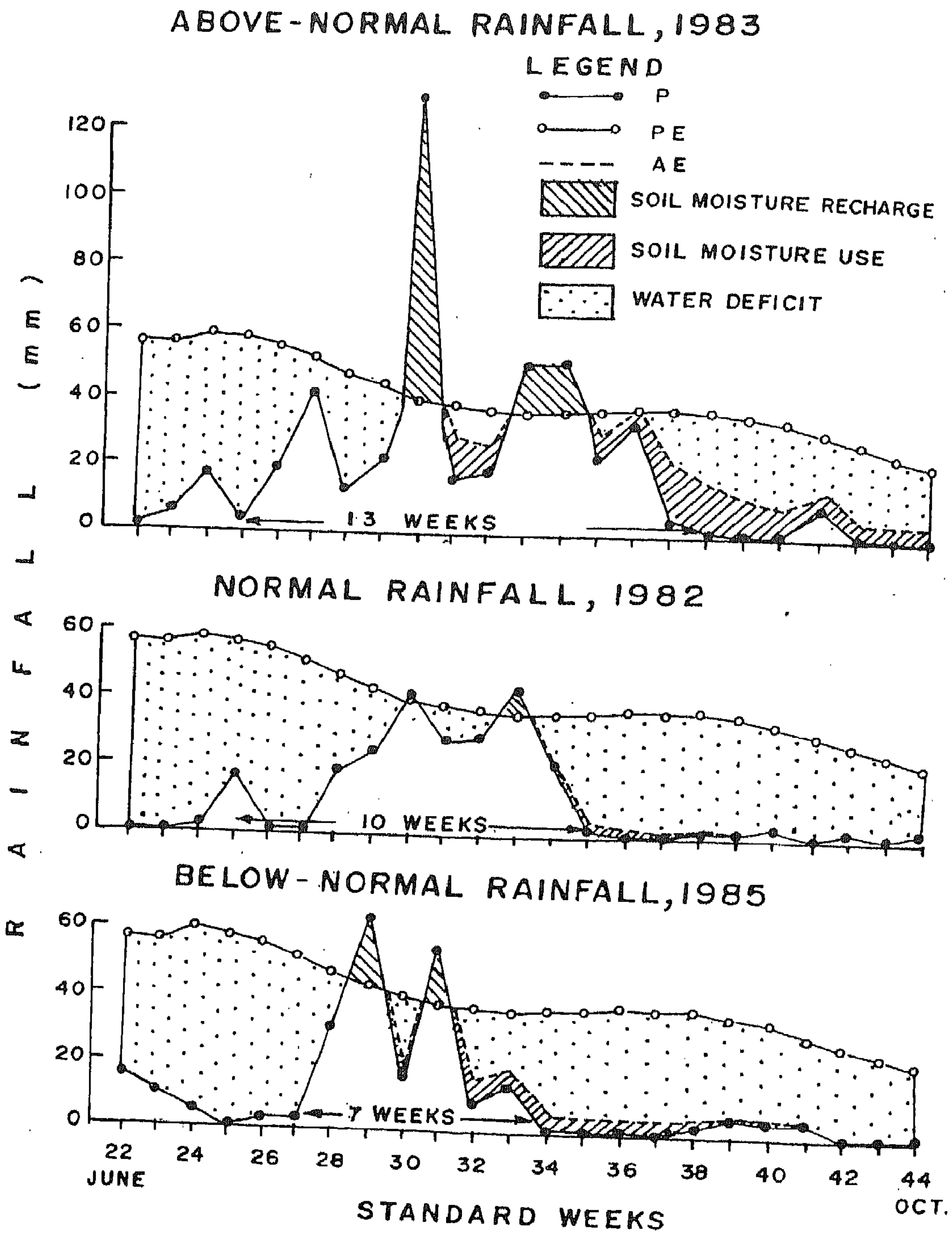


Fig.3 CLIMATIC WATER BALANCE OF MONSOON SITUATIONS IN WESTERN RAJASTHAN

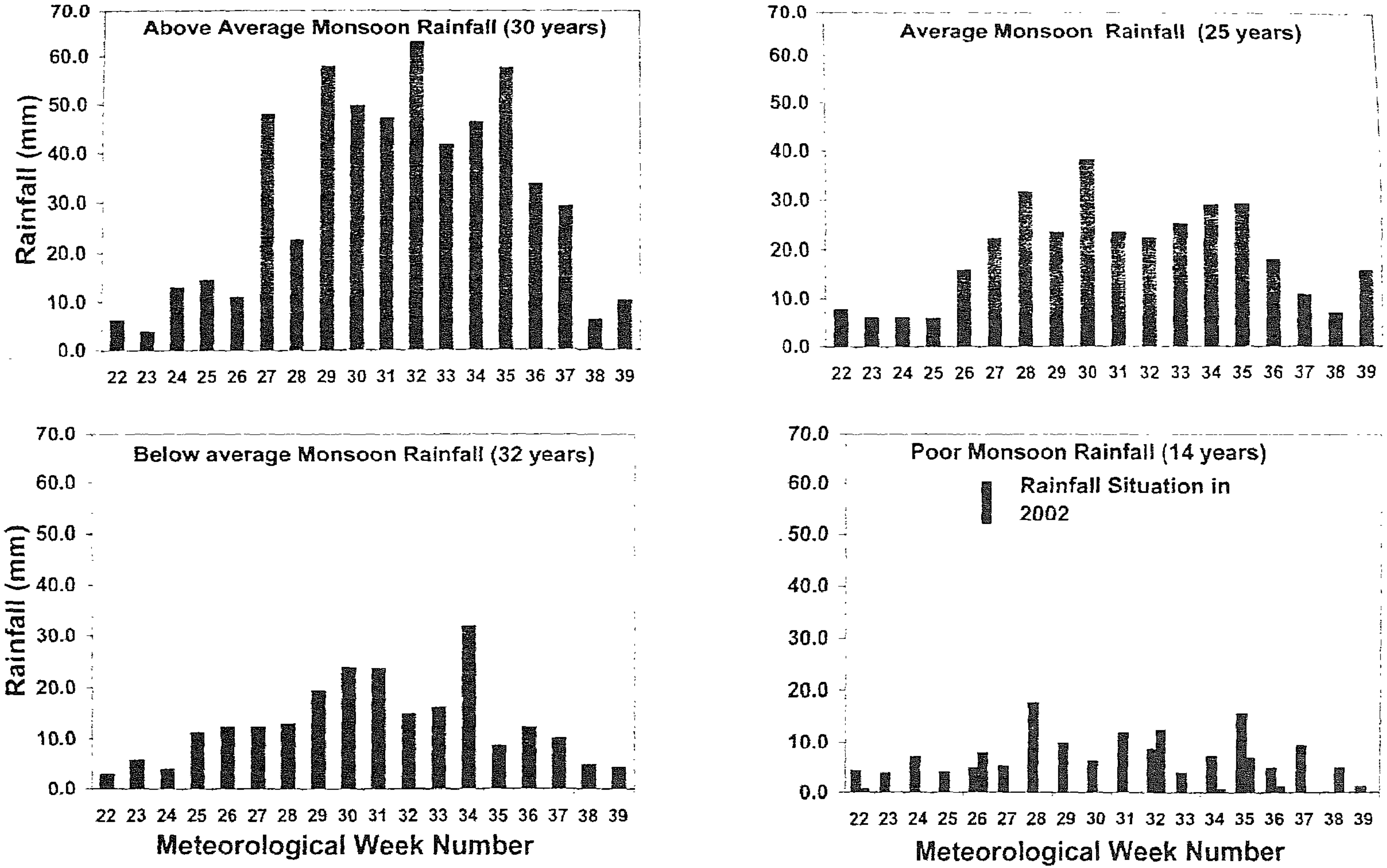
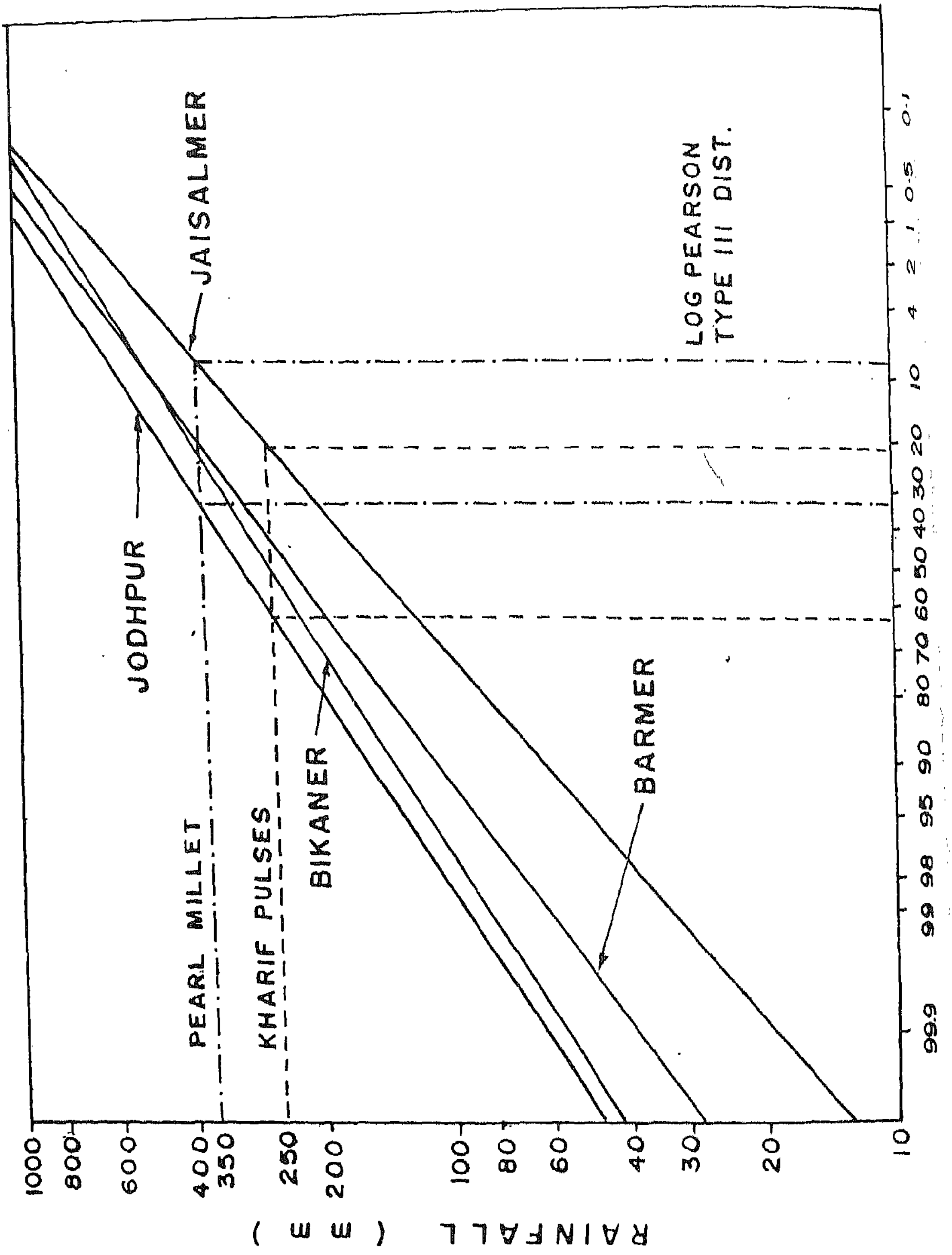


Fig.(4) Weekly rainfall distribution model under different category of monsoon over Jodhpur (1901- 2001)


JAISALMER
LOG PEARSON
TYPE III DIST.
JODHPUR
BIKANER
BARMER
PEARL MILLET
KHARIF PULSES
RAINFALL (mm)
1000
800
600
400
350
250
200
100
80
60
40
30
20
10
0.1
0.5
1
2
4
10
20
30
40
50
60
70
80
90
95
98
99
99.9

district. Farmers started their agricultural activities, including sowing of *kharif* crops, in the districts of Jalor, Pali and Barmer.

First fortnight of July received no rainfall and drought situation aggravated in the second fortnight of July 16- 31, 2002, due to failure of SW monsoon. Sown fields started drying due to severe water stress, coupled with high temperatures (>45°C) and westerly winds. Much of the area in western Rajasthan is still waiting for the first shower of this season. A small rainfall of about 1.2 cm in the first fortnight of August was not of much use for standing crops and sowing of kharif crops. Some natural grasses could be benefited with this little rain and can provide some relief to animals. The drought situation in western Rajasthan is alarming and calls for efforts for contingency planning and drought management.

Drought Monitoring and Early Warning at CAZRI

To meet the special requirements for agricultural practices on medium range time scale (i.e. 3 to 10 days), Government of India has established a National Centre for Medium Range Weather Forecasting (NCMRWF) with supercomputing facility. The NCMRWF is providing forecast based on dynamic model to meet the special requirement for the agricultural community. Multidisciplinary teams of experts frame forecast on the scale of cluster of districts and suggest strategies to meet different rainfall situations and drought to farmers. This is being done from 82 centres in India, including CAZRI, Jodhpur for arid Rajasthan.

CAZRI sends weather data on every Monday and Thursday and forecasts are received on every Tuesday and Friday from NCMRWF (DST), New Delhi. Based on these forecasts agrometeorological bulletin for Jodhpur and surroundings areas is prepared at CAZRI by an experts committee and broadcast through AIR and local newspapers. The bulletin covers spectrum of agricultural operations for the anticipated weather. This service is benefiting farmers since 5 years in collaboration with DST, New Delhi.

Impact Assessment of Drought (A Case Study)

Due to low and erratic rainfall, frequency of occurrence of droughts in arid region is much higher compared to that in other regions of India. Sometimes droughts occur in consecutive years, like those which occurred in 1984-87 and 1998-2002, having multiplier effect on human and livestock population. Popular saying in the Indian arid zone "in the course of a decade, one year would be a bumper crop (100%), five years of average produce (60-75%), three years of scanty harvest (40-60%) and one year of famine (<25%)." There is a defined and true impression that irregular and uncertain rainfall, followed by drought and famine, is inevitable every three years in the region.

Impact assessment refers to an action that allows for early estimates of the costs and losses associated with the occurrence of drought. These may be economic, social and environmental and as such difficult to quantify because of their nonstructural nature. Methodologies or techniques for estimating impacts, and the reliability of those estimates, are highly variable from one natural hazard to another.

During *kharif* 2002, sowing of kharif crop in Rajasthan suffered badly due to

Table 4. Impact of drought on productivity of pearl millet and kharif pulses in western Rajasthan

District/region	Yield during good monsoon year 1983	Per cent reduction in yield during drought years			
		1984	1985	1986	1987
Pearl millet					
Barmer	285	47	94	88	100
Bikaner	296	74	99	91	98
Jaisalmer	405	76	100	100	100
Jodhpur	337	47	93	86	94
West Rajasthan	431	36	78	69	89
Kharif pulses					
Barmer	119	-	85	90	68
Bikaner	254	49	91	98	100
Jaisalmer	54	73	100	100	100
Jodhpur	354	58	100	96	100
West Rajasthan	241	38	75	83	97

deficient rainfall to the extent of 54% during the monsoon. Rajasthan state received 139.8 mm rainfall between June 1 and August 15, which is 54% less than the average that resulted in achievement of only 41.54 % of the kharif sowing against the target of 12.9 m ha. At least in 8 districts of western Rajasthan, viz. Jodhpur, Jaisalmer, Jalor, Barmer, Pali, Sirohi, Bikaner and Hanumangarh, no or very little sowing could be done because of complete failure of monsoon.

A case study of the impact of drought on the productivity of pearl millet in western Rajasthan indicated that yield in 1984, 1985, 1986 and 1987 drought years decreased to 36 78, 69 and 89% of that recorded in the region in 1983 (Table 4). The productivity of pearl millet in the arid districts of western Rajasthan during the drought years (1984-85, 1985-86 1986-87 and 1987-88) showed that the mean productivity in 8 out of the 11 districts was less than 50%, the most affected districts being Jaisalmer, Bikaner, Barmer, Jodhpur and Jalor, indicating that the impact of drought on pearl millet productivity was severe in these districts during the period.

Peculiarities of the Region

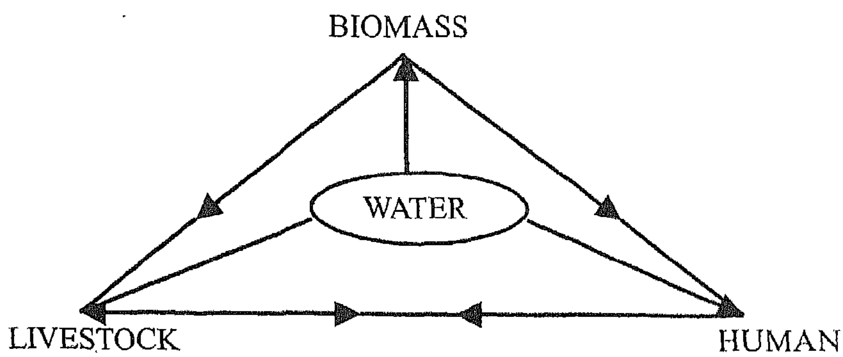
- Spurt in human (400%) and livestock (127%) population during the 20th century.
- Livestock outnumbering human by 4:1 in Jaisalmer as compared to 1.5:1 in the country.
- Overexploitation of groundwater, leading to decline in water table @ 0.20 to 0.40 m/year.
- Increase in fluoride and nitrate in groundwater.
- Neglect of traditional rain-water harvesting systems.
- Water-intensive cropping.
- Sandy, saline & hardpan soils.
- Rich bio-diversity, MPTs and grasses.
- Drought-hardy human being and animals.
- Traditional wisdom.
- Perennial fodder needs 28 million t year^{-1}.

Fodder Situation During Drought Year

Animal husbandry is the main source of livelihood in arid zone. About 10 m ha land in the region, including pasture, culturable and unculturable wastes and barren land, is available for grazing to about 11.28 million ACUs. The fodder requirement is about 28 million tonnes of dry fodder to feed 11.24 million ACUs in western Rajasthan. About 11 million tonnes of fodder is available with normal rainfall and deficit is 17 m (60%) tonnes. The deficit under drought condition is increased by about 80-95%. Therefore, at least to sustain our livestock as under normal year the additional requirement of fodder is about 17+8 =25 million tonnes of dry fodder during the drought year.

The Cycle of Sustenance

The survival of desert dwellers has been due to basically animals sustaining on perennial grasses, shrubs and trees. The targets of *kharif* and *rabi* fixed by State Government are neither realized nor required to be realized under the prevailing conditions. It calls for appropriate landuse planning with emphasis on perennial vegetation and animal resources. It will mitigate many problems of crop failures and fast depleting ground water. It is easily said than done. It may need education of farmers, mandates of State Government etc.



Contingency Planning

CAZRI has gone out to suggest contingency plans for varying rainfall situations, first up to 15th August and second upto end of October and sowing of *rabi* crops on conserved moisture. These plans have been widely circulated and we look forward to prepare a consolidated document for all rainfall situations in western Rajasthan.

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Contingency Planning for Drought

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The onset of monsoon, in northwest India has been delayed this year by a month. In other parts onset was normal but was followed by 3-4 week break in the rains. This caused drought of various degrees in the country in general and in Rajasthan, Punjab, Haryana, western UP and northern MP in particular. In such a situation, normal cropping practices are not possible, especially under rainfed conditions. In irrigated areas also, additional efforts are required for suitable water management strategy and agronomic manipulations in view of the increasing intensity of hydrological drought. The implications of delayed monsoon are more devastating in dryland agriculture. Under such a situation, suitable steps are needed for growing crops and their varieties, adopting special cultural practices, plant protection measures and efficient nutrient, soil and water management practices so as to minimize losses in agricultural production. The present paper is an attempt in this direction.

Normal Monsoon Behaviour and Possible Shifts

- South-west monsoon over different parts of the country sets in at different time between May and September. Its normal onset period over Kerala is around 29th May, and by the first week of June the northern limit of monsoon passes through Karnataka, Manipur and Tripura. By the second week of June, the limit passes through Bombay, Kolkata and the States of Assam and Arunachal Pradesh.
- The onset of monsoon over the northwestern parts of India is around the last week of June to the first week of July, by which time it covers the entire country. Monsoon withdrawal starts from the second week of September over the northern part and by the early October, the south-west monsoon conditions cease to operate.
- Breaks monsoon situations result from the changes in the track of tropical depressions from Bay of Bangal; their number in a given month give rise to dry spells over certain sub-divisions in any given year.

- The four broad scenarios for which one has to plan are as follows:

Delay in onset	Maximum of three weeks from normal date for the given region. This has happened in north-west India this year.
Timely onset and sudden break	This scenario has happened this year in many states.
Early withdrawl of monsoon	By last week of August.
Delayed withdrawl or extended monsoon	

There have been occasions in the past when late onset coincided with early withdrawal of the monsoon from several parts of the country, mainly in the northern and northwest parts. Average seasonal rainfall (mm) across India in different meteorological

Table 1: Average seasonal rainfall (mm) across India in different meteorological subdivisions

Sub-divisions	Annual rainfall (mm)	Percentage of annual rainfall			
		January-February	March-May	June-September	October-December
Bay Island	2995	3	15	59	23
Assam (including Manipur & Tripura)	2517	3	25	65	7
Sub-Himalayan West Bengal	3126	1	15	78	6
Gangetic West Bengal	1425	3	12	75	10
Orissa	1482	3	9	76	12
Bihar Plateau	1373	4	6	82	8
Bihar Plain	1203	3	6	85	6
Uttar Pradesh, East	1008	3	8	83	6
Uttar Pradesh, West	964	5	4	87	4
Punjab (I) (including Delhi)	625	9	7	80	4

Jammu & Kashmir	995	19	24	48	9
Rajasthan, East	704	2	2	93	3
Rajasthan, West	311	4	5	89	2
Madhya Pradesh, West	1005	2	2	91	5
Madhya Pradesh, East	1402	3	4	87	6
Gujarat region	976	-	1	95	4
Saurashtra and Kutch	483	1	2	93	4
Konkan	2872	-	1	94	5
Madhya Maharashtra	921	1	4	84	11
Marathwara	774	2	4	83	11
Vidarbha	1100	3	3	87	7
Coastal Andhra Pradesh	1008	2	9	57	32
Telengana	926	2	11	82	10
Rayalseema	678	2	9	54	32
Tamil Nadu	1008	5	15	33	47
Coastal Karnataka	3265	-	4	88	8
Interior Karnataka, North	675	1	14	65	20
Interior Karnataka, South	1245	1	13	68	18
Kerala	2996	1	14	67	18
Arabian Sea Island	1572	3	13	62	22

sub-divisions is given in Table 1.

Drought is a recurring phenomenon in the country. Probability of occurrence of drought in different meteorological sub-divisions is given in Table 2.

Brief Analysis of the 2002 Monsoon

The monsoon 2002 started on an optimistic note with a forecast of normal rainfall in the country. The rainfall activity in the beginning of June was quiet satisfactory. However, the vigour of monsoon dissipated in the last week of June, as a result of which the monsoon

Table 2: Probability of occurrence of drought in different meteorological sub-division

Meteorological subdivision	Frequency of deficient rainfall (75% of normal or less)
Assam	Very rare, once in 15 years
West Bengal, Madhya Pradesh, Konkan, Bihar and Orissa	Once in 5 years
South interior Karnataka, Eastern Uttar Pradesh & Vidarbha	Once in 4 years
Gujarat, East Rajasthan, Western Uttar Pradesh	Once in 3 years
Tamil Nadu, Jammu & Kashmir and Telengana and West Rajasthan	Once in 2.5 years

failed to advance and cover a large part of the northwest India. The behaviour of the monsoon till 31st July was erratic. Rainfall situation in various meteorological sub-divisions of India as on July 24, 2002, is given in Table 3.

Table 3: Rainfall situation in various meteorological sub-divisions of India as on 24th July, 2002

State	Monsoon rainfall (mm) June to September		Rainfall (mm) 1 June to 24th July			Deviation of rainfall of 2002 compared to	
	Average (1991-2000)	Actual (2001)	Normal	Actual (2001)	Actual (2002)	Normal	2001*
West UP	743	627	289	372	73	-75	-80
Haryana	511	480	191	287	59	-69	-80
East Rajasthan	614	521	232	351	82	-65	-77
West Rajasthan	297	251	106	159	39	-63	-75
Punjab	571	516	191	340	94	-51	-72

Orissa	1136	1434	505	930	304	-40	-67
East U P	869	889	348	453	164	-53	-64
East M P	1111	1154	435	498	209	-52	-58
West M P	868	736	350	454	206	-41	-55
Gujarat	883	960	488	599	328	-33	-45
Kerala	1962	1879	1337	1289	729	-45	-43
Coastal Karnataka	3063	2991	1925	1901	1229	-36	-35
Bihar Plains	1057	1046	420	389	523	24	-34
Saurastra & Kutch	385	499	288	343	234	-19	-32
Telangana	643	682	324	276	197	-39	-29
Coastal A P	548	579	245	192	151	-38	-21
Bihar Plateau	1132	1190	457	560	448	-2	-20
Vidarbha	865	890	432	491	406	-6	-17
Tamil Nadu & Pondicherry	314	273	111	68	61	-45	-10
South interi or Karnataka	562	643	350	267	242	-31	-9
Konkan & Goa	2356	2224	1582	1237	1141	-28	-8
Madhya Maharashtra	588	690	359	336	311	-13	-7
Gangetic W B	1275	1037	491	585	572	16	-2
Marathwara	657	62227	299	216	287	-4	33
North interior Karnataka	556	402	193	105	155	-20	48
Sub-Himalyan West Bengal	2067	1719	1010	663	1186	17	79
Rayalseema	470	415	127	49	109	-14	122

*In descending order; departure with respect to 2001.

The deviation of seasonal rainfall during June 1 to July 31, 2002, clearly indicates that except Gangetic West Bengal, Bihar and Sub-Himalyan West Bengal the rainfall in all other sub-divisions has been either deficient or scanty.

According to India Metrological Department (IMD) rainfall is being monitored in 523 districts. This year 384 (75%) districts have received deficient or scanty rainfall by 31st July, 2002. Out of these 208 districts have received cumulative deficient rainfall (-22 to -60% of LPA), 174 districts (29% of the total districts) have received scanty rainfall (-60 to -99 % of LPA). The states most adversely affected are listed in Table 4.

This weather phenomenon, though unusual is not unprecedented. During 1992 and 1995 also rainfall was deficient till the middle of July and its onset in Delhi was delayed till the second week of July. However, the absence of low-pressure area in the Bay of Bengal in the first fortnight of July is rather unusual. According to India Meteorological Department, a low-pressure area was formed over Bay of Bengal, which created optimism about its advancement in the sub-continent leading to rainfall and bringing relief to farmers by the end of July. The information available on 31st July from various sources on monsoon activity over the country indicated that the low pressure system weakened subsequently and as such the rainfall occurrence was only scattered and light to moderate, which did not provide much

Table 4: Severely affected states during monsoon, 2002

State	Remark
Uttar Pradesh	62 out of 63 districts are deficient or scanty
Haryana, Chandigarh and Delhi	All the 21 districts are deficient or scanty
Punjab	14 out of 16 districts are deficient or scanty
Rajasthan	All the 32 districts are deficient or scanty
Madhya Pradesh	39 out of 45 districts are deficient or scanty
Chattisgarh	14 out of 15 districts are deficient or scanty
Himachal Pradesh	All the 12 districts are deficient or scanty

relief to the already prevailing dry conditions in northern MP, western UP, Haryana, Punjab and Rajasthan.

