USING TECHNOLOGICAL TOOLS TO COPE WITH DROUGHT

Donald A. Wilhite
Center for Agricultural Meteorology and Climatology
University of Nebraska-Lincoln

Presented at the American Agricultural
Economists Association Meeting

Pullman, Washington
July 31, 1979

In the previous two papers we have heard of past, present and potential future impacts of drought in the Great Plains. My purpose is to now focus attention on how technology may assist us in developing new and innovative strategies to cope with future drought in the region.

Drought strategies can be classified in various ways. In a very general sense strategies may be viewed as short-term and long-term measures. Short-term measures are initiated after the onset of drought and are thus aptly termed "reactive" strategies. Long-term measures or "active" strategies are actions taken which are intended to reduce drought impact. The measures are activated in an attempt to foster a "drought-proofing" for drought prone regions, such as the Great Plains.

Drought strategies can be categorized also in terms of the focus of the intended alteration. We can separate strategies into two basic groups. First, those intended to modify the natural event subsystem and second, those intended to modify the agricultural subsystem. Modifications in the former can be broadly grouped under those intended to reduce demand (water conservation) and those intended to increase supply (water augmentation).

For the purposes of our discussion today I have classified technological drought strategies in still another way: (1) ultimate, (2) conventional and (3) innovative. The <u>ultimate</u> strategy for dealing with drought would be to possess the capability to predict or forecast its geographic occurrence and severity weeks or even months in advance. Such a capability would allow for management decisions to be made in advance of the crisis. These decisions would reflect thorough planning and the best possible allocation of resources given the pending drought.

Such a utopian situation appears to be many years away. Indeed, it may never be possible. Meteorologists must develop a better understanding of the physics of the atmosphere and ocean before weather or drought, as one of its components, can be successfully predicted far in advance.

Conventional technological drought strategies are here defined as those strategies which are currently routinely practiced in the Great Plains. These are primarily technologies developed in response to the droughts of the 1930s and 1950s. Such strategies include terrace and contour farming, strip cropping, windbreaks, stubble mulch farming and irrigation. These strategies employ proven technologies and are thus not intended to be the focus of attention in this paper.

For the remainder of my presentation I would like to focus on selected new and innovative drought strategies which I believe have considerable promise for application in the Great Plains. At the present time each of these strategies are in the research/development phase and are thus 5, 10 or more years away from widespread incorporation into the agricultural system of the region. On the other hand, each offers an innovative tool for dealing with drought.

Some innovative strategies focus on modifying the environment of the plant. Included in this category would be precipitation enhancement and the construction of innovatively designed windbreaks. The use of plant breeding and reflectants to improve crop water-use or photosynthetic efficiency are examples of altering the plant to better fit its environment.

Precipitation enhancement or rainfall augmentation has been practiced at many locations both inside and outside the Great Plains region for a number of years. Unfortunately, the overwhelming majority of these projects have been of an operational rather than a research nature. Thus, scientific evaluation of results has been difficult if not impossible. Based on the findings of a few controlled experiments some scientists have speculated that an increase in rainfall of 10-20% is possible for most of the Great Plains. It should be stressed, that although a few controlled experiments claim success, the real effects have not been conclusively demonstrated.

One difficulty with rainfall augmentation programs is that pressures from both the public and private sector increase sharply during periods of drought. Politicians are sometimes forced to make popular, although scientifically unsound, decisions. The very occurrence of drought suggests limited likelihood of alleviating its effects by cloud seeding. It is precisely during drought periods that the number of seedable clouds is sharply reduced.

Often times the potential economic benefits of weather modification are used to justify costs without consideration of alternative strategies which might achieve more substantial results. For example, land use regulation or water conservation represent viable alternatives to programs aimed at modifying the weather. Economic analyses which consider each of several possible alternatives is needed so that we will be able to better compare the relative costs and benefits of alternative technological solutions.

Windbreaks have been shown to be an effective way to improve water-use efficiency. New technologies may be developed for the construction of windbreaks to modify the microclimate of crops in drought affected areas. Research has shown that two row windbreaks are more effective in reducing the force of the wind than are the overgrown 6 to 8 row types planted in the post-1930s drought period. Multiple double rows of crops or wheat grass to shelter small grain fields has also proven effective in moderating the growing season microclimate. In winter these windbreaks increase the retention of snow on the ground. In western Nebraska experiments have shown that rows of corn can be an effective windbreak for increasing water-use efficiency and yield of sugar beets.

Since by nature plants are rather inefficient in the utilization of water and sunlight, modifications in plant architecture offer tremendous potential as a future drought strategy in the Great Plains. The ultimate objective of research programs now beginning is to improve the water use and/or photosynthetic efficiency of plants. Water use efficiency is defined as the ratio of crop material produced by photosynthesis to water consumed by transpiration. Intensive farming techniques such as heavy fertilizing and extensive weed control may produce 1 kg of material per ton of water used. The theoretical maximum is about 10-12 kg per ton of water used. Photosynthetic efficiency can likewise be greatly improved. Under intensive farming techniques this approximates 1 percent, but has a theoretical maximum of 8 to 10 percent.

The difficulty in achieving these theoretical maximums for water use and photosynthetic efficiency lie in the fact that photosynthesis and transpiration occur simultaneously, utilize some of the same structures in the leaf and are affected by the same environment. However, breeding programs which focus on alterations in plant height, leaf shape, leaf texture, leaf color and canopy structure can be effective in achieving this objective.

A reduction in plant height reduces water consumption since plants are exposed to less wind. Leaf shape is important in its effect on the exchange of heat between plant and atmosphere. Narrow leaves exchange heat more efficiently per unit area than do leaves of other shapes. Leaf shape also affects light penetration into plant canopies.

Leaf color has been demonstrated to affect the water-use efficiency of plants. Lighter colors reflect away a significant portion of solar radiation that would otherwise heat the plant. Experiments with barley at the University of Montana have shown that light color varieties yield as well as their darker counterparts while consuming less water. High reflectivity is also associated with leaf texture. The waxiness and hairiness which characterizes the leaves of some plants has been shown to decrease the absorption of solar radiation.

Each of the characteristics discussed above have been demonstrated to affect the water-use or photosynthetic efficiency of plants. If it were possible to design the optimum plant canopy, what would it look like? We speculate that for soybeans in eastern Nebraska, for example, the plant would have an open canopy that would allow light to reach the lowest and interior leaves as opposed to a dense canopy which restricts light penetration. Second, upper leaves would be upright to permit light to penetrate to the lower leaves. Lower leaves would be horizontal. Finally, leaves would fold down at night to represent a smaller surface so they would cool less rapidly.

Artificial reflectants, such as kaolinite and Celite, have been used on an experimental basis to increase the reflectivity of plants. Results have shown a reduction in transpiration by 15% with no decrease in photosynthesis. In fact, photosynthesis was actually increased as light rays were reflected into the normally light deficient inner canopy. Although successful on an experimental basis, the application of this technique does not appear to be economically feasible for routine use. It does provide guidance and a physical basis for improving crop adaptation to drought by breeding more reflective varieties.