STUDY

APPLIED ECOLOGY IN MANAGEMENT OF WATER RESOURCES IN RURAL ENVIRONMENT

J. Nemec

Scientific Collaborator of Swiss Federal Institute of Technology (ETH), Zurich, Switzerland

Outlook toward the year 2000 in population growth is the point of departure to evaluate possibilities of increase of agricultural production and still to conserve the rural environment, both in developed and developing countries. Special focus is given to irrigation and related water management, also in view of the possibility of climate change due to change in the global atmosphere.

applied ecology; agricultural production and environment; irrigation and water management

AGRICULTURAL PRODUCTION

Without doubt, the main effect of agricultural progress is that the world as a whole is better nourished and enjoys a better quality of life today than it did twenty-five years ago. Between the years 1961 and 1985, world agricultural production expanded by an average of 2.5% per year, well in excess of the annual 1.9% increase in world population.

Although the agricultural challenges of the sixties and seventies have been successfully met, there is grave concern for the future. FAO's 1987 revision of the study, Agriculture: Toward 2000, projects that the developing world's demand for food and agricultural products for all food and non-food uses will grow at 3.1% per annum over the period 1983/1985–2000. Meeting such increased demand involves massive increases in agricultural output, 20% in developed countries and 60% in developing countries by the year 2000. Such increases in agricultural production, particularly in the developing world, present mankind with serious but surmountable challenges.

Growth in crop production may be ascribed to changes in three factors: arable land, cropping intensity and yields. FAO's study projects that the overall sources of crop production growth in the developing countries, over the next fifteen years, will be very similar to past trends: nearly two-thirds would come from increases in average yields which would grow at an annual rate of 1.6% and is similar to that of the past 25 years. Over a fifth would accrue through increases in arable land, projected to grow 0.6% a year. The balance would be due to increase in cropping intensity which is projected to increase from an average level of 78% in 1982/1984 to 84% in 2000.

Translated into terms of actual land usage, these projections include:

- an 83 million hectare increase in the area of arable land, approximately 11 million of which would come from lands that are presently forested;
- two-thirds of the increase in arable land will be accounted for by an expansion of irrigation;
- a growth rate of fertilizer use (in nutrient weight) of 4.7% per annum (compared with the longer-term historical growth rate of 10.3% during 1961–1985) increasing fertilizer use to 78 kg/ha in comparison to the present 43 kg/ha.

DEVELOPED COUNTRY ISSUES AND PROBLEMS

Environmental problems in developed countries do result from mismanaged intensive agricultural production techniques. Particularly during the past fifty years, many developed countries have moved from small-scale subsistence farming practices to larger, more intensive systems of crop, livestock and forest production. Such 'industrial' agriculture dominates in many developed countries and is frequently highly subsidized. It is high-productive, capital- and input-intensive, using a narrow range of species. The agro-ecosystem is modified in favour of high specialized produce by using high levels of mineral fertilizer, pesticides and energy intensive farm equipment. Its key measures are productivity and economic efficiency which require capital investment, infrastructure development and advanced technical and management skills and experience. Such agriculture, has helped developed nations overcome the loss of agricultural land due to urban expansion, transport and communications and recreation. However, it has had negative environmental effects including those resulting from unwise application of fertilizers, heavy use of pesticides, soil erosion and water pollution.

ISSUES AND PROBLEMS OF DEVELOPING COUNTRIES

In stark contrast to intensive production in developed countries, environmental problems of developing countries arise from what can be described as over-exploitation and mining of the resource base.

Given that an average crop removes somewhere in the region of 60 to 90 kg of nutrient per hectare, average mineral fertilizer use in all developing countries is in the order of one-half of this requirement per hectare of cultivated land. In the LDCs it is less than one-fifth of the requirement needed to replace removed nutrients. Superimposed on this reality are the facts that:

- many developing countries are already cultivating all land that can be safely cultivated;
- marginal lands, including woodland needed to protect soils and water quality and regulate streamflow, are increasingly being put under cultivation in an attempt to meet demands;
- fallow periods are declining below safe limits and existing systems of management can no longer meet demands on a sustainable basis;
- improper water use and management on irrigated lands is resulting in increasing salinity and/or alkalinity;
- critical fuelwood scarcity is causing massive destruction of remaining forest lands.

The net result of these circumstances is land degradation on a massive scale; physical, chemical and biological degradation. As one senior official of a West African nation has well stated „a two-headed monster is eating our lands; in the north the desert is encroaching, in the south whole villages are sliding into ever-deepening gullies. We do not seem able to stop it".

IS POPULATION GROWTH THE ONLY FACTOR TO BE TAKEN OF THE BALANCE?