Peculiar features of monsoon, 2002

- In 2002 the monsoon set in on time in most parts of the country. This was followed by a break of more than two to three weeks in most cases.
- But for scattered showers, monsoon did not set in Punjab, Haryana, Delhi, Chandigarh, western UP and north-east Rajasthan, even up to July 31, 2002.
- Gujarat, a traditionally drought-prone area, received more rainfall this year, which even resulted in floods. This is quite unusual.
- It is probably for the first time that monsoon withdrew after only one-third of the total monsoon rainfall in the country was received.
- It is again for the first time that the rainfall received in the month of July was the minimum in last 100 years.
- Leaving aside the NEH region, Bihar and West Bengal, which were fully covered by this year's monsoon, almost all other states were partially or moderately covered. Even within the state, large variations ranging from scanty to excess have been reported.
- The indications from the monsoon behaviour are that the country is heading towards one of the worst droughts of this century. The impact by July 31, already exceeded the impact of 1987 drought.
- It is again a rare phenomenon that westerly winds dominated during July instead of wind direction from east to west during southwest monsoon season.

Impact analysis

The erratic rainfall in different parts of the country, particularly after June end, has affected the area coverage under rice, cotton, coarse cereals, oil seeds and pulses. The area under different kharif crops as on July 31,2002 is given in Table 5.

- Decrease in water level of major reservoirs, including Bhakra and Pong Dam, will affect the irrigated agricultural production, not only of *kharif* but also of the *rabi*. The total live storage in 70 important reservoirs in different parts of the country, as monitored by Central Water Commission for the week ending August 2, 2002, was 23.37 Billion Cubic Meter (BCM) against 52.16 BCM on the corresponding date of the previous year and 58.82 BCM, which is the average storage of the last ten years.

- The area coverage under rice in irrigated north-western states like Punjab has almost been achieved. However, the transplanted paddy crop has started suffering because

Table 5: Area coverage up to July 31, 2002 under different kharif *crops in relation to corresponding period of 2001*

		Area sown (Lakh hectare)	
Crop	Normal	This year	Last year
Rice	406.4	154.2	226.5
Cotton	88.76	57.84	64.07
Jowar	49.30	30.10	40.25
Bajra	93.35	46.80	80.40
Maize	57.62	48.20	58.94
Sugarcane	41.91	43.06	42.49
Jute	8.41	8.45	8.56
Groundnut	58.20	32.80	34.55
Soybean	63.78	48.58	58.17
Sesamum	13.95	7.70	12.31
Sunflower	5.85	2.74	0.75
Niger	4.65	0.38	0.74
Castor	8.37	1.92	2.39
Pigeon pea	35.15	23.27	28.12
Total Pulses	102.7	34.99	87.10

Source: DOAC, 2002

of the delayed monsoon. Withering of transplanted paddy in these states has already set in. The excessive pumping of groundwater through submersible pumps is adversely affecting the capacity and efficiency of centrifugal pumps installed in the vicinity of deep submersible pumps. This scenario may have adverse effect on the productivity of irrigated rice and other crops and also crop production in the forthcoming *rabi* season.

- In sizable areas of Rajasthan, MP, UP and Haryana soybean and pearl millet could not be sown due to delayed monsoon. This will have significant adverse effects on coarse cereal and pulse production. The situation calls for contingent plan to compensate this loss.
- Moisture stress, coupled with prevailing high temperature, is resulting in pollen shedding in case of maize, sorghum and pearl millet crops. It will adversely affect seed setting. There may be acute shortage of seed of these crops for sowing in *Kharif*, 2003.
- Fodder shortage in Rajasthan and western MP may have adverse impact on animal productivity. There will be possibility of animal and human migration from these areas to adjoining states.
- A model developed by All India Coordinated Research Project on Agro meteorology based upon rainfall received up to July 31, 2002, predicted a loss of 15% in *Kharif* production and 10 % in food grain production.
- Out of the 11 states hit by the drought, Haryana, Punjab, UP, Orissa, M.P., Gujarat, Tamil Nadu and part of Kerala are worst hit. Crops such as pearl millet, maize, soybean, groundnut and oilseed and pulses in general are adversely affected.

Strategy/Plan To Moderate/Mitigate Prevailing Drought Impact

Time-specific contingency plan for rainfed regions

The time specific contingency plan for the rainfed agricultural regions of India can be considered under 15 meteorological sub-divisions of India Meteorological Department (IMD). These are provided in Table 6.

Contingency plan specific to the worst affected north-western states

Irrigated areas of Punjab, Haryana and western Uttar Pradesh: More than 90% area targeted for rice cultivation has been transplanted. The farmers are maintaining good crop stand by maintaining irrigation application though at high cost. Because of non-recharge of ground water due to non-availability of rains, the decreasing tube well discharge is bothering the farmers. In case rain are not received by August 10, there is possibility of withering of the transplanted crop in 10-15% planted area. Since farmers are giving priority for irrigating the rice crop, the fodder crops like sorghum and maize are suffering adversely. This scenario may result in fodder scarcity in the region. Due to moisture stress at vegetative

Table 6. Proposed time-specific contingency plan for rainfed regions of India.

IMD sub-division (IMSD), Agro ecoregion (AER), Major production systems (MPS), Area domain (AD)	Crop Plan		
	15-31 July	1-15 August	16-31 August
IMSD: Punjab, AER: 9.1 MPS: MSD: Punjab, AER: 9.1 MPS: Maize-Rice AD: Submontaneous districts of Punjab, J&K, HP and Western UP	Short duration maize, moong, mash as grain crops. Pearl millet, Cluster bean, Sorghum and maize as fodder crops	Moong and mash, pearl millet, cluster-bean and maize as fodders. Sun-hemp or *Sesbania as green manure*	Pearl millet as fodder crop.
IMSD: Plains of Western UP, AER: 4.1, MPS : Pearl millet/Rapeseed and Mustard AD: Agra, Mathura, Aligarh, Bulandshahar, Meerut, Etah, Mainpuri and western part of Muazaffarnagar	Pearl millet, clusterbean, green gram, short duration pigeon-pea	Transplanted pearl millet, clusterbean, green gram and cowpea	Clusterbean, cowpea
IMSD : Plains of Western U.P., AER: 4.4, MPS : Fodder sorghum/pulses AD: Jhansi, Banda, Hamirpur,	Pearl millet, Clust erbean, Cowpea, pigeonpea and black gram as	Pearl millet, Clusterbean, and Cowpea as grain and fod	Pearl millet, Clusterbean, and Cowpea as fodder.

Lalitpur, Morena, Gwalior	grain crops	der. Pigeonpea and black gram as grain crops	
IMSD: Haryana, Chandigarh & Delhi, AER: 2.3, MPS : Pearl millet- Rapeseed/ Mustard AD: Hisar, Bhiwani, Sirsa, Mahendergrah, Gurgaon & part of Rohtak district	Short duration pearl millet (HHB -67), mungbean urdbean (T-9), Cowpea (Charodi) clusterbean (HG 365)	Transplanting of HHB-67 variety of pearl millet as grain crop or direct sowing as fodder crop	Moisture mayg be conserved for *toria sowin*
IMSD : Eastern Rajasthan AER : 4.2/2.1, MPS : Maize/ Pearl millet AD: Bhilwara, Tonk, Dugarpur, Ajmer, Chittorgarh, Rajasamand, Jalore, Sikar, Jodhpur, Churu	Sesame (RT-46), green gram (K 851, RM G 62) sorghum and cowpea as fodder	Sesame (RT-125), green gram (RMG 62), sorghum as fodder crop.	Sorghum as fodder, *toria (TL 15), taramira T27)*
IMSD: Jammu and Kashmir AER: 14.2/14.3, MPS: Maize AD : Jammu, Punch, Riasi, Muzzafarbad, Udhampur, Kathua	Pearl millet, cowpea, mungbean (direct sown), pearlmillet (transplanting)	Pearl millet + cowpea/clu-sterbean (fod-der) sorghum (fodder), maize + cow-pea/clusterbean (fodder)	Fodder as shown in 1-15 August and/or field preparation for September sowing of *toria, gobhi, sarson*
IMSD : Eastern U.P. AER : 9.2 MPS : Rice/Pearl millet AD : Varanasi, Mirzapur,	Short duration up land rice varieties (NDR-97, NDR 118, Barani deep,	Hybrid Pearl millet (NHB-3, NHB-4, BJ-104), green black gram,	Green gram, Bahar variety of pigeonpea sowing at 30

Jaunpur, Ghazipur, Sitapur, parts of Shahjahanpur, Lucknow, Barabanki, Rai Baraeli, Sultanpur	Cauvery, gram, Akashi, Mutmuri). In light texture soils green gram (T44, Mung 1), black gram (T9, pant Urd 19, Ootacamund 35, Narendra Urd 1). Pigeonpea Bahar and, Narendra Ar-har 1) sesame T-4, T-12, T-13	pigeonpea, sesame, niger (GA 10, Oota Pant camund), short duration upland rice varieties.	cm row spacing using 25 kg/ha seed. Niger varieties GA 10 and
IMSD: Madhya Maharashtra AER: 6.1, MPS: Rabi sorghum AD: Solapur, Bidar, Osmanabad, Ahmednagar, parts of Satara, Latur and Sangli	Sunflower, pigeon-pea, horsegram, setaria, castor, pearl millet Sunflower + pigeonpea (2:1) Pearl millet + horsegram (2:1) Pigeonpea + clusterbean (1:2) Castor + cluster-bean (1:2)	Sunflower, pigeonpea, castor Sunfl-ower + pige-onpea (2:1)	Sunflower, pigeonpea, castor Sunflower + pigeonpea (2:1) Sorghum for fodder
IMSD : Vidarbha AER : 6.3, MPS: Cotton/Sorghum AD: Akola, Warda, parts of Amravati, Yeotmal,	Pigeon pea, pearl millet, maize, sunflower	Pigeon pea, pearl millet, maize, sunfl-ower, castor	Pigeon pea, castor Reserve the land for *rabi, safflower*

Parbhani, Buldana and Khandesh and parts of Adilabad of A.P.			
IMSD: South interior Karnataka AER: 8.21 MPS: Finger millet AD: Bangalore, Kolar and Tumkur	Sowing of long duration varieties (Indaf 8, L-5, MR1) Transplanting of nursery of above varieties. Finger millet + red gram (8:1) and finger millet + field bean Little millet and foxtail millet Groundnut, Redgram + groundnut Sunflower hybrids, castor, soybean, chilies	Sowing of medium duration varieties (GPU 28, HR 911, PR 202) or transplanting Sowing of short duration varieties GPU 26) as nursery Sunflower hybrids KBSH 1, KBSH 42 or varieties Mordon and Niger Cowpea (KBC 1, KBC 2) and soybean (KBSH 2). Transplanting of chilies Maize, sorghum, bajra as fodder crop	Transplanting of short duration varieties GPU 28, HR 911 and PR 202). Cowpea (KBC1, KBC2, Lolita), horsegram (KBH1/PHG 9) Transplanting of chilies if protective irrigation available. Maize, sorghum, bajra as fodder crops.
IMSD : Western MP AER : 5.2 MPS : Soybean, Sorghum AD : Indore, Ratlam,	Short duration maize, Navjot, Sathi etc. Pigeonpea (ICPL	Sunflower, Til, cowpea, castor (varieties same as for 15-	Safflower (JSF1, JSF7, JSF 73, Sharda);

Ujjain, Dewas, Dhar, Khandwa, parts of Sehore	151, T21, Kh2, ICPL 87, ICPL 88-039) in deep soils. Sunflower (Morden, Surya, Manjira and other hybrids). Til (Bhadeli, TGK 22, TKG 37), Cowpea (Pusa, Komal, Pusa, Baisakhi, Castor (Ganesh and Var-una) Sorghum, Sundangrass, maize (African tall) Dinanath *grass and bajra as fodder crops.*	31 July season). Sorghum, Sundagrass, maize (African tall), Dinanath grass and pearl millet as fodder	sunflowere (Morden, Surya and Manjira); Til (RT 46); Rajgira (CO1, CO2); castor Maize (African tall as fodder crop
IMSD: Rayalaseema AER: 3.0 MPS: Groundnut AD: Anantapur, Kurnool, Chittoor districts of A.P.	Groundnut (vema na, TMV 2) + red gram (Palnadu)	Ground nut (TMV2, ICGV 91114)	Pearl millet (ICTP 8203, ICMV 221); green gram (MGG 295, MGG 40, PDM 54); dual purpose

			sorghum (M 35-1-1, NTJ 1,2,3,4); horsegram (AK 21, Marukulthi and local)
IMSD : Gujarat, Daman, Dadra and Nagar AER : 4.2 MPS : Pearl millet AD : Khera, Gandhinagar, Mehsana, Sabarkanta, parts of Ahmedabad Panchmahal, Banaskantha and Vadodara districts	Clusterbean, castor, fodder sorghum	Thinning of already planted crops. Castor and fodder sorghum	Castor, fodder sorghum, fodder sorghum + karingada
IMSD : Saurashtra, Kutch and Diu AER : 2.4 MPS : Pearl millet/Groundnut AD : Rajkot, Sundergarh, Jamnagar, Parts of Junagar, Bhavnagar and Amreli	Erect groundnut (GG 2, 5, 7); Til (G1, G2); hybrid pearl millet (GHB 235, 316, 558); green gram (K851, GM4); blackgram (T9); pigeonpea (ICPL 87, GT 101)	Blackgram (T9); forage-maize/sorghum (GFS 5), Castor (Gauch 1); Til (Purua 1)	Forage maize/sorghum (Gundri, GFS 5) Til (Purua 1).
IMSD : Orissa AER : 18.4 MPS : Rice	A. Upland (Rainfed) Blackgram	Niger, black	Horse gram,

AD : Uplands and medium lands of Balasore, Cuttack, Puri and Ganjam	(Setaria/Pant 30); green gram (PDM 54/K85 1); Til (Uma or local) early pigonpea (UPAS 120/ICPL 87); short duration radish, okra, cowpea (SEB 1,2 and clusterbean as vegetables	gram, raddish beans and cowpea as vegetables, early pigeon pea (ICPL 87/UPAS 120)	Sesame, Niger, Cowpea
	B. Medium land rainfed shallow submerged low land		
	Direct line sowing of short duration (about 100 days) rice varieties such as Khandaagir, Pathra, Laligiri or Udaygiri	Direct line sowing of extra early rice varieties as Heera, Vandana, Kalinga 111, ZHU 11-26, Rudra, Sankar and Jaldi 5	Land preparation for sowing of pre-rabi crops like mustard/ greengram/ early pigeonpea

phase, sorghum grown for fodder may possibly accumulate toxic levels of HCN. This may warrant monitoring of HCN concentration in drought-affected sorghum, so as to avoid animal mortality. The crop for the region is provided in Table 7.

Rainfall area of south-west Haryana and north-east Rajasthan: In general this region receives about 60-95 mm rainfall between July 1 and 20. Unfortunately, during this year the region did not receive sowing rain (>25 mm) during this period. As a result, most, of the area, which supports good crops of pearl millet, sorghum, oilseeds and pulses, could not be sown. Keeping in view the predicted probabilities of occurrence of rainfall in this region, following contingency plan is proposed (Table 8)

Table. 7 Contingent crop plan for Punjab and Western U.P.

Situation	Option		RainfallStatus			Remarks
	Crop	Variety	Before Aug. 1	August 2 to 10	August 11to 20	
5-8% rice area which could not be transplanted till July 23, 2002	Short duration early maturing rice varieties	Govinda	Yes	No	No	Seed availa-bility to be ensured
	Maize	All hybrids	Yes	Yes	Yes	
In case rain is delayed beyond August 10, 2002 nearly 10% of transplanted paddy may wither and may need replacement	Maize	All	Yes	Yes	Yes	Seed availa-bility to be ensured
	Castor	Hybrids	Yes	Yes	No	
	Blackgram	Mash 338	Yes	Yes	No	
	Greengram	Moong 613, 668	Yes	Yes	No	
In a situation of delayed rains beyond August 20, 2002	Maize, Sorghum, pearl millet may be grown as fodder Dhaincha as a green manure					Dhaincha seed may not be available in sufficient quantity.

Table 8. Contingent crop plan for rainfed region of Rajasthan and Haryana

Crops	Varieties	Probability date of occurrence of rainfall			Remarks
		26-31 July	***1 to 6 August***	***7 to 15 August***	
Pearl millet + cowpea (for fodder) or Pearl millet + Moth (for fodder)	Raj.171, MH 169+ C 151, Charodi-1, B 16, RS 19 Raj. 171, MH 169 + RMO 40, RMO 257 (for fodder)	Yes Yes Yes	Yes Yes Yes	Yes Yes No	85-90 days 65-95 days 10% higher seed rate 85-90 days 60-75 days 10% higher seed rate
Moth bean	RMO 40, RMO 257	Yes	Yes	Moth bean RMO 40	60-75 days 10% higher seed rate
Cluster bean	RGC 936 RGC 1002	Yes	Yes	For fodder (RGC 936)	85-90 days 10% higher seed rate

Tips for successful implementation of contingent plan

- Steps need to be taken up to ensure availability of quality seed of the above crops and its distribution to the farmers.
- Making fields free of miscellaneous vegetation, making strong bunds around the field boundaries to ensure maximum *in-situ conservation of rain water whenever it occurs.*

- Keeping seed/nursery of perennial fodder grasses and legumes ready for planting on bunds, field boundaries, slopes, etc.
- Pre-treatment of seeds with potassium nitrate or common salt @ 0.7 to 1.0 g L^{-1} water as pre-cursor to drought resistance. The seeds may be soaked in this solution for two hours at night and then sown in field after drying for 2-3 hours. Legume seeds should be treated with recommended fungicides and rhizobium culture before sowing.

Bundelkhand: Bundelkhand region remained almost dry till July 23, 2002. The cultivation of grain crops, pulses and oilseeds, etc., after first week of August should not be advocated. Major emphasis should be on cultivation of cereal-cum-legume mixture for fodder production (Sorghum+cowpea, pearl millet+cowpea). This is highly important as livelihood of a sizable population in Bundelkhand depends upon livestock. If the rains are delayed beyond August 20, no crops should be grown. All efforts need to be made to conserve the rainwater for raising successful *rabi* crops.

Contingency plan for salt-affected soils and areas having poor quality groundwater: Rainwater is the major source of ground water recharge. In addition to decreasing the depth to groundwater, the rainwater also helps in diluting the salt concentration of rechargeable groundwater, wherever such problem exists. Studies on groundwater resources indicated that 25 to 84% of the poor quality waters are also being used for cropping in several states of the country, which are currently under the threat of

Table 9. Percentage of the use of poor quality waters

State	Percentage use (estimated values)
Andhra Pradesh	32
Gujarat	30
Haryana	62
Karnataka	38
Madhya Pradesh	25
Rajasthan	84
Uttar Pradesh	47

drought (Table 9). During drought the salt load of groundwater increases markedly and salt movement towards surface layers of the soil profile also increases, thus making crop production almost impossible.

The soil salinity, alkalinity and poor quality waters are also mainly encountered in the arid and semi-arid areas, which are prone to frequent severe droughts. In the present scenario of drought conditions both short-term and long-term options are proposed.

Short-term strategies

Cultivation of salt-tolerant varieties of different crops is recommended for growing in salt affected areas. The promising varieties are listed in Table 10.

Table 10. Salt-tolerant crop varieties released by the CSSRI, Karnal

Rice	CSR-10, CSR-13, CSR-27, CSR-30
Wheat	KRL-1-4, KRL-19
Mustard	CS52
Gram	Karnal Channa (CSG 8962)

- Conjunctive and /or alternate use of limited ground waters of poor quality for irrigation. The CSSRI, Karnal, has standardized water quality guidelines based upon climate, soil, water and crop factors for use of poor quality waters. In all the drought-prone areas, these guidelines may be kept in mind while irrigating the crops using poor quality waters.
- Farmers having RSC waters for irrigation should be encouraged to use this water judiciously by applying gypsum as soil amendment. In order to facilitate quick utilization, it is recommended that gypsum should be kept in baskets (made from bamboo/mulberry sticks) and covered with jute sack and placed under the source of irrigation so that water is used for irrigation.
- Haryana, Punjab, Rajasthan, M.P., U.P. and A.P. should take up special extension programmes and provide gypsum freely and/or on soft loan term basis to promote use of alkali water.
- In the saline areas, if there is no rainfall during August, it is proposed that farmers be advised to give pre-sowing irrigation with saline waters and go in for *toria*

cultivation in September.

- Other appropriate option for saline areas will be to go in for short duration salt-tolerant clusterbean+pearl millet to be grown as fodder.
- Farmers may also go in for *dhaincha* as fodder and fuel under saline water irrigation (up to EC 6 dS m-1).

Long term

As a result of very scanty or no rainfall, there is going to be a severe problem of sufficient moisture availability for growing *rabi* crops as well. In addition, there will be severe shortage of fodder for cattle. Accordingly, the following strategic options are being proposed:

- The farmers having saline waters may go for *isabgol* cultivation as this crop can withstand the saline water irrigation (EC 8 dSm-1) during the *rabi* season and give profitable yield. *Matricaria* is another medicinal crop that can be cultivated even upto pH 9.5.
- Farmers should be advised to go in for higher seed rate (about 25% more seed) for all the crop during rabi season.
- The farmers may be educated by launching special campaigns to adopt zero-tillage practices for cultivation of wheat under late sown conditions.

Contingent plan for fodder production

Livestock is the major livelihood source of the arid-ecoregions, which are more frequently liable to experience drought. In the states like Rajasthan, 3 out of every 5 years could experience agricultural drought. The year 2002 is a typical year because most parts of the country is experiencing deficient and scanty monsoon. Problems of feeds and fodders are going to be wide spread this time because the states which used to donate fodder to the traditionally drought-prone states such as Rajasthan, Gujarat and Maharastra, will not be able to do so according to prevailing rainfall situation at the mid-monsoon season. We do have 65 million tons of food grains in our warehouses to provide food and employment network security even to landless people. Similar kind of arrangement does not exist for feed and fodder to provide security network for livestock.

Migration of animals from Rajasthan to Madhya Pradesh and Uttar Pradesh is an age-old drought escaping strategy. Fodder grasses are also generally transported from Madhya Pradesh Plateau to Maharastra and Gujarat. This year rainfall is deficient even in Madhya Pradesh and Uttar Pradesh. Therefore, migration of cattle to these areas or movement of grasses from these states seems to be non-feasible and we have crossed mid point of the rainy season. Irrigated states like Harayana, Punjab and western Uttar Pradesh may also not be able to spare fodder for arid regions because of the sub-normal fodder production in their own territories.

In light of the above scenario, options seem limited. However, in case the monsoon arrives upto 15th August 2002, then raising of crops like pearl millet, sorghum, cowpea, clusterbean, etc., for fodder can moderate the situation. However, if the rainfall continued to play truant beyond August 15, 2002, then we have to resort to creation of fodder banks till the next rainy season. There are following possibilities and resources to create fodder security network, particularly for future contingencies:

- Much of the rice crop in Punjab, Harayana and western Uttar Pradesh is combine-harvested, followed by burning of straw. A preliminary estimate indicates that about 20 million tons of rice straw is burnt in these states, alone which pollutes the environment. It is easy to convince the farmers to use these residues for the sake of livestock elsewhere. However, labour in these states is not available even for harvesting grains and that is why mechanized harvesting is a common feature. Therefore, budget should be earmarked out of the Calamity Relief Fund or National Calamity Contingency Fund to purchase machinery for reaping, bailing and densification of the paddy straw so as to minimize the cost of transportation and storage space. These bails can be moved to the critical areas for their use when there is scarcity of fodder. The paddy straw is not a nutritious fodder, contains more silica and requires fortification by urea, molasses or other products. However, fortification should be done only two weeks before its use for the livestock. If fortified paddy straw is stocked, it will attract fungus and will decompose at much faster rate.

- In a normal year this straw may remain unutilised and can be used for mushroom production and to make compost.
- Bhabhar grass *(Eulaliopsis binnata)* grows abundantly in the Shivalik region and has been use as the raw material in the paper and pulp industry. However, at present this raw material has been replaced by soft wood in northern India. There is hardly any buyer of this grass and it can now be utilized for fodder purpose. In fact, early growth of Bhabhar grass is already being used as a fodder in the Shivalik region and it is locally called a *mungri*. The second cut is made after a long gap for making ropes and pulp. The cycle of the second cut can now be curtailed and this grass can also be used for creating fodder bank. It may be fortified later according to its nutritional composition.
- Straw of wheat is still burnt by farmers, which can also be harvested, bailed and densified by the machinery proposed for paddy straw.
- Maize stowers and other residues which do not have other economic use can also be identified from different regions, for building up a fodder bank.
- Perennial grasses, which grow luxuriously during rainy season in different parts of the country, can be harvested and properly preserved to increase the fodder reserve.

Contingent plan relevant to all crops

Special package of practices: Following special packages of practices are recommended for the region.

- Making fields free of weeds to conserve water and nutrients for crop use.
- Reduction of plant density: In case of mid-season drought the crops should be suitably thinned out or rationed out in case of sorghum. In case drought occurs at very early stage , it is always better to resow with subsequent rain rather than allowing sub-optional poor plant stand to persist.
- For drought conditions, anticipating prolonged dry spell breaks, the practices of inter-row cropping helps in risk distribution. This can be achieved by including a companion crop like green gram and cowpea, than the main crops like sorghum or pearl millet.

- The recommended doses of nitrogen application should be reduced by 40% under unirrigated conditions and should always be applied at sowing/planting.
- Full recommended dose of P and K should be placed as basal dose.
- Resort to maximum possible use of organic bulky manures.
- Recommended plant protection measures may be adopted for *kharif* millets and pulses.
- Seeds of sorghum, pigeonpea, mung bean, cowpea, groundnut, sunflower and castor must be treated with Thiram or captan @ 2-25 g per kg seed.

Soil and water management practices: A number of soil and water management practices are required to be followed for the region. These are listed below.

- Seed beds may be kept ready so as to facilitate sowing immediately with the onset of rains. Fields should be properly levelled for uniform water distribution within the sub-plot.
- Broad bed and furrow, ridge and furrow, compartmental bunding and contour trench land configuration may be adopted in shallow alfisols as moisture conservation practices.
- Furrow sowing of *kharif* crops is needed at close plant to plant distance with wider inter-row spacing.
- Frequent inter-culture may facilitate the effect of loose soil as dust mulch.
- Wherever economically viable, mulching should be practiced in between crop rows using locally available mulch material.
- Wherever possible run-off may be harvested to make provision for protective irrigation at later stage/crop ripening.
- Major emphasis is to be given on *in situ rain* water conservation, harvesting excess run-off for re-use and groundwater recharge.

Some other useful irrigation water saving practices: Some strategies to save irrigation are also necessary to alleviate the problem. These are given below.

- Reduction of conveyance losses while irrigating the light textured soils. A simple and cheap technique is to spread a polythene sheet in the field channel before irrigating the field and then roll it back for irrigating the other field.

- Wherever possible the crop should be sown on ridged plots with irrigation every alternate furrow on rotation.
- Ensuring best use of rainwater. In case a rainfall of about 3-5 cm occurs near to irrigation date, the irrigation may be avoided.
- Light irrigation may be applied during initial growth stages when root growth is limited.
- Poor rainfall means lesser recharge to the groundwater. Since groundwater is the most dependable source of irrigation, its indiscriminate exploitation must be avoided. In hard rock areas, for improving well yields, long and continuous pumping should be substituted by intermittent pumpage.

Suitable crops for sub-normal and delayed monsoon: In present situation of the delayed onset of monsoon, following crops can be sown in respective states/areas.

- In case of further delay in monsoon beyond August 20, an early sowing of *rabi* crops is recommended to conserve whatsoever moisture is available in the soil. Apart from usual *rabi* crops, crop of *toria* may be taken. If soil has very less moisture, then taramira can be sown, especially in dry areas like those in Rajasthan and south-west Haryana.
- In Gujarat including Saurashtra, crops like pearl millet, blackgram, greengram, castor, fodder sorghum and in some cases groundnut may be planted. In north Gujarat, clusterbean, greengram and castor may be sown if monsoon is delayed till end of July.
- Millets, especially small millets such as foxtail millet, is one of the crops of choice. Specific varieties of foxtailmillet are available for different regions of the country. Small millets such as kodo, proso and little millet (kutki) are suitable for certain areas of Gujarat, M.P. and Chattisgarh.
- To meet the fodder needs, crops such as field bean, Anjan grass, yellow anjan, Marvel grass, Dharaf grass, Guinea grass, sorghum, cowpea, cluster bean, Lablab bean, maize and Teosinte could be grown.

