THE ECONOMICS OF IRRIGATION SYSTEMS

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Keywords: Irrigation, irrigation system, economics, capital investments, profit, market, tariffs, business plan, information, Internet.

Contents

1. Introduction. Background to the Economics of Irrigation Systems

Irrigated farming is a traditional agricultural practice developed over the centuries in countries with a hot climate. Many generations have expended important material and financial resources for the development of irrigation. In droughty regions, artificial increase of soil moisture content (using irrigation systems) is frequently the only measure capable of meeting the demands of the local population and industry for crop and animal products. Land irrigation improves the water–salt balance of the soil and sustains its economic fertility.

Irrigation farming involves a higher level of agricultural production standards, as compared to dry farming. Its specificity is the use of two principal means of production—land and water—in a single technology of crop production. From the viewpoint of economics, the increase in productivity in irrigation farming is due to capital investment into the fertility of irrigated areas.

An irrigation system (IS) is a technological synthesis of water management and agriculture, realized through transportation of water from a source to an irrigated field. Therefore, the economics of IS is closely related to the economics of water management and agriculture.

The construction and management of ISs have been continuously improved through application of science and technology. This can now be regarded as an independent branch of economic activity in the field of land development and land reclamation.

The productivity of agricultural land under natural conditions is mainly determined by the land category, soil quality, and climatic conditions. The effect of irrigation on land productivity differs across the world regions and depends on the natural level of soil moistening. In the droughty regions of Asia, Africa, the Middle East, and South America, the potential productivity of agricultural land increases significantly with artificial irrigation, in combination with other agricultural practices.

Irrigated areas constitute about 17% of the total farmland in the world and provide 50% of the global agricultural produce. In the Middle Eastern countries, irrigated fields yield 70% of the agricultural produce.

The volume of irrigation water conveyed to a field dictates the engineering parameters of the IS. This volume is calculated from data on the water budget of the soil and water consumption of each crop. Increase in crop yield from irrigation in the zone of insufficient precipitation is much higher than that in zones where rainfall is plentiful. In droughty regions, irrigation increases the productivity of the land by a factor of two or more.

The objective of irrigated is to decrease dependence of agriculture on climatic conditions. In tropical and subtropical regions, irrigation farming makes it possible to produce agricultural commodities (grain, fodder, vegetables, and fruits) all the year round. Though expenditure of labor, financial, and material resources per unit area of irrigated farmland are higher than those in dry farming, the gain in yield makes irrigation farming economically attractive.

In irrigated farming, water is an essential element of production. By period of water supply, two types of irrigation are distinguished: seasonal irrigation (SIr) and continuous irrigation (CIr).

SIr depends on the number and duration of rainy and dry seasons, and the height of floods. Water for irrigation is accumulated by the establishment of 30 to 40 cm high earth embankments on fields, and by construction of dams in order to retain rainwater and floodwater. This type of irrigation is widespread in southern and south-eastern Asia.

CIr makes use of rivers, water reservoirs, wells, and other water sources via the construction of a complex irrigation system, including mechanical or gravity water extraction, inter-farm conveying channels, networks of farm channels, gutters, and pipelines delivering water to particular fields, and irrigation equipment to ensure appropriates rates and timing of irrigation.

2. Economic Features of Irrigation Systems

Centuries-old practice of irrigation development and economic activity on irrigated lands shows that:

- Irrigated lands permit sustained growth of valuable moisture-loving crops;
- Organization of agricultural production in irrigated land, with allowance for market conditions, permits a farmer to obtain a higher profit;
- The perfection of existing ISs is accompanied by an increase in material and financial expenditure, as compared to the establishment of new ISs on additional areas;
- The possibilities of constructing inexpensive water utilization systems have mainly been exhausted by now;
- The construction of facilities on inhabited land generally favors the organization of a new setting system, transforms lifestyles on the newly developed land, and creates new jobs for the economically active population;
- The involvement of human, water, and land resources into economic activity on the same developed area significantly stimulates the economy, both in the irrigated zone and beyond;
- The need to avoid or mitigate negative environmental effects of IS installations and of irrigation itself increases the capital intensity of an irrigation project;
- The main legal entities in the irrigation water market are those involved with carrying out the day-to-day management of hydrosystems including water sources, large-scale water supply arteries (conveying channels), feeder structures, and different protective units (flood control, storm-water management, dewatering, coast-protection, etc.).

Knowledge of world practice in the joint management of water and land resources makes it possible to avoid errors and to efficiently organize the production.

