Planning for Drought

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Planning for Drought

Toward a Reduction of Societal Vulnerability

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FOREWORD

The single most difficult task for a representative democracy is to engage in long-range planning. If we are planning for something which, moreover, no one believes (or wants to believe) will happen and which might require us to work or restrain now to avoid a possible disaster later, the task is even more difficult.

Stated differently, if you tell me that an action today *will* harm me, I will probably avoid doing it. Tell me that a pattern of behavior together with certain external conditions *could* harm me, and I might try to beat the odds.

In short, governments of our type seem doomed to lead an existence that abhors long-range planning. The most striking example of this is the drought scenario. The day that I took office, I realized that the single most devastating event that could befall our beautiful state was a widespread drought.

Fortunately, I inherited and recruited a group of advisors that were combat veterans from the 1976-77 Great Plains drought. My friend and advisor, Jim Exon, also admonished me about the problems of dealing with the effects of a widespread and prolonged drought. We formed a small working group in the summer of 1984, and I agreed to make drought planning a high priority for the Kerrey administration. We received enthusiastic support and cooperation from the University of Nebraska and the natural resources related state agencies.

Also fortunately, an evaluation of the governmental response to the 1976-77 drought assessment and response effort had been completed at the University of Nebraska. We decided that Nebraska would be among the first states to develop a truly comprehensive state drought response plan. In a parallel effort the University of Nebraska's Center for Agricultural Meteorology and Climatology and the Illinois State Water Survey organized the International Symposium and Workshop on Drought.

As I reflect on my four years as governor and specifically my participation in the fall 1986 Symposium, I have learned many lessons.

Government can react to disasters in one of two ways. One approach is to wait until an event occurs and try to mitigate the consequences by whatever means available as quickly as possible. Alternatively, procedures may be developed before a disaster that will define mechanisms to respond to various kinds of events. The first of these approaches is crisis management and the second is risk management.

There are a number of barriers to effective risk management in general and to drought planning in particular. One obstacle is that the typical mode of operation is

crisis management. The amount of resources consumed as solutions are found for consecutive crises leaves few, if any, resources for risk planning efforts.

Another barrier to drought planning is the uncertainty of drought itself. Drought prediction is a tenuous process, if not totally impossible. In addition, each drought is unique in its magnitude and duration, and thus its impacts also differ. These uncertainties increase the difficulty of effective drought planning.

Perhaps the greatest barrier is spawned by a lack of interest in risk management. Such endeavors have no visual effect and do not receive much attention from the media and, consequently, the public. Government is less likely to plan for things like drought without public interest or demand. Elected representatives would rather deal with issues that are high profile and will serve as testimony to their constituents.

However, recognition of the advantage of risk planning (in terms of time and money) may be significant enough in times of tight budgets to give it a higher profile. Nebraska has made some movement in that direction. Interest has been strong enough that a drought plan has been developed and will be maintained as part of overall risk management in state government.

Drought management and planning is certainly an important policy issue today and in the future. I applaud the efforts of the coorganizers of this symposium and workshop for undertaking this task. Perhaps the information presented on drought prediction, monitoring, impact assessment, adaptation, and response, as well as the research priorities and recommendations for future actions included in this volume, will stimulate additional intellectual activity on this important policy issue and, ultimately, reduce society's vulnerability to drought.

Robert Kerrey

PREFACE

Scientist, politician, businessman, or concerned citizen—each of us has a particular perception of drought. Even within these groups, there are significant differences in perceptions of drought, based on our experiences, training, and environment. Meteorologists and sociologists, for example, view drought as quite different problems—the former striving to predict or explain the physical causes of drought or describe the magnitude of the precipitation deficiency while the latter is more interested in the effects of the deficiency on people and their institutions.

To those who study drought, regardless of our perspective, it is clear that drought is a normal feature of climate and its recurrence is inevitable. And, the widespread occurrence of severe drought during the past decade repeatedly underscores the vulnerability of both developed and developing societies to its ravages. Whether referring to the well-documented recent tragedies of Ethiopia or the economic impacts of the 1986 drought in the southeastern United States, the message seems clear—society has typically chosen to react (i.e., employ crisis management) to drought rather than prepare (i.e., employ risk management) for it. With few exceptions this approach has been, at best, ineffective.

The International Symposium and Workshop on Drought was organized to review and assess our current knowledge of drought and to determine what research and information is needed to improve national and international capacity to cope with drought. The symposium and workshop was intended to provide a forum for discussion of the physical and societal implications of drought within the context of a variety of spatial scales, from local (i.e., farm level) to supernational regions (i.e., the Sahel), and also within the context of economically developed as well as developing nations. Discussions initiated at the symposium were to culminate in the workshop. The purpose of the workshop was to draw attention to drought as a policy issue, one that can be managed more effectively through an interdisciplinary and cooperative effort from the scientific and policy communities. The ultimate goal of the workshop was to establish the rudiments for a "plan of action" to facilitate drought preparedness on a global scale. Attendance at the symposium was open to all who wished to participate, though the number of participants in the workshop was restricted to maintain a proper working environment.

A comprehensive symposium program was organized around six principal themes: (1) prediction; (2) detection, monitoring, and early warning; (3) impact assessment; (4) technological and sociopolitical adaptation; (5) the role of government in planning for and responding to drought; and (6) the role of international and donor organiza-

tions in planning for and responding to drought. The program was carefully organized and speakers were recruited on the basis of their expertise in one or more research areas or in some aspect of drought policy.

In the papers included in this volume, many interesting and, at times, conflicting viewpoints of drought are presented. F. Kenneth Hare, a scientist with vast experience and insight into the drought condition, introduces Part 1 with a discussion of drought and desiccation, providing personal reminiscences to illustrate his points. His overview gives the reader a fascinating perspective on drought and the need to recognize its many facets and to "know one's enemy." The second and final paper in Part 1 reviews the way scientists define drought in order to achieve a better understanding of its far-reaching impacts, and concludes with several recommendations on a conceptualization that incorporates both physical and social measures of drought that have local or regional significance.

In Part 2, Eugene Rasmusson provides an overview of the global prospects for drought prediction from a meteorological perspective, giving attention to what progress has been made, what techniques are providing the most skillful predictions, and where and when we can expect the most progress in future predictability. Specific assessments of the prospects of prediction for Northeast Brazil and Australia and Indonesia follow. Vit Klemeš concludes the section with an examination of the predictability of drought from a hydrological point of view.