- In southern parts of the country, crops like sorghum, pearl millet, redgram and groundnut are recommended. Horsegram in shallow soils and sunflower in deep soils is also recommended.
- Wherever quality seed is not available, local procurement from adjoining areas may be made and used after checking for seed germination.

Suitable drought-tolerant and early maturing varieties: A list of promising drought-tolerant and early maturing varieties of different crops is given in Table 11. Depending upon the site specificity and present scenario of monsoon, choice of varieties may be made.

Table 11. Suitable drought resistant/tolerant early maturing varieties of different crops

Crop	State	Suitable varieties
Pearl millet	Rajasthan	Pusa 23, RHB 90, Pusa 605, HHB 60, HHB 67, HHB 68, Raj 171, ICMH 356, JBB 2
	Gujarat	Pusa 23, Pusa 605, GHB 15, GHB 235, GHB 316, Nandi 8, Nandi 32, Icmh-356
	Andhra Pradesh	Sabouri, ICTP 8203, Ananta, ICMV-221
Sorghum	Rajasthan	CSH6, CSH 13, CSH 9, CSH 16, CSH 14, SPV 96, CSH 17, CSV 15, CSV 10
	Gujarat	CSH 9, CSH 13, CSH 16, CSV 15, CSV 13 GJ 39, GJ 37, GSH 1, GH 40, GH 41.
	Andhra Pradesh	CSH 16, CSH 9, CSH 13, PSH 1, CSV 13, SPV 462, CSV 15.
Maize	Rajasthan	Mahikanchan, Prakash, Ganda 11, Shakti, Pusa, Hybrid 1, Pusa Hybrid 2
	Gujarat	Guj. Makki 1, Guj Makki 2, Prakash, Pusa

		Hyb 1, Pusa Hyb 2, Gaurav Shakti
	Andhra Pradesh	Harsha, Deccan 103, Deccan 109, Deccan 107, MMH 133, Prakash, Pro 311, Bio 968
Sesamum	Rajasthan	RT 124
	Gujarat	RT 54, RT 103
	Andhra Pradesh	YLM 11, T78, Sweta T II
Castor		All available hybrids and varieties
	Andhra Pradesh	Jyoti, Deepti, Kranti
Sunflower	Rajasthan	PKVSH 27(H), PKVSH 9
	Gujarat	Guj Sunflower, Sungene 85(H)
	Andhra Pradesh	TNAU-SUP-10
Mothbean		All available improved varieties such as RMO 40, RMO 257
Cowpea	Rajasthan	V 505
	Gujarat	GC 3
Green gram	Rajasthan	ML-267, Pusa 105, RMG 62, MUM 2
	Gujarat	PDM 11, Pusa 105, BM 4, Guj Mung 3
	Andhra Pradesh	WWG 2, Pusa 9072, Madhura 295, IGG 407, IGG 450
Blackgram	Rajasthan	T-9, Pant U-19
	Gujarat	T-9, Pant U-19
	Andhra Pradesh	T-9, Pant U-19, LBG-17, LBG-402, LBG-20
Horsegram	Rajasthan	AK-21, PHG9

Foxtail millet	Rajasthan	Gavari, Meera
	Andhra Pradesh	Prasad, Krishnadevaraya, Narasiharaya, AK-132-1
Fodder Crops		
Clusterbean	Rajasthan	DP safed, FS 277, HFG 119, HFG 156, Bundel Guar 1, Bundel Guar 2
	Gujarat	Bundel Guar 1, Bundel Guar 2
Pearl millet	Rajasthan	Raj Bajra Chari 2, Giant Bajra
	Gujarat	Rajko, Raj Bajra Chari 2, Giant Bajra
	Andhra Pradesh	Giant Bajra, Raj Bajra Chari 2.
Sorghum	Gujarat	SSG 59-3, MFSH 3, Harasona, Guj Frage Sorghum 1, HC 136, Raj Chari 1, PC 6, PC 9, PC 23
	Andhra Pradesh	PC 6, PC 9, PC 23, HC 136, Raj Chari 1, SSG 59-3, X 998, MFSH 3, Hara sona
Deenanath grass	Rajasthan	Bundel Deenenath 1, Bundel Deenanath 2
	Gujarat	Bundel Deenenath 1, Bundel Deenanath 2
	Andhra Pradesh	Bundel Deenenath 1, Bundel Deenanath 2
Cowpea	Gujarat	Bundel Lobia 1, Bundel Lobia 2, EL 4216, UPC 287, UPC 5286, UP C 8705
Napier x Bajra Hybrid	Andhra Pradesh	NB 21, IGFRI 10, CO 1.
	Gujarat	CO 1
Maize	Rajasthan	African tall
	Gujarat	African tall
	Andhra Pradesh	African tall

Field bean	Gujarat	Bundel sem-1, JLP 4.
	Andhra Pradesh	Bundel sem-1, JLP 4.
Guinea grass	Andhra Pradesh	Macuenni Hamail
Cotton	North Zone (Haryana, Punjab, Rajasthan, Western (U.P.)	(a)Desi varieties : LD 327, LD 491, HD 107, RG 8, Lohit (b)American varieties: Bikaneri Narma, H 777
	Central Zone (M.P., Maharashtra, Gujarat)	(a)Desi Varieties: Maljari, AKH4, AKA 8401, Y-1, G.Cot 11, G.Cot 13, G.Cot 17, G.Cot 19. (b)American Desi Hybrids: PKV 081, LRA 5166 Desi Hybrids : DH 7, DH 9, Pha 46
	South zone (Karnataka, Tamil Nadu, A.P.)	(a)Desi Varieties : Raichur 51, DB 3-12, K 10, K 12 (b)American : LRA 5166
Sugarcane	Tropical zone (A.P., M.S., Karnataka, Tamil Nadu, Kerala, Orissa, M.P., Gujarat)	Co 740, Co 7219, Co 8011, Co 8014, Co 86010, Co 86032, Co 92002 Co 85019, Co91010, CoM 88121 (Krishna) CoG 93076, 85 R 186 (Harita), CoV 92102, CoA 89085 (85 A 261), CoR 8001, CoC 671.
	Sub Tropical Zone (Punjab, Haryana, U.P., Bihar)	Co1148, CoS 767, Co 7717, Co 87263, BO 91, BO 128

Rice	Suitable upland rice varieties across the States	Tulasi, Vandana, Aditya, Rasi, Jawahar Rice 3-45, Anjali
	Andhra Pradesh	Somasila
	Chattisgarh	Dateswari
	Kerala	Harsha
	Madhya Pradesh	Rasmi
	Orissa	Lalitagiri, Udayagiri
	Rajasthan	Vagadhan,
	West Bengal	Kanika, Jamini
Millets	Royalseema region of A.P., parts of	Foxtail millet:
	Karnataka and M.S.	Prasad (SIA 326): matures in 80-85 days can be planted upto end of August. Krishnaadevaraya and Narasimaharaya : Produce more stover than prasad. AK 132-1: highly drought tolerant.
	Western Rajsathan	Foxtail millet: SR 11 (Gavari), SR 16 (Meera)
	MP and Chhatisgarh	Little millet: JK-8 Matures in 70-75 days. Suitable for contingency planning, Evolved at JNKVV, Jabalpur. Kodo millet: JK-76, RBK-155
Fodder crops (under late	Western Rajasthan	Field bean: Bundel Sem-1 Anjan Grass: Marwar Anjan

onset of Mon-soon)		Yellow Anjan: Marwar Dhaman
	Saurashtra Region of Gujarat	Marwar grass: GMG-1 Dharaf grass: GAUD-1
	Punjab and Haryana	Sorghum (Single cut): HC-136, HC-171, HC-308, HC-6 Sorghum (Multicut): Punjab Sudex, LX-250 Maize: J-1000 Teosinate: TL-1 Cowpea: CS-88 Cluster bean: HFG-156, Guara-80, Bundel Guar-3 Lablab bean: JLP-4 Guinea grass: PGG-10, PSG-101
	Western Uttar Pradesh	Sorghum (Single cut): Pusa chari-6, HC-136, UP chari-1, UP chari-2, Pant chari-3, Sorghum (Multicut): Meethi Sudan, SSG-59-3, Pusa chari-23 Cowpea: UPC-287, Bundel Lobia-2 Lablab bean: JLP-4
	Madhya Pradesh & Chattisgarh	Sorghum (Single cut): JC-6, HC-171, HC-308 Sorghum (Multicut): JC-69 Cowpea: UPC-287, UPC-5286 Lablab bean: JLP-4

Crop-Group and Cropwise Contingency Plan for *Kharif* Season

Pulses

- In the event of late monsoon arrival the pulse crops which can be planted preferably up to 15th August or till 1st week of September are: blackgram, greengram, pigeonpea and moth bean
- In case of greengram and blackgram all varieties recommended for *kharif* season may be grown up to first week of September. Sowing after first week of September may be done only for the purpose of fodder.
- Only specific varieties of pigeonpea, recommended for pre-rabi planting, may be grown till first week of September. These varieties are Bahar, Pusa 9 and rabi arhar 20 (5) for the States of Bihar, West Bengal, Orissa, Andhra Pradesh, Maharashtra and Gujarat. Planting of early pigeonpea is not possible in states like Punjab, Haryana and western U.P. where early maturing varieties of pigeonpea normally are grown in the first week of July.
- Crops like moth bean can be grown for grain as well as fodder till the second week of August in the state of Rajasthan and Gujarat.

Oilseeds

- In case of oilseed crops, sesame can be planted up to third week of August, whereas niger can be sown upto September. Since the per hectare requirement of seed in case of sesame is very low all out efforts must be made to cover more area under sesame to utilize the land in the event of failure of other *kharif* crops like maize, pearl millet and other minor millets.
- Similarly, castor can be grown successfully up to the first week of September in the areas suitable for its cultivation.
- The other two important oilseed crops, soybean and groundnut, are likely to suffer heavily if rains are further delayed. However, groundnut can be planted up to September in a few southern states. Therefore, efforts should be made to cover more area under groundnut in Andhra Pradesh, Tamil Nadu and Karnataka.
- Since the rains are delayed, there seems good possibility of coverage for *toria* in

Punjab, Haryana, Madhya Pradesh, Uttar Pradesh, Bihar and W. Bengal. Therefore greater emphasis is to be given to cover more area under toria crop. All recommended varieties of toria may be promoted as *rabi* crops.

Cotton

- In the northern zone, cotton crop is grown entirely under irrigated condition and the present drought spell all over the country is not going to have a major impact in the irrigated cotton belt of the northern zone.
- In the event of shortfall in the availability of canal water, it is suggested that the farmers may adopt alternate furrow irrigation, which will economize water requirement by nearly 50%.
- Use of micro-irrigation system, such as drip and sprinkler, may be advocated wherever feasible and in the event of limited water availability.
- Central zone is mainly rainfed. In this zone, cotton is taken as a rainfed crop and is subjected to the vagaries of monsoon. This year, in particular, due to late onset of monsoon and the aberrations being witnessed, many parts in the zone are likely to be affected seriously due to moisture stress.

The following moisture conservation measures are suggested for effective utilization of the available water in the soil as well as the likely precipitation in the remaining part of seasons.

- Development of ridge and furrow across the slope for effective conservation of soil moisture as well as rainwater.
- Use of organic mulches such as *Subabul* loppings, straw etc. to conserve the soil moisture.
- Repeated interculture operation to keep the field weed free.
- Wherever water resources are available, such as lake, ponds, wells, etc., protective irrigations can be provided to the crop.
- Micro-irrigation system as suggested above, may also be adopted wherever possible for improving the water use efficiency and cover more area.
- Nutrient input management through foliar applications is suggested.

- In those areas of central zone where sowing has not been undertaken so far, short duration varieties recommended for respective states by State Variety Release Committee/ Central Variety Release Committee may be planted latest by July 31, 2002. Beyond end the of July, alternative crops such as castor and pigeonpea may be cultivated looking to the local condition.
- The contingency measures suggested for central zone are also applicable for the rainfed areas of south zone, especially Andhra Pradesh and Karnataka. In the winter cotton areas of Tamil Nadu, sowings are yet to be taken up.
- In the central zone, varieties of *arboreum* which have higher degree of tolerance to drought conditions, such as Maljari (for Madhya Pradesh), AKH 4, AKA 8401, Eknath, Sweta, AKA 5, Turab Y1 (for Maharashtra) and varieties of herbaceum (for Gujarat) may be cultivated.
- Early maturing varieties of G. *hirsutum*, such as PKV 081, **Rajat**, Anjali, LRA 5166 etc., may also be planted where sowing has been delayed because of continuous drought.

Sugarcane

The current season's sugarcane crop (2002-2003) is facing severe drought in many states of the country. The drought has adversely affected the elongation phase of the crop, thus limiting the cane length. If drought continues further, it many prove detrimental both to productivity and quality of crop in the ensuing crushing season. This warrants saving the crop under such situation as far as possible. The contingency plant for the benefit of the growers to protect the crop from complete failure is as under:

Soil Moisture Conservation

- The dried lower leaves of the standing cane crop may be stripped and used as mulch in the inter-row spaces of the crop. This well conserve available soil moisture by controlling weeds and cutting down surface evaporation.
- The intercultural operations may be undertaken to create dust mulch to break soil capillaries for checking surface moisture loss.

Efficient Irrigation Management

- Provide extensive (light life saving) irrigation over larger cane area rather than intensive (heavy) irrigation in limited area may be practised.
- Adopt to alternate furrow irrigation to effect water economy.
- Under limited water availability conditions, irrigations should be scheduled to cover the drought susceptible varieties and ratoon stands in the first instance. The irrigation may be phytophased to avoid soil moisture stress at consecutive critical stages of crop growth.
- Sprinkler irrigation system may be operated during period of less evaporative demand to maintain optimum soil moisture regime.

Crop and Nutrient Management

The crop stands (both plant and ratoon) have already been exposed to drought in the early elongation phase of the crop. Therefore, it would be advisable to adopt the following management practices to save the crop and revive its further growth.

- Weed control through herbicides may be taken-up particularly in late planted cane. Where herbicide application is not feasible, the weeds may be cut and used as surface mulch to conserve soil moisture.
- Earthing-up operation could also be taken in autumn and timely planted crops which have attained reasonable height. The furrows created in this may be utilized for light irrigation, covering more cane area.
- If drought persists the sugarcane crop with poor growth failing to form millable canes may be harvested in October to raise ratoon stand from such crop. The harvested material may be used as seed cane for autumn planting and/or feeding to the cattle.
- The last dose of nitrogen meant for elongation phase, if already not applied, may be top-dressed only with light irrigation or after rains.
- Spray of 2.5% urea with 2.5% KCI or MOP may be useful in areas where some soil moisture is available. This well imparts drought tolerance to plants.

Plan for autumn planting of sugarcane crop (2002-2003)

- The area meant for autumn sugarcane planting should be kept free of weeds and conserve soil moisture to start early planting.
- Autumn sugarcane may be intercropped with short duration hight-value mid-season income generating crops like *toria, mustard, peas, spices, etc. This will also encourage farmers to go for planting more acreage under autumn sugarcane, giving higher cane yield and sugar recovery.*
- Winter initiated ratoon of early sugarcane varieties may be intercropped with high density early bulking forage crops like senji to protect the stubble sprouts from injury, enhance soil fertility and provide forage to animals.

Pearl millet

- Planting of pearl millet hybrids is not advisable. Even early maturing hybrids like HHB 67 should not be planted beyond July end.
- Wherever crop has been planted and suffering from moisture stress, the plant population may be reduced and shallow interculture (dust mulching) may be practiced.
- The Pearl millet may be grown mixed with pulsed up to the 1st week of August as fodder crop, which may give at least fodder to some extent.

Rice

Rainfed: In traditionally rice growing rain-fed areas, where rains are likely to come late and where a normal transplanted rice crop is ruled out, short duration upland rice varieties or those rice varieties that are suitable for direct seeding either in dry or wet condition and subsequent flooding, are recommended for direct seeding. In certain areas, delayed transplanting can be done with older nurseries if these varieties are suitable. Suitable rice varieties for different situations are listed in Table 11.

Irrigated: Irrigation at 1 to 4 days after disappearance of ponded water in case of rice produces almost similar yields as are obtained with continuous submergence. This practice economizes more than 30% of irrigation water without lowering the rice yields. Farmers may be advised to strictly follow this irrigation schedule for already transplanted rice crop.

Last irrigation to paddy can be terminated 14-17days before the harvest. This saves about 16 cm of irrigation water without any yield reduction. The farmers need to be apprised about this practice well in advance as the short duration, early-maturing paddy varieties are likely to mature by August end. Irrigation to such varieties may be withheld beyond August 15, and the same water can be effectively used for main season planted varieties.

Small millets

Rayalseema region of Andhra Pradesh, parts of Karnataka and Maharashtra : Foxtail millet is one of the choice of these regions in view of its drought-least tolerance possibility , major pests and diseased, photo insensitivity and assured modest yield. For fox-tail millet in Andhra Pradesh, Karnataka and Maharashtra, application of 40:30:0 kg NPK/ha as basal dose for achieving quich growth and withstanding drought is recommended.

Western Rajasthan: Foxtail millet *(knagni)* a well known drought hardy crop, can give reasonable harvest in areas where annual rainfall is less than 400 mm. Varieties of fox-tail millets, viz. SR 11 (Gauri) and SR 16 (Meera), are suitable for delayed planting and these mature in 80 days. SR 16 has stay green character and gives higher fodder yield also. Application of 10-20 kg N/ha as basal dose is beneficial in withstanding drought and giving higher yield.

Gujarat: Small millet are not important in the state except in the region of Dangs and adjoining areas. In years of extreme drought and erratic monsoon small millets like *kodo, proso* and little millet could be ideal crops for contingency planning for producing quickly fodder and grain.

Madhya Pradesh and Chattishgarh: Little millet *(kutki)* is one of the important crops of tribal areas of M.P. and is well known for early maturity and resilience. *Kodo* millet is another crop grown extensively is these areas and popular in tribal areas. *Kodo* millet varieties viz. JK-76 matures in 80-85 days and RBK 155 matures in 90-95 days. Application of 10-20 kg N/ha as basal dose is beneficial.

Future Strategy

Drought is a recurring phenomenon, particularly in arid and semi-arid regions. Some permanent solution to moderate and/or mitigate its devastating impacts on human and livestock populations is required. Some of the suggested options are as follows.

Improving general ecology of the arid regions

- Increasing perennial vegetation component through large scale plantation of drought tolerant trees, bushes and grasses of food and fodder value in all kinds of waste lands and vacant lands and as a component of farming systems.
- Creation/renovation of rainwater storage structures in each village. Let the whole village water be conserved and re-utilized in the same village.
- Strict implementation of *in-situ* rainwater conservation practices, such as terracing, contour bunding, land shaping, vegetative barriers in all areas pron to drought.
- Up gradation of productivity of natural range lands/grasslands through reseeding, inclusion of leguminous component and introduction of top feed perennials.

Creating alternate livelihood resources

- Promoting subsidiary occupations such as mushroom cultivation, sericulture, bee keeping, post-harvest handling of products obtained from dryland crops such as trees, bushes, grasses, etc.
- Promoting cultivation of drought-tolerant medicinal and other high-value industrial crops.
- Promoting the use of unexploited/under exploited food and feed resources such as edible cactus and genus *Prosopis. Some of these crops are already exploited for multiple use in different parts of the world.*

Creation of feed and fodder banks

Feed and fodder banks need to be created by conserving crop residues and other miscellaneous vegetation (palatable tree leaves, bushes, grasses, etc.), which grow naturally during monsoon in different parts of the country. Fruits and pods of many trees naturally growing in dry areas can be exploited as feed source. Pods of *Prosopis juliflora* has been commercially exploited in countries like Brazil, Argentina, Mexico, Peru, Senegal, etc., as a human food and cattle feed. This tree is nature's gift to mankind and it grows naturally in dry regions and produces fuel-wood, timber and fruits of high economic value.

Impact of Delayed Monsoon on Kharif Crops in Haryana: Contingency Plan

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Haryana state lies between 27°39' and 31°N latitudes and between 74° 31' and 77° 30' E longitudes. It has three distinct climatic sub-zones. Yamuna Nagar, Ambala, Karnal, Panipat and Kurukshetra districts fall under the sub-tropical monsoon climate, with mild and dry winter and hot summer. Sirsa district has a tropical, hot arid climate. Hisar and other districts have a tropical, hot semi-arid climate. The total annual rainfall ranges from 300 mm over the extreme western parts adjacent to Rajasthan, to 560 mm on the extreme south and 1080 mm over the extreme north along the eastern border of the state. The state, as a whole, receives a total annual rainfall of 593 mm. The south-west monsoon generally covers the entire State by the last week of June, and remains active till August, with 5-11 rainy days in each of these 3 months. It begins to withdraw from the State in the last week of August or first half of September. During winter (November to March) Haryana receives 60 mm of rainfall, which although is low, has great significance for agriculture. The weekly rainfall (mm) in Haryana during monsoon season of year 2002 (June 20-August 14) is given in Table1.

Table 1 . Rainfall (mm) in Haryana during 20.6.02 to 14.8.02

Station	20.06.02 to 26.06.02			27.06.02 to 3.07.02			4.07.02 to 10.07.02		
	Actual	*Normal*	Departure	*Actual*	*Normal*	*Departure*	*Actual*	*Normal*	*Departure*
Ambala	1	28	-95	11	44	-74	65	75	-18
Bhiwani	0	7	-100	0	16	-64	46	26	79
Faridabad	0	8	-100	6	30	-63	10	39	-75
Fatehabad	1	7	-92	11	20	-100	0	19	-100
Gurgaon	14	9	44	0	31	-100	2	36	-94
Hisar	0	9	-100	0	19	-90	4	21	-80

Jhajjar	0	5	-100	2	24	-100	5	26	-81
Jind	1	10	-95	0	31	-100	17	26	-32
Kaithal	0	13	-100	0	17	-100	21	27	-23
Karnal	0	13	-100	0	27	-100	13	51	-74
Kurukshetra	0	19	-100	0	25	-100	19	43	-57
Mohindergarh	8	9	-12	0	24	-100	6	25	-78
Panchkula	-	30	-	-	63	-	52	72	-28
Panipat	0	15	-100	0	22	-100	8	38	-80
Rewari	1	7	-80	2	21	-90	7	25	-72
Rohtak	0	8	-100	8	33	-74	5	30	-85
Sirsa	16	4	298	0	10	-100	13	13	0
Sonipat	0	9	-100	0	23	-100	0	36	-100
Yamunanagar	0	40	-100	27	51	-48	88	63	39
	11.7.2002 to 17.7.2002			18.07.2002 to 24.7.2002			25.07.02 to 31.07.2002		
Ambala	0	67	-100	5	68	-93	5	70	-93
Bhiwani	0	34	-100	0	32	-100	0	32	-100
Faridabad	0	52	-100	2	58	-97	1	43	-98
Fatehabad	0	25	-100	0	28	-100	0	25	-100
Gurgaon	1	54	-98	28	53	-47	0	49	-100
Hisar	0	31	-100	0	30	-100	0	29	-100
Jhajjar	0	42	-100	0	33	-100-	0	36	-100
Jind	0	51	-100	0	29	-100	0	30	-100
Kaithal	0	38	-100	8	30	-73	10	29	-65
Karnal	0	59	-100	0	43	-100	18	38	-52
Kurukshetra	0	56	-100	0	53	-100	25	43	-41
Mohindergarh	0	46	-100	0	39	-100	0	29	-100
Panchkula	-	79	-	-	-	-	-	82	-
Panipat	0	49	-100	0	42	-100	0	41	-100
Rewari	0	43	-100	3	46	-93	0	36	-100
Rohtak	0	55	-100	2	51	-97	2	41	-94

Sirsa	0	27	-100	1	25	-98	0	24	-100
Sonipat	1	51	-98	0	54	-100	0	50	-100
Yamunanagar	0	60	-100	9	78	-88	0	73	-100
	1.8.2002 to 7.08.2002			8.8.2002 to 14.08.2002			Season update		
Ambala	44	75	-41	279	90	211	438	561	-22
Bhiwani	1	29	-97	20	38	-47	97	231	-58
Faridabad	12	46	-75	85	43	95	150	333	-55
Fatehabad	0	30	-100	0	25	-100	26	191	-88
Gurgaon	10	45	-78	23	51	-50	87	344	-75
Hisar	0	29	-100	12	31	-60	28	215	-87
Jhajjar	0	33	-100	57	35	63	68	256	-72
Jind	9	29	-77	8	30	-75	56	261	-79
Kaithal	0	32	-100	53	37	45	96	240	-58
Karnal	110	46	142	33	53	-38	200	380	-45
Kurukshetra	72	40	82	49	46	5	211	354	-41
Mohindergarh	0	36	-100	2	52	-97	27	278	-90
Panchkula	0	-	-62	137	91	51	189	603	-69
Panipat	17	45	-88	18	48	-63	67	324	-79
Rewari	6	51	-100	37	51	-29	110	291	-65
Rohtak	0	41	-100	118	38	212	136	316	-57
Sirsa	2	18	-90	0	23	-100	54	157	-66
Sonipat	19	44	-57	59	44	32	96	331	-71
Yamunanagar	81	89	-10	133	83	60	379	586	-35

* Data collected from IMD's Meteorological Centre, Chandigarh

Crop Situation

The details of the area under different *kharif* crops during 2001, (targets, actual sown, shortfall and estimated crop damage) are given in Table 2. All the principal crops of the *kharif* season were adversely affected either due to non-sowing or delayed sowing and moisture stress in the standing crops. The crop-wise situation is discussed below:

Table 2 . Kharif season's crop statistics (provisional) in Haryana

(000,ha)

Crop	Area covered during *Kharif* 2001	Area covered during *Kharif* 2002			Estimated crop damage (%)		
		Target	Area sown	Shortfall	100	>50	>25
Paddy	1027	950	625	325	20	150	455
Bajra	586	620	274	346	247	27	-
Maize	18	50	25	25	-	-	-
Jowar	104	120	110	10	33	30	-
Pulses (*kharif*)	33.4	70	52	18	47	5	-
Total food grains	1768.4	1810	1086	714	-	-	-
Sugarcane	162	170	170	0	10	30	130
Cotton	630	610	550	60	112	110	328
Oilseeds (*kharif*)	5.6	6	3.7	2.3	3.7	-	-
Guar	-	200	31.7	168.3	31.7	-	-
Grand Total	2566	2796	1841.4	954.6	-	-	-

Paddy

The area under paddy during 2001 was 10.27 lakh ha. During *kharif* 2002, the target was 9.5 lakh ha. Keeping in view the programme of diversification, an action plan was drawn to divert 1.00 lakh ha area from paddy. Up to July 2002, an area of 6.25 lakh ha area was covered, as against 7.30 lakh ha during last *kharif*. The paddy crop was affected by the delayed monsoon in the following ways:

- In the areas having average/poor quality water, there was salt deposition in the root zone and the crop ether failed or was likely to fail.
- Moisture stress adversely affected the growth and tillering of standing crop.
- Delayed transplanting was expected to result in low yield.
- Delayed transplanting of Basmati rice was expected to delay the sowing of wheat in the following *rabi* season.
- Delayed monsoon had put more pressure on groundwater and as a result depletion of

water table took place at a faster rate.

- The cost of cultivation of paddy increased due to increased use of diesel sets/generator sets and lowering down of pits for housing the electric pump sets.

There had been rains in the 2nd week of August in some of the paddy growing districts of the state, but the loss could not be compensated.

