## 5.5 CONTRIBUTION OF THE JOINT FAO/IAEA DIVISION OF ATOMIC ENERGY IN FOOD AND AGRICULTURE TO IMPROVING WATER USE EFFICIENCY

by

Y. Barrada

## Contribution of the Joint FAO/IAEA Division of Atomic Energy in Food and Agriculture to Improving Water Use Efficiency

Despite the growing water shortage problem, the efficiency of irrigation and the efficiency of water use are rather low so that great quantities of water are wasted. This is true even for highly developed countries. A recent study using information secured on 21 selected Bureau of Reclamation projects in the 17 western states of the United States of America, indicated that the average project water conveyance efficiency for 1949 to 1960 was 63.1 percent but ranged from 17.5 to 82.7 percent (U.S. Dept. Interior 1962). Reservoir storage efficiencies for these projects were not available. Average farm irrigation efficiencies for these projects for the same years ranged from 32.3 to 78.2 percent with an average of 59.8 percent. It goes without saying that the cited values are likely to be appreciably higher than the corresponding ones prevailing in most developing countries. Assuming no leaching requirements and neglecting the reservoir storage losses (if involved), farm irrigation efficiency with gravity systems often averages 45 to 55 percent and conveyance efficiency 70 to 75 percent, depending on the type of channels. The overall project irrigation efficiency would thus usually range from 31 to 40 percent.

A recent FAO report (de Mèredieu and Pillsbury) states that "there is no single factor as important for saving water as proper use of water on the land". The report goes on to say that the universal use of proper water techniques would allow for an increase in the world's irrigated area of 50 percent or more, using the same amount of water. Owing to the very large amounts of water involved in irrigation projects, even a slight improvement in irrigation and water-use efficiency would result in immensely great benefits. For example, the U.A.R. now has at its disposal about $60 \times 10^9$ cubic metres of water per year (after completion of the Aswan High Dam Project). Should irrigation and water-use efficiency be improved by only 5 percent, this would be equivalent to the production of $3 \times 10^9$ cubic metres of water (at the site of the dam without any evaporation and conveyance losses).

The importance and great need for improving irrigation and water-use efficiency are well known to agronomists and considerable efforts are being made to achieve this goal. Improvements in irrigation and water-use efficiency are, however, not easy to carry out. They have to be based on sound studies covering almost all the research fields aiming at increasing crop production and reducing water losses. They require a high level of understanding and management skill from the farmers, taking into account the cost of applying certain beneficial techniques in relation to monetary return. The main investigations and developments needed for improving irrigation and water-use efficiency would, among others, include the following:

(a) Developing economic methods of controlling seepage and evaporation during storage and conveyance of water.

(b) Development of more efficient irrigation techniques with special emphasis on a better and more homogeneous distribution of water.

(c) Estimation of crop water requirements including leaching requirements under well-defined conditions, taking into consideration the effect of water quality on both water requirements and crop yields.

(d) As either too much or too little water causes a yield reduction, the rate of water flow throughout the irrigation time should be regulated according to the permeability of the soil, so that although water infiltrates to the rooting zone, unnecessary losses due to runoff or deep percolation are avoided. Also the amount of water applied and the interval between two successive irrigations should be determined in relation to different values of soil-moisture storage capacity and the rate of evapotranspiration so that the harmful effect of drought periods on crop yields can be minimized.

(e) Often the deficiency of only a single plant-food element causes a marked loss of water-use efficiency. As the element becomes scarce, the rate of growth as measured by the assimilation of $CO_2$ is greatly reduced with no corresponding decrease in the transpiration. Adequate fertilizer application and the supply of all deficient nutrient elements can therefore greatly increase the efficiency of water use.

All these investigations would benefit a great deal from the use of isotope and/or radiation techniques. The Joint FAO/IAEA Division of Atomic Energy in Food and Agriculture sponsors activities along the indicated lines, in the form of individual or coordinated research programmes and through cooperation with the Division of Technical Assistance in planning and implementing projects aimed at improving the efficiency of water use with the aid of isotope and radiation techniques.

