SOME ENVIRONMENTAL AND SOCIAL ASPECTS OF WATER RESOURCES DEVELOPMENT

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ABSTRACT

Carbon emissions from the use of fossil fuels are increasing. Global warming continues resulting in more violent and destructive storms. The world population is increasing by nearly 90 million annually. Forests are rapidly being destroyed in the developing countries. Irrigated area per capita and food grain production are declining. The competition from the cities for water is increasing. Many aquifers are being polluted and/or over pumped. However, deforestation, soil erosion, population growth, and flooding decrease with water resources and other economic developments. Large new areas can be brought into agricultural production through the construction of irrigation and drainage facilities. There are many good sites for large dams in the developing countries. These dams can be used for hydropower, flood storage, irrigation supplies, and domestic water. Hydropower is clean energy and should be substituted for a large portion of the present use of fossil fuels. Benefits from fertilizers increase with increasing availability of water. Governments and politicians are poor managers of water resources. Many large development possibilities are international in scope. Electrical grids should be more interconnected and possibly continental in scope. Few if any developing countries have an institutional capacity for coordinated water resources developments. The international lending agencies should give priority to the financing of national and international water resources development authorities that at least partially privatize water resource management. Also priority should be given to those projects and activities that improve the environment.

INTRODUCTION

A brief summary is given in order to indicate some

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aspects of the environment and how they relate to water resource development. Brown et al. (1996) give an overview of trends that are shaping our future. Carbon emissions from burning fossil fuels are increasing. This results in global warming. As temperatures rise, warmer oceans release more energy into the atmosphere. Storms are becoming more intense, violent, and destructive. Increased temperatures are decreasing corn and wheat yields. The deforestation of the planet continues unabated. This results in more runoff, soil erosion, flooding, and silting of reservoirs. Forests once covered 40 percent of the earth's surface. Now they blanket only 27 percent of it. Most deforestation has occurred since 1950. In 1995 the world population increased by an estimated 87 million people. World grain land area is shrinking. Grain harvested per person declined by more than one percent per year during the last 11 years.

The need for water resources development is now more urgent than ever. Some of the needs are given as follows:

1. To increase production of clean energy to substitute for that from fossil fuels.
2. To increase water storage for flood control in order to reduce flood damage.
3. To increase irrigation and drainage in order to meet the needs for food and fiber of our increasing population.
4. To improve national economies, particularly those of developing nations.
5. To create employment opportunities
6. To decrease, and if possible eliminate the perceived need for destroying forests to provide lands for the production of food crops and of forage for livestock.

Some case histories are given and recommendations are made with respect to actions to be taken and policies changed. The problems are global. The solutions require world-wide concern and action.

IRRIGATION

Irrigated area per capita has been declining since 1979. About 40 percent of the world's food supply is produced on irrigated lands. In some countries more than 50% of foreign exchange earnings come from irrigated crops. Given the need to increase global food supplies the importance of irrigation has never been greater. However prospects for expansion are limited in many countries. Over-pumped aquifers face depletion or pollution. An estimated cultivated area of 10 percent in China, 33 percent in Iran, large areas in India, Texas, and 75 percent of the water for crops in the Arabian peninsula depend on over-drafted groundwater (Brown et al., 1996).

FAO (1995) prepared a study of water resources in Africa. The average costs per hectare given for irrigation development range from $5,000 to $25,000 USD. Of the irrigated area 64 percent is for food grain production and 13 percent is in fruits and vegetables. Brown et al. (1996) indicate that the U.S. export price of corn is roughly at $150 US per ton. At this price very few new irrigation projects for food grain production will be profitable.

Hargreaves (1995) used data from California to compare labor requirements and net farm gate profits for various other crops with those for food grains. The other crops were mainly fruits and vegetables. These required an average of 13 times as much labor and produced 13 times as much profit as the food grains. The use of fossil aquifers or the depletion of aquifers for food grain production can not be justified when the use of the water could produce much greater benefits when used for the irrigation of high value crops. In many cases groundwater should be largely reserved to make up defects in surface supplies during drought years.

Agriculture is facing increasing competition from cities for water supplies. Demands for industrial and domestic water will increase with urbanization and with population growth. In California and the South West, cities have purchased water rights from farmers.