Cotton

An area of 6.30 lakh ha was covered under cotton during *kharif* 2001. A target of 6.1 lakh ha was kept for the *kharif*, of which an area of 5.50 lakh ha was covered. The less area coverage though was not on account of the prevailing drought-like situations, but due to large-scale damage to the crop during the previous *kharif* by the attack of American bollworm. The sowing of cotton in any case was over by the end of May.

The delayed monsoon resulted in moisture stress conditions in the cotton crop, leading to poor plant population and stunted crop growth. The lack of rainfall during June in particular had adversely affected the growth of plants. The attack of pests and diseases, however, was under control due to the prevailing hot and dry conditions. The incidence of leaf curl virus (CLCuV) in cotton has become a major concern as the level of incidence ranges from 6-70%. Approximately 15% crop has failed, an equal number suffered more than 50% damage.

Sugarcane

During *kharif* 2001, an area of 1.62 lakh ha was covered under sugarcane and the target was kept at 1.70 lakh ha, which was achieved. Sugarcane is grown under assured irrigation and the active growth period is July-September. Because of hot and dry season, however, the crop was adversely affected and the incidence of top borer was very high. Around 10% of the crop failed, another 30% had stunted growth. There was no formation of canes; the overall loss was around 50-60%.

Pearl millet

This crop was worst hit by the failure of monsoon in the State. A target of 6.20 lakh ha was kept for *kharif* 2002 against the coverage of 5.86 lakh ha during *kharif* 2001. The pearl millet crop was sown on 2.74 lakh ha area against the coverage of 5.50 lakh ha during the corresponding period in *kharif* 2001. The crop was adversely affected and started withering. No heading took place and the crop was only fit for grazing.

Kharif pulses

Arhar and mung are the major *kharif* pulses. A target of 70,000 ha area coverage was kept for *kharif* 2002, against the coverage of 33,000 ha during *kharif* 2001. The sowing was done in 52,000 ha. The crops of mung and moth have failed, while 10-15% arhar crop survived.

Kharif oilseeds

Sesamum is the main oilseed crop of this season and is followed by groundnut and castor. About 95% of the oil seed crops was already damaged due to prevailing drought condition.

Maize

A target of 50000 ha area was fixed for *kharif* 2002 against 18,000 ha area that was sown during *kharif* 2001. So far maize could be sown in 25,000 ha area. Fortunately, rainfall was received in the maize-growing areas of Ambala and Panchkula districts and crop condition was above-average but sowing was delayed in the remaining regions, covering 35,000 ha. The productivity of maize was expected to be adversely affected due to delay in sowing and heavy incidence of shoot borer.

Kharif forages

As mentioned earlier pearl millet failed and similar was the situation of clusterbean and sorghum in the State. An area of 1.70 lakh ha was covered against the target of 1.20 lakh ha. During *kharif* 2001 sorghum was sown in an area of 1.04 lakh ha. Sorghum, though sown under assured irrigation conditions, the crop also suffered from water stress, adversely affecting both green and dry fodder.

Contingent Plan

In view of delay in onset of monsoon, long-term dry spell after sowing/transplantation, early withdrawal of monsoon, and heavy monsoon causing flood in some pockets, a broad-based contingent for Haryana state has been prepared. Some of the measures spelt out in action plan are suggestive in respect of different crops. These measures are mentioned below.

Paddy

In case rainfall is not received by the end of July, there is likelihood of the area to remain uncovered under paddy. The following alternate crops can be grown:

- Short duration oilseed crop of *toria* is likely to occupy majority of the area remaining uncovered under paddy. Toria can be planted after 15th August and up to mid September. HSDC has been asked to make arrangements for toria seed.
- Sizeable area would be covered under short duration pulse crop, Urad, for which seed is available with HSDC, NAFED and private sector.
- Some area will be diverted to maize, for which the seed of short duration hybrids is available with private traders and HSDC.
- Some area will be diverted to early sowing of potato in the month of September after which sunflower can be taken up during *Zaid-rabi*.
- Vegetables are also likely to cover some of the remaining unsown area.

Pearl millet

- If there is no rain till July end in pearl millet growing areas of the State, there is no scope for pearl millet grain crop. Soil moisture may be conserved for *rabi* crops.
- When there are showers /mild rains during first week of August, the farmers may be advised to grow pearl millet/cluster bean, even in the mid- August for fodder. Secondly, the farmers will be advised to conserve moisture for early/timely plantation of mustard in September/October.
- The areas where cotton and sugarcane have failed and if there are rains, these areas can be brought under toria, forage *pearl millet*, sunflower, or vegetables.

Likely Fall-out on *Rabi*-season Crops

In rainfed districts Faridabad, Jhajjar, Rohtak and Sonepat, which received rains in the 2nd week of August 2002, the moisture can be conserved for sowing of *rabi* pulses and oilseeds. However, these crops are sown in the month of October when the mean temperature is around 25-30°C. Because of meager rain in *kharif* 2002, it may be difficult to retain the moisture till that time.

- Wheat is taken as irrigated crop in the State, sown from mid-November to midDecember. Considering the water deficit, the varieties like C-306, WH-147,WH-283,Raj 3765, etc., should get attention of the agriculture managers.
- In all *rabi* season crops, the damage due to termite is likely to be quite significant, and requires a special campaign for control.
- Spices like fenugreek needs to be popularized.
- Extensive use of bio-fertilizer (*Rhizobium* and *Azotobacter)* is suggested to cut down the cost and meet the hunger and thirst of plants.
- Insurance of quality inputs (seed, fertilizer, agro-chemicals) is necessary.

Effect of Drought on Animal Component

During the drought, animals become more prone to diseases and therefore special care need to be taken to maintain good health of livestock. During drought, the availability of green-fodder and other nutritious feed becomes restricted, leading to nutritional stress on the animals. It is a well-established fact that nutritional status of an animal has a direct relationship with parasitic diseases. Therefore, in drought conditions the existing parasitic diseases like parasitic gastroenteritis, fasciolosis and amphistomosis, ticks and tick-borne diseases like theileriosis and babesiosis might get aggravated, leading to morbidity, mortality and huge production losses to the farmers. Malnourished animals in drought-hit areas suffer the most from disease "Pica", caused by internal parasites. It has been observed that such animals suffer more from Trypanosomiasis (surra) and mange, which further add to the economic burden of the farmers due to heavy production losses. In general, the effect of parasitic diseases gets enhanced, leading to severe clinical diseases in malnourished animals as compared to well-fed animals.

The farmers are advised to go for mass deworming of their animals. Acaricidal/insecticidal sprays are also recommended. Moreover, they should provide balanced diet and clean water to their animals. The clinical camps may also be arranged at regular intervals in drought-hit areas.

Long-term Future Planning

- Declare water a national resource
- Establish seed banks for drought tolerant, early maturing varieties/ hybrids of mung, moth, grain cowpea, pearl millet, clusterbean and sesamum where 100-200 q of quality seed in each bank is reserved for such situation, which occurs after a gap of 4-5 years.
- Encourage planting of less-water-requiring crops and discourage those requiring more water.
- There is a need for strong parallel national policies on population and agriculture.
- Plan for linking of different rivers in the country.
- Bring compulsory legislation for rainwater harvesting

Some Considerations for Drought Management in Indian Arid Zone

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In the Thar Desert, located in western Rajasthan, rainfall failure is a common phenomenon. About 6 to 7 years in a decade are rainfall-deficit, or drought years, out of which 3 to 4 are severe drought years. The drought of 2002 may be termed as unique in the sense that people in the region did not experience such a severe drought in their lifetime. Perhaps this could be the driest year in the last 100 years. The scientists have to think about developing research strategies that are short-term, so that some immediate relief may be given to the farmers and livestock. Long term planning should also be considered so as to take advance action to avoid such a crisis in future.

Short Term Strategy

For immediate planning we can group the farmers into two categories, i.e., irrigated farmers and rainfed farmers. In irrigated areas most of the farmers, whether having large, or medium to small holdings, can maintain livestock and sustain families during such severe droughts with the irrigation water they have. Under dryland or rainfed agriculture, where there is no irrigation water, only large farmers can maintain their families and livestock during severe druoghts, because generally they keep food grains and fodder reserves for 2 to 3 years. The small and medium farmers in rainfed agriculture and the landless farmers, who are dependent chiefly on goat, sheep, cattle and camel herds, are most hard-hit. We have to think for them. The farmers need food for their families, feed and fodder for their livestock and often enough cash, and hence employment to buy food and fodder. The traditional *kharif* season practice in the rainfed area is to mix the seeds of pearl millet, moth bean, mung bean, clusterbean, sesame and *kachri* for sowing during the drought years, so that at least some crop yield could be ensured. There are also some traditional plant protection measures. All these need critical evaluation and research for wide adaptability. The landless farmers have large herds of camel and cattle and large flocks of sheep and goat, ordinarily migratory in nature, and their problem is how to feed their livestock and where to provide drinking water. Immediate solution for such farmers is to allow migration of all the livestock to Indira Gandhi Canal command area, where drinking water is available. In the canal-irrigated area top-most priority may be given to the use of irrigation water for cultivation of the fodder crops. Farmers in the are grow commercial crops like mustard and cumin during rabi season, and cotton and other crops during *kharif* season. In order to provide the badly needed fodder during severe droughts we have to think for the rabi season crops. The farmers who are prepared to grow fodder crops in the rabi season should be compensated by giving subsidy so that they voluntarily come forward to grow fodder crop in the canal command area. Similarly, in the areas where tube wells are the source of irrigation, the farmers should be motivated to cultivate as much fodder as possible and the government should buy their produce so that they are compensated for not growing crops like mustard and cumin. More emphasis should be given to crops like barley, which can be grown for fodder, and after taking one cutting it can be grown for hay. Adoption of these practices may provide immediate relief to farmers and livestock.

The nonconventional feed available in the forest area, including the leaves and pods of trees and bushes, should be harvested and their nutritive quality should be evaluated and enhanced by treating them with urea or molasses, and if need be, mixed with the mineral nutrients so that farmers can get enriched fodder for their livestock. *Prosopis juliflora* is a miraculous forest tree that was introduced in the Indian Desert in the first half of the last century to stabilize the moving sand. The tree proliferated very aggressively and has virtually become a weed today. It has excellent regeneration capacity and is growing well on wastelands where no other vegetation is found. Unfortunately, the leaves of the tree are non-palatable. It would be better if biochemists can analyze the leaves of *Prosopis juliflora*, and suggest palatability through treatment with chemicals, so that animals can be maintained on the leaves of *P. juliflora*.

Another important issue that needs our attention on top priority is the availability of drinking water, particularly in the rural areas where groundwater is not only brackish, but also often contains high fluoride and in some areas nitrate and other toxic elements.

Scientists should suggest socially acceptable, economically viable and easily treatable techniques through which these waters can be made potable.

Long Term Strategy

In the arid and semi-arid regions, where drought and long dry spells is common, we should adopt integrated farming systems having crop production, coupled with animal husbandry. A tree component should also be there. The tree component should be able to provide much needed shade to the livestock and should be multipurpose, so that it can provide fruits, top feed, and timber and fuel wood. Adoption of integrated farming systems helps farmers to maintain their livestock on tree leaves and fruits during severe droughts like the current one, and harvest fruits for cash benefits. The livestock can also give income through milk and manure.

In the IGNP command area the government should pass a resolution that in future the land in Phas II command will be allotted only for broad activities like animal husbandry. For example, in Jaisalmer district the Pali area is full of sevan grass (*Lasiurus sindicus*). If this land is reserved for animal husbandry and irrigation can be given twice or thrice in a year through sprinkler, cattle, sheep and goat can be maintained very well without much problem. This area is also good for selective breeding of indigenous cattle. We have very good indigenous breeds of cattle like Tharparkar in Jaisalmer, Kankrej in Barmer and Rathi in Bikaner area. Similarly in sheep, goat and camel the region has excellent breeds. Therefore, cross breeding may not be a viable proposition and selective breeding should be adopted.

In the IGNP command area sandy undulating land should not be levelled, but may be brought under agroforestry, horticulture, silvipasture system, by giving water through sprinkler set. Farmers should not be allowed to plant high water-requiring crops like cotton, rice, etc. In other areas, where irrigation is available through energised wells and tube wells, the crops requiring low water be planted, and an integrated farming system should be adopted. Depending on the size of land holding farmers can go for dairy farming, and in the wastelands, which are not suitable for cultivation, silvipasture system should be adopted under irrigated as well as rainfed conditions. Government of India, Government of

Rajasthan and ICAR should join hands to manage drought as a long term strategy, and prepare a location-specific, sustainable, economically viable, and socially acceptable integrated farming system for different categories of farmers.

Research efforts are also necessary for improving the grain and fodder storage facilities available with the farmers, so that they can ensure safe reserve of food and fodder for a period of 3-4 years, and withstand the vigour of drought. Traditionally, the large farmers of the region used to store fodder for 7-8 years, without any problem of attack from termites and other pests, and without much loss of quality. Such indigenous technical knowledge is fast dwindling, and modern technologies have not yet been able to provide alternatives/improvements for the farmers. These need the attention of researchers.

Crop Management Strategy under Drought Situation in Rajasthan

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Droughts are not uncommon in Rajasthan. Droughts of low magnitude and extent occur in some part of the state almost every year. While the human and livestock population withstand the effects of moderate droughts, severe droughts badly affect the quality of life of humans and even endanger the survival of the livestock in many areas. Agriculture is most immediately affected by droughts and sometimes famines result. Agricultural management therefore, is of strategic importance in combating droughts and famines in the state, particularly in arid western parts. In such management strategy, not only food but fodder resources also require serious attention. A general assessment reveals that most areas in arid western Rajasthan face severe drought once in three to four years (Table 1).

Table 1. Drought occurrence in Rajasthan

Drought frequency (in years)	Districts affected
Once in three years	Barmer, Jaisalmer, Jalor, Jodhpur and Sirohi
Once in four years	Ajmer, Bikaner, Bundi, Dungarpur, Sriganganagar and Nagaur
Once in five years	Alwar, Banswara, Bhilwara, Churu, Jaipur, Jhunjhunu, Pali and Swaimadhopur
Once in six years	Chittorgarh, Dholpur, Jhalawar, Kota and Udaipur
Once in seven years	Tonk
Once in eight years	Bharatpur

Source: Rajasthan Patrika, August 4, 2002

During the last three consecutive years, i.e., 1999, 2000 and 2001, most areas in the state have been badly affected by drought. Due to droughts in the last five years crops and human population have been severely affected (Table 2). Apart from the direct effect of drought on agriculture and livestock population, the rural landless labourers lose opportunity of work in agriculture sector and thus their livelihood is also badly affected. In essence, droughts disturb the economy of the region and devastate the destiny of the common people.

Table 2. Effect of droughts on crop area and human population

Year	Number of affected districts	Number of affected villages	Affected human population (Lakh)	Affected crop area (lakh ha)
1997-1998	24	4,633	14.91	13.62
1998-1999	20	20,069	215.00	64.96
1999-2000	26	23,406	261.00	78.18
2000-2001	31	30,583	330 .00	89.47
2001-2002	18	7,964	69.70	26.53

Source : Rajasthan Patrika , August 04, 2002

While droughts occur on account of frequent failure of rains, agricultural production is mostly determined by the quantum as well as the distribution pattern of rains. Even low, rainfall but with uniform distribution over the crop growing period can ensure good production level. This is evident from the data on agricultural production *vis-a-vis* rainfall provided in Table 3.

For example, in the year 1990-91 the rainfall was 727 mm, giving a total production of 156 lakh tonnes. In contrast, in 1999-2000 the rainfall was only 490 mm, but total production was 173 lakh tonnes. Similarly in 1994-95 also, in spite of 688 mm rainfall the production was only 164 lakh tonnes, and in 1996-97 the production was 186 lakh tonnes with rainfall of 757 mm. Unfortunately, neither amount nor distribution of rains is favourable during the current *kharif*, 2002.

During the *kharif* 2002, the state received only 138 mm of rainfall up to August 10, which was a very disappointing feature. It is likely that the state may not receive rains beyond 200-250 mm, which would be for less than the rainfall received in the worst drought year of 1987-88 (320 mm). Distribution of rains in different months in a normal year, in a drought year (1987-88) and in the current season is given in Table 4.

Contingency planning for crop management for the state should be done taking cognizance of the crucial facts regarding the rains that have occurred and the likely scenario of agricultural production during the *kharif* and *rabi*, 2002 - 03.

Table 3. Area, production and rainfall pattern in Rajasthan

Year	Cropped area(Lac ha)			Production(Lac tonnes)			Rainfall (mm)			
	Kharif	Rabi	Total	Kharif	Rabi**	Total*	June to Sept.	Oct. to Jan.	Feb. to May	Total
1985-86	125.92 (9.70)	55.45 (28.93)	181.37 (38.63)	24.01	78.72	102.73	377.7	73.7	51.4	502.8
1986-87	127.41 (12.82)	48.98 (30.69)	176.39 (43.51)	25.48	66.66	92.14	422.1	13.4	28.5	464
1987-88	88.29 (9.83)	44.79 (30.07)	133.08 (39.95)	13.37	57.04	70.41	266.0	17.8	36.2	320.0
1988-89	133.44 (9.23)	54.95 (34.42)	188.39 (43.65)	64.1	75.19	139.29	511.4	18.8	3.9	534.1
1989-90	127.66 (10.15)	51.37 (34.46)	179.03 (44.61)	51.55	65.51	117.06	410.7	0.06	43.7	454.5
1990-91	130.53 (8.07)	63.26 (38.45)	193.79 (46.52)	68.22	87.71	155.93	699.3	9.8	18.2	727.3
1996-97	129.86 (11.83)	77.07 (55.60)	206.93 (67.43)	63.5	122.62	186.12	701.9	12.6	42.7	757.2
1997-98	131.3 (11.77)	92.05 (54.99)	223.25 (66.76)	68.14	125.62	193.76	564.1	103.7	22.7	690.5
1998-99	116.59 (12.93)	95.5 (54.42)	212.09 (67.35)	52.23	130.29	182.52	492.2	67.9	29.3	589.4
1999-2000	128.9 (11.00)	71.7 (55.00)	200.6 (66.00)	53.07	119.59	172.66	437.0	24.0	28.7	490.1

Source : 50 Years of Agricultural Development in Rajasthan, Statistical Cell, Directorate of Agriculture, Government of Rajasthan.
Note : Data in parenthesis indicate irrigated area.
* Except fruit, vegetables, fodder etc.; ** Including sugarcane production.

Crop Management Strategy

Planning for the Current kharif

Mixed cropping of bajra and guar/cowpea for fodder: Widespread drought has created a situation of acute shortage of fodder throughout the state. There is urgency to increase fodder production, with emphasis on quality fodder as far as possible. Therefore, it would be desirable to put as much area as possible under mixed cropping of bajra (pearl millet) and a legume like guar (clusterbean) or cowpea. Fodder pearl millet variety Raj. bajra

Table 4. Amount of rainfall (mm) received in Rajasthan

Month	Normal year*	1987-88	2002
May	7.70	23.28	-
June	47.60	38.8	463
July	190.20	46.60	13
August	193.40	168.40	61.91
September	100.70	12.17	-
October	11.00	0.90	-
November	3.10	0.00	-
December	3.60	14.70	-
January	5.90	2.16	-
February	4.30	1.17	-
March	5.60	7.51	-
April	2.00	4.21	-
Total	57590	319.94	137.91

Source: Rajasthan Patrika , August 01&19,2002. *Normal rainfall (575.10 mm) based on rainfall data from 1901 to 1970; ** up to 10 August.

chari - 2 may be planted by the 3rd week of August, if rains occur.

Wider row cropping: Under drought situation, delicate balance between available soil moisture regime and expected crop growth and production is of paramount importance, as success or failure of the crop is determined by this single factor. Under rainfed condition during soil moisture deficits wider row spacing pays (Table -5).

Table 5. Effect of plant population and crop geometry on seed yield of Pearl millet

Row x Plant spacing (cm)	Plant population (lakhs/ha)	Seed yield (q/ha)				
		1988	1989	1990	1991	Mean
50 x 15	1.3	2.65	15.60	29.67	6.67	13.65
75 x 10	1.3	2.32	13.97	27.22	7.00	12.63
45 x 13.5	1.66	2.04	13.33	19.89	5.00	10.06
30 x 15	2.22	1.32	9.67	10.67	4.33	6.50
CD at 5%	-	0.61	4.39	6.31	1.98	-

In view of the above it is suggested that bajra mixed with guar/cowpea should be sown at 60 cm row spacing in preference to 30-45 cm row spacings. Such stand geometry optimizes plant population in relation to limited soil moisture available during the monsoon season. As a consequence, the crop plants sustain their growth through flowering and succeed in setting grain till maturity.

Dust mulching and weed control for soil moisture conservation: To optimize the soil moisture supply to ensure crop maturity, it is necessary to efficiently conserve the available soil moisture. Since weeds compete with crops for soil and water, timely weed control may efficiently conserve soil moisture. Timely hoeing, coupled with mulching through dust, breaks the capillary continuum, minimizes evaporation losses and conserves the soil moisture.

Foliar nutrition for improving water use efficiency: Inadequate rains and intermittent dry spells adversely affect growth and development of crops wherever sown. Soil nutrient supply is also restricted because of unfavourable moisture regime. Since nitrogen deficiency has adverse effects on both vegetative and reproductive development of crops, it would be worthwhile to supply nitrogen through foliar feeding, as top dressing of urea may not be possible under prevalent dry spells. A foliar spray of 1 per cent urea can accelerate crop growth and thus improve water utilization capacity of the crop plants.

Foliar spray of thiourea has been shown to be effective in improving drought tolerance of moth and guar. Two foliar sprays of 500 ppm thiourea at vegetative and flowering stages increased the grain yield of moth by 59%. Similarly, foliar sprays of 0.1% thiourea at 25 and 45 days after sowing increased the seed yield of cluster bean by 96%. Seed soaking, along with foliar spray of thiourea, increased the yield of moth bean and cluster bean under rainfed conditions (Tables 6 & 7).

Crop thinning to ensure production: In the event of early withdrawal of monsoon the crops may dry up and fail without setting grains. To avoid this situation, the mid way corrective measure by crop thinning may conserve soil moisture and help in grain development and maturation. Thinning of alternate crop rows may be attempted to ensure utilization of available limited soil moisture by the left over crop plants during critical

Table 6. Effect of thiourea application on yield and net returns of moth bean (mean data from 1998 to 2000)

Treatment	Seed yield (q/ha)	Additional yield over control (q/ha)	Per cent increase in yield over control	Net return (Rs/ha)
Control	3.80	-	-	4052
Seed soaking in 500 ppm thiourea	5.00	1.20	31.6	6012
One foliar spray of 500 ppm thiourea at flowering	5.60	1.80	47.4	65.57
Seed soaking + one foliar spray of 5000 ppm at flowering	7.19	3.39	89.2	88.41
Two foliar sprays of 500 ppm thiourea at vegetative & flowering stage	6.06	2.26	59.5	6860
Seed soaking + two foliar sprays of 500 ppm thiourea at vegetative & flowering stage	7.92	4.12	108.4	9541
CD at 5%	0.49	-	-	

periods of grain initiation and maturity. This agro-technique will work as providing "life saving water" to the crop in order to sustain moisture supply to complete maturity. The thinned out crop plants may be used as fodder for livestock.

Table 7. Effect of thiourea application on yield and net returns of clusterbean (mean data from 1997 to 1999)

Treatment	Seed yield (q/ha)	Additional Yield over control (q/ha)	Per cent increase in yield over control	Net return (Rs/ha)
Control	2.92	-	-	6405
Seed soaking in 500 ppm thiourea	4.06	1.14	39.0	9753
0.1% thiourea spray at 25 & 45 DAS	5.73	2.81	96.2	14215
Seed soaking 500 ppm thiourea + 0.1% thiourea spray at 25 & 45 DAS	7.51	4.59	156.2	19504
CD at 5%	1.01	-	-	

Planning for the forthcoming rabi

In the event of monsoon failure there is not only severe shortfall in the *kharif* production, but the *rabi* production also experiences a setback, if there are no winter rains. Crop planning for the *rabi* should, therefore, be based on efficient rain water conservation and most judicious management of available irrigation water in crop production. Optimization of crop yield, rather than maximization, should be the goal of *rabi* agriculture during low rainfall years. Some suggestive measures for optimization of agricultural production during the *rabi* are given below.

Efficient rainwater conservation: In many areas in the State, mustard crop is grown in fields that are kept fallow during *kharif.* For maximum *in-situ* storage and conservation of rains that may occur in the season during September it would be necessary to keep such fallow fields weed-free so as to prevent evapotranspiration losses. Also, deep ploughing will create soil conditions for maximum interception of falling rainwater, thus avoiding surface run-off. Ploughing operations should preferably be done during evening hours to prevent moisture losses due to high temperature and insolation during the day hours.

Cropping pattern for optimizing rabi production: Under drought situations, oilseed and pulse crops, having a large area under rainfed conditions, suffer the most. Though cereals like maize and pearl millet may also suffer badly, the rural livelihood and economy are largely contingent upon production of oilseed and pulse crops. It is estimated that a reduction in *kharif* oilseed by about 4.04 lakh tonnes is likely to occur in 2002, as compared to *kharif,* 1999 (Table 8). Such shortfall in *kharif* oilseed production needs to be offset by increased production of *rabi* oilseed, chiefly mustard. Similarly, reduction in *kharif* pulses (0.65 lakh tonnes) should be offset by increased production of gram in the *rabi* season.

There is an urgent need to increase fodder production for sustaining livestock health and productivity during drought years. It would also be necessary to increase seed spice production for improving the purchasing power of the drought-affected farmers in the State. In view of the above, it is suggested that the area under wheat may be reduced to the extent of 25- 30% and diverted to cropping of mustard (10-15%), cumin (8-10%) and fodder crops (8-10%). Similarly, area under barley may be reduced by 40-50% and diverted to cropping of

Table 8. Expected reduction in crop production during kharif, 2002

Crops	Production during 1999 ('000 tonnes)	Per cent reduction in area sown under crops during *kharif* 2002 in comparison to target (Up to August 10, 02)	Expected production during 2002 ('000 tonnes)	Expected reduction in production in comparison to 1999 ('000 tonnes)
Groundnut	264.0	24	200	63
Soyabean	601.0	54	276	324
Til	15.6	100	-	15
Total	880.6	-	477	403
Kharif pulses	117.7	55	52	64
Guar seed	231.6	85	34	196

Source: Rajasthan Patrika, August 12, 2002

gram. A tentative area allocation and expected production plan is given in Table 9 as a suggestive measure to optimize *rabi* production in view of the expected shortfall in the *kharif* -2002 production.

It is pertinent to point out that though such allocation of area will result in reduced output of staple wheat, this may not adversely affect the rural livelihood and well-being immediately. On the contrary, it is expected that the suggested cropping pattern will prove profitable to the common farmers.

Timely sowing: During low rainfall years, yields of *rabi* crops will be determined mostly by the crop management practices that ensure maximum utilization of available soil moisture and irrigation water, which will be falling far short of the requirement. Timely planting of rabi crops will, therefore, have a great bearing on moisture utilization by crops and ultimately on crop yields. Needless to emphasize that disease and pest infestation are also less when crops are planted in time.