A common limiting factor in the operation of ISs is high water expenditure per unit of output. Operational water loss from ISs reaches 36% in India and 50% in Greece and Algeria. In developed countries such as Israel, unproductive losses are almost excluded by the substitution of surface systems by drip and subsurface irrigation units.

3. Operation Economics of Irrigation Systems

The art of management is determined by the combination of state and private interests, regardless of the social system. As applied to agriculture, the interests of the state involve the steady production of foodstuffs for domestic consumption (to reduce dependence on imports) and for export (to benefit the balance of payments). On the other hand, the farmer’s interest is to maximize profit from his own labor.

These interests often come into antagonism. On its part the state (in order to reduce imports and to stabilize the economy, etc.), plans the volume of irrigation and sets the objectives for the kind and volume of agricultural products. The source of funding and the efficiency of particular irrigation projects depend on the interests of the state and individual farmers.

An irrigation system as an object of the economy depends on the economic situation, and the market for agricultural commodities, and, at the same time, exerts its own impact on these factors. The economic state of an IS is determined by its budgetary balance.

The main economic target of ISs is to render paid services to agricultural water consumers (AWC) by delivering high-quality fresh water at the prescribed time and place, and in the required volume. The efficiency of these services is evaluated for working, redesigned, and newly constructed ISs on the basis of the economic design, with allowance for current-outlay and capital costs, as well as for proceeds from services rendered.

Under conditions of paid water consumption, the role of operational gauging services increases, as well as the need for more accurate water assessment, because any supply shortfall is fraught with disbenefit.

ISs must be ready both to supply their clients with water in the event of failure of traditional water sources and to compensate AWCs and other water consumers for their losses. For example, if enhanced extraction of groundwater results in decrease of the water table and deterioration of the environment, the IS should perform the remedial work.

The IS must also pay water consumers for any shortfall caused by disturbance of the water regime of source water reservoirs.

IS establishments have restricted opportunities to effect cost reductions, because the absolute value of normal operating expenses, independent of overall performance, is very high. In addition, the results of IS activities significantly depend on the natural conditions. It is clear that natural features of watercourses, including alteration of low-water and high-water seasons, should be taken into account. In the high-water periods, with an excess of water in the system, it is possible to divert water to meet consumers' requests, in excess of the planned rate, at a reduced price, in order to create more demand for ISs and a reserve of funds for payment of damages in the event of lack of supply through the fault of the IS.

At the same time, the problems of cost reduction should not be ignored, especially in regions with streamflow re-supply and redistribution. Local water management organizations should have their own sources of finance. Their funds are derived from:

- water charges;
- compensation for damage to water quality and the environment during water extraction, transportation, and consumption;
- allocations for the increase of water resources, and
- other sources provided for in the law and subordinate legislation.

The received amounts are redistributed as direct financing and credits allotted to agricultural enterprises for economic programs or water use projects and to administrative districts for environmental protection. The relationships between the ISs and their agricultural clients are controlled by the agreements regulating the service conditions and the responsibility of the parties and providing for incentives and sanctions for ISs and AWCs. This ensures efficient mutual control, supported by the liability of contracting parties and their interests in improvement of the results of their activity.

4. Tariff and Price Policies

Because of diverse climatic conditions and variations in the water consumption of crops, straight-line rate and two-part rate schedules are used as the main kinds of remuneration for IS services.

The determination of the pricing mechanism and the water consumption tariff precedes any contract between the IS and a client.

Water delivery rates should be calculated so that the expected income is sufficient for covering operational expenses, paying the water-supplying organization, and gaining some profit. Straight-line rate (SLR) schedules are suitable for regions where water consumption by agricultural crops is steady or varies only slightly from year to year. In regions of unsteady and insufficient soil moistening, where the irrigation rates depend on the rainfall, the two-part rate (TPR) schedule is suitable.

The financial stability of an IS should not depend on the volume of water consumed by its clients. It is unacceptable for the interests of the IS to be threatened by decrease in AWC demand for water. For this purpose, it is recommended that services should be rendered to the AWCs at an agreed price and using the TPR, which is calculated from the total costs, the profitability level, the irrigated area, and the volume of water delivered.

Water supply to AWCs at the TPR is justified by the important fixed capital of the IS, whose management charges (e.g., depreciation, salaries, and maintenance expenses) do not depend on their use. These operating expenses should be covered by the clients, regardless of the volume of water consumption.

The fixed (by hectare) tariff rate for each client is dependent on the irrigated area that is guaranteed during the request peak period. On the other hand, the tariff rate should depend on the water management resources of the enterprise guaranteeing the agreed water supply: the higher the water supply, the higher the tariff rate.