Part 3 presents the technology currently available to detect, monitor, and provide early warning of the onset of drought conditions using both surface and satellite networks. The overview papers were prepared by Kenneth Hubbard (surface monitoring systems) and Compton Tucker and Sam Goward (satellite systems). Examples of the application of these technologies in Australia and the semiarid regions of Africa are presented. Part 3 concludes with a discussion by Norton Strommen and Ray Motha of the operational early warning agricultural weather system developed by the World Agricultural Outlook Board of the U.S. Department of Agriculture.

Part 4 presents examples of current research on drought impact assessment methodology and the details of specific programs recently established to provide early warning of the impact of drought on various geographic scales. The overview paper on impact assessment methodology was prepared by Martin Parry and Timothy Carter. The particular programs chosen were the drought early warning program of NOAA/NESDIS/AISC and the food shortage assessment and prediction program of the Ethiopian Relief and Rehabilitation Administration. John McIntire's paper illustrates the importance of incorporating the concept of impact assessment into an operational phase of an early warning system.

Part 5 discusses two issues of critical importance to the theme of the symposium. First, Michael Glantz examines the interrelationships between climate, particularly drought, and economic development in sub-Saharan Africa. Second, Norman Rosenberg considers the global implications of climate change, such as that brought on by carbon dioxide enrichment of the atmosphere, on the frequency and severity of drought.

In Part 6 consideration is given to the role that societal adaptation and adjustment can play in mitigating some of the worst effects of drought. In his overview, Steven Sonka argues for integrating models of the adjustment process, beginning at the

farm level and aggregating to regions. This is followed by case studies from South Australia, India, and the U.S. Great Plains.

The role of government in planning for and responding to drought is the subject of Part 7. Donald Wilhite explores drought as a policy issue that governments have traditionally responded to through crisis management. The case studies that follow describe the experiences of Botswana, India, Northeast Brazil, and South Africa and provide further evidence of the need for a proactive approach to drought management.

In Part 8, Harold Dregne draws from his years of experience in international agriculture to discuss the role of international organizations in coping with famine and the effects of drought on agricultural production systems. Clifford May of the New York Times discusses the role of the media in identifying and publicizing recent droughts, particularly in Ethiopia. Dawit Giorgis, former director of the Ethiopian Relief and Rehabilitation Administration, documents the actions of the Ethiopian government and other organizations during the recent drought.

In Part 9 Tom Potter summarizes the discussions of the symposium, reflecting on the objectives of the meeting, the lessons learned, and the challenges that lie ahead. He emphasizes the need to identify data and information needs, available techniques, and ways to implement and evaluate the usefulness of those techniques. These objectives were addressed in the workshop.

The final section of the volume presents the results of the workshop discussions on how best to foster drought planning efforts in both developed and developing nations. Following the identification of the constraints to drought planning and ways to overcome these constraints, each of five task groups responded to a set of specific questions on the use of available and emerging technology in strategy formulation, research priorities to further this goal, and recommendations for further actions by governments and international and donor organizations. Part 10 concludes with a ten-step planning process, distilled from workshop discussions, that national and provincial governments could follow to facilitate the establishment of drought plans on a global basis.

Progress toward improving the drought coping capacity of national and provincial governments and international and donor organizations through better planning was the principal goal of this symposium and workshop. The information, experiences, and recommendations presented in this volume represent the collective wisdom of an interdisciplinary and international roster of scientists and policy officials. Their insights and recommendations will provide the intellectual basis for a model that can assist all drought-prone nations in achieving a more effective drought management strategy.

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Few realize the time, energy, manpower, and financial resources required to organize and conduct an international symposium and workshop, as well as assemble and edit the proceedings. The results of such an effort are presented in the pages that follow.

Two years have elapsed since the idea for a symposium on drought preparedness first emerged at the Climate-Related Impacts Networkshop at the National Center for Atmospheric Research in Boulder, Colorado. The list of persons who have contributed to the successful completion of this project seems endless, certainly too long to mention here without fear of some omission. Their contribution is gratefully acknowledged. However, the efforts of several persons at the University of Nebraska-Lincoln must be highlighted. The editors would like to thank Sharon Kelly and Roberta Sandhorst, who provided secretarial assistance for the numerous organizational aspects of the symposium, and Nancy Brown for her patience and diligence in typing manuscripts and tables. Special thanks go to Keith Bartels for his desktop publishing expertise, patience, and persistence in preparing the manuscripts in final form.

The editors wish to express their appreciation to the contributors, who so willingly agreed to write papers for inclusion in this volume. Thanks also to the many workshop participants that shared their ideas and experiences with the hope of stimulating progress toward a "plan of action" for managing drought in a more effective manner, and to the reviewers, whose valuable suggestions added immensely to the final product.

We acknowledge the contribution of the sponsors and supporters of this symposium and workshop. The Institute of Agriculture and Natural Resources of the University of Nebraska–Lincoln and the Illinois State Water Survey of the Illinois Department of Energy and Natural Resources contributed our time and other resources for a successful meeting. The U.S. National Science Foundation, National Climate Program Office/NOAA, Cooperative State Research Service/USDA, U.S. Agency for International Development, University Corporation for Atmospheric Research, International Agricultural Programs Office of the University of Nebraska, United Nations Development Program, United Nations Environment Program, and World Meteorological Organization provided financial support and valuable advice.

We would like to thank Norman Rosenberg and Peter Lamb, who supported our involvement in this important professional endeavor and assisted us in the development of the symposium program and some organizational aspects of the meeting.

Lastly, the editors are indebted to Deborah Wood for her countless hours assisting us with the organizational aspects of the symposium and workshop and, more recently, for editing and proofreading the manuscripts. Her contribution to each of the manuscripts is clearly evident.

D.A.W. and W.E.E.

PART 1

Background

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CHAPTER 1
DROUGHT AND DESICCATION: TWIN HAZARDS OF A VARIABLE CLIMATE

F. Kenneth Hare

INTRODUCTION

My earliest recollections are of an intense drought, all of sixty-five years ago. Nineteen-twenty-one set records across much of England, and my childhood home on Salisbury Plain was in the thick of it. I remember still the midsummer dropping of the linden and copper beech leaves, the withering of the fruit, and drying up of all the wells but one, our deepest. Even the river became smelly, weed-choked and insect-laden; the trout went belly-up in July, and we lost our fishing tenants, who weren't prepared to pay for lifeless putrefaction. I remember nothing before that time, and virtually nothing for two or three years on. But that drought is still vivid; it made me a climatologist for life.

