Kates, R. W., 1972. "The Hazard of Drought", Patterns and Perspectives in Environmental Science, Washington: National Science Foundation, pp. 218-221.

cole crops and other green and yellow vegetables, from fruits and nuts, cattle, buffalo, sheep, goats, pigs; chickens, turkeys, ducks, and geese.

Research is heavily concentrated on crops of commercial importance. Research on such crops and their commercial production does not help the subsistence farmer who must trade his small surplus for the necessities of life — salt, needles, cloth — that he is unable to produce. We need social science to guide us to the assimilation of the subsistence farmer into commercial agriculture or to urban industry. Until recently, applied research in most developing countries was poorly financed and completely lacking in relevance to the problems of local farmers. Even where research was directed at producing practical results, it was generally concentrated on cash crops for export rather than on basic food staples.

It is not enough to produce high yields of nutritious grain. In India, prices for fine-grain rice from old, low-yielding native varieties are virtually unrestricted while prices of the coarser high-yielding varieties are controlled. Total production is reduced by diversion of acres from high-yielding to low-yielding varieties. The affluent pay for what they want; the poorer consumers become dependent on rationed supplies of low-quality grain.

The Institutions — Industrialized nations of the world have — in institutions widely varying in structure — produced, taught, and applied the scientific information that is the basis of agricultural technology. In the United States, federal-state cooperation among the U.S. Department of Agriculture (USDA) and state agricultural experiment stations in each of the states provides a useful means of coordinating research, teaching, and service. Agricultural research has had the objective of producing results useful in improving the productive capacity of the land, the efficiency of crop, livestock, and forest production, the use of agricultural products, and the welfare of rural people.

This system, while close-knit, is not closed. Inputs from all the science of the world and important contributions to it are commonplace. Shull at Princeton, East at Harvard, and Jones at the Connecticut Agricultural Experiment Station at New Haven all contributed to the scientific basis on which hybrid corn was developed. But so, too, did a hundred others in USDA and the state agricultural experiment stations who painstakingly identified and modified the genetic stocks and the ways in which they could be used effectively in producing commercial seed for every latitude in which corn is grown.

Developing nations must have their own institutions for agricultural teaching, research, and service. They emulate the model on which our Land Grant College system was conceived. They may find other organizations better suited to their needs. In any case, they must have institutions of their own to produce, teach, and apply the science and resultant technology basic to efficient agriculture in a coordinated manner.

The Hazard of Drought

In most of the world, where men till the soil or graze animals, drought is a recurrent phenomenon. Given the preponderance of agriculture as a source of livelihood in the world, drought emerges as the major natural hazard of geophysical origin for man in terms of areal extent and numbers of population affected, if not in the intensity of harmful effects. Because it is a recurrent phenomenon, human adaptation or adjustment becomes possible. Indeed, most agricultural systems involve some adaptation.

This statement takes as its starting point a human ecological context for the discussion of drought adaptation, illustrates the process of adjustment with two examples from widely differing societies, and concludes with suggestions for the development of certain lines of scientific endeavor that promise to broaden the range of drought adjustment available to agriculturists.

What is Drought?

In this ecological context, drought is defined as a shortage of water harmful to man's agricultural activities. It occurs as an interaction between an agricultural system and natural events which reduce the water available for plants and animals. The burden of drought is twofold, comprising the actual losses of plant and animal production and the efforts expended to anticipate drought, and to prevent, reduce, or mitigate its effects.

Several important concepts follow from this definition of drought. First, for the purpose of this statement, only agricultural drought is being examined; plant-water relationships that affect, for example, watershed yield are not considered. Second, drought is a joint product of man and nature and is not to be equated with natural variation in moisture availability. Natural variation is intrinsic to natural process and only has meaning for man in the context of human interaction. Third, the measurement of successful adaptation is in the long-term reduction of the social burden of drought, not simply in the increase in agricultural yield. The scientific effort required to improve human adaptation to drought must meet the same standards of efficacy, technical feasibility, favorable cost, and social acceptance that should govern any adaptive behavior.

Farmer Adaptation to Drought

In at least three parts of the world, the problem of human adaptation to drought is under continuing, intensive study. Saarinen has studied farmers' perceptions of the drought hazard on the semi-arid Great Plains of the United States; Heathcote has studied pastoral and agricultural farming in Australia; and Kates and Berry have carried out pilot studies of farmer perception among smallholders in Tanzania. By way of illustration, the work of Saarinen and Kates can be compared directly, using farmer interviews from comparatively dry areas of the respective countries. The focus in Figure VII–10 is on actions, on alternative adjustment strategies to reduce drought losses.