Balanced fertilizer use for improving water use efficiency: For proper root and shoot development, adequate plant nutrient supply is a pre-requisite. Basal application of fertilizers, alongwith organic manures, therefore, is a must for improving early crop growth, water use efficiency and crop yield. Micro-nutrient deficiency, for example, zinc in wheat should be corrected in the deficient areas. Recent experiments at ARS, Navgaon-Alwar have

Table 9. Suggested cropping pattern and allocation of area under crops during rabi, 2002-03

Particulars	Wheat	Barley	Mustard	Gram	Cumin	Fodder Crops
Area under crops during *rabi* 1999-2000('000 ha)	2650	181.0	2495	975	1397	NA
Suggested reduction in area under crops(wheat & barley during *rabi* 2002-03 in comparison to *rabi* 1999-00 ('000 ha)	650 -800 (25-30%)	70-90 (40-50%)	-	-	-	-
Additional area available for crops(mustard, gram, cumin and fodder-oat, barley, lucerne & kasani) after diverting area from wheat and barley ('000 ha)	-	-	265-395 (10-15% from wheat)	390-480 (40-50% from barley	210-260 (8-10% from wheat)	210-260 (8-10% from wheat)
Expected area to be sown under crops during *rabi* 2002 -03 ('000 ha)	1850 -2000	90-110	2760 -2890	1365 -1455	1607 -1657	210 -260
Expected total production during rabi 2002-03 ('000 tonnes,based on average yields of crops)	4400 -4800	180-220	2760 -2890	955-1019	482-497	-

Note : Average yield per hectare of wheat (24 q), barley (20 q). mustard (10 q), gram (7 q), and cumin (3 q) have been used in calculating expected total production.

indicated that potash application benefits mustard as it reduces the incidence of alternaria blight, as well as white rust. Potash application @ 40 kg K_2O ha^{-1} is beneficial for increasing mustard production in the state.

Sulphur fertilization necessary for increasing mustard production: Mustard is a heavy feeder of nutrient sulphur. Sulphur application not only increases yield of mustard but it also improves the oil content and quality. Application of 40 Kg S ha^{-1} through gypsum has been found to be the most effective in improving yield and quality of mustard. This needs to be popularized widely amongst the mustard growers in the state.

In recent years, foliar spray of thiourea, a sulphydryl compound, has been found effective in increasing seed yield of mustard by 15-25% (Table 10). Two foliar sprays of 0.1% thiourea at flowering and seed initiation stages increased seed yield signiflclantly at Fatehpur, Kota, Sumerpur, Sriganganagar, Bikaner, Jaipur, Alwar and Bharatpur. In view of such large-scale effect of thiourea, it is suggested that farmers may be advised to adopt this technology to increase mustard production. It has been also observed that foliar spray of thiourea protects mustard against frost.

Deficit irrigation for optimizing water use and agricultural production: In arid western Rajasthan, *rabi* crops are most likely to suffer moisture shortage even under irrigated conditions as irrigation water supply will be severely restricted. Under the circumstances, optimum irrigation to the crops like wheat, mustard, cumin, etc., may not be possible at all the critical stages during the *rabi*. Since water use efficiency will usually be high under limited water supply to crops, deficit irrigation at all critical growth stages will be more desirable than adequate irrigation at only a few critical stages. This will also help in expanding available irrigation water over larger cropped areas. As a consequence, total agricultural production will increase even under restricted availability of irrigation water that is bound to occur in arid areas during *rabi* 2002-03 in the state.

Table 10. Seed yield of mustard as influenced by foliar application of thiourea (mean of 1998 - 99 to 2000 - 01)

Treatments	Seed yield (kg/ha)		Mean	% increase over control
	ARS,Navgaon	ARSS,Kumher		
Control	1571	1318	1444.5	-
Water spray	1665	1372	1518.5	5.12
Thiourea (0.1%) spray	2031	1617	1824.0	26.27

The history of incidence of droughts and the large scale damage to the quality of life of human and livestock population simply reinforce the fact that Rajasthan is a drought-affected state. This also raises a question as to why the state is failing year after year in managing drought? Perhaps we have ignored the basics of sustainable development, i.e., management as per the carrying capacity of the agro-ecosystem. In arid areas of the state, this issue of agro-ecosystem is of strategic importance in drought management on a long term basis. We should develop a policy of using available land and water resources in an ecologically efficient manner and not in an exploitative manner. Diversification of agriculture in a farming system mode should also receive priority in developing a long term policy on agricultural management under drought situation in the state.

Contingency Plan for Horticulture

D. G. Dhandar

Central Institute for Arid Horticulture, Bikaner

Despite being one of the largest states in India, Rajasthan receives minimum rainfall. The state harbors about 61% (19.6 m ha) arid area of the country, which is mainly spread over 13 districts in western Rajasthan, namely Jaisalmer, Barmer, Bikaner, Ganganagar, Nagaur, Jodhpur, Hanumangarh, Churu, Jhunjhunu, Sikar, Pali, Jalor and Sirohi. Major part of the rainfall is received during the southwest monsoon period i.e., June to September, that contributes to about 91-96% of the total annual rainfall. The average annual rainfall in western Rajasthan varies from ~ 500 mm in the eastern part to less than 100 mm in the westernmost part. Since the distribution of this meager rainfall is erratic, it often leads to protracted droughts and a serious impact on the state's economy. This calls for extra efforts and finances to manage the drought. The magnitude of the burden can be judged from the fact that since independence the state has spent about Rs. 4000 Crores to combat drought.

The drought of the year 2002 is a severe one. In the year 2001, the state received a total monsoon rainfall of 309.1 mm between 1st June and 15th July, while in 2002 the monsoon rainfall for the period was only 72.6 mm. The long-term average rain for this period is 134 mm. Since some rain was received in the last week of June, the farmers planted crops in nearly 10% of the total cropland, but these failed because the rainfall received between 1st and 15th July was only 3.5 mm and there was no rainfall thereafter. The situation is very serious in western Rajasthan, where >90% area of pearl millet has been severely affected.

Strategies to Combat Drought

In order to mellow the impact of drought on agricultural economy it is necessary to develop strategies by which some subsistance becomes available to the farmers. Keeping this in view, a contingency plan has been developed by the Central Institute for Arid Horticulture, Bikaner, which can help the farmers to mitigate the adverse effects of drought in the region.

Young Orchards

The farmers would be advised through extension activities to take proper care of their young orchards by adopting following technologies:

- The farmers may be advised to use drip irrigation/point irrigation system wherever facilities are available, while in other areas catchments having 5% slope towards the basin of the plant may be made so as to harvest rain water.
- Use of inorganic fertilizer may be minimized and use of organic manures and compost be encouraged.
- To economize on the irrigation water, marginal quality tube well water may be mixed with available rainwater for irrigation.

Cultivation of Short Duration Crops

Short duration and drought-resistant cultivars of crops should be planted. Varieties *released by* CIAH of *Mateera* (AHW-19 & AHW-65), *Kachri*, (AHK-119 & AHK-200) and Snapmelon (AHS-10 & AHS-82) may be cultivated. These can produce fruits within 60-70 day after sowing. Farmers may also be advised to harvest mateera at younger stage (loea), which is more commonly used as a vegetable in this region.

Seed treatments: The farmers may be advised to sow primed seeds of suggested crops, which will hasten germination and improved seedling growth.

Use of wastewater: In order to efficiently use even the wastewater, the farmers need to grow vegetables in small plots in their courtyard by using wastewater. For this, CIAH can provide small packets containing seed and fertilizers.

Availability of seeds: Seed production is one of the mandates of CIAH, Bikaner. At present the institute is having the sufficient quantity of seeds of *mateera, kachri* and snapmelon, and provide seeds to farmers at subsidized rates.

Assistance to Local Administration

CIAH can associate itself in various drought relief programmes of the State government, and provide technical support to minimise the adverse effects of drought. Similar technical support may will also be extended to various developmental agencies like State Agricultural Universities, NGO's and State line departments.

Press Release

The institute can release press notes at periodic intervals, providing information on crops/varieties to be cultivated, technologies for efficient water utilization, cultural practices to be adopted and measure to be taken for marketing of their produce.

Contingency Plan for Livestock During Drought in Rajasthan

V. K. Singh

Central Sheep & Wool Research Institute, Avikanagar

In Rajasthan 32 districts were declared drought-hit in 2002 and about 500 lakh metric tonnes of fodder was required for 500 lakh livestock in 39810 villages. According to preliminary estimates, the fodder requirement was likely to be 8 to 10 times higher than that during 2000-2001 drought, which had hit 30583 villages in 31 districts of the state. The available fodder was estimated to last only up to January 2003. Fodder shortages in the neighbouring states due to widespread drought might complicate the situation. Some of the technologies developed at the Central Sheep & Wool Research Institute (CSWRI), Avikanagar, may help to alleviate the problems for livestock. These technologies are discussed below.

Management of Feed Resources

The most important aspect to combat drought impact on small ruminants is management grazing resources for which severe steps have been suggested.

Pasture improvement

- *In situ* moisture conservation through bunding around the field boundary and contour bunding in the field.
- Weeding and inter-cultivation, including bush clearance in established pasture.
- Application of organic manures (FYM, compost, sheep manure etc) in adequate quantity and use of inorganic fertilizer where ever soil moisture condition is favourable.

Nutritional strategies

Nutritional technologies developed at the Institute and their proper application in the field will not only contain the losses but would also be useful in maintaining the flocks. The following suggestions need consideration.

At Institute level

Urea molasses liquid feed: Liquid molasses, containing 2-3% uniformly distributed urea and fortified with 1.5% complex mineral mixture, 0.5% common salt and about 1 million units (IU) of vitamin A activity per 100 kg of diet is called "urea molasses liquid diet". During feed scarcity it can be fed in liquid form separate from the bulky parts (fodder) of the ration. Urea molasses liquid feed can form an economic and viable system of livestock feeding during acute shortage of fodder.

Pelleting of wheat bran with molasses and mineral mixture: Because of the cheaper cost of wheat bran and molasses and easy availability, these could be used to meet the essential requirements of nitrogen/protein and energy in ruminants. Such feed, either in the form of blocks or pellets, could be used for feeding all classes of ruminants.

De-oiled rice bran based urea-molasses-mineral enriched block: De-oiled rice bran, a by-product of rice milling industry, is available in large quantities. In normal situation, due to high silica content and low nutritive value, it is used in a limited quantity as a cheaper feed ingredient in concentrate mixtures for livestock. Under emergency situation, it can be used as major dietary component after fortification with urea, molasses and mineral mixture to meet the immediate nutrient requirement of the animals. A feed formulation of 90 kg de-oiled rice bran, 7 kg molasses, 1 kg common salt and 1 kg mineral mixture will cost about Rs. 234 per quintal. Such formulation can be tried as emergency measure to meet the immediate nutritional requirement under conditions of scarcity.

Urea-molasses-mineral enrichment of fodders: In the absence of nutritious forage or fodder, the ruminants no longer can subsist only on dry and poor quality fodders that too in scarce quantity. To overcome this problem, enrichment of these dry fodders with urea, molasses and minerals is advisable to ensure the proper fermentation in the rumen and subsequent nutrient utilization. The preparation of 100 kg roughage-based enriched feed, containing 88.8 kg wheat straw or any other straw/Stover, 10 kg molasses, 1 kg urea and 0.5 kg mineral mixture, will cost about Rs. 232 per quintal.

Formulation of cheaper concentrate mixtures by using damaged wheat grain: A substantial quantity of damaged wheat grain becomes available during storage with Food Corporation of India. Such damaged wheat grain, not suitable for human consumption, may be used as animal feed under scarcity situation. By using damaged wheat grain with other feed ingredients, some cheaper feed formulation can be developed and tried for feeding of livestock as supplementary ration. A feed formulation having 53 kg of damaged wheat grain, 20 kg mustard cake, 25 kg de-oiled rice bran, 1kg common salt and 1 kg mineral mixture will cost about Rs. 323 per quintal.

Use of mineral bricks: Inadequate feeding regime as a result of acute feed scarcity often leads to mineral imbalances and other associated problems in livestock. Such a situation can effectively be dealt with supplementation of mineral bricks. These bricks are cheaper and easily available in the market. The cost of one mineral brick of 3.0 kg weight is around Rs. 23.

State or National level plan

Sugarcane bagasse: At present, a large quantity of sugarcane bagasse is being used in paper industry. The use of bagasse, along with urea and molasses spray as animal feed during scarcity as well as in normal situations, has given satisfactory results. This strategy was successfully applied in Maharastra during the drought of 1972-73. The cattle camps were set up around the sugarcane factories located in the drought-affected zones. Large scale feeding of bagasse, molasses in combination with urea and mineral supplements was adopted. The feed formulations developed through experimentation were tried on nearly 40,000 cattle without any detrimental effects. The rations tried are detailed in Table 1.

Table 1. Rations for adult and growing animals as per body weight:

Feed ingredients Body wt.	150-300 kg	50-150 kg
Bagasse	2.0 kg	2.0 kg
Molasses	0.4kg	0.8kg
Sugarcane tops chopped	8.0 kg	3.0 kg
Urea	22 g	40 g
Common salt	30 g	20 g
Sterilized bone meal	20 g	20 g
Trace element mixture	0.5 g per animal twice a week	0.5 g per animal twice a week

In case of non-availability of sugarcane tops, the ration should be fortified by 5000 IU of Vitamin A.

The preparation of feed can be carried out by simple method and using available farm equipment. The bales of bagasse are spread in layers of 15-20 cm, and urea and molasses can be mixed in empty drums. Approximately 33 % water may be added to reduce the paucity of material. The urea and molasses mixture is sprayed over the bagasse, and turned frequently to ensure proper soaking of the solution. For spraying of urea-molasses solution a garden hand shells can be used. This process could be used with groundnut shells, dry tree leaves, coarse forest grasses and such other materials, which become available around the areas of the short supply.

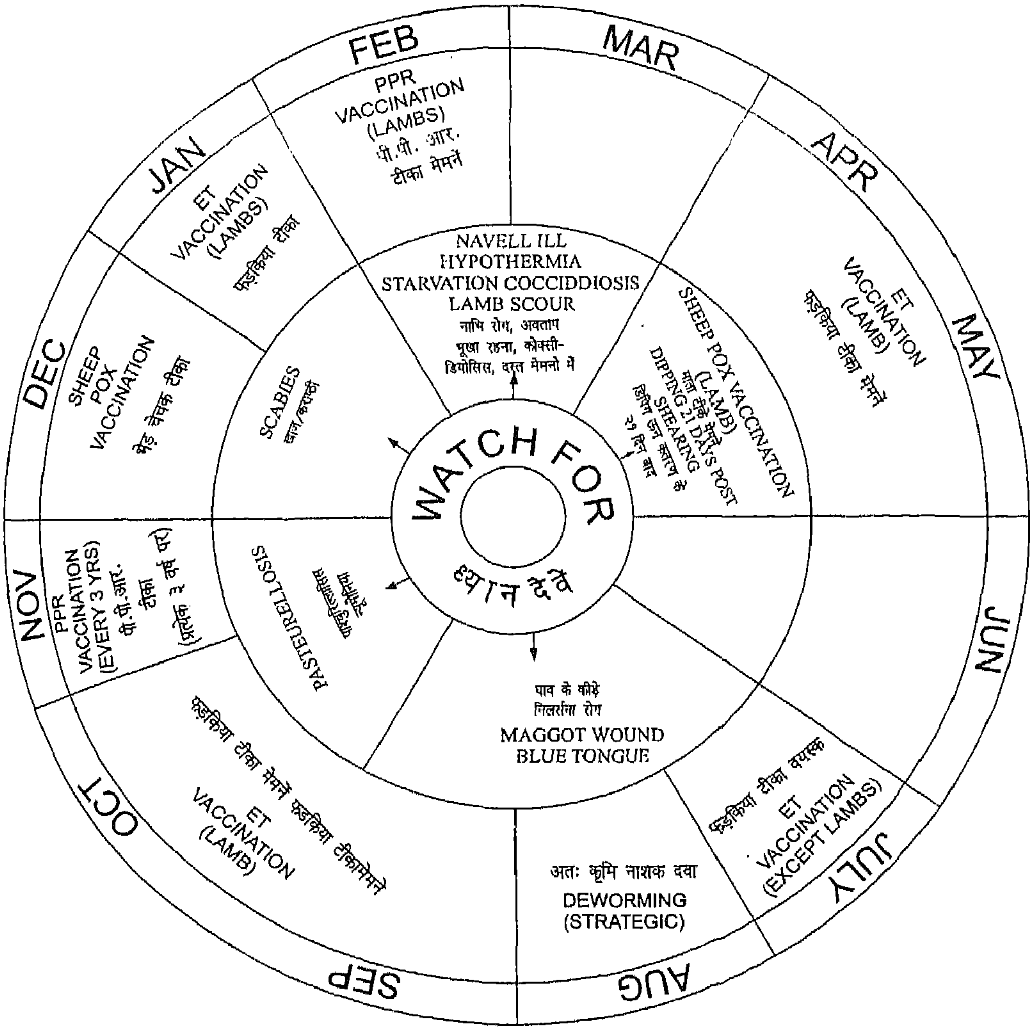
Under such emergency situation, the State or Central Government may divert the sugarcane bagasse from paper industry to animal feeding. The transportation of bagasse is also easier, as at present paper mills transport bagasse in bales.

Health strategies: In drought conditions prolonged protein energy imbalance may occur in sheep making them more susceptible to infectious diseases. The situation is known as malnutrition. The losses due to this condition increases manyfold in malnourished flocks as these are often attacked by secondary pathogens. During drought internal parasite load remains at a lower level, but its effect is ameliorated and manifested in the form of bottle jaw, anasarca and death, as the animal may not be able to tolerate pathogenic effect of parasitism. To control the losses due to infectious disease and GI nematodiasis, vaccination and drenching should be followed as per enclosed calendar (Fig. 1).

Plant poisoning: During drought many plants contain cyanogenic glucosides (HCN), which cause acute poisoning with a syndrome of dyspnoea, tremors, convulsions and sudden death. The concentration of this toxic material increases in immature, stunted sorghum, Sudan grass, many weeds and linseed. When consumed by animals this lead to very high mortalities within no time. The following treatment is suggested.

Treatment	Sheep and Goat	Other animals (Cattle & Buffalos)
Sodium nitrate 1g	1 g	22mg/kg
Sodium thiosulphate 3g	3 g	600mg/kg

SHEEP FLOCK HEALTH MANAGEMENT CALENDAR



Sodium Thiosulphate alone by intraruminal injection at hourly intervals 3-4 times or 30 mg per cow orally is also beneficial. Treatment may be repeated if required.

Prevention: Animals should be checked from grazing the toxic plants.

Pregnancy Toxaemia in sheep: The disease may occur in advanced stage of pregnancy, particularly if the animals are under decline plane of nutrition during the last two months of pregnancy, leading to high mortality.

Starvation: Although sheep by nature tries to fill its belly by consuming edible vegetation/roots etc., during extensive drought conditions animals may starve, and during starvation hypocalcaemia is commonly noticed, followed by ketosis. In lactating ewes there is reduction in the milk yield and increase in weakness of cardiac and skeletal muscles in terminal stages. In such cases readily assimilated carbohydrates (Glucose saline i/v, glucose orally or Gur by drench) should be given in small quantities at frequent intervals. Calcium Borogluconate should also be given as per requirement. Special care to lamb/ kid/ calves be provided to save their life. Foster feeding/ bottle feeding with required hygienic measures use to be helpful.

Physiological interventions

The physiology of the animals is seriously affected under drought condition. To control the situation following measures are suggested.

- The rams, ewes and lambs can be maintained on alternate day watering during entire period of drought.
- The productive sheep (rams, ewes and lambs) can be reared on moderately underground saline waters, containing up to 3500 ppm (3.5 g/1) of total soluble salts (TSS) during drought period in salt affected areas.
- The safe limit of Fluoride concentration in drinking waters of productive sheep varies from 2.25 to 4.5 ppm.
- In areas of acute fodder shortage long distance grazing should be avoided as it may result in negative energy balance.
- Animals should not be watered immediately after return from grazing.

Breeding strategies: The important germplasm is at stake during unfavourable environmental conditions. It is essential to conserve the same for future. The following recommendations are made.

- Farmers may be impressed upon to maintain bare minimum number of sheep during crisis. Animals with more than one S.D. below average weight of the flock may be disposed off to avoid starvation death.
- Restricted breeding may be considered. Mediocre level sheep may only be bred

and avoid stress on sheep with very high and very low body weight

- Impress upon the concerned agencies to protect elite males at all costs.

Employment Generation: During the adverse environmental conditions such as drought there is lack of employment. Flowing suggestions are made for utilizing the wool for employment generation.

- The institute can impart training in woollen spinning and weaving, if fund is provided by State / Central Govt. agencies/ICAR. The approximate expenditure per trainee will be Rs. 100/- per day, including boarding and lodging. A batch of 10 persons can be trained at a time for vocational training.
- The blankets produced can be chemically finished and sold.

Strategies for migratory flock: Sheep from of Rajasthan normally migrate to neighbouring states due to the depleted grazing resources during drought conditions. Under severe drought conditions the number and duration also increase. As a result the migratory animals are put to extra stress in covering long distances in search of grazing resources and drinking water. The animals become weak, debilitated with losses of production and may lead to abortions of pregnant animals and deaths due to toxaemia. In addition losses due to plant poisoning is also encountered *en route*. In order to reduce losses due to stress of migration aggravated by drought condition. The following measures are recommended.

- The range-managed sheep are able to meet their protein requirement by intensive selection on plant parts rich in protein, whereas the loss of production is primarily due to energy deficiency. Accordingly, the migratory sheep have to be provided energy supplements at the point of intervention *en route*. It is recommended that cheapest source of energy supplements such as damaged wheat fit for livestock consumption from F.C.I godowns may be released for the purpose. The rate of supplementation will be 200 g/head/day with free grazing to meet the rest of requirement.
- The migratory flocks under the unprecedented drought condition of the year may be allowed to graze on reserve forest to protect the precious animals from extinction. It is envisaged that by allowing sheep grazing on forest land the fragile ecology will

not be disturbed. The sheep by preference pickup fallen vegetation on the ground and do not disturb the growing plant, 50% of the D.M. consumed by the sheep is recycled back to the ground as enriched manure.

- The migratory animals which are under nutritional stress are vulnerable to many contagious diseases resulting in epidemics. Therefore it is recommended to strengthen the check points of State Animal Husbandry Departments along the route of migration, with contingency medicine viz. Anthelmintics, Antidiarrhoeal, antibiotics, analgesics etc. In addition, all migratory flocks should be vaccinated against FMD, Sheep-pox, PPR, etc.
- Simultaneously fully equipped Ambulatory clinics may be positioned at critical points to support health coverage of the flocks.
- All interstate migration restrictions be relaxed in view of the prevailing severe drought conditions to save the precious livestock wealth of the country.

Plan of action: CSWRI will act as a nodal agency to implement the plan with the help of Extension workers. The course of action will be taken up in following broad ways:

- ***Demonstrations:*** It is proposed to have demonstrations on the various adoptable technologies mentioned above under head 1-6. A team of the Scientists will be visiting villages adopted in TOT area and will lay one demonstration per village on each technology.
- ***Distribution of extension literature:*** Institute has developed some literature, which could be of use to deal with the situation. These will be distributed among the farmers. Some NGOs operating in the locality will be encouraged to participate in the programme and will be appraised with the suitable technologies, which can be adopted and demonstrated by them at farmers level.
- ***Employment generation:*** This Institute can spare two-hand looms with woollen material and preliminary processing machinery needed prior to weaving. Contractual labour from adjoining/T.O.T. area can be deployed for weaving purposes and may be paid charges at the rate of per blanket weaving.

- ***Radio/ TV Talk:*** In normal course, the scientists of the Institute are delivering radio talks on All India Radio, Jaipur, covering various farm-related topics. In view of the prevailing drought situation, attempts will be made with Extension Section of the Institute and Staff of All India Radio, Jaipur and Jaipur T. V. Station to be more frequent and concentrate on the topics covering various aspects of animal husbandry and health cover during the drought.
- ***Meetings with the farmers:*** It is proposed to have frequent interactions with the farmers to know the ground realities of the situation and for on the spot solutions. A team of scientists from the Institute will be visiting villages to discuss the problems of the farmers. Keeping in view the availability of feed resources and types of livestock owned, farmers will be appraised with the solutions.

Greening Thar Desert Through Ground Water Recharge

V. M. Sikka

Central Ground Water Board, Jaipur

In the Thar Desert of Western Rajasthan groundwater is being utilized indiscriminately. Consequently, the level of groundwater is declining at an alarming rate. To meet the increased demands for fresh water in future, immediate attempts are required to be made, not only to rationalize its use, but also to recharge it.

Attempts are being made here to visualize the tedious, but feasible task of recharging the depleted aquifers of the Thar Desert by surplus water from Indira Gandhi Nahar Pariyojana (IGNP), as well as conjunctive use of surface and groundwater and Ghaggar river floodwater. Occurrence of water logged conditions in the IGNP command areas and emerging scenario of groundwater depletion in other parts calls for judicious management of the available water resources. A chronic drought-prone state like Rajasthan cannot afford to waste its precious water resources by following traditional and inefficient flood irrigation practices and by growing high water requiring crops like paddy and sugar cane. The scope of this presentation is to prepare a conceptual approach as regards lifting of surplus canal water and other available sources of water for irrigation and groundw3ater recharge. Detailed micro-level studies are essential before execution of any mega-scheme of recharging the groundwater. It is a scheme for which there is no immediate alternative, and survival and prosperity of people in the Thar Desert is linked to its successful implementation. Objectives of the present study are as follows:

- Evaluation of available hydrogeological data for locating areas conducive for groundwater recharge.
- Demarcation of areas with rapidly depleting groundwater resources that are likely to get dried up in near future.
- Assessment of available surplus surface water from various sources.
- Evaluation of rainwater harvesting prospects for groundwater recharge.
- Qualification of the volume of water that can be recharged in the potentially

depleted aquifers like Lathi formation, Nagaur-Palana formations, alluvial formations, etc., and districtwise break-up thereof.

- To suggest appropriate scientific techniques for artificial recharge of groundwater in different areas.
- To combat water logging hazards in IGNP command areas.
- Formulation of groundwater management strategy for its sustainable development and turning the Thar Desert into lush green fields.

Rajasthan state, having an area of 342,239 km^2, covers 10.5 % of the nations geographical area, but it has only 1.15 % of the water resources of the country. Thar Desert lies to the west of Aravalli hills and accounts for 60% area of Rajasthan state. Ephemeral rivers like Luni, Kantli and Ghaggar are the only drainage systems in the desert terrain. The geology of the area is represented by rocks of the Delhi Supergroup, igneous intrusive, Bap Boulder Beds, Lathi, Tertiary and Quaternary deposits. Apart from alluvial aquifers, Borunda Limestone, Lathi formation and Nagaur-Palana Sandstone are the potential aquifers of the desert.

The groundwater conditions in the study area vary widely. The depth to water table is within a few centimeters in the irrigation commands, and more than 100 m in parts of Lathi basin. The quality of groundwater also varies from highly saline in some parts to thick fresh groundwater in Lathi basin, Nagaur-Palana basin, Barunda Limestone and some alluvial areas in the eastern part. In general, quality of groundwater deteriorates with depth.

In the eastern part of the desert, comprising the districts of Jhunjhunu, Sikar, Churu, Nagaur, Jodhpur, Pali and Jalor, replenishable groundwater reserve has been emptied over large areas by excessive use of groundwater for irrigation. This has led to acute drinking water shortage.

In the IGNP command area the water levels are shallow due to water seepage from canals and over-irrigation in crop lands. Large areas along the canal have either become water logged or are threatened by water logging in Ganganagar, Hanumangarh and Bikaner districts, unless immediate remedial measures are taken.

In-storage ground water resources of the Thar Desert are estimated to be about

92,000 MCM and the annual replenishable groundwater resources are about 3613 MCM. There is an urgent need for undertaking large-scale groundwater recharge in view of the rapidly depleting groundwater resources. Deeper groundwater level provides plenty of scope for filling up huge volume of water in the unsaturated zones up to about 10 m bgl, especially in the unconsolidated/semi-consolidated formations. Estimates suggest that about 14,700 MCM of water can be recharged in Lathi basin alone. A total of about 71,000 MCM of water can be recharged to groundwater in the region.