In the same country, 1920 and 1922 were unremarkable. Nineteen-twenty-one experienced a drought of the classical sort—one where the rain stops falling and then starts again when the drought is over, usually within the year, as it did again in England in 1976. I suspect that 1986 will turn out to be that way in Georgia and South Carolina, where drought has already run two to three years. I don't know what causes these short-term droughts, or even whether *cause* is a useful word when you are talking about a system like climate, which is boundlessly variable, wide open to space, and utterly dependent on the oceans. Certainly, we know of nothing external to climate itself as potential causes. Climate is inclined to be manic-depressive; its moods are pathological. Yet we are aware that it gets back to normal—and we bet on it, by our economic strategies.

Contrast my experience at that time, and your own personal recollections of drought, with what Africans will remember of the 1970s and 1980s. The Sahel went through a severe drought at the outset of the 1970s. The Sahelian drought, more even than the so-called food crisis of 1973-75, put climate on the front pages of the newspapers. Then it rained again in 1974 and 1975. The drought was over, the conventional wisdom decided (as did most governments and United Nations agencies). But it wasn't. It came back, intensified, and spread—until by 1985 it was an international disaster, at its worst in Ethiopia, but wrenchingly effective over most of the tragic continent. It wasn't a drought, but a desiccation—a prolonged, gradually intensifying nightmare from 1968 until 1984. In 1985 and 1986, rains have been more abundant in many areas. The desiccation may be over. But I want to stress the difference between the two ideas—drought and desiccation. The one resembles mononucleosis: you get it, but you get over it (after examinations are over!). The other is like a chronic wasting disease. You get it, but you don't get over it. It slowly worsens.

I'll try to justify this distinction with a few personal reminiscences. What I've learned, in the course of a long professional life, is that one must add a personal sense of what matters to the insights that theory can give. I admit to being an all-out supporter of the modelers. I believe that our major thrust, as research workers, has got to be toward the mechanics of drought and desiccation—what causes them, how they evolve, and what they evolve into. Atmospheric scientists like myself pin their faith on the satellite, the supercomputer and the stray genius that knows how to model the climatic system (though not if he or she wants to spend the entire budget for drought research!). But to use such resources effectively, one must know one's enemy—how drought strikes, what it does, and how to cope with it. That's what this international symposium is about.

THE NATURE OF DROUGHT

Our institutions, it seems to me, all function on the assumption that drought will not endure. And this is what, for most of us, experience says will happen. The time and space scales of drought limit the stress it can place upon us and the damage it can do.

Climatic drought is, among other things, the failure of expected precipitation, over a period long enough for it to hurt. Abundant rainfall in the Great Basin would be accounted a dry year in the Corn Belt. Our institutions, technology, farm calendars, and assumptions about energy demand all relate to an accepted expectation of precipitation—its amount, the form it takes, the time of year at which it comes. Built into this expectation are all kinds of allowances for variability—for the usual uncertainties of runoff, snow melt, soil moisture recharge, peak transpiration demands, and so on. We expect variation in all these things as well as in the normal impact of precipitation.

I treat climatic drought as being the incidence, for a damaging period of time, of things outside this broader kind of expectation. If you accept my usage, drought is a phenomenon of the moist climates; there are no droughts in the rainless Sahara or Atacama deserts. In fact, human settlements at the oases within the deserts see floods from excessive rainfall as the chief threat to their crops and irrigation systems. Drought is a meaningless term when rain is a rare event.

Long ago we built into this notion of expected precipitation the role of soil water storage, which modulates the actual delivery of water to plants, air, ground water, and ultimately runoff. The better indices of drought that we use—those of Palmer (1965) and Bhalme and Mooley (1983) in particular—use this idea, as do the various water budget schemes used by hydrologists. Atmospheric scientists are gradually learning how to incorporate this crucial element into their models of climate over land surfaces—and even to ask whether it cannot be scanned adequately from satellite altitudes.

Behind these small advances, however, we have remained very largely in the position that we can predict neither the beginning nor the end of specific droughts; and we can say little in advance about their intensity, geographical extent, and root causes. Droughts occur on what may be the least predictable time scale of atmospheric events. We have had to treat them, as the lay world does implicitly, as stochastic in nature. There are experts here who will show that some progress is being made; but we are a long way from prediction. Moreover, we now realize the limitations of periodicities in rainfall records. Recent research has shown, via spectral analysis of current and proxy climatic records, that there is no firm twenty-or twenty-two-year Hale-related rhythm in

Great Plains rainfall, though several periods in the range of fifteen to twenty-five years show statistical significance (Stockton and Meko, 1983). Neither farmers nor governments can make much use of such vague information. Most of all we need to know, if such quasi periodicity is there, what mechanisms underlie it. We are a long way from such understanding. The climatic forecaster will get no free lunch from the statisticians.

This same research has also confirmed what we knew from experience: that severe drought in North America is quite limited in duration—it does not usually affect successive growing seasons—and is also spatially restricted. Maps of Palmer's drought index have a mesoscale look about them. Areas of severe drought usually alternate with moist areas only a few hundred kilometers away. Adjacent states or provinces may be affected (as in the 1986 southeastern drought), but this is rarely true of a large part of the continent. Even in the 1930s, severe drought extended across much of the Great Plains only in a few years. The droughts of 1983, 1984, and 1985 in the Canadian prairies affected only parts of the spring wheat belt. The economic impact of spatially extensive drought is very much greater than the patchwork quilt pattern normally displayed by the rainfall maps would indicate.

Work by Nicholson (1982) has shown, in contrast, that African rainfall displays remarkable spatial coherence. At its peak, the great desiccation of the 1960s, 1970s, and 1980s affected almost the entire continent. In 1984 no less than twenty-three contiguous countries were listed by FAO as suffering from consequent food shortages.The African desiccation was devastating partly because it was so widespread: There can be no help from your neighbor if she or he, too, is hungry.

Why does rainfall sometimes fail? Amazingly there is no clear answer. We can surmise (and in selected cases demonstrate) that the causes may include lower-than-normal precipitable water (not true in Africa in 1972); more widespread tropospheric subsidence, and hence greater stability, suppressing convection; an absence of rain-generating disturbances; complex air-sea interactions, so lovingly treated by Jerry Namias; and perhaps even microphysical variations in atmospheric aerosol. But there is still too much surmising and too little concrete knowledge.

I vividly recall the drought of 1933-34 in southern England, when front after front crossed the country dry. Was this due to reduced vertical motion, or drier midtropospheric air? There was no simple way of answering, because research into quantities of rainfall was not—and still is not—conducted on the relevant time scale.