The two studies were carried out quite independently; therefore, it is of considerable interest that the data from differently phrased questions are comparable. The available, perceived strategies for mechanized U.S. grain farmers are not intrinsically different from those of hoe-cultivator Tanzanians. The mix of perceived adjustments differs, however — more actions in total being proffered by the U.S. farmers, more of these related to farm practices, and more of these requiring high-level technological inputs. Tanzanian farmers seem more inclined to pursue adjustments not directly related to agricultural practices, and thus are more prepared to change their livelihood pattern than to alter their specific cropping behavior. Thus, the major contrast that emerges is between a flexible life pattern with an unchanging agricultural practice as opposed to a more rigid life pattern with an adaptive agricultural practice. These behavioral patterns are suggestive of either alternative perceptions of nature itself or of opportunity for mobility. The Tanzanian farmer seems willing to move with an uncertain nature; his American counterpart appears ready to battle it out from a fixed site.

Figure VII–10 — COMPARATIVE PERCEPTIONS OF FEASIBLE ADJUSTMENTS TO DROUGHT

TANZANIA FARMERS

If the rains fail, what can a man do?

ADJUSTMENTS	No. of Replies	Percent of Total
Do nothing, wait.	17	12.14
Rainmaking, prayer.	15	10.71
Move to seek land, work, food.	51	36.43
Use stored food, saved money, sell cattle.	16	11.43
Change crops.	9	6.43
Irrigation.	15	10.71
Change plot location.	4	2.86
Change time of planting.	—	0.00
Change cultivation methods.	1	0.71
Others.	12	8.57
		99.99

Adjustments per farmer = 1.07

U.S. FARMERS

If a meeting were held and you were asked to give suggestions for reducing drought losses, what would you say?

ADJUSTMENTS	No. of Replies	Percent of Total
No suggestions	16	8.25
Rainmaking, prayer.	2	1.03
Quit farming.	1	0.52
Insurance, reserves, reduce expenditures, cattle.	16	8.25
Adapted crops.	2	1.03
Irrigation.	46	23.71
Change land characteristics by dams, ponds, trees, terraces.	26	13.40
Optimum seeding date.	—	0.00
Cultivation: stubble mulch, summer fallow, minimum tillage, cover crops.	78	40.21
Others.	7	3.61
		100.01

Adjustments per farmer = 2.02

The table shows the replies received from farmers in Tanzania and the United States when questioned about what they were willing to do in case of drought. Some 131 farmers in Tanzania and 96 in the U.S. were queried. In Tanzania, farmers mentioned an average of only one possible adjustment whereas U.S. farmers could think of an average of more than two to overcome the drought problem.

Broadening the Range of Available Adaptive Behavior

A farmer or rancher faces the recurrent, often perennial choice of plant or grazing location, of the timing of plant and cultivation, of the appropriate crops or stock, and of methods of cultivation and grazing. In seeking to broaden the agriculturist's range of choice of drought adjustment, the scientist offers his usual and somewhat paradoxical knowledge: We know more about plant-water relationships than seems evident from the application of our knowledge; but we know less about these relationships than we need to know in order to apply the knowledge widely.

Data Base — We could *now* provide for many parts of the world much improved information on which to base these decisions. To do so we would need to bring together the scattered record of climate, the fragmentary knowledge of soil, the dispersed experience with varieties and breeds, and the complex measurements of the impact of cultivation or grazing practice on available soil moisture. Within a framework of water-balance accounting, simulated traces of climatic data can provide probabilities of moisture availability directly related to specific varietal needs or stocking patterns. If these probabilities are used as appropriate weights in programming models, crop yields may be balanced against drought risk, desirable planting times determined, or the role of labor- or capital-intensive moisture-conserving practices assessed.[1]

A special role for the use of such data is for the planned agricultural settlement. Wherever men are induced to move to new, often strange environments, greater drought risks are often incurred as a function of their ignorance. The dust bowls of the American West, the Virgin Lands of the Soviet Union, and the Groundnuts Scheme of colonial Tanganyika provide tragic evidence of the universal cost of learning about new environments even with, or perhaps because of, the application of considerable technology. Thus, much might be done for both the indigenous and pioneer agriculturalist through the assemblage of the available data base, through the identification of missing information by systems analysis, through the filling of critical gaps by experiment and field research, and through the distillation of the final product in such form as to provide meaningful answers to the perennial questions of farmers, ranchers, and planners be they peasant or agro-industrial producers.