It is estimated that 1,300 MCM of surplus IGNP water, made available through conjunctive use of surface and groundwater, and 148 MCM of Ghaggar floodwater could be used to recharge the dry aquifers of the Thar Desert. Besides, a substantial quality of water can be made available for recharge by changing the existing cropping patterns and irrigation practices. It is proposed to consider the construction of two more lift canals namely, Churu-Ladnu lift canal and Barmer lift canal, which would serve the twin purpose of irrigation and groundwater recharge.

On the basis of hydrological set up, the entire desertic terrain is classified into five zones for augmentating groundwater resources through the proposed groundwater recharge scheme. These are described below.

Jhunjhunu-Sikar-eastern Churu area: The Nohar-Sahawa lift canal system may be extended eastward (preferably close to the Aravalli hills) to fulfill the water requirement and for groundwater recharge purpose. Ghaggar flood water may also be utilized to achieve the objectives. Keeping in view the geomorphological and hydrogeological situations, recharge in this area can be achieved by making recharge pits and utilizing abandoned wells and tube wells. Return flow from canal irrigation would adequately recharge the groundwater. Construction of check dams, along with inverted wells across the Kantli river, is also suggested for augmentating groundwater resources.

Nagaur-Palana basin and adjoining areas: The depleted aquifers of this basin and in its adjoining terrain may be recharged by extending Gajner lift canal system, Bangarsar lift system and also Nohar-Sahawa lift system, and developing a network of canals for irrigation. Because of the deeper water level and higher evaporation rates, groundwater here needs to be recharged through injection wells after filtration.

Lathi Basin-Bhadka and adjoining areas: Groundwater recharge in Lathi basin and adjacent areas in parts of Jodhpur district can be made feasible by southeastward extension of Kolayat, Phalodi and Pokaran lift canal systems. Surface spreading of water may not be fruitful in the area due to deeper water level and higher evaporation rates and, therefore, canal water may be injected into the abandoned dug wells and tube wells after necessary filtration/treatment. Recharge/injection wells are also to be constructed at appropriate locations.

Jodhpur-Pali-southwest Nagaur areas: Jodhpur urban area is already receiving IGNP water through a lift canal, which is being stored in Kaylana Lake. The urban area is facing damage to civil structures due to a rise in water level. Urban water supply from Kaylana lake should, therefore, be reduced and the surplus water from the lake be made available for the recharge to groundwater. Similarly, other reservoirs and natural depressions may also be filled up with surplus water of IGNP, which in turn may be utilized for recharging groundwater elsewhere.

Depleted aquifers in Borunda Limestone and that in Teori-Mathania, Doli-Pal-Jhanwar area may be recharged using stored lake water through irrigation and recharge structures. Check dams may be constructed at suitable sites across the Luni riverbed and its tributaries in order to harvest the run-off for recharging groundwater. Roof-top rain water harvesting may also be taken up in urban areas like Pali.

Jalor-Sirohi-Barmer area: Narmada river water is proposed to be brought in this area. Development of canal irrigation itself can recharge groundwater in the area. Construction of percolation tanks may also be taken up in addition to construction of check dams across the bed of the Luni and its tributaries at suitable locations.

The proposed scheme is considered to be feasible on technical, as well as economic ground, and its successful implementation would transform the Thar Desert into a green, prosperous and drought-resistant area forever.

Watershed Management for Mitigation of Drought

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Drought is directly related to water shortages in an area that causes serious damages and severe losses to economic development of India. It has occurred 25 times in a period of 125 years since 1875. Efforts at central and state governments level are made to minimize/mitigate the ill-effects of drought through several schemes/programmes by providing short term and long term measures in the drought-affected districts/areas, of country. Watershed development approach is suggested for visible impacts in the drought-affected districts/regions. Rain water conservation, harvesting and utilization technologies are listed for *in situ*/on-farm and *ex situ*/off-farm effective water use to sustain crop growth, and promote ground water potential. On the whole, the short term measures may be carried out on a war-footing basis and long term measures be implemented through watershed development (project) approach for sustainable benefits.

Drought, flood, cyclone, earthquake, landslide and fire are the natural phenomena that cause widespread damage and set back to economic development of any nation. Drought occurs over an extended period of time and space, making it unpredictable, and losses are not quantifiable easily. Therefore, the impact of it on the techno-economic and socio-economic aspects of agricultural development and growth of the nation is severe and results slowly in huge losses.

India's National Agricultural Policy, adopted in July 2000, attaches much importance to reducing the risk in agriculture due to natural calamities, such as drought and floods. It says that, "In order to reduce risk in agriculture and import greater resilience to Indian agriculture against droughts and floods, efforts will be made for achieving greater flood proofing of flood-prone agriculture and drought proofing of rainfed agriculture, or protecting the farmers from vagaries of nature. For this purpose, contingency agriculture planning, development of drought and flood resistant crop varieties, watershed development programmes, drought-prone areas and desert development programmes and rural infrastructure development programmes will receive particular attention."

Accordingly, drought mitigation and flood prevention measures are taken up in the forms of schemes and implemented on regular basis to prevent the ill-effects of these natural calamities and sustain the productivity of land water and enhance it wherever possible. Yet, immediate measures/steps are also needed to restore the lost equilibrium/balance of the dynamics of use of land and water, crop, and human and animal population in the affected areas.

Background

Till the middle of August, 2002, failure of SW monsoon resulted in chronic agricultural drought in 12 states of the country, including U.P., Punjab, Haryana, H.P., Rajasthan, M.P., Karnataka, A.P., Orissa, Chattisgarh, Maharashtra and Tamil Nadu. If this situation persists, some more states may experience drought. The ill-effects of drought include shortage in food, fodder, drinking water, as well as health hazards, depletion of water (availability), crop failure and migration of livestock. Therefore, it is proposed to take up remedial measures to minimize/mitigate the ill-effects of drought in these states.

Definition and Occurrence of Drought

Droughts are the results of acute water shortages due to lack of rains over extended period of time, causing severe socio-economic problems. Droughts have been broadly classified by the National Commission of Agriculture (1976) into three categories as meteorological, hydrological and agricultural. While meteorological drought refers to significant decrease (more than 25%) of rainfall over an area hydrological drought results in marked depletion of surface water and drying up of reservoirs, lakes, streams, rivers, cessation of spring flows and fall in ground water level. Agricultural drought occurs when soil moisture and rainfall are inadequate during the growing season to support a healthy crop growth to maturity.

Evaluation of last 125 years data shows that there were 25 drought years since 1875; 1916 was one of the worst drought years when more than 70% of the country was affected. During the last 50 years, India experienced more than 14 major droughts, of which 1987 drought was the worst, affecting almost half of the land of the country. The major droughts in the last 50 years were:

Year	% area affected in the country	Category of Drought
1951	33.2	Moderate
1952	25.8	Slight
1965	42.9	Moderate
1966	32.3	Moderate
1968	20.6	Slight
1969	19.9	Slight
1971	13.3	Severe
1972	44.4	Moderate
1974	29.3	Moderate
1979	39.4	Moderate
1982	33.1	Moderate
1985	30.1	Moderate
1986	19.0	Slight
1987	49.2	Severe

The analysis of 125 years data indicates the occurrence of drought in the country as given below:

Meteorological sub-division	Frequency of deficient rainfall (75% of normal or less)
Assam	Rare, once in 15 years
West Bengal, Madhya Pradesh, Konkan, Bihar & Orissa, South interior Karnataka, eastern Uttar Pradesh & Vidharba	Once in 5 years
Gujarat, East Rajasthan, Western Uttar Pradesh	Once in 3 years
West Rajasthan	Once in 2.5 years

In India, drought occurs more frequently in the arid and semi-arid regions, where the range of variation in annual rainfall is high. In the arid areas mean annual rainfall is generally less than 400 mm. So, drought is a very frequent phenomenon. In semi-arid regions, where the mean annual rainfall varies from 400 to 1000 mm, drought occurs in 40 to 60% of the years, either due to deficit seasonal rainfall during cropping season, or due to inadequate soil moisture availability. The average annual rainfall of the country as a whole is 116.3 cm. The area of the country under different ranges of annual rainfall are given in Table 1.

Table 1. Average annual rainfall regions in India

Average annual rainfall (cm)	Name of Regions	% area of country
Less than 40	West Rajasthan	6
41-100	Plains of West UP, Haryana, Chandigarh & Delhi, Punjab, Jammu & Kashmir, East Rajasthan, Gujarat Region, Saurashtra & Kutch, Madhya Maharashtra, Marathwara, Coastal A. P., Telangana, Rayalaseema, North Interior Karnataka	43
101-250	Nagaland, Manipur, Mizorum & Tripura, Gangatic West Bengal, Orissa, Jharkhand, Bihar, East U.P., Uttranchal, Himachel Pradesh, West M.P. East M.P., Vidarbha, South Interior Karnataka, Lakshadweep	41
More than 250	A & N Islands, Arunachal Pradesh, Assam & Meghalaya, Sub Himalayan West Bengal & Sikkim, Konkan & Goa, Costal Karnataka, Kerala	10

Watershed Management Approach

The impact of drought is more apparent in rainfed areas. The production and productivity of land and water are affected severely by drought in these areas. While irrigated area contributed 55% of the total food grain production of 211 million tonnes during the year 2001-2002, rainfed area contributed 45% of the production. Of the net sown area of 142 million ha in agriculture, rainfed area accounts for 62% of it (85 million ha) and the balance is irrigated area. Any disturbance in the productivity of the rainfed area directly affects the food (grain) production in the country. Therefore, mitigation of adverse effects of drought on agricultural production is urgently required.

Watershed approach has become the key for improvement of productivity of rainfed areas and their ecological restoration. Generally, the technologies selected for watershed development are engineering based on the land use pattern these technologies can be selected for adoption for arable land, non-arable land and drainage line treatment in the watershed. Projectisation approach and Ridge to Valley concept are the accompanying requirement for the success of watershed approach in area improvement/development.

Components of Watershed Management

Watershed development involves conservation, regeneration and judicious utilization of natural resources, particularly land, water, vegetation and animals. It aims to bring about an optimum balance between the demand and use to maintain sustainability. Watershed is a land-area that drains to a common outlet, and has components soil and land management, water management, crop management, afforestation, pasture/fodder development, livestock management, rural energy management and other on-farm and non-farm activities, and development of community skills and resources.

Among all these components, soil (land) and water are the basic resources. While soil, or land is static, water is dynamic in nature. Therefore, effective water conservation, harvesting and utilization is crucial and critical for the success of watershed programme. In case of drought-affected areas, it is important to identify and execute the location-specific water conservation measures in the watershed so that all water available from rainfall is conserved, stored and utilized within the watershed and promote ground water recharging.

Planning for Drought Mitigation- Short-term and Long-term Measures

The remedial measures that are needed to mitigate the drought are short-term and long-term measures.

Short-term measures include:

- assuring the availability of drinking water and food grains,
- fodder availability enhancement-opening of depots,
- food for work programs,
- cattle camps, and
- relief work.

Long-term measures include:

- crop planning for rainfed areas,
- rainwater management,
- ground water recharging and retapping, and
- planning for available reservoir storage.

Rainwater Conservation and Harvesting Technologies

The rainwater conservation and harvesting technologies involve on-farm (*in-situ*) and off-farm measures:

- Land shaping and land grading measures (Bunding, broad bed and furrow system)
- Small ponds and small reservoirs (Farm pond, Tanka, Khadin, percolation pond, Sunken pond, Dug-out pond, etc)
- Drainage line treatment (Check dams of different size, shapes and permanency; spillways and stop dams and other water harvesting structures)
- Any other indigenous water harvesting structures (*Nadis, Talabs*, lakes, *Khadin, Johads, Kundis*, wells, *Baoris*, etc.).
- Inter-terrace land treatments for different agro-climatic regions: (Table 2.)

Improvement of Groundwater Potential

Recharging the groundwater reservoir helps in storing the surplus rain water in a safe zone. This can be done through traditionally/indigenous techniques and modern techniques for recharging groundwater.

Long-term measures

The long-term solutions for drought proofing include the development of farm,

Table 2. Inter-terrace land treatments for different agro-climatic regions:

Region (with average rainfall)	Suggested land configuration options
Arid (<400 mm)	• Inter-plot water harvesting of 1:1 of cropped to uncropped land (slope of microcatchment on both sides)
	• Inter-row water harvesting
	• Dead furrows at 3.6 m intervals (suitable for Alfisols)
Semi-arid (400-1000 mm)	• Contour farming (cultivation and sowing) Sowing across the slope and ridging the land between rows
	• Graded bunds on grade of 0.2 to 0.3% with provision of drainage
	• Graded border strip (130x11 m) with 0.1% grade (for deep Alfisols)
	• Compartmental bunds for raising crop on conserved soil moisture (Vertisols and Vertic Inceptisols)
Sub-humid (1000-1800 mm)	• Broad beds and furrows (Vertisols having problem of drainage)
	• Graded furrows at a grade of 0.2 to 0.3%
Humid (about 2000 mm and above)	Raised and sunken beds
	• Inter-plot water harvesting (growing high water requiring crops in beds)

ponds, desilting and repair of irrigation tanks. Wherever possible, sprinklers and drip irrigation are to be adopted. Recycle and re-use of wastewater, particularly for industries and municipal requirements, is an important technique to mitigate the drought. Transfer of surface water from surplus river basins to deficit areas need to be taken up. Rainwater harvesting and groundwater re-charging schemes are to be implemented and if necessary, financial and technical assistance need to be provided for the execution of the schemes. Measures like pricing of water as well as electricity will restrict misuse of water and power. However, adequate legislation is to be made for cost recovery. Most importantly, people have to be educated about the use of latest technique of irrigation and necessary to conserve water.

Water harvesting and recharging of groundwater

Water harvesting encompasses techniques to induce, collect and store the surface runoff and groundwater for future beneficial use. It is a common practice to harvest rain water from house roofs, hilly and rocky surfaces, and store it in cisterns or tanks for domestic use.

Technique for water harvesting

Traditional methods for water harvesting: In India, the traditional methods of harvesting rainwater are being practiced for centuries. The designs of the traditional structures were mainly based on structural stability, and very little consideration was given for preventing evaporation losses, seepage losses and pollution. The type of rainwater structures varies from State to State.

Modern techniques of water harvesting: Based on modern technology and scientific inputs, the Central Ground Water Board, under the Ministry of Water Resources, has developed various techniques for harvesting of rainwater. These techniques are site-specific. Sizes of these structures depend on catchment area, runoff availability, infiltration rate of the soil, and depth to water level below ground, water quality, etc, whereas duration construction of traditional structures these scientific parameters were ignored.

The details of the newly-developed rain water harvesting techniques from roof tops as well as other catchments are given below:

- Underground/surface storage tanks: Underground or surface storage tanks are generally used to harvest roof top rain water for direct use, instead of recharging to groundwater. The technique is generally implemented in hilly terrains, high rainfall areas or islands where underground aquifers are not feasible for recharging.

- Recharge Pits and Trenches: Recharge pits are constructed for recharging the shallow aquifers. These are constructed 1 to 2 m wide and 2 to 3 m deep, which are back-filled with boulders, gravels and coarse sand. Recharge trenches are constructed when the permeable strata is available at shallow depth. Trench may be 0.5 to 1 m wide, 1 to 1.5 m deep and 10 to 20 m long, depending upon availability of water. These are back-filled with filter materials.
- Recharge Shafts with or without recharge wells: For recharging the shallow aquifers which are located below clayey surface, recharge shafts of 0.5 to 3 m diameter and 10 to 15 m deep are constructed and back-filled with boulders, gravels and coarse sand. If the aquifer is deep seated, a shallow shaft, along with recharge well is designed to recharge the deeper aquifers.
- Lateral recharge trench with or without recharge wells: For recharging the upper as well as deeper aquifers lateral trench, 1.5 to 2 m wide and 10 to 30 m long, depending upon availability of water with one or two bore wells, are constructed. The lateral trench is back-filled with boulders, gravels and coarse sand.
- Recharge wells: Recharge wells of 100 to 300 mm diameter are generally constructed for recharging the deeper aquifers and water is passed through filter *media to avoid choking of recharge wells.*
- Use of abandoned dugwells and tubewells as recharge structures: Existing dugwells may be utilized as recharge structure and water should pass through filter media before putting into dug well. Similarly, the existing abandoned tubewells may be used for recharging the shallow/deep aquifers. Water should pass through filter media before diverting it into abandoned tubewells.
- Spreading techniques: When a permeable stratum starts from top then this technique is used. Water is spread in streams/Nalas by making check dams, nala bunds, cement plugs, gabion structures or a percolation pond.
- Subsurface dykes: Subsurface dykes are suitable for valleys and streams whose baseflow is available for longer duration in the streams and imperious layer exists/is available at shallow depths from the surface.

Convergence of other production components/activities in the watershed

Once the watershed development/management approach is selected for area improvement, integrated and participatory methods follow automatically for optimal use of basic and other resources in the watershed. Accordingly, convergence of all other supplemental programs run by the state and central governments under watershed development such as crop production, soil improvement, fodder development, energy development, afforestation and other non-farm activities in the selected watersheds, is necessary for overall development of the watersheds.

Concluding Remarks

This paper has highlighted the rainwater conservation and harvesting measures and groundwater recharging techniques, keeping watershed as a development unit of land and water. Other organizational and socio-political aspects, as well as economic aspects, are left to the wisdom of planners. Govt. of India is operating several schemes/projects/programmes that are relevant, directly or indirectly, to the minimization of ill effects of drought. Presently there is no policy on drought per se and has been addressed in a sectoral manner and by individual Ministries. Drought contingent plans are yet to be prepared at the central and state levels and the coordination mechanism between the centre and the states prone to drought are yet to be put in operation. Last, but not the least, there is a need to strengthen the national climatological and hydrological capabilities to ensure establishment of early warning systems and to suggest measures for strengthening drought preparedness and management, including drought contingency plan at local, national and regional levels.

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Droughts: Economic Dimensions

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Droughts, being one of the common natural calamities causing huge losses of life and properties, affect all sectors of an economy. But more anxiety is felt in agriculture as the syndrome of loss begins there. Though agriculture is the primary sector of Indian economy, it is always taken for granted as it consists of millions of small units with no organization and lobby. It will be remembered only under crisis of calamities like droughts, floods, cyclones etc. as the national defence is remembered only when there is war or external threat. Perhaps, a better treatment and long run solution to these problems will be more helpful.

India being a vast country is a unique case where some regions receive high rainfall and others suffer from drought. It is also not uncommon that in the same area, they occur simultaneously or droughts and floods occurring in succession year after year. Though it is difficult to say the number of districts affected by drought, but in general, 99 districts are often drought prone. Though droughts of different intensities occurred in the last 10 years, but 7 of them are considered to be disastrous.

Impact of Drought

The most obvious impact of drought is a fall in foodgrain production. For instance, during 1987 drought, foodgrain production fell by 7 million tonnes. During 2000 drought, foodgrain production declined by 9 million tonnes. Thirty three million people were affected in the state of Rajasthan alone. Table 1 provides a picture of fall in foodgrain production in worst droughts in the last two decades.

With fall in foodgrain production, food and nutritional security of people will be affected. Along with that, scarcity of drinking water and fodder for animals become important. There will be large-scale migration of population from rural areas to urban areas for work and food.

Since agriculture provides many raw materials to industry, industrial production gets affected. It also gets affected in view of fall in the uptake of inputs from industry like

Table 1. Growth in agriculture during droughts

Drought Years	Fall in foodgrain production over previous year (%)			Fall in Ag. GDP growth over previous year (%)	Fall in GDP growth rate over previous year (%)
	Total	Kharif	Rabi		
1986-87	4.66	6.27	3.12	0.2	0.02
1987-88	2.14	7.56	+3.91	-1.0	0.05
1991-92	4.54	8.57	0.21	-1.1	4.3
1995-96	5.79	6.28	5.99	-0.3	No Change
1997-98	3.84	2.30	5.12	-1.5	3.0
2000-01	6.66	2.08	12.67	0.1	1.2

Source: a) Agricultural Statistics at a Glance, 2002
b) Economic Survey, 2001-02
c) Hand Book of industrial policy and statistics (1998)

fertilizers, pesticides etc. As a result of all these adverse affects, gross domestic product falls, partly in the same year as well as in subsequent years (Table 2).

Table 2. Growth in agriculture and manufacturing during droughts

(Growth rates in %)

Year	Agriculture	Manufacturing	GDP
1957-58	-1.21	3.85	-4.49
1965-66	-11.04	0.93	-3.65
1979-80	-12.77	-3.22	-5.20
1991-92	-1.55	-3.65	1.30

The pathway of adverse impact can be explicitly seen in terms of low investible surplus, low or no input use, low adoption of technology, low income, low/no demand for industrial inputs and outputs, no/low raw material supply to industry and thus the whole economy gets affected. Though droughts/floods used to fuel inflation further, in recent years, because of sufficient buffer stock and relatively well-managed food distribution system, inflation is not affected much.

Mitigating Drought

Drought management is one of the important strategies of the Central and State Governments since many years. One can find change of focus in it over the years. For instance, during 18th Century, the strategy consisted of adhoc approaches without any definite base or principle. During 19th Century, emphasis on saving life was stressed alongwith achieving maximum possible economy in relief expenditure. During 20th Century, the strategy was comprehensive by meeting food and nutritional needs of all sections of the population as per their energy requirements, supply of drinking water and health care facilities and adequate fodder for cattle.

Perhaps, the policy response to drought was evolving over the years with reference to each disastrous drought year. For instance, during 1965-66 drought, building up of a reliable public distribution system was singled out as a measure to address drought. The agricultural development strategy was centered around green revolution with emphasis on seed-cum-fertilizer revolution in the growth pockets of the country. During 1972 drought, evolution of massive employment generation strategy was evolved for enhancing purchasing power of the drought-affected people. During 1979 drought, revision of drought relief manuals, emphasis on creating durable productive assets like digging of wells, construction of roads etc. were emphasized. In 1987 drought, access to food and maintaining quality of life were stressed through food for wok programme. Thus, approaches in general moved towards drought mitigation or prevention than cure. However, in terms of need and requirements, such improvements are far inadequate in terms of spread, intensity and quality.

Needed Policies and Strategies

Policies and strategies need to be defined in terms of short term, medium term and long term.

Short term

- Execution of need-based employment generation schemes
- Ensuring supply of drinking water
- Adequate feed/fodder for cattle (from surplus regions)
- Proper reservoir maintenance
- Short duration drought resistant crops, management practices etc.

Medium term

- Strengthening agricultural research
- Institutional reforms
- Infrastructure development
- Diversification
- Water harvesting and artificial rechange of ground water
- Crop insurance
- Indigenous technical knowledge
- NGO participation

Long Term

- *Creation of surface storage*
- Integration of small reservoirs with major reservoirs
- Integrated basin planning for managing demand in harmony with natural capabilities of environmental system
- Inter-basin water-transfer from surplus river basin to deficit areas

Role of R&D

R&D is one of the important enduring elements of drought management strategy. Bringing marginal lands under plow, overstocking of grazing land, institutional, organizational and economic support during crisis period will not offer permanent solution to the problem. Institutional and policy reforms without technological changes prove sterile and ineffective. Technologies are already available and some more are experimented with. They need to be transferred and adopted by farmers.

Some suggestions for technological interventions for reconstruction of Indian Arid Zone

Twenty million people barely eke out a living from agriculture and animal husbandry in the arid regions, which constitute 10% of the geographical area of India. Bringing marginal lands under the plough, or overstocking of shrinking grazing space does not offer a permanent solution. Neither do measures of institutional, organizational, or economic support. The role of technology is crucial.

Several technology options that hold promise are available now, and others are being experimented with. The extent to which these options are availed of by the farmers, how support mechanisms are organized to facilitate such adoption and how marketing system develops to absorb the output from the region will determine the quality of life in the arid zone. The technologies include dryland crop production, sheep and goat husbandry, grassland and pasture improvement, ber plantation and afforestation. The available evidence on the successful adoption of these technologies suggest that schemes like grassland and pasture improvement and arid zone afforestation can be taken up as drought relief measures because they are also labour intensive. A case can also be made for increasing credit flows to the arid zone under the DPAP, NREP etc. and for encouraging private investment to fund these activities. To ensure better long-term land use, dryland crop production may have to be confined to areas receiving more than 300-400 mm rainfall. Since animal husbandry has major advantages in arid zone, emphasis on production of fodder crops, growing multiple cut varieties, perennial grasses, *Kharif* fallowing, better dairy management practices, mobile veterinary clinics, organizing and coordinating animal migration activities, improvement of local breeds through breeding the need to be given attention.

If these technologies are used in a package, needed food, fodder, fruits and fuel can be produced in the arid zone. But massive financial resources are needed for this, which calls for pooling of resources at individual, state, national and even international level.

Conclusions

Droughts occur frequently in India causing considerable economic losses and hardships to human and animal population. On a limited scale, traditional wisdom and knowledge are effective to minimise the drought effects. But over a period of time, they have become ineffective requiring short/medium/long term policies and interventions. In this, the role of technology is critical. Science holds promise for reconstruction of arid zone. Along with science, resource mobilization is also critical. Above all, long run planning and serious implementation is a must.

Drought Management Strategy for Asia Pacific: FAO Initiative

(With Particular Reference to India)

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The Asia and Pacific Region is drought-prone. Every year, drought occurs somewhere within the 40 countries that make up this region. In the drought-affected areas, the most damage is in the food and agriculture sector. For example, immediate crop and livestock losses mean hunger and malnutrition for the vulnerable communities. Long-term decline in productivity due to diminished areas, reduced investments and slow recovery lead to poverty and chronic food insecurity. The risks associated with the complex drought-dryland problem may worsen due to climate change. Global warming is expected to lead to more pronounced dry and wet weather conditions. Asian summer monsoon precipitation could vary more and water availability may decline in arid and semi-arid Asia. If these changes occur, drought damages would increase.

Drought impact on food and agriculture is especially severe because as much as two-thirds of the region's agricultural land is rainfed with large parts in arid and semi-arid zones. In these dryland areas, delayed or reduced precipitation due to ENSO, climate change and other local conditions exacerbate the growing water shortage faced by the nearly 650 million of the region's poor inhabitants. Right now there is no clear solution in sight. Water scarcity and difficulty of finding cost-effective and environment-friendly projects limit irrigation as a solution.

In the region's drought-prone countries like China, India, Iran, DPR Korea, Myanmar, Pakistan and Sri Lanka, severe droughts were reported once every three to four years during the last 50 years. Since the mid-nineties, prolonged and wide-spread droughts in consecutive years have occurred in India, Iran and Pakistan. Frequency of droughts has also increased in DPR Korea, China, Myanmar and Sri Lanka. The response has been varied within and among the countries. On the whole, these may be characterized as *ad hoc*, short-term and superficial. Few drought-prone countries have gone beyond immediate food and feed relief, temporary employment generation and distribution of seeds and other inputs for the next crop. Such limited assistance has often been judged as too little too late. Typically, there is no strategy and long-term action plan for drought prevention and management. More often, drought mitigation and relief measures stop after a while and are forgotten until the next incident. Consequently droughts have exacerbated hunger, malnutrition and chronic food insecurity by degrading grazing lands, decimating livestock, depleting groundwater reserves, depredating marginal soils and devastating standing crops. More worrisome, these have reduced productivity and set back sustainable development. What is urgently needed in drought-prone countries is appropriate technology to prevent, mitigate and manage droughts in the agricultural sector.