Here on the Great Plains the answers will have to come from better understanding of mesoscale rainfall systems—for example, the mesoscale convective complexes (MCCs) first named by R. A. Maddox (1980) only in 1980—and their relation both to synoptic-scale control and to the remarkable diurnal effects that give a nocturnal rainfall maximum to the eastern Plains. The journals are full of good papers on these developments. But we need to apply them to the mechanics of drought, itself a large mesoscale event in most cases.

The same is true in the United Kingdom, where equally distinguished work has been done on the mesosynoptic scale linkages, and where multilevel baroclinic modeling of rainfall has achieved some spectacular successes. In the United Kingdom, drought is unmistakably related to year-to-year variations in blocking, which is not so simply true in North America. But blocking is itself a difficult event to predict.

And so, I end this part of my talk with a pessimistic conclusion: that drought is still largely unpredictable, and its causes are obscure. This may well remain so. But at

least we know now what the questions are, and we are working hard to answer them. Those who are concerned to make human institutions drought-proof, or at least drought-aware, are not wasting their time. The climatologist is not on the point of making their work superfluous—or of going out of business.

WHAT OF DESICCATION?

From the standpoint of human strategy, drought is a well-understood hazard: our tactics—and strategies are compounded of tactics—are to outwait it. Nature adopts a similar approach. Natural ecosystems outlive prolonged drought with little or no change. Individual plants and animals die, but the populations to which they belong survive, and even flourish—since drought eliminates aggression from less hardy species. Xerophytic ecosystems are among the world's most patient and stable systems. Anyone who has visited a semidesert just after the rains return has seen the miracle reenact itself, as luxuriant life reassumes possession of the land.

Human society places more value on the individual than does nature, and we are disquieted when farmers are driven off their land, or when thousands of Africans are forced to migrate to escape starvation. So our ability to outwait a drought depends on who and where we are, and on how long it lasts. But always there is in our minds the conviction that the rains will, indeed, come back. Meanwhile we wait, economize, defer decisions, and watch our individual and collective bank accounts or grain stores with growing anxiety.

Vastly more demoralizing is a true desiccation—a prolonged period in which drought slowly and intermittently intensifies. Even natural ecosystems may be confounded by two or three decades of progressively decreasing rainfall. Fortunately such episodes are rare in North America, and almost unknown in western Europe. But they are a fact of life and death in Africa and Australia—and, I suspect, elsewhere.

The Sahelian drought itself exemplified the process of desiccation. Nicholson's work, supported by similar analyses by Winstanley (1974), Lamb (1982), and others, has shown that African rainfall has in recent years exhibited much spatial coherence—as I stressed earlier. But it also showed that the great drought of 1968-73 was part of a much more prolonged and profound disturbance of rainfall over much of Africa. In the Sahelian and Sudanian belts of northern and western Africa, the 1950s and early 1960s were remarkably wet, and in the early 1960s these favorable conditions spread to the plateaus and mountainsides of east Africa. It was a joyous time for the African colonies to gain their independence, as so many did at that time. It was a green, productive world that they inherited. It was easy for statesmen to assume that these lush conditions would continue—and political suicide for them to move more cautiously.

Unfortunately, the good times did not last, through no fault of the new nations. From the mid-1960s on, rainfall decreased haltingly but remorselessly over much of Africa. In Sudan and the Sahel—the semidesert scrubs and savannas of North Africa—the decline led to the great drought of 1968-73. Moderate rains returned in 1974 and 1975, but then the desiccation resumed, reaching its dreadful climax in 1984. I do not need to remind you that this further desiccation also affected East Africa, and for a time southern Africa, too. All of us still remember the faces of dying Ethiopian children, thanks to television cameras.

With the perspective of hindsight we can now see that this was indeed a desiccation—a progressive increase of drought intensity, mitigated by occasional years of relative abundance. I have not seen the consequences analyzed in quite these terms, but I imagine that the political and economic impact has been more serious than that of a severe drought alone. In particular, the periods of remission took everyone's eyes off the ball. At the United Nations Conference on Desertification in 1977, all sense of urgency had departed from the politicians present because there had been two better years (actually still subnormal) immediately before the Conference. The drought was over, in their minds. In fact, the second round, more severe than the first, had already begun.

Another desiccation of this kind was observed in central Australia between 1945 and 1972 (Hare, 1983). Locally it was perceived as a succession of dry years, which are scarcely news in the semidesert interior rangelands of the desert continent. Nevertheless, it was a true desiccation of part of the already dry interior, with a slow intensification spread over more than two decades. Alice Springs was in the midst of it. Australian pastoralists are an adaptable breed; but by 1972, when conditions were at their worst, many station holders had almost forgotten what the better years could mean to their flocks, herds, and horses (and the water in their wells).

Desiccations mean many things that short-term drought does not mean. One is the increasing strain on human institutions, and on people, none of whom is likely to perceive the situation with any accuracy. I am sure that some part of the deterioration of Africa's political life has arisen from the long desiccation, which was neither expected nor recognized by those who were trying to make new nations out of the colonies. It is one of the bitter ironies of history that nature should have turned so sour just as Africans were trying to take command of their own destinies.

And, of course, desiccation means a great drawdown of water resources. The great rivers of West Africa—Senegal, Niger, Chad—have progressively fallen, until the inland delta of the Niger and the flood-plain lands of the Senegal have become difficult or impossible to farm. The Nile at the Aswan High Dam fell to dangerously low levels. Lake Chad has all but disappeared (as it has done before in history). Ground water everywhere has been mined, as it always is under such conditions. In a drought the loses can be made good, but not so in a true desiccation. Woody vegetation, and organic content in soil, disappear and do not return for decades. Desiccation means a loss of capital stock, a writing-off of assets, perhaps also permanent impoverishment.

I have no idea why such prolonged episodes occur, though I have speculated in print about the effect of various feedbacks—albedo, soil water shortage, and perhaps others (Hare, 1983). We all wonder about the relation between rainfall in semiarid Africa, Australia, and monsoon Asia; the ENSO phenomenon; and other quasi-periodic processes. Much of the effort being put into the World Meteorological Organization's World Climate Research Program, and into ventures such as Tropical Oceans and Global Atmosphere (TOGA) and WOCE, aims at the prediction of such long-term changes. We are not yet sure that they *are* predictable, at least with present monitoring and computing facilities and present levels of theoretical understanding.

So far, during my lifetime, such desiccation has always ended with rain—for example, in Australia in 1973-74, in such abundance that Lake Eyre, nearly dry for a decade, rose to a 10,000-year maximum level within a year. So far this has not happened in Africa, where 1985 and 1986 rains have, as far as I know, been adequate rather

than abundant—though experience will vary from country to country. But perhaps the African desiccation really has ended. I do not know.