The need for water conservation in the western United States is urgent. Various States and organizations have established weather station nets for the computation of reference evapotranspiration (ET_o). Usually a well-watered site is required for ET_o computations. The Hargreaves 1985 equation (Hargreaves et al.,1985; Hargreaves and Samani, 1985; Jensen et al 1990; and Hargreaves, 1994) requires only temperature measurements. When the weather data are from well-watered reference sites, estimates of ET_0 are very comparable with those from some of the Penman equations including the FAO Penman-Montieth for periods of five or more days. For arid and semi-arid non reference weather sites the bias due to aridity of the Hargreaves method is significantly less than for ET_o computed with the more complex methods.

There is some possibility of water conservation by means of defect irrigation. If Y is relative yield and is equal to one for the maximum yield under prevailing conditions with adequate water. Adequate water is assumed to be when X=1. The equation for relative yield based on field research with several crops is:

$$y = 0.8x + 1.3x^2 - 1.1x^3 \quad (1)$$

The data used were for X between 0.30 and 1.20. The equation is not valid for lower values of X. Its validity for values above 1.20 depends upon crop, variety, fertility, and other conditions. Equation 1 from Hargreaves (1975) was used by Hargreaves and Samani(1984) to calculate the amount of defect irrigation required to maximize profits for various crops and conditions.

Increasing demands for food production and for economic growth will make it necessary to investigate possibilities for increased water storage and more water transfers over long distances. One possibility is storage on the Yukon and other western rivers for irrigation in western Canada western United States and northern Mexico. In Latin America, there are numerous sites for large multipurpose dams. These could provide storage for irrigation and hydroelectric energy. The electricity can greatly increase the feasibility of pumping and for pressurized irrigation. In some countries there is a very large potential for new irrigation developments.

DRAINAGE

Gupta et al. (1992) found an average yield decline of 10 percent per day of submergence. This is from 11 trials in India. The yield decline varied with crop and with temperature. The decline increased significantly with increasing temperature. With excessive rainfall, crop growth is slowed due to decreased availability of oxygen in the root zone.

Hargreaves and Lasso (1994) used the ratio of the 75 percent probable expected precipitation (P_{75}) to ET_o to define excessive precipitation. Ratios of P_{75}/ET_o for 10 day intervals were used. It was found that 83 percent of Colombia has 10 or more consecutive 10 day periods of excessive rainfall with ratios of P_{75}/ET_o exceeding 1.33. In Latin America and Africa a total of 33 countries have regions with excessive rainfall for periods of three or more months. In Colombia, only 18 percent of the area has a dry season of 100 or more days.

An area of 38,550 km^2 of the eastern piedmont and plains of Colombia is considered suitable for capitalized agriculture. The soils lack fertility but have good internal drainage, are nearly level, and have favorable structure. With some flood control, drainage, and fertilization, this area could become very productive. It is believed that the potential for increased agricultural production in Colombia and other high rainfall areas is very large. Unfortunately, few if any of these countries have an institutional capacity for multipurpose water resources development planning.

The areas or regions requiring drainage are frequently best developed by a well coordinated water resources development program. This is illustrated by eastern Bolivia. This area comprises 30 million hectares of recent and Pleistocene alluvium. Only a small portion of this region has been developed for crop production. The northern portion has excessive rainfall for several months. Much of the southern portion is too dry form crop production without irrigation. Large areas flood and vast regions have a high water table requiring drainage.

Sites for large dams on the Rio Grande and Rio Beni in Bolivia appear excellent. The hydropower potential appears to be outstanding. Although there is great potential for development, Bolivia has one of the lowest per capita incomes in the Americas. Much of the food is imported. Development of these and other areas can alleviate possible future food shortages. The hydropower generated could also reduce dependence on fossil fuels.

Brown and Kane (1994) list 25 developed countries with essentially stable populations. These countries are increasing the forested area. Water resources development in the developing nations can assist in reducing the population growth and deforestation. In the developed countries, increased production of electricity can at least partially substitute for the use of fossil fuels. The costs of developing clean energy sources may be less than the losses that otherwise might occur from flood and hurricane damage if the global warning trend continues.

FERTILIZERS

Crop yields and profits may be increased significantly by the use of fertilizers. However, benefits from fertilization depend on water adequacy. The element of greatest influence on crop yields is nitrogen (N). Lines of equal yields (isoquants) may be graphed as functions of water use or crop evapotranspiration (ET_c) and N. If ET_c is not seriously limiting at any stage of growth, isoquants of yield indicate a line of optimum N as a function of ET_c. Graphs of isoquants for a large number of crops have resulted in a generalized equation. The equation is:

$$N = K_n * ET_c \tag{2}$$

where N is in kg/ha and ET_c is in total mm per crop season. K_n varies with crop, variety and other conditions. Field research has resulted in values of K_n ranging from 0.10 to 0.38. In each case the optimum N has been approximately proportional to ET_c .