FAO Conference on Management of Disasters (Chiang Mai, June 2001)

As part of its Medium-Term Plan (2002-2007), FAO is improving its inter-departmental coordination through defining Disaster Prevention, Mitigation and Preparedness, and Post-Emergency Relief and Rehabilitation as one of the five Priority Areas for Inter-disciplinary Action (PAIA, Fig. 1). FAO approach to disaster management, including tropical cyclones, floods, droughts and earthquakes, is similar to that of the United Nations International Strategy for Disaster Reduction (ISDR), entitled 'A Safer World in the 21st Century: Risk and Disaster Reduction'. Following adoption of the Disaster Management PAIA in November, 2000, FAO RAP (Regional Office for Asia and Pacific) organized a Regional Conference on Early Warning, Prevention, Preparedness and Management of Disasters in Food and Agriculture at ministerial level at Chiang Mai, Thailand, in June 2001. The following recommendations, related to drought, were adopted in the Chiang Mai Conference (Anonymous, 2001):

- The Conference learnt that drought-prone countries in the region experience wide annual fluctuations in productivity and output. The prevalence of subsistence agriculture in these countries exacerbates the vulnerability of farming systems and livelihoods.
- The Conference also learnt that the frequency and impact of droughts have increased over the years. This is attributed to the movement of people to marginal

lands, agricultural intensification, growing water scarcity and climate change. It agreed that drought-related disasters would worsen unless drastic interventions are taken immediately.

- The Conference observed that the urgency of drought combating action, at the outset, varies in time and with the country and area. Also, many public and private agencies deal with the problem. In such circumstances, efforts are often sporadic and fragmented and they lead to nowhere. The importance of continuous integrated actions was emphasized. The Conference called for the establishment of task forces/partnerships/consortia of all public and private stakeholders to solve the drought problems.
- The Conference recognized that existing response programmes for drought-prone areas tend to be limited in scope and depth. They typically focus on immediate needs such as drinking water, food, crop and livestock loss prevention, and short-term employment. The assistance given is generally inadequate and understandably, limited to accessible people and areas. The Conference urged new approaches, strategies and methods to protect farming systems, resources and livelihood in drought-prone areas.
- In considering recent drought-fighting measures for agriculture, the Conference highlighted the importance of prioritizing areas and peoples for resource allocation. Otherwise, resources would be spread too thinly to be effective. The Conference recommended that vulnerable areas should be prioritized on the basis of agro-ecological zones. Within the selected areas, issues for R & D and drought-combating actions should also be prioritized.
- The Conference agreed that from the economic perspective, integrated watershed management coupled with enterprise diversification based on carrying capacity and product value addition should be the main thrust. This line of action would ensure optimum resource-use, sustainability and income maximization. The Conference recommended that governments give high priority to watershed management, water harvesting and conservation, crop and livestock diversification, agro-forestry and agro-industry management.

- The Conference underscored the importance of farmer participation in R & D. Only when farmers, scientists and extension workers operate as a team could new technologies suitable for local conditions emerge in drought-prone areas. The Conference recommended that R & D institutions undertake more on-farm research, with the full participation of farmers in indigenous knowledge assessment and adoption, resource appraisal, problem identification and programme implementation.
- On farming systems and best practices, the Conference considered old and newly emerging technologies for drought preparedness and mitigation. It covered contingency crop planning, *in-situ* rainwater harvesting, village and farm ponds, underground cisterns, crops, varieties and cropping systems, crop combinations, weed management, planting density, soil and crop management, integrated nutrient management, alternative land-use systems and others. The Conference recommended that governments and concerned institutions accord high priority to R & D of drought-resistant technologies and practices.
- The Conference recognized that early warning, and continuous monitoring and decision support systems are integral components of a programme to protect farmers' livelihoods. Only if these components are effective, farming adjustments and corrections be made in time; and optimal decisions taken to maximize returns/minimize losses, especially with mid-season and terminal droughts. The Conference suggested for drought management, and a decision support system based on crop growth models, drought mitigation technologies, market forecasts and resource information.
- The Conference also realized that appropriate R & D strategy and action plans are critical for sustainable development of arid areas. To support sound planning, it recommended that the action plans be applied to selected areas based on the same watershed, or having similar farming or other key characteristics. It further suggested that R & D plans be divided into short, medium and long-term activities.
- In this regard, the Conference went on to identify gaps in research and technology

development. It recommended additional work for a number of areas on a priority basis in the Asia-Pacific Region, namely, identification of research subjects/issues in each agro-ecological zone, early warning and decision support systems, soil quality enhancement, agro-bio-diversity issues, farming systems, participatory technology development, and technology assessment and refinement in drought management.

FAO-CRIDA Expert Group Consultation on Farming Systems and Best Practices in Drought-prone Areas in Asia and the Pacific (Hyderabad, January 2002)

On the basis of findings and recommendations at Chiang Mai Conference, FAO RAP launched its Disaster Management PAIA with a Regional Expert Group Consultation on Farming Systems and Best Practices in Drought-prone Areas at Hyderabad, India, during January 2002. The following recommendations were adopted in the Hyderabad Consultation (Anonymous, 2002):

Recommendations at the policy level

1. That a regional strategic drought preparedness project be established. This project would have several elements and support individual countries in their drought preparedness initiatives and activities. Initially it could take the form of a collaborative partnership network with one or more coordinating nodes. The future shape would depend on subsequent policy decisions. The elements could include:
   a. coordinating emergency stocks of food and other drought reserves and their maintenance,
   b. information flow for drought early warning and monitoring,
   c. information flow for drought preparedness and response (eg, new climate research findings, new land and water management practices, new drought-tolerant breeds and varieties, social and community processes to help communities prepare for drought, what to do when drought is forecast, and ways to purify drinking water),
   d. monitoring of regional drought severity and extent to assess climate change

impacts,

e. focusing priorities for research and development agencies,

f. capacity-building for a strategic approach to drought preparedness and response,

g. focusing priorities for emergency relief agencies, and

h. making sure drought is not forgotten as soon as rains arrive.

2. That national, state and regional policies provide for conservative management and maintenance of all reserves developed as part of drought preparedness initiatives, whether they be reserves of food, surface or groundwater, seeds or fodder.

3. That drought preparedness be factored into all levels of the sustainable watershed development programs and that participative community-based action-learning processes be used to empower watershed communities to manage natural resources so as to be better prepared for droughts.

4. At the national level, all countries be encouraged to enact policies to support preparation of a National Drought Mitigation Plan, involving all the ministries and concerned organizations, including NGOs.

5. Drought support policies should, to the extent that is appropriate in the particular circumstances, encourage self-reliance by farmers. In other words, drought preparedness may be factored into their normal farm management plans and activities.

6. All countries concerned with drought be encouraged to develop/improve their drought declaration/revocation processes and to share information on these processes, recognizing that although they are commonly based on threshold criteria for rainfall deficits and other relevant factors, they may be location-specific and operate differently at different levels, and where possible they have local community involvement through processes that help maintain morale in the face of drought.

7. At national and state level policies are required that ensure there are adequate reserves of food and drinking water as well as seeds of suitable varieties and

livestock fodder, suitably located or able to be imported to be available in a timely manner.

8. At the national and state level policies should ensure that financial support is provided for strategically planning and implementing water conservation programs as part of ongoing budgetary arrangements for drought mitigation programs on short term and long-term perspective.
9. With regard to India, the Third National Development Plan should ensure optimal provision for drought-related programs.
10. That a strategic review be undertaken to assess the scope for increasing the irrigated area by diverting river water to dry zone to provide irrigation water for presently *rainfed farms.*
11. Policies at all levels should encourage the uptake of more water-efficient technologies such as drip irrigation and rehabilitation of traditional storages.
12. Research and development is essential to build capability to handle drought and policies should provide support and encouragement for research and the application of findings.
13. Policies at all levels should recognize that social interactions are important to maintain morale and social capital in the event of drought. Land care (local people acting to resolve local problems) movement is a powerful agent for building social capital in rural communities to cope with weather adversities, such as drought.

R & D to support drought preparedness and responses

14. Various drought indices should be researched and promoted so that data from regular observations can be used to more effectively warn of drought dynamics. Research should develop and apply ways to monitor and predict, through remote sensing, direct measurement and simulation models, the current and future water conditions of the soil-plant-atmospheric continuum.
15. Undertake a complete resource analysis and study of land use in drought prone areas to emphasize the importance of drought occurrence, climate resources, potential productivity of crops, environmental problems, land use patterns, cropping systems,

water and forest resources, livestock and fodder resources.

16. Climate-soil-production systems need to be critically evaluated from a sustainable resource management context in drought-prone environments. To help manage agriculture and coordinate the relationship between development and environment, research should be conducted on:

- Soil degradation
- Water erosion control
- Water-use efficiency improvement
- Comprehensive development of farming, forest and livestock husbandry and environmental improvements
- Cropping patterns
- Tillage systems
- Water management
- Use of drought resistant crops
- Soil moisture conservation practices and runoff techniques among farmers.

17. Research and development, while being wherever appropriate systems-focussed and strongly interdisciplinary, should use participative processes to take advantage of the wisdom of farmers and their traditional practices. Research should also focus on the integration of the technical and socio-economic aspects.

18. Operational costs of irrigation systems are a major hindrance for adoption by farmers. Research is needed to develop and apply low cost techniques of water harvesting and water conservation such as mulching and micro-relief modification.

19. The key to successful farming in drought-prone areas is not 'farming land', rather it is 'farming water'. Simple tools to show the farm or field water balance, and the on-farm level of efficiency of water or rainfall use in terms of crop yield generated should be developed for use in action-learning processes with dryland and irrigation farmers.

20. Best practices should be considered in a holistic framework that recognizes the need for significant benefits to farmers, matching with individual farmer's socio-

economic conditions and the least deleterious effects on the environment.

21. Research workers and extension agencies should, as a matter of routine, adopt participative processes to improve end-user awareness and the pace of diffusion.
22. Climate risk research and development has to be taken up as a high priority to provide tools and guides for timely decisions for drought management. The increased risk of drought with global warming should be investigated.
23. The major research thrust on understanding and predicting climatic variability, using global factors like El Nino and Southern Oscillation Index (SOI), is essential for improving predictability of droughts. The capability for assessing seasonal prospects using seasonal climate forecasts and system simulation models has to be developed to support real time decisions.
24. Due emphasis be paid on catchment management of the major rivers in the hilly region in order to sustain a favorable flow rate of the major rivers and to minimize siltation of the major reservoirs.
25. Development of short duration and drought-tolerant crop varieties for the drought-prone areas.
26. Establishment of drought information network/databank to provide the data and interpretation on future drought occurrence forecast, location, intensity, duration and impact on different sectors.
27. Farm advisory technologies on rational and efficient use of water to improve productivity of agricultural crops, appropriate cropping patterns, conservation technologies of rainwater and providing forecast and early warning services for stakeholders.
28. The potential for so-called inferior, but drought-hardy species such as *Prosopsis* and *Opuntia* to provide raw materials for employment generation activities, along with post-harvest processing technologies, should be investigated and promoted.
29. Explore possibilities for drought-tolerant breeds of livestock and varieties of crops to help build drought tolerance and resilience of farming systems.

Recommendations relating to the operational or local/farm level

30. Extension and awareness activities should reinforce awareness that droughts recur and the focus should be more on sustainable natural resource management, even when drought comes, rather than responding to the drought when it is imminent.
31. Farmers need to have strategic approaches developed well ahead of time so they know what action to take if they are warned of a coming drought.
32. Participative action learning processes are a powerful way and should be used wherever possible to empower people to understand processes and adopt improved technologies.
33. Providing water to remote villages in the country by using stationary and mobile tankers.
34. Creating public awareness about the drought and educating on efficient use of water through information media.
35. Timely input supply at the farmers' doorsteps by extension agencies to recommend the efficient crops, contingency plans, etc., for overcoming weather aberrations.
36. It is essential for the farmer to adopt the technology for drought proofing, improving the soil quality, water conservation on watershed basis using rainfall, runoff, soil moisture and ground water efficiently.
37. By nurturing legumes on wastelands, field bunds, etc., they can become sources of nutrients. Also, alternate land use systems based on perennial multipurpose trees, dryland horticulture, livestock and others are essential to reduce the risk in rainfed farming systems.
38. Integrated nutrient management with quality compost should become a wide spread adoption.
39. Valuable information provided by the Agromet Weather Advisories and Remote Sensing Agencies should help the farmer as decision support systems to reduce the drought vulnerability.
40. Increase the irrigable area under the minor irrigations system by rehabilitating the old and defunct minor ones and prevent water shortages in rainfed farming through

deep and shallow agro wells. Also, boost minor irrigation systems with tapping ground water in the command area of the minor tanks.

41. Crop diversification in the well-drained soils in the major irrigation systems where most of the water is consumed for paddy cultivation.
42. Introduction of water saving irrigation systems, specially the pressurized drip and sprinkler irrigation methods, for the drought-prone areas.
43. Drought can have grievous social impacts and the need for social interactions to maintain morale is critically important.

Regional Strategic Framework for Disaster Management in Food and Agriculture (July, 2002)

Recognizing the serious negative impact of natural disasters on agricultural productivity and food security in Asia and the Pacific, the 25th FAO Regional Conference urged member states to make disaster prevention and mitigation an integral component of sustainable agriculture and rural development programmes (FAO, 2002a, Fig.1). The vision of Strategic Framework is sustainable food and nutrition security of disaster-prone communities by managing risks, reducing vulnerabilities and enhancing resilience of farming systems and protecting the environment. The objectives of the regional framework strategy are as follows:

- strengthen monitoring, early warning and forecasting systems of impending food emergencies, and agricultural and nutritional vulnerabilities;
- raise research and development in food and agricultural disaster management; and
- mobilize manpower and funds for disaster management within the framework of sustainable agriculture and rural development.

Interventions in emergencies can be best described in terms of a sequence of events, sometimes referred to as a disaster cycle, with distinct phases, each requiring different action. The eight types of action or phases of the emergency sequence are: (1) Prevention, (2) Preparedness, (3) Early Warning, (4) Impact and Needs Assessment immediately following a disaster, (5) Relief, when immediate humanitarian assistance is required, (6) Rehabilitation, when the first attempt to rebuild the rural livelihood system takes place, (7)

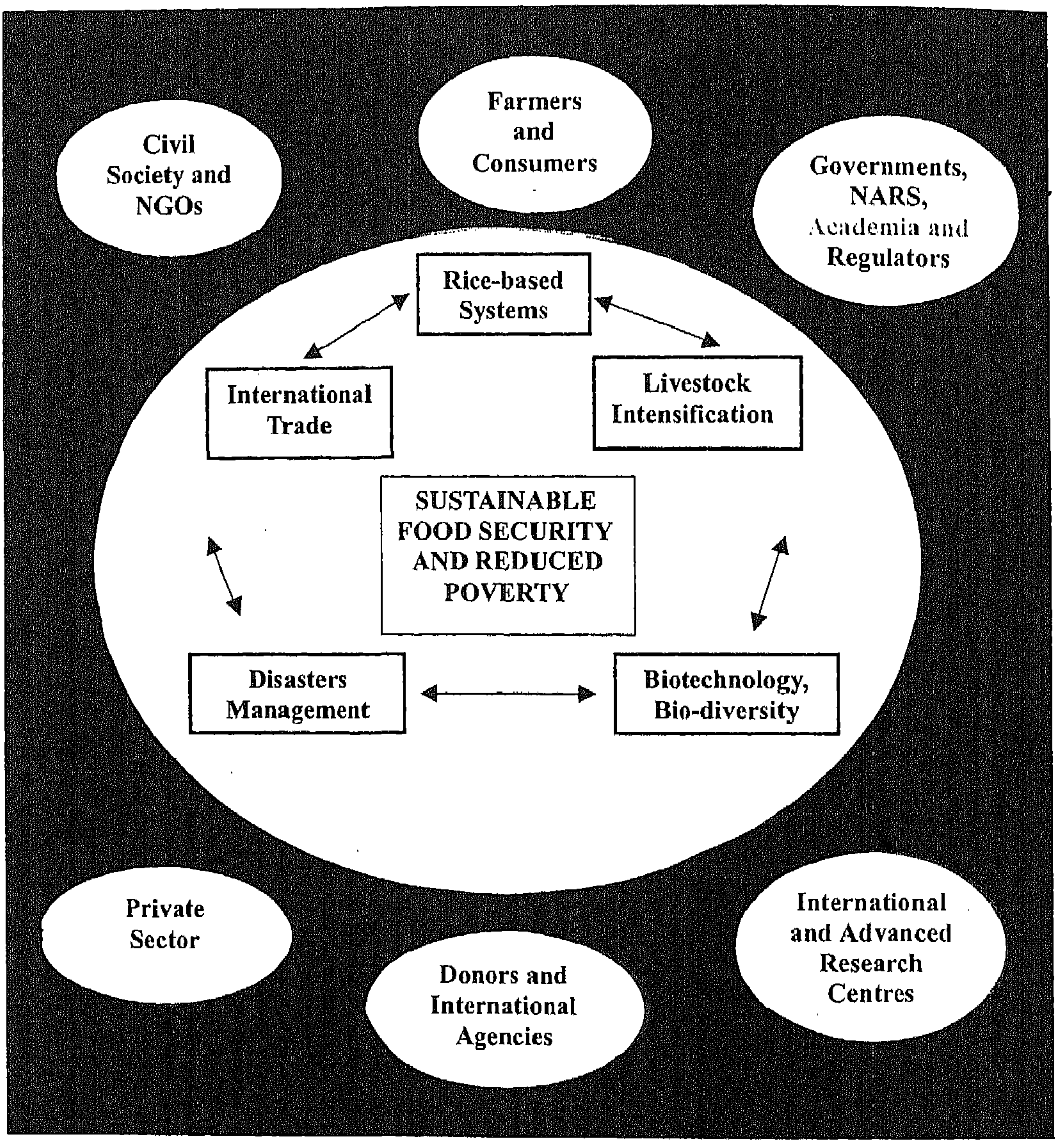

Fig 1. Stakeholders and priority areas for inter - disciplinary actions (PAIA) to strengthen food security, lessen poverty and sustain environments (FAO, 2002a).

Reconstruction, when the destroyed infrastructure is replaced and investment can take place, and (8) Sustainable Recovery, when conditions permit return to a development process. The key areas for strategic intervention under each action/phase are depicted in Table 1.

A regional disaster unit or task force will be created in FAO RAP to implement the programme on prevention, preparedness, early warning and management of disasters in food and agriculture. The RAP Disaster Unit (RAPDU) will work closely with all stakeholders in the Region, including UN technical and funding agencies, international banks, disaster prevention and relief organizations, NGOs and CSOs. In this regard, it will establish working arrangements and foster mutual support with the UN OCHA, WFP, ISDR Secretariat, Asian Disaster Preparedness Centre (ADPC), Asian Disaster Reduction Centre (ADRC) and other similar specialist organizations. RAPDU will pay special attention to mobilization of donor support including developing-country donor support within the framework of TCDC/ECDC. In this endeavour, existing sub-regional associations such as ASEAN and SAARC will be used to provide leverage. The Strategic Framework will be implemented at the regional and national levels within the framework of TCDC/ECDC, essentially through:

- information exchange,
- institutional building/strengthening,
- promotion of research and development in organization, management and technologies of disaster preparedness,
- training and extension; and
- pilot study.

Regional Project on Drought Preparedness (Concept Framework, August 2002)

To meet the need for drought management R & D, FAO has developed a regional project to gather appropriate technologies, and test and extend them to drought-prone areas within the framework of TCDC (FAO, 2002b). Such a project will serve to change mindsets, stimulate new approaches, and encourage well-thought out strategies and long-term plans for drought management.

Rationale

- The incidence and impact of droughts in the region's food and agriculture sector is increasing. But comprehensive long-term action plans to prepare for and manage droughts are lacking in many drought-prone countries.

Table 1. Proposed measures under operational strategies for disaster management in the Asia-Pacific Region

Prevention	Preparedness	Early Warning	Impact and need assessment	Relief	Rehabilitation, reconstruction and sustainable recovery
Introducing Food Insecurity and Vulnerability Mapping Information Systems (FIVIMS)	Promote appropriate database for preparedness and planning	FIVIMS	Establishing methods impact and needs assessment for community and government	Improving collaboration of all players at local, national, regional and global levels	Integrating all actions with the development process
Strengthening guidelines for agricultural vulnerability reduction	Support disaster preparedness planning in farming systems	Establishing/ strengthening national EWS	Improving comprehensiveness, timeliness and accuracy	Increasing cost effectiveness of distribution mechanisms	Building physical and institutional infrastructure
Encouraging hazard resistant and protective structures	Strengthen Asian, national and local level FIVIMS	Establishing/ strengthening agro-meteorology units	Promoting community and government participation	Mobilizing resources (foods, inputs, funds and support)	Raising R & D for resilient farming systems
Promoting land and water use planning and zoning	Create mechanism for disaster management	Upgrading crop assessment and forecasting methods	Linking national, FAO/WEP and donor assessments	Instituting nutrition surveillance	Strengthening agricultural micro-credit systems
Developing community decision-making and action	Support nutritional information and health care	Linking national, regional and global EWS		Building systems for monitoring and evaluation	Improving access to land and other means of production
Building community self-reliance	Develop mechanism for loss and damage compensation	Improving two-way farmer-EWS information flow			Raising farm and off-farm incomes of the poor
Improving disaster proof farming systems including: -Crop diversification -Integrated farming systems -Contingency crop planning -Disaster mitigation practices -Hazard resistant practices -Pilot projects	Stock emergency food, feed, fodder and agricultural inputs Encourage agriculture-related employment projects Work towards effective involvement of local communities				

- Even when there is advance warning of droughts, most small farmers especially those in arid and semi-arid lands, do not know what to do or do not have the resources to undertake mitigating measures, or fail owing to ineffective measures undertaken.
- There has been insufficient R & D in drought management in most of the countries.
- Drought management models with appropriate technologies developed by leading R & D agencies have not been tested and extended throughout the region.
- Farmers, businessmen and governments have been reluctant to invest in rainfed drought-prone areas.

Objectives

The development objective is sustainable food security in drought-prone areas through resilient livelihood systems.

The specific objectives with regard to drought preparedness and management in the food and agriculture sector are:

- strengthened R & D,
- establishment of communities of learning at national and international levels; and
- enhanced policies and programmes as well as capacity to develop resilient agricultural livelihood systems in drought-prone areas.

Project strategy and institutional arrangements

The strategy is to initiate sharing of knowledge in drought management among participating countries. The focus will be on networking, exchange of expertise and experience and capacity building. The guiding principle will be building on the existing knowledge base.

Six countries with large drought-prone arid and semi-arid areas namely, China, India, Iran, Myanmar, Pakistan and Sri Lanka will be selected to participate in this project. The focal institution in each country will undertake a pilot project on drought management. Over a five-year period, the country pilot projects will (i) test models and technologies; (ii) undertake technology exchange; and (iii) train domestic and foreign drought management workers.

A systems approach, stressing comprehensive and integrated actions, will be adopted. The pilot projects will cover all aspects of drought management, including prevention, preparedness, early warning, impact and need assessment, relief, rehabilitation, reconstruction and sustainable development in a concerted fashion. The knowledge generated in the six participating countries will be disseminated to other drought-prone Asia-Pacific countries.

At the regional level, the project will be headquartered in FAO RAP. It will be operated by the RAP Field Operations Branch and guided by a RAP Technical Group Task Force. At the country level, the project will be implemented by the national focal institution such as the Central Research Institute for Dryland Agriculture of India (CRIDA), the ministers of Agriculture in China and Iran, etc. Each national focal institution (NFT) will be expected to execute the following action programmes:

- establish a pilot drought management project, using the most appropriate participatory model and technologies;
- using the pilot project as a base, train national and international drought workers;
- test new technologies transferred from other countries; and
- guide and support expansion of the drought management model to other parts of the country.

At the end of five years, the NFT, as well as the Regional Network is expected to continue to operate using their own funds. The NFT may become the national drought management R & D Centre. The Regional Network headquarter may be moved to participating countries on a rotational basis. The ultimate beneficiary will be the small farmer in drought-prone arid and semi-arid areas in the region.

Concerned parties at the international level will include among others: ICRISAT, ADPC, IWMI, ADRC and IRRI. Their technical expertise in drought preparedness and management will be tapped for technical backstopping in planning and implementation. Funding agencies such as the World Bank, IFAD, ADB and GEF will be kept informed with a view to promote their involvement in follow-up investment.

Outputs

The project will deliver the following tangible outputs:

- network of pilot projects for R & D and technology transfer;
- tested models for drought management, incorporating appropriate technologies;
- national plans of action for drought management (PDM);
- manuals on actions to be taken and rules to come into force in the event of drought; and
- training of trainers, policy makers and technical personnel.

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Recommendations

The participants felt an urgent need to have a national policy document on drought management. It should be comprehensive and deal with both short and long term measures for drought mitigation. Need for an effective, reliable and dependable early warning system for drought was also felt. The participants suggested that appropriate linkages between research organization, administrators and developmental agencies, including NGOs, be developed and strengthened to effectively manage such calamities.

Several other short and long term strategies were proposed, which are listed below.

Short Term

Crops

- Since drought has badly affected the kharif crops this year, prospects of improving production of rabi crops may be explored to offset Kharif losses to some extend. Since drought has badly affected the kharif crops this year, prospects of improving production of rabi crops may be explored to offset Kharif losses to some extend.
- Mid-season corrections in the standing karif crops, e.g., in situ moisture conservation, weed management, adjusting crop density to match available soil moisture, irrigation, wherever available should be applied to save the life of crop.
- Package for rabi crops may be kept ready to take advantage of the eventual late rains or winter rains.
- There is a need to develop rainfed farming packages of cropping system for: (a) delayed onset of monsoon, (b) timely onset of monsoon, but intermittent droughts due to erratic distribution of rains, (c) terminal drought due to early withdrawal of monsoon, and (d) extended monsoon period due to late withdrawal of monsoon.
- Efficient cropping zones should be identified as per agro-ecological subzonation.

Livestock

- Due to drought the infectious diseases, like sheep pox, may increase. Adequate vaccination to prevent this and other infectious diseases and drenching schedule of deworming may be adopted.

- To economize on water resources, watering of livestock may be done on alternate days, and immediately after grazing. Likewise, long distance grazing may be restricted to avoid fatigue and conserve energy.
- The small ruminants having medium body weight should only be bred during drought period so as to conserve the fodder.
- Unproductive animals may be culled so as to save fodder for productive animals.
- The current drought situation is likely to result in massive animal migration. Therefore, measures may be taken to provide water, fodder, health care and shelter during migration of animals. Also shearing wool and marketing facilities during migration may be taken into consideration.

Fodder

- Different crop residues like rice and wheat straw, bhabhar grass, stover from maize, pearl millet, sorghum and fodder collected from perennial grasses need to be properly utilized.
- Straw can also be used for mushroom cultivation to increase the farm income.
- Under drought condition the fodder availability is not only poor but the quality is also poor. Therefore, fodder has to be imported from neighbouring states in the form of fodder bales/compact blocks. If the fodder is imported from drought-affected areas, it should be fortified with urea, vitamin-A to prevent malnutrition. Care need to be taken to avoid possible toxicity from NO_3 and HCN in fodder obtained from drought-affected areas.
- Precious sevan-based grassland deep in the desert is being eroded at an alarming rate. There is an urgent need to rejuvenate and restore these sevan-based grasslands
- Fodder and seed banks should be established at Panchayat Samiti level to ensure

their timely availability.

- Agro-industrial byproducts and unconventional feed, such as rice straw, mustard straw, sugarcane bagasse, *P. juliflora* leaves and pods should be included in animal feed with proper supplementation.
- Wherever water is available, including IG canal command area, efforts may be made for cultivation of fodder crops rather than fruit crops and arable crops.
- Possibility may be explored for utilization of existing non-edible green biomass for fodder. If needed, this may be fortified with conventional forage.

Water

- Rain water harvesting measures need to be refined so as to make them more efficient and efforts made to conserve the harvested rain water.
- Bringing more land under crops during rabi season through adoption of pressurized irrigation like drip or sprinkler system will make up yield reductions registered during kharif season.

Livelihood

- Alternate sources of livelihood for the people in the drought-affected areas need to be created so as to cushion the adverse effects of drought on farm families.
- Food for work programme need to be focused around the developmental works that could be used for drought proofing during subsequent droughts. These may include development of watersheds and improvement of rangelands and water storage structures to meet drinking water needs of livestock.
- To minimize wastage, water should be charged on volume basis.