WHAT OF THE FUTURE?

The whole point of my talk is the bearing these events have on the future. We are now largely convinced (not quite all of us) that a lasting climatic change is in progress, because of a greenhouse warming of the troposphere and surface. Some remain skeptical. Others prefer to wait for empirical evidence that a true warming signal is stepping out of the noise. The noise level is very high, so that signal detection is difficult. Nevertheless, the conviction is growing that a greenhouse warming is in progress and will be unmistakable within a decade or two.

Going with the model predictions of rising temperatures are less confident foreshadowings (not all models agree) of decreased moisture availability in midlatitude continental areas—most notably in the Great Plains, prairies, and Midwest (the great American granary, as Dean Abrahamson calls it). We have several drought years in the southern Canadian prairies, and I am often asked: "Is this the beginning of a greenhouse desiccation?" I can't answer the question confidently. What the Manabe-Stouffer-Wetherald modeling at the Geophysical Fluid Dynamics Laboratory at Princeton University has predicted is in any case an increase in evaporation, rather than a decrease in rainfall (Manabe and Stouffer, 1980). And people are not conscious of evaporation as a critical control. Actually the events of the past decade throughout the Plains have been unremarkable, in a statistical sense. I doubt whether the greenhouse effect has yet stepped out onto center stage.

I want to close by suggesting that this desiccation, if it happens, will show itself to the public as an intermittent and erratic increase in the duration, frequency, and extent of drought. We are all familiar with how it will feel. Many recent summers have simulated the ordinary conditions of a doubled greenhouse effect. In Canada the entire ENSO-plagued year of 1982-83 gave us a dry run for such conditions. The winter was 2–6° C above normal across the entire country (as was true also of much of the United States). The Great Lakes barely froze, and could have been navigated. Snow cover was drastically reduced in the south, but increased elsewhere. The subsequent summer was also hot (1–3° C above normal), and there was severe drought and searing late summer heat over much of the Canadian prairies and the spring wheat belt of the United States. Had we known that this was coming we could have drastically altered our economic strategy—planting winter wheat instead of spring, navigating the Great Lakes more freely, and altering our handling of water at the dams. But, of course, we did *not* know, so that considerable stresses arose, and opportunities were lost.

The trends in temperature and (possibly) available soil moisture associated with the greenhouse effect will be very slow indeed by comparison with the interannual differences that we already take in our stride—and which completely dominate public perception of climatic influences. If we are to meet these changes in a reasonable way, we shall have to deal with the same effect that showed itself in Africa in 1974 and 1975—when temporary increases of rainfall lulled the politicians into comfortable slumber. I have little hope that North American politicians will be more alert. But I am confident that people like those in this room can at least persuade engineers, farmers, and business

people who make long-term investments that the present climate may *not* be the right assumption for decisions with long-term effects. A whole new generation of interpreters has grown up—social scientists who know the myths of the climatologist, and can translate them into meaning for the hard-hatted, hard-faced men who tend to run the world's business. Many of the best of these interpreters are here in this auditorium.

I appreciate being invited to open this conference, which is being held in the heart of the American granary. My own origins were in a wheat-growing area. My earliest recollections were of drought. It has fascinated me ever since. I look forward to a week of excellent discussion.

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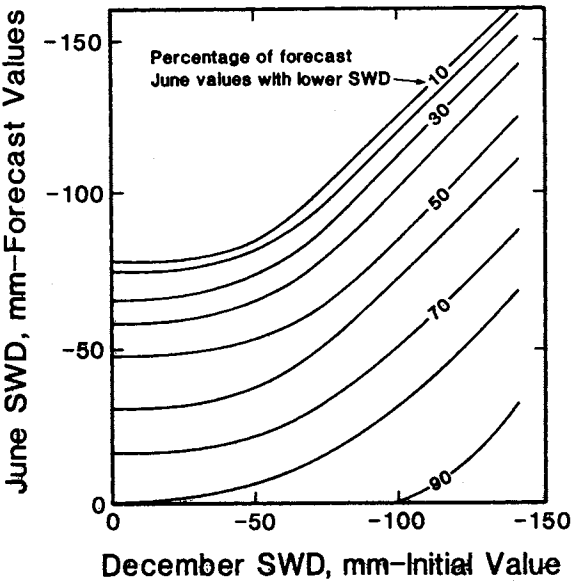

Fig. 6 Probability of soil water deficit (SWD) being lower than shown values in six months' time, given current SWD in the Namoi River basin.

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drought—tend to be shorter than periods of low ground-water levels, which may be indicative of "hydrological" droughts in terms of water supply shortages (drying up of wells, disappearance of springs, and so forth). Note, for example, that a longer drought is revealed in the solid lower line in 1976-77 than in the solid upper line, where the drought is obscured because of its partial compensation by abundant soil moisture.

To summarize, hydrology has a great potential for tracing the effects of meteorological droughts through the various hydrological subsystems and hence for real-time forecasting and statistical prediction of droughts or water shortages that affect users dependent on different sources of water supply.

CONCLUSIONS

It is beyond the scope of hydrology to offer an exhaustive analysis and complete understanding of the phenomenon of drought. Drought has many causes; hydrological causes are last among these. However, hydrology provides important insights, both into the effectiveness of methodologies used to analyze geophysical records for periodic or cyclic patterns to use in long-term drought forecasting and into the physical processes responsible for the modifications and transformations of the basic "drought signal" supplied by the precipitation record. These latter processes are of paramount importance to the short-; and medium-range forecasting of droughts that affect users dependent on different sources of water supply. In both cases, the value of the contribution of hydrology is directly proportional to the depth of insight into and understanding of the physical mechanisms controlling the various types of hydrological processes; it does not depend much on skill in fitting hydrological records with formal mathematical models aimed merely at preservation of various parameters and patterns of historic records. Unfortunately, present-day hydrology is dominated by the latter tendencies and, although the realization of their sterility is slowly increasing, much effort is needed to change hydrology's course to a direction in which its great potential can bear fruit.

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tional structures such as the Agricultural Climate Situation Committee and the Drought Assessment and Response System of Nebraska are necessary to ensure the exchange of information (and benefits of such an exchange) obtained from the system.

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fall connection (see, for example, the paper by Nicholls in this volume) were to be made, it would be a straightforward matter to run the statistical assessment on data that have been stratified to include only those years believed to be more appropriate. A confident forecast of below-average seasonal rain based on an expected major swing in the Southern Oscillation, for example, would suggest *a priori* that the statistical forward assessments ought to be calculated only on those data below the mean (or median), or, better still, if sufficient data were available, only on those years when similar swings were observed.