The second (volumetric) tariff rate (payment of 1 m^3 water delivered) is set in addition to the fixed tariff. It is calculated from the variable charges of the IS, i.e., expenses for transportation of the unit volume of stored (procured) water. These expenses include electricity charges and water transportation charges.

The TPR put all clients onto a similar basis, because the one who achieves advantageous conditions should pay for this advantage.

The calculation of TPR for a working IS, with an account for its proper interests, includes the calculation of the tariff rates per 1 ha of irrigated area and 1 m^3 of delivered water, as expressed in national currency (n.c.). It is performed from the formulas:

Hectare Tariff Rate:

$$Ht = OEa\frac{(1+P)}{IA} \tag{1}$$

where Ht is the tariff for the irrigation of 1 ha, n.c./ha; OEa denotes the annual normal operating costs of the IS (in n.c.); P is the profitability, %; IA is the area irrigated by the IS, ha.

OEa includes:

- The total management charges of departments, pump stations, electric power stations, and drain wells;
- Maintenance of production buildings, infrastructure (civil buildings, communication facilities, and roads), and transportation facilities;
- Care of plantations;
- Equipment costs;
- Depreciation charges;
- Interest expenses on short-term credits, and
- Insurance contributions; etc.

cubic meter tariff rate:

$$Ct = \frac{Twf \cdot Vwi + OEv(1+P)}{Vwd} \tag{2}$$

where Ct is the tariff for 1 m^3 of water (in n.c.); Twf is the price of 1 m^3 water taken from the WF (n.c.); Vwi is the total volume of water intake from the water facility, m^3; Vwd is the total volume of water delivery for irrigation, m^3. OEv (in n.c.) denotes conventionally variable operating costs, including:

- maintenance of hydraulic structures, gauging stations, barrages, channels, pumping stations, electric power stations, and wells;
- electricity charges;
- cleaning of the irrigation system;
- protecting, regulating, and flood-control works;
- leveling of dams and channels, and
- provision of emergency stores.

TPR does not exclude the application of SLR as its particular form under certain conditions, i.e. steady volume of water delivery, constant irrigated area, and fixed maintenance costs.

An example of the two-part rate calculation

1. Return (for a conventional IS):
    - irrigated land area, 56 000 ha;
    - volume of water intake from WF, 300 million m^3;
    - volume of water delivery, 250 million m^3;

- normal operating costs, 2 213 700 n.c.;
- variable operating costs, 3 677 900 n.c.;
- price of water taken from WF, 0.01 n.c..

2. Design parameters:
    - profit (on costs at a profitability of 8%), 218 600 n.c.;
    - two-part rate:

    per 1 ha of irrigated area, 39.53 n.c.;
    per 1 m^3 water, 0.015 n.c

Tariffs calculated from formulas 1 and 2 reflect the interests of IS. The allowance for all expenses permits the IS to protect its capital from aging and consumption. Regular preventive measures and general overhauls are carried out in order to prevent or reduce functional depreciation of capital funds. These expensive operations are financed from operating income, particularly from service (water delivery to AWCs) income. Therefore, the asked price may be unprofitable for AWCs.

Mutually acceptable (negotiated) price of water is found by seeking mutual compromises or other sources for reimbursement of IS and AWC costs. A consensus may be reached at the expense of profit. A unified price of water (from a water source) is generally fixed for the whole water-management basin.

In a project, the study and analysis of commercial profitability for each crop are performed for both current and design conditions with allowance for the run of the market, inflation rate, development of equipment and technologies, and increasing material inputs, etc.

5. Economics of Reconstructed and Constructed Irrigation Systems

The high cost of IS refurbishment (without increase in output) which frequently exceeds the cost of a newly constructed IS, is not recoverable from lower costs as a result of lower consumption. For an individual farm, it is more profitable to keep paying for water loss from the irrigation network under the old irrigation regime, than to meet the reconstruction expenses. Therefore, new IS projects are become more attractive. Such projects are generally initiated by governments. Through an executive board (attached to a ministry or department), the government manages the organization and fulfillment of an irrigation project and pronounces judgement about the water tariff, land rent, subventions, interest rate, additional insurance tax, and the distribution of the profits between the contributors of IS construction and maintenance.

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Bibliography

FAO, 1982. General Guidelines for the Analysis of Agricultural projects, no.14. FAO-UNI, Rome.

Levine, J.R. and Baroudi, C., 1995. Internet Secrets, PB.

Ryskulov D.M., 1985. Calculation of capital investment efficiency in the design of reclamation structures. *Reports of Soviet Experts, United Nations Economic and Social Commission for Asia and the Pacific,* Tashkent.

UNIDO, 1978, Guidelines for Feasibility Studies.