Among the activities sponsored by the Joint FAO/IAEA Division of Atomic Energy in Food and Agriculture is the "Coordinated Programme on the Application of Radiation Techniques to Water-Use Efficiency Studies". This programme was initiated in 1965 and aims at making the best possible use of the limited amounts of water available for crop production in arid and semi-arid regions. Identical experiments were and are being carried out to obtain evapotranspiration data under different climatic conditions through the following methods:

(a) Directly through the daily weighing of hydraulic lysimeters; $E_t$

(b) Indirectly by following the changes of moisture content in the soil profile with a neutron moisture metre; $E_t$

(c) Computing the potential evapotranspiration after "Penman"; $E_o$

(d) Evaporation from an open class-A pan.

Based on the results of this experiment, it is expected that a fairly good estimate of the actual evapotranspiration under certain well-defined conditions could be made through soil-moisture measurements with a neutron moisture metre and through bringing appropriate correction factors to either the potential evapotranspiration computed after Penman or to the open pan evaporation. Examples of the developments made and results obtained through this programme are indicated below.

The weighable hydraulic lysimeters were developed during the implementation of the programme through replacing the metal by rubber holsters (nylon covered with a layer of neoprene), the water manometre by a pressure transducer and the gypsum candles placed to ensure adequate drainage under a suction of 1/3 of an atmosphere by ceramic ones. There are, however, still problems associated specifically with the operation of hydraulic lysimeters in addition to the problem of the fundamental nature of all types of lysimeters, namely the degree to which the lysimeter crop is representative of the field crop. It was impossible to pack the soil in lysimeters to the same density as in the field and the water holding capacity of the lysimeter soil was higher. Appreciable differences in plant height were recorded with the maize crop. Difference in plant height causes appreciable difference in absorbed energy due to the proportional, additional exposed area of the projecting aides. In spite of all the indicated problems, the use of weighable lysimeters is necessary for water balance studies to take into consideration the loss of water through deep percolation (drainage). The lysimeters used in the programme are essentially those designed by the East African Agriculture and Forestry Research Organization (E.A.A.F.R.O.) and their volume is 2 x 2 x 2 metres.

The experiment carried out by E.A.A.F.R.O. in Kenya during the period 1965 to 1969 indicated the following:

(a) Meteorological data were recorded in an enclosure established immediately upwind of the experimental site and in a second meteorological screen mounted on a strong vertical metal pipe in the field so that the screen height could be adjusted to 30 cm above the crop. Comparison between temperature and humidity records from the two screens over a period of 4 months did not reveal any appreciable differences and the difficult operation of the field screen proved to be unnecessary.

(b) The evaporation estimate according to Penman ($E_o$) was higher than the evaporation measured from a raised grid pan, while neighbouring rice fields were flooded with water. The contrary was observed due to advection when the neighbouring fields were dry after harvesting rice. The evaporation of intercepted water contributed appreciably to the high $E_t/E_o$ ratios observed in Kenya as peak values occurred in periods of silking and maximum ground cover; for the 1968 crops, however, the peak was absent at the tasselling/silking stage and occurred with the onset of heavy rain when the leaves were drying off and transpiration rate was very low. The effect, as expected, is greater in taller, aerodynamically rougher crops (maize) than in shorter crops (beans).

(c) Although sprinkler irrigation makes possible a reasonably good uniformity of water application, variations of up to 15 percent were observed and the amount of water lost through evaporation before reaching the soil amounted to about 15 percent of the total irrigation water applied through sprinkler heads.

This coordinated research programme will be terminated towards the end of the year and a detailed report is envisaged for publication early in 1972. A closely related investigation, which was not considered as a part of the abovementioned coordinated programme, was carried out on maize during 1967 in Hungary by the Research Institute for Irrigation and Rice Cultivation. The results indicated mainly that:

(a) The highest yield of 10.65 tons/ha was obtained for shorter irrigation intervals, applying a total of 242 mm of water in addition to 198 mm of rainfall. The yield increase was significant in comparison with the treatment receiving a total amount of 442 mm irrigation water applied in longer intervals. The grain yield increase in comparison with the control treatment (which depended only on rainfall) varied between 24 and 33 percent according to the irrigation treatment.