CONCLUSIONS

The Australian Drought Watch System, despite its implicitly simple approach and its reliance on rainfall alone as an indicator of drought, has proved to be an effective tool for alerting the nation to incipient drought conditions and monitoring the course of extant drought. Further, the principles involved have provided several spinoffs, which have enabled past droughts to be objectively cataloged and probabilities of future droughts to be estimated. Like most statistical forecasts based solely on past data, its success lies in the principle that there will be no imminent significant change in the frequency distribution of the data being processed. There will be much to concern us if, as feared by some, this assumption will be proved wrong in the decades to come.

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The data presented in Figs. 1 and 2 are intended to represent an initial indication of the promise of drought monitoring using satellite imagery.

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UTILIZATION OF WEATHER ASSESSMENTS

The agricultural weather analysis provides the U.S. agricultural sector with accurate data on potential markets and on supplies of potential competitors. Daily and weekly briefings provide an opportunity for the JAWF staff to interact with USDA commodity analysts and alert them to recent and seasonal agricultural weather conditions. The commodity analysts also provide JAWF with information on crop status and crop condition, based on tours and communications with agricultural counselors assigned to U.S. embassies around the world. Weekly briefings are also given to the secretary of agriculture and his staff to provide them with an overview of global weather conditions that may affect agriculture. A monthly interagency Africa briefing is conducted to provide analysts at USDA and other interested agencies with a detailed account of current weather conditions on the famine-plagued continent.

A significant increase in the demand by commodity analysts and policy-level decision makers for near real-time weather data and assessment information of the type developed by JAWF has occurred recently. In addition to daily briefings of current global agricultural weather, alerts of anomalous conditions affecting agriculture are included in daily highlights summarizing agricultural developments for USDA officials.

SUMMARY

The ultimate goal of JAWF is to provide accurate, concise, and timely information on agricultural weather as it affects global crop production. Agriculture, one of the nation's largest industries, is still an important positive contributor toward reducing the size of the U.S. trade deficit. U.S. farmers have become increasingly dependent on highly variable world markets. Agricultural weather is one factor that affects these markets. Proper use of the global agricultural weather data base, guided by results from experimental field research, may help American agriculturalists maintain the status of a highly efficient, flexible production system capable of meeting national and international food needs.

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As Whitehead noted (quoted by Hare in Kates, et al., 1985), "It is how the past perishes that the future becomes."

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climatic variability must be included in assessment and planning efforts in order to identify the linkages that are most amenable to policy intervention.

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agricultural impact assessment for developing countries. However, new assessment tools must not only be continually developed and verified, but capability must also exist to rapidly transmit early warning information to the user.

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CONCLUSIONS

The Early Warning System continues to be vital to the Relief and Rehabilitation Commission as a planning tool for guiding internal aid allocations and requests for international aid. Every effort is being made to strengthen and improve the capacity of the system in the following four general areas so as to increase both the types of information provided and the number of user agencies, and to strengthen the system's links with the response and intervention system:

1. The direct technical improvement of the Early Warning System and its component parts and the strengthening of the system's ability to undertake research and mapping exercises when necessary.
2. Increased cooperation between and within government agencies participating in the system, and between the system and international organizations and nongovernment organizations.
3. The improvement of the collection and dissemination of early warning and other general information.
4. The improvement of specific intervention mechanisms in response to early warning and other general information.

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NOTES

1. The semiarid tropics (SAT) are those regions of the tropics receiving between 400 mm and 1100 mm of rain per year in a single season. In Africa, they include the Sahel, the northern band of the West African coastal countries, and much of the lowlands of Eastern Africa.

2. This ignores the possibility that the cumulative deficit over several years may have been quite large, even if the production deficit in the crisis year may have been small. In addition, Sen's analysis is based on district data; farm surveys show that the within-district variation is large in Ethiopia and the Sahel. These facts do not invalidate Sen's thesis, but they increase the information burden of relief authorities.

3. None of the above should be taken to mean that urban classes in Africa were not affected by the price increases. They did suffer income losses and malnutrition must have increased, but there was much less starvation. It should also not be taken to mean that there is no long-term malnutrition in Africa; extensive research shows that there is.

4. The second part of the sentence is weaker than the first, because there are highly vulnerable populations in which catastrophes can occur rapidly. Ravaillon (1986) showed significant rice market failures in Bangladesh for short periods from 1972 through 1975. In spite of the brevity of these periods, severe famine occurred in 1974; the famine was partly related to the market's failure to move rice from surplus to deficit areas.

5. Ormieres reports declarations by Chadian officials that relief would be withheld from regions supporting an insurrection.

6. The academic literature also insists on the possible displacement of private storage by public storage. This concern is valid in developed countries, with well-functioning grain markets and active speculation, but it is not a problem in developing countries. Others have suggested that a further demerit is the absence of an insurer; that is, who would be willing to bear these risks?

7. Admittedly, such reserves would have to be filled at the outset with concessional imports, and the demerits noted above would still apply.

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haustive. Clearly, many publications now exist that discuss how drought has affected a local community, the environment, water resources, livestock, a sector of an economy, international trade, foreign assistance, and so forth. These publications constitute a large body of case-specific information, not only for sub-Saharan Africa but for other developing and developed countries as well. Yet, the literature related to economic development has focused little attention on drought (a recurring, aperiodic phenomenon) as a constraint to economic development.

To gain a proper understanding of why societies that are partially or wholly in the arid and semiarid tropics and subtropics have had great difficulty in developing their economies, one must consider, along with other relevant factors, the implications of recurrent prolonged meteorological, agricultural, and hydrologic drought. Paraphrasing the adage that war is too important to be left to the generals, I would assert that drought considerations are too important to be left only to the meteorologists.

This paper does not claim that all constraints on development in African societies are the result of droughts (or, more broadly, climate variability). It does claim, however, that drought must be integrated into the already lengthy list of natural and societal influences that can adversely affect the economic development in sub-Saharan Africa.

NOTES

1. Drought is not a problem for developing countries alone. Coping with recurrent drought episodes has also been a formidable task for leaders of industrialized countries, as was the case, for example, in the 1930s and 1950s in the U.S. Great Plains and in the mid-1950s in Soviet Central Asia (Brezhnev, 1978). There is considerable speculation among scientists today about whether and how society in the United States could cope with a return of a 1930s-like U.S. drought in, say, the 1990s (e.g., Bernard, 1980; Warrick, 1984; Bowden, et al., 1981).