The foregoing scenarios of future food consumption and production do not, however, take into consideration the existing observational evidence (and a scientific basis for concern) about the change in composition of the global atmosphere. Yet agricultural production, on one side, and water resources development and management on the other, are obviously among the two most important humanity-sustaining activities which could be affected by this generally called climatic variation. The two above activities are very much linked, as the simplest way to offset the decrease of food production caused by a change consisting of less rain and more heat is to provide additional water. The latter is, however, necessary not only for agricultural production in regions which might be adversely affected, but also for other human needs such as for water supply for population and animals, for their healthy well-

-being, and for power production both with respect to hydropower and cooling water for other power production facilities. Last but not least the increase in frequency of extremes of water availability, which we are witnessing presently, be it droughts or floods, will in all climatic regions increase the dangers to the safety of man in any society, regardless of its social and economic conditions. Thus water resources management will no doubt become an important partner of the agricultural production.

Yet water projects are formulated and initiated for the next half century and beyond, on the assumption that not much will change with the rivers and the ground water. Climatologists have concentrated their attention with respect to the changing atmosphere predictions on global means of climate variables, and this mainly because they have little other choice. The CO_2 effect involves in particular changes in global mean temperature. This change will necessarily be accompanied by changes of all climate variables, of which precipitation and evaporation are the most important for a realistic evaluation of the climatic sensitivity of water resources systems. But for this latter purpose, regional and smaller scale details of the future changes are needed. The capability of today's science for predicting these details is limited. Nevertheless, thanks to the particular property of the runoff component of the hydrological cycle balance, because runoff is a residual of two normally larger variables, precipitation and evaporation, it is obvious that the impact of the changes will be largest wherever this balance is already precarious under present circumstances with respect to the lower limit of the runoff variable, namely, where it presents a frequent deficit. Such areas are identifiable and, unfortunately, in many cases located in developing countries.

WATER MANAGEMENT ON CONTINENTAL SCALE

Having in mind these facts, it is possible now to consider how at present some kind of human control is fairly regularly exercised over water resources for agricultural purposes. Tab. I shows the global distribution of irrigated land in the major countries involved in 1984. In devising such a table, we immediately have to face a difficulty that will accompany us throughout this review: the statistics of irrigation are not very satisfactory (certainly not to numerate scientists) and there is much room for doubt as to the quantitative measures of the situation. Data about the amount of irrigation land depend on definitions as to what exactly constitutes irrigation, as well as on the data-gathering resources available. We have to consider whether the simpler forms of intervention in natural water systems are or are not irrigation; we also have to consider whether national statistics make sufficient allowance

I. Countries with major involvement in irrigation: irrigated areas in 1984 (10^6 ha)

China	45.42	Spain	3.14	Sudan	1.70
India	39.70	Italy	2.97	Argentina	1.66
United States	19.83	Afghanistan	2.66	Australia	1.63
Soviet Union	19.48	Romania	2.61	Philippines	1.43
Pakistan	15.32	Egypt	2.47	Chile	1.26
Iran	5.73	Brazil	2.20	Bulgaria	1.21
Indonesia	15.42	Turkey	2.14	Nigeria	1.20
Mexico	5.10	Bangladesh	1.92	Peru	1.20
Thailand	3.55	Iraq	1.75	South Korea	1.20
Japan	3.25	Viet Nam	1.75	France	1.16

Source: FAO (1986)

II. Continental distribution of irrigated area, 1984

	Irrigated area (10^6 ha)	Percentage of world total
Asia	136.865	62.30
North America	20.461	9.31
Soviet Union	19.485	8.87
Europe	15.710	7.15
Africa	10.390	4.73
South America	7.979	3.63
Central America	6.914	3.15
Oceania	1.869	0.85
Developing countries	157.198	71.56
Industrial countries	62.475	28.44
World	219.673	100.00

Source: FAO (1986)

for the amounts of initially irrigated land which, for one reason or another, fall into disuse.

Tab. I shows the predominance of Asian countries on the world irrigation scene. Tab. II illustrates this further with the continental distribution of irrigated land. Nearly two-thirds of the world's total of irrigated land is in Asia. Over two-thirds of the global aggregate is in the developing countries.

PROBLEMS OF IRRIGATION

Inefficient and ineffective water use leads to crop production levels which are often considerable below potential, due to reductions in cropped areas and reductions in crop yields per unit area. Good management of irrigation water is generally considered of crucial importance to raising agricultural output.

There is a variety of problems and obstacles associated with inefficient and ineffective use of water. They are partly of a technical nature and partly related to socio-economical and institutional conditions.