Water-Saving Cultivation — A number of the critical gaps in our knowledge have already been identified. For example, data on water-yield relationships in less than optimal conditions are difficult to obtain. We know for most plants how much water they need to survive and how much water they can use if water is readily available, but we know little about the trade-off between these two points. The breeding of new varieties has, to date, seemed to require more rather than less water for the high-yielding varieties; there seems little widespread exploration in breeding of the balance between yield and water need.

Though some water-saving cultivation methods are widely practiced, the actual effects of some measures are disputed, partly because these effects seem to vary greatly with soil, slope, rainfall, and cultivation practice. For example, tie-ridging, a water-conserving practice in semi-arid tropical areas has a very mixed effect depending on the crop, soil, slope, and pattern of rainfall encountered. The proper timing of planting or grazing requires much more analysis. The probability of below-average rainfalls that might lead to drought is calculated in certain standard ways, usually involving the assumptions that rainfall events are independent and that the relative frequency or some mathematical isomorphism of historic events provides useful probabilities of future expectation. But neither of these approaches adequately forecasts the persistence of below-normal rainfall characteristic of drought conditions in temperate areas or the monsoonal delays associated with drought in tropical areas. Forecasts of persistence require knowledge of the climatic mechanisms associated with the phenomenon and forecasts of monsoonal delay require understanding of the associated weather systems.

Irrigation — For a considerable part of the world, irrigation represents a crucial drought adaptation. But irrigation efficiency is notoriously low; the amount of water wasted prior to field application from conveyance, seepage, phreatophytes, or in misapplication is very high. For all of these sources of water loss, the potential contribution from applied research is great.

Nevertheless, in many parts of the world, water availability is far in advance of water utilization because farmers are slow to adopt the new system. It is with irrigation, as with the adoption of new hybrids or in the choice of any new adjustment, that the social sciences have a special role in bridging the technical isolation that characterizes much research and development and in placing such efforts into the ecological matrix of farmers' life styles, agricultural systems, and socio-institutional settings. For many farmers, acceptance of irrigation literally means the acceptance of a new way of life. Thus, the question is still wide open as to which farmers make the best settlers for the great new irrigation projects now on the drawing boards of many developing countries. Or consider the achievements of the Green Revolution. We are told that the rapid adoption of high-yielding rice and wheat, particularly in South Asia, will give needed breathing space in the critical Malthusian struggle for survival. But we are warned that such adoption comes at a cost of further stratifying rural society and intensifying existing trends that create classes of prosperous landowners and landless rural workers. An even more complex social interaction is found among farmers on the shores of Lake Victoria who seem to be shifting from drought-resistant millet to bird-resistant maize because their children, who formerly stayed in the fields at harvest time to protect the crops from bird pests, are now in school!

All of the foregoing, the propensity to adopt innovations, rural class stratification, even bird pests, are factors capable of analysis, if not solution, within a framework of human ecological systems analysis. But just as plant breeders have had to develop strategies of genetic change and varietal development capable of providing new strains quickly, so must social scientists begin to develop analytic frameworks capable of accepting varied data and providing better, if not the best, answers.

Priorities for Scientific Effort

Priorities for scientific effort designed to broaden the range of choice available to those who are subject to recurrent drought can be listed as follows:

1. The assemblage and analysis of existing data in a systems context and its preparation for use in such form as to help answer the agriculturists' perennial questions: where, what, how, and when to plant or graze?
2. A review of the relationship between the development of high-yielding varieties and their moisture requirements, with a view to developing cereal grains combining drought-resistance and higher-yielding qualities.
3. A search for simplified forms of systems analysis or critical-path analysis capable of identifying crucial obstacles, needs, niches, and interactions in agricultural systems related to broadening the range of drought adjustment.
4. Improvement in the efficiency of irrigation water use.
5. Review and analysis of existing dry-land cultivation methods with a view to improvement and wider dissemination of moisture-conserving techniques.
6. Research on climatic and weather systems is designed to provide better forecasts of persistence in temperate areas and monsoonal delay in tropical areas.

The thrust of these suggestions is in application, to make more use of what is already known through synthesis and systems analysis or simply scientific review, to seek a marked advance through social science technique in the adoption of what we already know, and to seek selected new knowledge where the gaps in existing knowledge are great or the opportunities seem particularly rewarding.