2. In fact, the belief that the climate of the tropics is a primary factor in underdevelopment and the climate of the temperate regions is a factor in industrialization persists today, not only among "northerners" but among some "southerners" as well. For example, Bandyopadhyaya (1983) wrote:

> In India and other tropical countries I have noted farmers, industrial labourers, and in fact all kinds of manual and office workers working in slow rhythm with long and frequent rest pauses. But in the temperate zone I have noticed the same classes of people working in quick rhythm with great vigour and energy, and with very few rest pauses. I have known from personal experience and the experience of other tropical peoples in the temperate zone that this spectacular difference in working energy and efficiency could not be due entirely or even mainly to different levels of nutrition. I had no doubt at all in my mind that the principal interpretation lay in the differences in temperature and humidity between the two climatic zones (p. vi).

3. Streeten (1976) referred to these boundary conditions as initial conditions. By initial conditions he meant those conditions that the migrants (in the North American

case, the immigrants) discovered upon arrival; for the developing countries he apparently referred to the existing conditions with which they had to cope at the time of independence. He noted the reluctance of writers "to admit the vast differences in initial conditions with which today's poor countries are faced compared with the pre-industrial phase of the more advanced countries"(p. 9).

4. Although Kamarck (1976) referred only in passing to the adverse impacts of the Sahelian drought of the early 1970s, he was one of the first to draw attention to drought as having an adverse effect on the development process. In reference to drought in Northeast Brazil, he noted, "Although these droughts [in Brazil] are a major obstacle—perhaps the biggest one to economic development—development approaches heretofore have tended to invest mainly in fixed capital of various kinds rather than in necessary research to find out how best to handle the droughts" (p. 20).

5. Torry's (1984) reference to a distinction between underlying (ultimate) and catalytic (proximate) causes of famine are of direct relevance to discussions of drought and its societal impacts. Torry noted:

> Proximate causes are situational and originate shortly prior to or during an emergency. Ultimate causes can be construed as predisposing conditions transforming proximate causes into famine distresses....In fact proximate causes (e.g., drought) can land a household in the clutches of famine with or without the involvement of ultimate causes (p. 8).

However, while a specific drought may be considered a proximate cause of famine, droughts as recurrent phenomena can be considered an underlying cause.

6. In the past, most African countries have put a relatively low value on their meteorological services. Such services were considered of value mostly for aviation, not only during colonial times but during post-colonial periods as well. Recently, there has been a growing interest in, and support for, many of the national and regional (e.g., AGRHYMET in Niamey, Niger) meteorological services in sub-Saharan Africa. Some of these services have become more active in assisting decision makers by identifying how meteorological information might improve the value of their decisions. Meteorological services are increasingly being called on to provide input for decision-making processes regarding agricultural development and for early famine warning systems.

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probability of change and the *possibility* that it could be quite serious in certain regions of the world.

Our knowledge of the direct response of plants to carbon dioxide enrichment of the atmosphere is more secure. Photosynthesis rate will increase in all the higher plants, but most in the C_3 species; transpiration will be reduced in all higher plants, but most in the C_4 species. Because of stomatal closure induced by CO_2, the C_4 species, important in the subhumid and semiarid zones, might be able to avoid or minimize the impact of increased aridity. Plants grown in CO_2-enriched air also reduce the impact of water stress on photosynthetic rate and yield by maintaining a better internal water balance (greater turgor). Deeper rooting habit, increased soil organic matter content with its consequent increase in soil water holding capacity, and other responses stimulated by CO_2 enrichment of the air may also tend to alleviate the moisture stress that would follow from the reduced precipitation and increased evaporation rate in regions so affected by climatic change.

Assessing that which is known and that which is yet unknown about the mechanisms of climatic change, the regional specificity of the changes to expect from the "greenhouse effect," and the direct effects of carbon dioxide enrichment on plant growth and water use leaves us uncertain as to whether the drought-prone areas of the world will be better off or worse. But we are now aware that climatic change is highly probable and that the changes may be profound in many places. The drought-prone regions may have less resilience and their resources may already be severely strained; hence, they are among the regions that require attention most urgently.

In my view, it is essential that governments and international agencies give considerable support to study of the potential impacts of a wide range of possible climatic changes on the natural resource base and on the societal and economic implications of such changes. Decisions will, of necessity, be required and it is our task, as scientists and administrators, to reduce the degree of uncertainty facing decision makers as much and as quickly as possible.

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NOTES

1. B. G. Mendoca, Geophysical Monitoring for Climate Change Division, NOAA. Unpublished data on atmospheric transmission of solar radiation at Mauna Loa Observatory, 1958-85.

2. The albedo of green vegetation fully covering the ground is in the range of 18-24%. Bare light-colored sandy soil may have an albedo of 40-50%.

3. In a recent (Aug. 20, 1986) telephone conversation with R. T. Wetherald, I learned that the control case ($1xCO_2$) predicts that mean seasonal (J, J, A) soil moisture content is equal to 6 cm in the total root zone 1 m deep. The Manabe-Wetherald model does not consider the geographic distribution of real soil types and moisture-holding capacities.

4. The measurements at Cozad were made by means of the Bowen Ratio-Energy Balance method.

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Implementing the concepts advanced will require considerable effort and ingenuity in specific situations. The payoff from successful efforts, however, can be substantial. Included as potential advantages are the following factors:

1. Improved societal responses to drought depend on actions of decision makers; therefore, the viewpoint of decision making is a natural perspective to generate useful investigations.
2. The decision-making perspective allows evaluation of mechanisms to reduce societal drought vulnerability over the entire range of possible weather events.
3. The uncertainty associated with climate variability can be identified explicitly.
4. The interaction of climate and nonclimate factors (such as economics, individual behavior, and physical constraints) in affecting drought-related decision making can be assessed.
5. The interdisciplinary, problem-oriented nature of drought can be effectively accommodated using quantitative models in a decision analytic framework.

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trict to the farmer who develops an efficient practical method for reducing the effects of drought should be considered.

8. Support programs should be developed to assist farmers in replanting trees and improving the aesthetics of the environment.

Overall, the policies, guidelines, and arguments for and against drought relief funding have changed little over the last twenty years. In general, the policies are based on a crisis management response. But drought must be seen as a normal part of the climate. Continuing programs need to be developed in all years to encourage the farmer to adopt practices that enable him to build resources to withstand the effects of drought and other weather hazards, such as floods and winds. Financial assistance will probably be available to farmers in future droughts, and it should be allocated, at commercial rates of interest, to farmers who are likely to remain viable.