Long Term

Fodder

- The wastelands should be utilized for plantation of fodder trees and development of natural pastures, and in the event of late rains more areas be brought under silvopasture and hortipasture systems.

- *P. juliflora* trees are abundantly present in the region. Attempts may be made to improve quality and palatability of *P. juliflora* leaves and utilizing its pods after grinding as supplement of cattle feed.
- Cactus, *Alianthus excelsa* and thornless *Prosopis* may be propagated as feed for livestock drought-prone areas.

Water

- Ground water use should be rationalized and efforts be made to bank more upon the dynamic resources than on the static one.
- Rational use of ground water is necessary, and attempts may be intensified to recharge the existing ground water pockets.
- There is a need to develop a national water grid to fill major water reservoirs already created in the drought-prone areas and make the efficient use of this water to mitigate the adverse impact of drought.
- Overexploitation/misuse of ground water and surface water resources should be restricted.

Livestock

- Elite livestock germplasm should be conserved for replenishment of the stock after termination of the drought.
- Area-specific native breeds should be encouraged. For example, Rathi, Tharparkar, Kankrej, Malvi, Nagauri cows, Surti buffaloes, Marwari, Magra, Chokla, Nali, Malpura, Sonadi sheep and Marwari, Jhakrana and Sirohi goats need higher attention.
- The germplasm of good male and female animals need to be conserved.

- To increase the farm income, value-added products may be encouraged for marketing. For example, wool may be converted to products like blankets, shawls, namdas, carpets, etc., skins may be processed as leather goods, bone, etc., may be used as manure and value addition may be attempted in milk and milk products as well as in fruits and vegetables.

Drought mechanism and forecasting

- Linkages may be developed and strengthened across the disciplines and institutions involved in drought prediction and drought management for efficient short-term, medium term and long term planning.
- *Relationship between aerosol dust and other pollutants and anomalous* rainfall/temperature need proper investigation in the light of recent UN report on the region.

Landuse planning

- Policy frameworks on water, land use and drought at national level need immediate attention, with legal restrictions on over-exploitation of natural resource base.
- Based on resources and agroclimatic conditions there is an urgent need to develop sustainable and profitable farming and cropping systems.
- The carrying capacity of the region, for both human and livestock population may be worked out.
- Promoting agroforestry and alternate land use systems, involving perennial plants and livestock may be encouraged and other income and employment generating activities be explored.
- Studies on socio-economic impact of drought need to be intensified, for effective policy making.

Appendix-I

CONTINGENCY PLAN FOR DROUGHT IN WESTERN RAJASTHAN

Central Arid Zone Research Institute, Jodhpur

I. Strategy for Crop Management

Contingency operation	Possible period of monsoon arrival			
	20-25 July	26-31 July	1-6 August	7-15 August
Field preparation	Field bunding, removal of bushes and harrowing across the slope			
Crop varieties recommended (in order of preference)	Mung bean (RMG 62, K 851	Moth bean (RMO 40, RMO 257)	Moth bean (RMO 40, RMO 257)	Moth bean (RMO 40)
	Moth bean (RMO 40, RMO 257) Clusterbean (RGC 936, RGC 1002)	Clusterbean (RGC 936, RGC 1002 Mung bean (RMG 62, K 851)	Clusterbean (RGC 936, RGC 1002)	Clusterbean for fodder (RGC 936)
	Cowpea (C 152, Char odi 1, V 16, RS 9)	Pearl millet for fodder (Raj 171, MH 169) with cowpea (Charodi 1, V16, RS 9, FS 68)	Pearl millet for fodder (Raj 171, MH 169) with cowpea (Charodi 1, V 16, RS 9, FS 68)	Pearl millet for fodder (Raj171 MH 169) with cowpea (Charodi 1, B 16, RS 9, FS 68)
	Pearl millet, extra-early to early variety (HHB 67, ICMH 356, RHB 30)	Pearl millet for fodder (Raj 171, MH 169) with moth bean (RMO 40, RMO 257)	Pearl millet for fodder (Raj 171, MH 169) with moth bean (RMO 40, RMO 257)	
	Pearl millet (HHB 67, ICMH 356, RHB 30) with mung bean (RMG 62, K851			

	20-25 July	26-31 July	1-6 August	7-15 August
Pre-treatment of seeds for drought resist-ance and crop growth	• Soak the seeds in potassium nitrate or common salt (7.5-10 g per 10 L water or 1.5-2 teaspoons per 10 L bucket of water) at night for 2 hours, then dry it for 2-3 hours, before sowing. • Thiourea, if available, @ 5g per 10 L water, or 1 tea spoon in 10 L bucket of water for 2 hours; then dry for 2-3 hours and use for sowing.			
Sowing	In furrows at 60 cm row to row spacing for grains and broadcasting for fodder			
Seed rate	Normal rate	Increase seed rate by 10-15% of normal (fodder crop)	Increase seed rate by 10-15% of normal (fodder crop)	Increase seed rate by 10-15% of normal (fodder crop)
Fertilizer Basal N: P (10:20 kg/ha)	For mung bean, Moth bean and cowpea	For mung bean, Moth bean and cowpea Basal N:P (10:20 kg/ha)	For mung bean, Moth bean and cowpea No fertilizer	For mung bean, Moth bean and cowpea No fertilizer
millet	For Pearl millet Basal (20 kg N/ha); top dressing (20 kg N /ha), depending upon rain	For Pearl millet No basal; top dressing (15-20 kg N / ha)	For Pearl millet No basal; top dressing (15-20 kg N / ha)	For Pearl No fertilizer
Insect pest and disease manag ement	• Mung bean, moth bean and cowpea should be treated with 2 g carbendazim per kg of seeds to check dry root rot, or treat the seed with Trichoderma culture @ 4 g per kg of seeds. • Clusterbean seeds should be soaked in 0.025% Streptocycline solution (1 g in 4 L water) for 2 hours to check bacterial blight. • To check termite attack, Endosulphan 4% dust should be mixed in soil @ 25 kg per hectare at the time of sowing of all crops.			

Days to maturity for different varieties of crops

Pearl millet		Mung bean		Moth bean	
HHB 67	65-67 days	RMG 62	60-75 days	RMO 40	60-65 days
ICMH 356	70-75 days	K 851	60-75 days	RMO 257	60-75 days
RHB 30	70-75 days				
Raj 171	85-90 days	Clusterbean		Cowpea	
MH 169	85-90 days	RGC 936	85-90 days	C 152	90-95 days
		RGC 1002	85-90 days	Charodi 1	60-65 days
				V 16	90-95 days
				RS 9	80-85 days

Issues of contingency planning for crops

- The State Government machineray may be mobilized immediately for arranging seeds of suggested varieties.
- Rhizobium culture should be made available and legume seeds be treated with its suitable strain. The sequence will always be in the order of fungicide, followed by Rhizobium.

Mid-season corrections for crops already sown

- Weed control and inter-culture (running the sweep between the rows).
- Dust mulching crust breaking.
- Reducton of plant population removal of alternate rows in case of drought (if the rows are originally spaced at 30 cm).
- Proper plant protection measures.

II. Strategy For Livestock Management

- Utilization of poor quality roughages, such as wheat and rice straw by enrichment with 2-4% urea.
- Urea molasses mineral blocks feeding for maintenance of livestock.
- De-worming and vaccination of livestock, and culling of unproductive and surplus animals.
- Establishment of fodder banks at Panchayat Samiti level for proper distribution in villages.
- To conserve energy of animals, grazing should be resorted to only during

morning and evening hours.

- Proper utilization of roughages with the addition of groundnut hull and masoor straw. Also, mix 25% of tumba cake in the concentrate mixture to reduce the cost and increase the availability of concentrate.

III. Long-term Strategies for Drought Mitigation

- Rain-water harvesting and its recycling through sprinkler/drip system for efficient production and management of farming systems.
- Development of Common Property Resources, including grazing lands, Orans, Nadis, etc., and their efficient management.
- Landuse planning on watershed/Index catchment/ Khadin basis, with inclusion of multipurpose tree species and animals in farming system mode. The systems could be agri-horticulture with ber, agro-forestry with *Prosopis cineraria*, *Tecomela undulata*, *Acacia Senegal*, silvi-pasture (grass with fodder shrubs *Ziziphus nummularia* and trees *Colophospermum mopane* and *Hardwickia binnata*).
- To evolve highly drought-resistant and efficiently productive crop varieties of legumes, oilseeds and fodder crops.
- To popularise cultivation of drought-hardy and highly remunerative traditional medicinal and high-value plants like Guggal, Asvagandha, Shatawari, Tumba, Sonamukhi, etc.
- Development of suitable infrastructure for marketing of value-added products and income generation for alleviation of poverty.
- Harnessing of solar and wind energies for utilization in agriculture.

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Crop Weather Scenario *Kharif* 2002

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The erratic behaviour of the 2002 southwest monsoon, leading to widespread drought conditions across many regions of the country, caused a severe setback to the agricultural production during the current *kharif* season. The present paper discusses the actual weather and crop scenario as it unfolded during *kharif* season up to 31st August, and the expected scenario thereafter, to enable taking contingency plans such as adoption of alternate short-duration and drought-resistant crops and varieties to minimize the crop losses during the *kharif* and also to plan for the *rabi* crops.

Erratic Behaviour of Monsoon, 2002

After a relatively good start, the 2002 southwest monsoon weakened and drought conditions prevailed in many parts of the country, while some of the northeastern states got affected by floods. The drought in 2002 was more widespread than the last worst drought of 1987, when only the northwestern states of Gujarat and Rajasthan were largely affected. The major drought affected states during 2002 were Uttar Pradesh, Punjab, Haryana, Rajasthan, Madhya Pradesh, Karnataka, Chhattisgarh, Andhra Pradesh, Himachal Pradesh, Orissa, Tamil Nadu, and Maharashtra. On the other hand, though the states like Assam, West Bengal and Bihar were affected by floods, the quantum of rainfall was also low in these high rainfall regions. Deficit conditions were also observed in Kerala and coastal Karnataka.

Onset and progress of monsoon

This year, the southwest monsoon arrived over Kerala on 29 May, 3 days in advance of its normal date of 1 June. Initially the advance of monsoon was normal and it covered the northeastern states, south peninsula and some of the adjoining areas in central India by 12 June. Subsequently, the monsoon became weak and remained sluggish for about a week. It, however, revived slightly with the formation of a well-marked low-pressure area on 20 June.The monsoon remained active until 4 July and covered some more areas in central

India. The first half of July experienced dry spell throughout the country due to break in monsoon conditions, with the formation of another low-pressure area in the Head Bay on 15 July. With its subsequent movement to the land the monsoon advanced into west Uttar Pradesh, Delhi, Haryana and some more parts of Rajasthan by 19 July. The monsoon trough shifted to the foothills on 22 July and remained there till the end of July, resulting in weak monsoon conditions. No improvement in the monsoon status was noticed and some parts of west Rajasthan and adjoining Punjab and Haryana remained uncovered by the monsoon till 15 August.

Synoptic features and associated rainfall activity

Till the end of August, 2002, eight low-pressure systems (LPS) were formed; a majority of them in northwest Bay of Bengal, which produced widespread heavy rains in many parts of central India. The history of these rain-bearing systems is summarized in Table 1. It can be seen from the table that during July there were only three LPS for a total period of 9 days. During the remaining days in this month, break in monsoon conditions prevailed twice, during 5^{th} to 15^{th} and during 22^{nd} to 30^{th}.

Table 1. Low pressure systems during 2002 monsoon (up to the end of August)

Date of formation	Date of weakening	Area of formation	Area of weakening
20 June	28 June	Northwest Bay	Southeast Rajasthan
03 July	05 July	Bihar and neighbourhood	Bihar and neighbourhood
15 July	19 July	Northwest Bay	East Madhya Pradesh
31 July	02 August	Northwest Bay	Chhattisgarh
08 August	14 August	Northwest Bay	Bihar and neighborhood
16 August	19 August	Head Bay	Chhattisgarh
22 August	26 August	Northwest Bay	Gujarat
29 August	02 September	Northwest Bay	Central Madhya Pradesh

These synoptic systems have led to large-scale variations in the distribution of monsoon rainfall in time as well as in space. The temporal distribution of monsoon rainfall largely depends on the time of formation of these LPS, while the place of formation and their movement largely determine the spatial distribution. The large spikes in the daily rainfall are associated with these LPS. Due to the break in monsoon conditions for nearly 22 days, the rainfall in July, which is normally the rainiest month in the country, is very much below its normal. Though three LPS have formed during July, these have not improved the rainfall situation in July. On an average rainfall in the country is more than normal in June and near normal in August, while in July it is well below the normal.

Monthly and seasonal rainfall variations

Comparison with past records (Table 2) indicates that July 2002 is the driest month during the last 132 years (1871-2002), which received only 134 mm as against the long-term average of 274 mm. The rainfall received during other three monsoon months (June, August and September) and the seasonal rainfall during the historical low rain fall years with deficient (<-19% of normal) rainfall in July are also given in Table 2. During the years of deficient rainfall in July, the other three monsoon months also received less than their normal rainfall (except for June in 5 years and for September in one year), leading to deficient seasonal (June to September) rainfall during all the eight years, with deviations varying between -24% to -15%. This suggests that in 2002 also, the rainfall likely be received in September would be less than the normal resulting in deficient seasonal rainfall. During the last severe drought of 1987, the country received about 75% (207 mm) of its normal rainfall in July, with a seasonal total of 697 mm (-18%), while during 2002 only 49% of normal rainfall was received in July, with a seasonal total of 566 mm up to 29 August. From these values the severity of the current drought intensity can be adjudged. The October rainfall during the years of deficient July rainfall is also presented in Table 2. In six out of the eight (75%) years, the October rainfall was lesser than its normal (78 mm), with deviations varying between -81% and - 7%. This suggests that during 2002 the country may receive less than normal rainfall in October too. The rains that occur during monsoon withdrawal in September and October are very crucial for *rabi* crops. Deficient rainfall during these two months can lead to a greater fall in *rabi* agricultural production during *rabi* season in the country.

Table 2. Monthly distribution of rainfall (mm) in the historical years with deficient (<-19%) rainfall in July during 1871-2002 (deviations (%) from normal are given in brackets)

Year	June	July	August	September	Jun-Sep	October
Normal	163	274	243	171	852	78
1918	181(11)	144(-48)	221(-09)	106 (-38)	651 (-24)	15 (-81)
1911	193 (18)	154 (-44)	211 (-13)	180 (05)	737 (-14)	73(-07)
1877	143 (-13)	157 (-43)	157 (-35)	148 (-13)	604 (-29)	108(38)
1972	123 (-25)	184 (-33)	217 (-11)	129 (-24)	653 (-23)	63 (-19)
1899	195 (20)	188 (-31)	144 (-41)	102 (-40)	629 (-26)	51(-35)
1987	116 (-29)	207 (-25)	237 (-02)	138 (-20)	697 (-18)	87(11)
1982	130 (-20)	216 (-21)	269 (10)	121 (-29)	735 (-14)	49(-38)
1941	164 (01)	218 (-20)	210 (-14)	136 (-20)	728 (-15)	68(-13)
2002	196 (20)	134 (-51)	236 (-03)	---	---	---

Spatial distribution of monsoon rainfall

As stated above, the spatial distribution of monsoon rainfall is largely governed by the location in which formation of the LPS and their subsequent movement takes place. During 2002, a majority of LPS formed were in the northwest Bay of Bengal and six out of the eight LPS weakened over the eastern states, without even reaching the central part of the country. Only the 1st and the 7th systems could reach the western part. This erratic behaviour of the LPS resulted in deficient rainfall in many areas across the country. The rainfall deficiency was particularly severe in Rajasthan and the adjoining areas of northwest India. Similarly, due to break in monsoon conditions in July, when the monsoon trough was shifted towards the foothills of the Himalayas, northeastern part of India received excess rainfall.

In June 2002, the rainfall was normal to excess in the central parts of India and also in some parts in southeast and northeast India as well as Jammu & Kashmir. The excess rainfall in central India was mainly due to the passage of a LPS, which moved up to southeast Rajasthan. In July, about 2/3rd part of the country received less than 50% of the normal rainfall. Some areas in northeast India received excess rainfall due to break in monsoon conditions. In August also, the rainfall was normal to excess in central India and in some areas in northeast India and Jammu & Kashmir, leaving the other areas of the country deficient rainfall.

The subdivisional distribution of the total rainfall from 1st June to 31st August, as prepared by the India Meteorological Department is summarized in Table 3. Only one subdivision in northeast India received excess rainfall, while 16 subdivisions, a majority of which are located in central and northeast India, received normal rainfall. The seasonal rainfall was deficient in 16 subdivisions mainly located in northwest India and south India. Three subdivisions, viz., West and East Rajasthan and Haryana, Chandigarh and Delhi, received only scanty rainfall during the current monsoon up to 28th August.

Table 3. Categorywise distribution of sub divisional rainfall (1 June to 28 August 2002)

Category	Number of Subdivisions	Subdivisions
Excess (+20% or more)	01	Sub-Himalayan West Bengal Jammu & Kashmir; Uttaranchal; Assam & Meghalaya; Nagaland, Manipur, Mizoram & Tripura; Bihar; Jharkhand;
Normal (+19% to 19%)	16	Gangetic West Bengal; East U.P.; Saurashtra & Kutch; Konkan & Goa; Madhya Maharashtra; Vidarbha; Marathwada; North Interior Karnataka; Telangana and Coastal Andhra Pradesh
Deficient (-20% to 59%)	16	Himachal Pradesh; Punjab; West U.P.; East U.P; Arunachal Pradesh; Gujarat; West M.P.; Chhattisgarh; Orissa; Coastal Karnataka; South Interior Karnataka; Rayalaseema; Kerala and Tamil Nadu
Scanty (-60% to 99%)	03	West Rajasthan; East Rajasthan and Haryana, Chandigarh & Delhi

Crop Conditions during Kharif 2002

Delayed and weak monsoon conditions that existed during July and early August either delayed or did not allow farmers to sow the crops even upto mid-August in the northwest part of the country (west U.P., Haryana, Punjab, Rajasthan and Delhi). Some of the crops sown with the normal onset of monsoon in the peninsular part were subjected to severe stress, and seedling mortality was very high. The statewise crop information as on 7th August 2002 is described below.

Himachal Pradesh: Transplanting of rainfed paddy was affected severely and majority of rainfed crops withered due to moisture stress in July. The situation improved with the receipt of rainfall towards the end of July and first week of August. Agricultural operations in progress were: transplanting of rice, top dressing of nitrogen in maize and harvesting of apple and pear in Kullu and upper hills. Heavy rains in the first fortnight of August destroyed crops in Chamba district. Widespread rains were experienced in the second week of August.

Punjab: Only northern districts received some rains during the last week and drought-like situation prevailed. Crops were taken under irrigated conditions. In rainfed kandi area, crops like maize and mung could not be sown for lack of rains. Rice could not be planted in some areas of southwestern districts. The agricultural operations in progress were: earthening of sugarcane, transplanting of basmati, sowing of pulses, etc.

Haryana: Due to delayed monsoon, rainfed *kharif* crops sown in May were completely damaged. Agricultural operations in progress were interculture in cotton crop and irrigation in standing crops.

Rajasthan: Due to delayed and inadequate rainfall, *kharif* crops were sown only on a fraction of normal-sown area. The crops included pulses (40%), cereals (48%), oilseeds (48%), sugarcane (42%), cotton (58%), guar (16%), and other crops (22%). The areas sown under different zones were: Jaipur (44%), Bharatpur (47%), Ganganagar (37%), Kota (46%), Udaipur (81%), Bhilwara (75%), Bikaner (3%), Jodhpur (6%) and Jaisalmer (1%). Where ever rains were received agricultural operations were in progress.

Gujarat: Prolonged dry spell during July caused drought like situation. About 40% of *kharif* crop was damaged due to moisture stress. About 60% of millet and 80% sesame crops were damaged. Due to rainfall after 10th August, most of the crops revived. Agricultural operations in progress were: inter-culturing and weeding operations, transplanting in paddy and field preparation for tobacco transplanting.

Maharashtra: Due to better seasonal rainfall conditions, about 93% of the normal crop area was brought under cultivation.

Uttar Pradesh: With the receipt of rainfall after 31st July, transplanting of rice under both assured irrigation and rainfed conditions was taken up. Due to delayed monsoon total crop area sown was about 50% of the normal.

Madhya Pradesh: Majority of the rainfed crops experienced moderate to severe moisture stress during July. Rains in August revived the early-sown soybean crop.

Chhattisgarh: The rainfall in the state as a whole was deficient by 48% and all the districts were classified either under deficit, highly deficit or scanty rainfall conditions upto the end of July, 2002. Available moisture was sufficient for normal rainfed crops, but was inadequate for rice crop. Beushening and transplantation was taken up on areas wherever irrigation facilities were available. Weeding was taken up in upland crops and plantation of *kharif* vegetables were in progress.

Jharkhand: Percentage coverage of crops across the 3 different zones ranged from 28.0 to 31.6 in rice, 59.4 to 77.1 in maize, 32.3 to 43.7 in pulses, 31.6 to 37.0 in oilseeds, and 10.1 to 71.4 in ragi. Dry spell during July has adversely affected the direct sown kharif crops. The crops regained their vigour after the receipt of rains from 2 August onwards. Transplanting of paddy in lowlands was in progress.

Orissa: Out of 30 districts in Orissa, moderate to severe water stress was experienced in 23 districts due to scanty rainfall. Sowing in upland was minimal, and large area remained uncultivated. Direct-seeded rice was limited to the lowland areas, while beushening was taken up in some places. About 52% of the normal rice-cropped area could be covered up to 31st July, 2002. It was 40% in respect of pulses and 30% for oilseeds. However, 98% of the area under fibre crop was covered by the end of July. The rice crop, wherever planted during the normal sown time, was in the vegetative stage and water was needed to save the crop.

Andhra Pradesh: Due to deficient rainfall conditions in 19 districts, transplantation of paddy was delayed. With the revival of monsoon in the first week of August, rice was transplanted on 22.07 lakh hectares out of 81.80 lakh hectares area under rice. The crop statistics, as provided by the State Government on 7th August, showed that only 20% of area under rice and 70% under coarse cereals could be covered. Similarly, about 75% of the normal pulse area could be covered, whereas it was only 37% in respect of total oilseeds. On the whole, about 42% of average cultivable area could be covered, thus leaving a majority of the cropped area uncultivated.

Assam: About 3.22 lakh hectares of cropped land was affected by flood up to the end of July. Due to heavy rainfall after 10th August, more areas were inundated in Tinsukia, Dibrugarh, Sibsagar, Jorhat and Lakhimpur districts, and about 3 lakh hectares of newly transplanted rice crop was damaged.

Bihar: In south Bihar, due to drought-like conditions, paddy seedlings were wilted in the nursery. In north Bihar, unprecedented early floods affected 17 districts and damaged standing crops. Agricultural operations in progress were: transplanting of rice and top dressing in rice/maize.

West Bengal: *Aus* paddy was damaged in the districts of Bankura, Purulia, Malda and Birbhum due to deficit rainfall conditions. Agricultural operations in progress were harvesting in jute, pest management in *Aus* paddy, preparation of seedbed in cauliflower.

Kerala: Though the monsoon was weak, moisture stress was not significant in central and northern Kerala for major crops. Following agricultural operations had commenced: basin preparation, application of organic manure in coconut and fertilizer application in arecanut. Paddy was in panicle initiation to milky stage and black pepper was in berry development stage.

Production Estimates

From the rainfall index values for the months of June and July, 2002, for the entire country and the SOI values for the corresponding period, food grain production estimates have been worked out using the model developed at AICRP on Agrometeorology. These are presented separately for *kharif* food grain production and the annual rice production

(Table 4). For comparison purposes, production estimates in some of the earlier drought years, viz., 1972, 1982 and 1987, have also been shown in the production table. About 8% reduction in total food grain production during the *kharif* season, 2002, and about 14% reduction in annual rice production have been estimated.

Table 4. Advance estimates of all-India kharif foodgrains and annual rice production

Rainfall Index			SOI	Production Index (June-August)	Production (M Tonnes)	
June	July	August			Expected (trend value)	Estimated (Dev. from expected)
All-India *kharif* foodgrain production						
198.2	45.6	319.8	-7.1	91.6	110.9	101.6 (-8%)
All-India annual rice production						
210.2	53.0	314.1	-7.1	84.2	95.2	81.9 (-14%)

Contingency Crop Planning in Different Agro-ecological Regions

The weak and delayed monsoon has necessitated planning for alternate crop strategies in case the rains fail upto mid-August. The alternate crop planning to meet the weather aberrations in different regions has been evolved by AICRPDA and is presented in Table 5. As for the choice of suitable varieties, it is left to the regional centers and extension agencies to decide, keeping in view their timely availability.

Table 5. Contingency crop planning up to middle of August in India

Agro-ecologicalregion	Region/State	Production system	Contingency crop plan up to mid- August
Sub-humid to humid sub-mountain region	Uttaranchal, west UP, north Haryana and parts of H.P.	Maize/Rice	Grow community rice nursery and transplant

Sub-mountane (semi-arid)	Punjab, J&K, HP, west UP Districts of Jammu and Kithus of J&K	Maize/Rice Maize	Fodder crops of maize, cowpea Mung, black gram, cowpea, sunflowers
Semi-arid	Haryana, Chandigarh, Delhi Eastern Rajasthan	Pearl millet, Rape seed and Mustard Pearl millet	1) Transplant pearl millet 2) Sow clusterbean, cowpea, mung bean Sow mung bean and cowpea.
Dry sub-humid Oxi/Incepti/Vertisols	Eastern UP (Varanasi, Mirzapur, Jaunpur, Ghazipur and Bali districts Eastern MP	Rice/ Pearl millet Rice/Soybean	Short duration rice, Pearl millet, black gram, mung, fodder crops of sorghum, pearl millet, maize. Early variety of rice pigeon pea,groundnut, mung, black gram and minor millets.
Semi-arid *Inceptisols*	Western UP Gujarat (Kaira, Gandhi nagar, Mehsna, Baroda, Ahmedabad) Marathwada	Pearl millet/ Rapeseed, Mustard Pearl millet Rabi Sorghum	Pearl millet, black gram, mung, pigeon pea, groundnut, castor Finger millet, sunflower, castor Setaria, pigeon pea,

			kidney bean, horse gram, castor
Hot dry semi-arid Entisols/Inceptisols/ Vertisols	Southwest Maharashtra	Rabi Sorghum	Setaria, sunflower, pigeon pea, horse gram, castor
	North Karnataka and south Maharashtra	Rabi Sorghum	Setaria and cotton
	East Rajasthan	Maize	Mung, black gram,cowpea
	West M.P.	Soybean/Sorghum	Sunflower
	Vidarabha	Cotton/Sorghum	Cowpea, sorghum
	Tamilnadu and Pondicherry	Cotton/Sorghum	Sorghum, pearl millet (conditions beyond 1st August)
Arid Vertisols	Saurashtra & Kutch district	Pearl millet/ Groundnut	Cotton, castor, sesame
	N.I. Karnataka Bellary region	Rabi Sorghum	Sorghum, sunflower, coriander
Dry sub-humid uplands Oxisols	Jharkhand	Rice	Transplant finger millet
	Orissa	Rice	Transplant finger millet
Semi arid Alfisols	Telangana	Sorghum	Finger millet
	S.I. Karnataka	Finger millet	Finger millet
	West UP (Jhansi)	Fodder Sorghum/ Pulses	Sorghum, pigeon pea, soybean, groundnut
	Bundelkhund uplands	Pearl millet, Sorghum, Maize	Sorghum, maize fodder, pearl millet
Arid Alfisols	Rayalseema	Groundnut	Pearl millet, setaria, sunflower, cowpea

Participants of brain storming session

Dr. A. S. Faroda Chairing contingency planning session