(b) The control treatment gave a relatively high yield of 8 tons/ha. Measurements with the aid of the neutron moisture metre showed that plants made use of a considerable amount of the water stored in the soil. This amount was estimated to be about 130 mm of water.

(c) Inadequate water supply reduced the grain/stalk ratio.

(d) The most efficient use of water among irrigation treatments was that of the treatment which gave the highest yield (2.1 kg. grain/$m^3$ of water). The control treatment showed an apparently higher value of 2.4, as the decrease in the amount of water stored in the soil was not taken into consideration.

(e) For maize grain the percentage of N derived from the fertilizer was significantly higher in irrigated treatments than in control treatments.

In all other programmes sponsored by the Joint Division, the importance of moisture content in soil profiles, irrigation to supplement rainfall or as the main water supply, management practices aiming at reducing water losses, and adequate drainage are fully recognized. Therefore, in all the Division's coordinated research programmes aiming at increasing yields through proper application of fertilizers, due consideration is given to the effect of soil moisture on nutrient uptake, yield and the efficiency with which fertilizers are used. Examples are briefly indicated below.

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Results obtained under the coordinated programme on the Use of Isotopes to Study the Efficient Use of Fertilizers in Tree Culture, initiated during 1966, have shown that soil moisture plays an important role in the pattern of root activity in trees. For example, experiments on coffee in Kenya showed that in the wet season root activity is widespread in the upper 15 cm of soil. In dry weather, as the soil dries out, root activity is restricted to a certain depth. In all crops studied - cocoa, coffee, citrus, coconuts, soil palms - root activity was found to be more intense in the wet season when soil moisture is not a limiting factor.

The Coordinated Wheat Fertilization Programme started during 1968 and is now the Division's main programme in the field of soils, irrigation and crop production. The programme aims at increasing the yield of wheat, mainly through adequate application of fertilizers and improvement in the efficiency of their use with the aid of isotopes N-15 and P-32. The effect of environmental conditions, the related evaporative demand, rainfall, amounts and intervals of applied irrigation water, and the moisture content of soil profiles on the nutrient's uptake, the yield of wheat and the quality of grain will be given due consideration. Institutes in Brazil, Greece, Hungary, India, Italy, Lebanon, Mexico, Morocco, Pakistan, Peru, Romania, Turkey and the U.A.R., are coope-rating in the abovementioned coordinated research programme. As an example, the re-sults of an experiment carried out on winter wheat in Hungary during 1968/1969 indi-cated that not only the yield was increased through applying one or two supplementary irrigations but also the total nitrogen content was affected, as can be seen in the following table:

AVERAGE TOTAL IN PERCENTAGES

| Treatment | $N_o P_o K_o$ | $N_o PK$ | NPK (N = 150 kg/ha) | | |
|---|---|---|---|---|---|
| | | | 150 kg at planting | 75 kg at planting 75 kg at tillering | 50 kg at planting 50 kg at tillering 50 kg at beet stage |
| | in wheat grain | | | | |
| No irrig. | 1.71 | 1.70 | 1.97 | 1.95 | 2.13 |
| one irrig.* | 1.72 | 1.87 | 2.21 | 2.12 | 2.15 |
| two irrig.** | 1.77 | 1.88 | 2.13 | 2.20 | 2.41 |
| | in straw | | | | |
| no irrig. | 0.39 | 0.39 | 0.61 | 0.54 | 0.62 |
| one irrig. | 0.43 | 0.46 | 0.72 | 0.61 | 0.68 |
| two irrig. | 0.39 | 0.52 | 0.69 | 0.65 | 0.74 |

* at tillering stage
** at tillering and beet stage

The obvious effect of moisture content on the total N percentage in grain will be further investigated when our new coordinated research programme aiming at increasing plant protein production is initiated.

Late in 1969 the Joint FAO/IAEA Division of Atomic Energy in Food and Agriculture initiated a programme on "Rice Production" for South East Asia and the Far East. The programme aims at increasing yields through adequate fertilizer application and the development of proper water-management techniques which would lead to the provision of adequate drainage and to water savings, especially during the dry season. Ceylon, China, Indonesia, Korea, Pakistan, Thailand and Vietnam are cooperating in this programme.

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