Droughts generally have affected the farming community in the past, but there is increasing evidence that water supplies to cities and industries will be affected in future droughts, and this in turn could influence the amount of funds available for farmers.

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NOTES

1. More details, and results from other lines of questioning, can be found in Taylor, Downton, and Stewart (in press).

2. Monthly PDSI values were aggregated for comparison with farmers' recollections of "drought years." PDSI values of -1.0 or below (Palmer's "drought threshhold") were added to give a rough index that includes both drought severity and duration. Separate PDSI plots of values for each of the five study areas revealed very similar patterns. Therefore, the values were added across the five regions, and the results are plotted in Fig. 1.

3. The Pearson product-moment correlation coefficient was -0.65 for the period 1960-84.

4. The regression coefficient for June was smaller than the coefficient for July and of opposite sign, so its effect was to *remove* some of the cumulative moisture information contained in the July Palmer Index value.

5. This difference between groups was statistically significant at a 99% confidence level, using a chi-squared test.

6. Based on a stepwise discriminant analysis.

7. This difference in drought expectation is statistically significant at a 95% confidence level based on nonparametric analysis of variance using the Kruskal-Wallis test.

8. The north-south difference is statistically significant at a 99% confidence level using a Wilcoxon test.

9. Based on a nonparametric analysis of variance using the Kruskal-Wallis test.

10. The comparison with age used the chi-squared test; the comparison with experience used the Wilcoxon test.

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recent studies have addressed the issue of drought policy, or lack of it, in the United States and have concluded that we should now move toward drought planning with the aim of improving its efficiency. The development of a national drought plan is proposed as an effective way of implementing these recommendations in the United States. In Australia, two national drought committees have considered the benefits of a national drought policy that would be the basis for a plan. A national drought policy, although only recently formulated, has now been adopted. Similar progress has been made in South Africa. Actions of this type have been called for in all drought-prone nations by the World Meteorological Organization (1986).

In the United States a national drought plan could encourage and perhaps provide incentive to states to take a more active role in planning for drought. In fact, drought planning should be coordinated between the states and federal government. In the past, most states have played a passive role, relying almost exclusively on the federal government to come to the assistance of residents of the drought-affected area. Although the federal government has accepted this role, improving government response to drought requires a cooperative effort. States must develop their own organizational plan for collecting, analyzing, and disseminating information on drought conditions. Cost-sharing of drought assistance measures should be pursued as a means of involving state government in drought assistance. The level of state involvement in drought planning in other countries must be determined on a case-by-case basis.

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government also has developed a long-term national food strategy as a framework for the development of arable agriculture.

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1. The security of the food system at the national level does not mean food security at an individual level. Despite a buffer stock of 30 million tons of food grains, some people do not have adequate food supplies. The need is, therefore, to ensure food security to all the people under all conditions.
2. Development of water harvesting and watershed management would help ensure the prosperity of individual farmers. This requires community action, which is difficult in a democratic society.
3. Past experience shows that only in 1978 and 1918 has drought-year production dropped below 10% of the peak production. Therefore, maintaining a buffer stock of 12.5-15% of the peak production should be adequate. It would also help if crop production could be diversified, oilseed imports reduced, and the deficiency of pulses eliminated.

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ment. In terms of organizational structure, the plan is administered by a single agency, SUDENE, and an interagency committee.

In addition to the achievements made in drought planning, the government needs to define more accurately the objectives of the policy to assure greater equity and more incentives to adopt adequate practices to overcome the old "drought industry" that unfortunately is still active in the Northeast. One of the principle obstacles is the regional agrarian structure, which is responsible for the fact that in the new Projeto Nordeste, born in the surges of the last drought and destined to incorporate the old special programs, the landowners have been given fundamental consideration.

If the New Republic is able to fulfill its promises of agrarian reform—an accomplishment that will basically depend on the political support the group can gather—the government should ensure not only access to the land but also the sensible integration of the various approaches to strengthen the small landless producers and the small landowners. Water supply studies, technological support, and services should be directed to meet the needs of this vulnerable section of the population.

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2. Examining environmental deterioration, both permanent and temporary (e.g., the replacement of palatable plant species by less useful ones; range rehabilitation rates).
3. Inventorying, computerizing, and updating future potential drought aid to farmers, farm by farm, according to assessments of each farmer's water and soil conservation and grazing management practices. This information would be conveyed to the farmer before the next drought for future drought-aid funding or tax incentive.
4. Reassessing the effectiveness of drought indices (including improving drought severity models in terms of crop yield estimations under moisture stress) and the effectiveness of soil, water, and grazing conservation management on soil water status.
5. Prompting funding agencies to fund research before the onset of droughts, because sound drought research is measured in hundreds of thousands of dollars, but drought aid is measured in billions of dollars.
6. Concentrating even more research and interaction into the complex socio-politico-environmental Third World, with its unique problems in respect to drought.

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However, ground-water depletion has already led to the beginning of the end of that kind of drought proofing. And the same future awaits the pump-irrigated oases in the Libyan interior. Where surface water is the irrigation source, droughts still have an adverse impact. Drought in Ethiopia reduced crop production in the Sudan Gezira in 1984 because there are no major water storage dams on the Blue Nile. Lake Nasser shelters Egypt from the capricious variations in low and high flows in the Nile, but there is no similar protection for irrigators along the Niger River or many other rivers in the dry regions.

Expansion of irrigation in India and humid southeast Asia has wrought miracles in two short decades. Better rice cultivars and a package of practices that include irrigation have been responsible for greatly increased cereal yields. Asia has a long history of successful irrigation and was able to capitalize on the yield-increasing capabilities of improved cultivars of rice, wheat, corn, and sorghum. Sub-Saharan Africa has no such history of water management, and the dry regions have few perennial rivers and meager ground-water supplies. Irrigation in the dry regions has only a limited potential, and most of that is in small-scale pumping by individual farmers (Moris, et al., 1984). Reliance for crop production in the foreseeable future will have to be placed on dryland agriculture.

CONCLUSIONS

Coping with agricultural drought demands advance planning and the accumulation of excess food supplies in favorable years. For excesses to be available, cultivators must be able to respond to the opportunities presented by those favorable years: the drier and more drought-prone the area, the greater the need to capitalize on the good years. Research on soil-plant-climate relations and the application of that research to cultivators' fields is essential. Lack of proven acceptable practices in developing country dryland agriculture is a major handicap to achieving food security and preventing famines. Even more important, however, may be a poorly developed education system and inadequate transportation facilities, to say nothing of inappropriate government policies.

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