Isoquants of yield and also of net profits, were graphed as functions of N and P_2O_5 with ET_c constant for the average of eight trials with corn in Mexico. The graphs indicated optimum yields and profits with the equation:

$$P_2O_5 = 15 + 0.20N \tag{3}$$

with a maximum N of about 100 kg/ha. P_2O_5 was also in kg/ha. The maximum net profit increase due to fertilization was 42 percent. Fertilization if used with well managed irrigation can produce large increases in crop yields. However, if the cop suffers much water stress the fertilizer increases the stress and may produce little or even negative benefit.

THE ENVIRONMENT

Reductions in population growth and in the use of fossil fuels would do much to improve the environment. However, deforestation and stream and aquifer pollution are more directly related to water resource development. Deforestation is inversely related to development. Brown et al. (1996) give annual rates of deforestation averaging 79 thousand hectares for the industrial regions and 9874 thousand for the developing regions. The worst region is Latin America and the Caribbean with 6047 thousand hectares deforested annually. Some of the countries with the most rapid rates of deforestation have the most potential for irrigation and hydropower development.

A study by the Canadian International Development Agency (CIDA) gives the irrigable area of Honduras as 885,100 hectares. The irrigated area does not exceed nine percent of the potential. At least 15 sites for large dams have been investigated for hydropower. Most of these can also provide irrigation and/or flood control benefits. Honduras also has one of the most rapid rates of deforestation. Due to unemployment and a continuing per capita economic decline, campesinos have cut mahogany forest and burned the timber in order to plant corn.

In the 1940's Greece was a deforested country with much poverty, flooding, and soil erosion. Construction of large dams, rural electrification, land consolidation, and irrigation made reforestation possible. Vast areas were reforested within a 30 year period. Brown et al. (1996) indicate that the forested area of Europe is now increasing by 191 thousand hectares annually.

Deforested regions can be reforested. Polluted rivers can be restored. Parfit (1993) describes various successful restoration activities in the United States. Too much of the activity in the United States related to the environment obstructs desirable development. More expense and effort is needed for the investigation and implementation of beneficial water resources developments.

The air pollution of the large cities in Brazil has largely been cleaned up. The automobiles are now powered by alcohol. Much of the alcohol comes from sugar cane produced on irrigated lands. The irrigation was made possible by the construction of large dams. Hydropower is also clean energy. A serious effort is needed in order to determine to what degree clean energy can be substituted for energy from fossil fuels.

Albertson (1996) recommended the use of a five percent mixture of hydrogen in gasoline to produce a clean burning fuel. Hydropower from water resource developments could be used to produce the hydrogen.

PRACTICAL APPLICATION

Politicians and governments are seldom good managers of water and other natural resources. There are many good possibilities for water resource development that should involve more than one country. Large regions or continents can benefit from electrical grid interconnections. Large developments can be financed more easily if more than one country is involved.

Few of the developing countries have the institutional organization or capabilities for well coordinated water resources development planning. The Tennessee Valley Authority and the Puerto Rican Water Resource Authority are examples of successful coordinated water resources developments. At one time the Chief of Water Resources Planning of Pakistan attempted to organize an international water resources development authority. International lending agencies should assume a major role in promoting regional and international water resources development agencies. Priority needs to be given to agencies that can develop resources in a manner so as to improve the environment.

The International Irrigation Management Institute (IIMI) in collaboration with the Utah State University Climate Center, the Government of Japan, and with technical review from the Australian National University is developing a World Water and Climate Atlas. The Atlas provides both printed and digital media including temperature and net evapotranspiration (NET). NET is ET_o minus P_{75} and indicates irrigation requirements and also excess precipitation requiring drainage. The Atlas shows NET in color on monthly maps with contours of temperature above 10°C. The digital portion of the Atlas, published on 18 CD-ROM includes graphical 10-day, monthly, and summary information. Data may be retrieved by latitude and longitude or for river basins. The Atlas is being published as a means of improving and facilitating water resources planning and development.

CONCLUSION

The carbon emissions from burning fossil fuels are increasing particularly in the developed countries. Deforestation is increasing in the third world countries. The world population increased by an estimated 87 million in 1995.

The global warming due to carbon emissions has resulted in increased flooding and hurricane damage. Construction of large dams can have a large positive influence on the environment. Electrical energy can be substituted for energy from fossil fuels. Economic development can reduce deforestation and slow population growth. Large areas in the developing countries are suitable for food production providing irrigation, drainage, and flood control facilities are constructed.

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