On the technical side there are the problems of losses of water in the conveyance and distribution system. As a result, part of the land remains uncropped and parts of the cropped area receive less water than needed. The supply of water is often unreliable because of improper control and operation of the main system, and this results in water shortages which alternate with excessive delivery.

Closer to the farmer's field, the distribution of water is unequal, with the farmers at the head of the system receiving more water than those downstream. At the farmer's level the field irrigation methods and distribution system layout are often inadequate; so are the irrigation practices, which are associated with defects in the delivery and field irrigation systems, and with the inaptitude of the farmer in applying the available water to the crop for optimum results.

A considerable portion of the water lost from conveyance canals and fields will flow to the deeper subsoil and recharge the groundwater reservoir. Where groundwater levels are already high (and this normally so in extensive plains), this recharge will cause the water-tables to rise to within the root-zone of the crops. Since groundwater normally contains dissolved salts, the damage resulting from such conditions of waterlogging is aggravated by the accompanying salinization of the soil. These two forms of degradation, i.e. **waterlogging and soil salinization pose extremely grave constraints to agriculture and the environment.**

Irrigation modifies the natural eco-system through its influence on: the water balance in quantity and timing, changes in land use and alteration to the biodata. Inevitably, this occurs in proximity to human settlement and usually in circumstances of increasing population intensity associated with development. In this way, any effects which are harmful to human health are rapidly compounded. Community health problems of this nature are extremely persistent. The hardship, misery and damage to the work force caused by water-related diseases, particularly the vector-borne diseases including malaria and schistosomiasis, have had so severe an impact on some major irrigation schemes that they are threatened with economic collapse.

The complete elimination of health risks from irrigation may be practicable only in a small minority of schemes which can be isolated from external sources of transmission and infection, or reinfection. However, there are many measures which can be applied to control, contain and reduce the risk. Generally, success depends on an integrated approach which combines environmental management, chemical, medical, sanitation methods and educational campaigns to counter the spread of disease and to achieve a sustained high level of control. The basis for establishing effective health protection in irrigation schemes lies in the proper planning, design, construction and management of those schemes, with an understanding of the environmental, ecological and social issues accompanying this form of development. This calls for the selection and operation of a suitable reticulation system which, through its ability to control water supply will also permit accurate and economical use of insecticides, herbicides and molluscicides. Control consideration should however extent far beyond limited engineering considerations, to such issues as location and standards of settlements, domestic water supply, sanitation and recreational services, reduction of human, water and vector contact through changes in the method of irrigation, and perhaps even changes in farming systems and the degree of mechanization.

CONCLUSIONS

When taking into consideration the two aspects, namely the population potential of rained lands at low input levels and the continental distribution of irrigated area, it appears that in order to secure a larger food supply to the population toward the year 2000, major improvements in water resources management will be necessary in large areas of the developing world. This rather uneasy situation will be further depending on the capacities of the governments to:

a) offset the impact of the deteriorating environment and thus provide a sustainable development which would prevent such deterioration;
b) offset the impact of the possible changing climate, which in the water management context means not only to improve food security by irrigation in regions of increasing drought conditions but also provide sufficient amount of drinking water and prevent catastrophes that may result from an increased frequency of floods.

References

ARAR, A.: Problems and current issues related to irrigation development. Proc. Workshop FAO/Government of Turkey, Sanli Urfa, Turkey, 1988.

HIGGINS, G. M. – THIRLEY, J. B.: Agriculture and environment: Conflict or cooperation? Proc. Int. Conf. on Environment and Development, Milan, 1988.
NEMEC, J.: Food demand and supply balance in the world and the role of agricultural water management in the world food production. Proc. ICID Regional Conf., Dubrovnik, 1988.
FAO. Land, Food and Population. Inform. Doc. Rome, 1986.

Received for publication on February 5, 1996

NEMEC, J. (Švýcarský polytechnický institut, Curych, Švýcarsko):

Aplikovaná ekologie v hospodaření vodou v zemědělství.

Scientia Agric. Bohem., 27, 1996 (3): 229–236.

Výhled do roku 2000 v růstu počtu obyvatel je hlavním důvodem pro hodnocení možností zvýšení zemědělské produkce a zachování životního prostředí venkova v rozvinutých i rozvojových zemích světa. Speciální pozornost je věnována zavlažování a vodnímu hospodářství také z hlediska možnosti klimatických změn jako důsledku změněného ovzduší na Zemi.

aplikovaná ekologie; zemědělská produkce a životní prostředí; zavlažování a vodní hospodářství

Contact Address:

Prof. Jaromir Nemec, Scientific Collaborator of Swiss Federal Institute of Technology in Zurich, 92 Route de Valavran, 1294 Genthod, Switzerland