Effectiveness and Social/Environmental Impacts of Irrigation Projects: a Criticial Review.

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Contents:

1. Irrigation Developments in the World
2. Irrigation Benefits, Costs, and Side Effects
3. Water-logging and Salinity
4. Problems in the Management of Irrigation Water
5. Example of Impact Assessment of and Irrigation and Flood-Control Project
6. Summary, Conclusions, and Recommendations
7. References

1. Irrigation Developments in the World

Irrigation is generally considered an effective way of increasing agricultural production. It can supply the water needed for crop growth when rainfall is limited or, in more humid climates, it can bridge dry spells and reduce agricultural risks. The areas under irrigation in (semi)arid and (sub)humid regions is about equal.

Up to the end of the 19th century, irrigation developed relatively calmly. Around the year 1900 the irrigated area (roughly 50 x 10^6 ha) was about one quarter of what it is today. Often, the irrigation system was a communal effort of otherwise independent land holders (***communal type of irrigation***).

Under colonialism, feudalism, or dictatorships, both the land and the irrigation system were sometimes owned by one single person or organization (***enterprise type of irrigation***). After 1900 governments became more involved in irrigation because:

- Water began to be regarded as government property as the demand for good quality water was growing, but its availability was diminishing;
- The development of new water resources became technically so complicated that it remained outside the reach of small communities;
- Large scale projects were *en vogue*; they were believed to be more cost efficient than small scale projects;
- Government import and export policies required the cultivation of commercial and industrial crops.

Government involvement led to the ***utility type of irrigation*** , in which the land remained largely the property of the farmers (but not in socialist countries) but the water was distributed by a governmental agency. At the same time, however, the land holders became more dependent on governments, because the land was allotted according to government regulations (sometimes on lease) and the farmers were instructed which crops to grow (or not to grow) and when, where and how to grow them.

10^6

% of
ha
1955

In the last decades, vast investments have been made in new irrigation schemes or in improving existing ones. For example, World Bank and IDA lending to irrigation is the largest sector within their programs of agricultural and rural development.

In the period 1948-82, agricultural loans amounted to U.S.$ 27 billion, of which more than 10 billion was for some 285 irrigation projects. Total project costs have been about 2.5 times the amount of the loans (*Hotes 1984*).

Apart from World Bank, other banks, government, international donor agencies, and private enterprise have invested considerable sums in irrigation. As a result of all these efforts, the total irrigable area has increased enormously (Table 1.) and it has been estimated that at present some 800 to 1000 million people are involved in some form of irrigated agriculture.

Table 1. Irrigable areas in 1955 and 1983

	1955		1983		Increase	
	10^6 ha	% of world total	10^6 ha	% of world total		
Developed countries	28	23	61	29	33	118
Developing countries	93	77	152	71	59	63
	----	----	----	----	---	
World total	121	100	213	100	92	76
India + Pakistan	33	27	55	26	22	67
China	31	26	45	21	14	45

Sources: *Gulhati* (1955), *FAO* (1984)

In spite of the huge investments, the results of irrigation schemes are generally far below expectations. Summaries of disappointing experiences can be found in *Bottrall* (1981), *CGIAR* (1983), *OECD* (1983), *USAID* (1980 and 1983), and *Hotes* (1984).

Hence, national objectives of irrigation development (e.g. self-sufficiency in food, earnings from experts or savings from imports, higher rural incomes) are seldom realized.

Although literature on the disappointing results has been multiplying since 1970, it appears that lessons learnt are not put into practice. *Wiener* (as early as 1976), writes: "*The repeated failures have not deterred governments from continuing to pursue policies proven to be ineffective*".

Undoubtedly, some authorities and constructors must have pocketed financial gains from the projects.

The causes of disappointing results are manifold, but they cab be put into two categories:

- Unrealistic assessments of the required investments, the natural and the human resources (including management ability), and the farmer's needs;
- Neglect of the, often negative, impacts on the environment and on the socio-economic conditions,

In the hope of contributing to the increasing awareness about the limitations of irrigation, this article discusses the second broad category. Although the two categories cannot be viewed independently of each other, the first category (relating more to the malfunctioning of the project proper) will, in the following, only incidentally be touched upon.

2. Irrigation Benefits, Costs, and Side Effects

The aim of irrigation (Figure 1) is to increase one or more of the following items:

- The cropped area (more land under crops);
- The crop yields (more crop production per ha per season);
- The cropping intensity (more crops per ha per year);
- The diversity of cropping (more kinds of crops).

Irrigation systems have primary benefits (those benefits that relate to the aims of the system) and primary costs (those costs that relate to the construction, maintenance and operation of the system). Unfortunately the benefit/cost ratio of many irrigation projects, especially in developing countries, is unfavourable (*Hotes* 1984) because:

- The primary benefits (actual crop yields and irrigated area) are less than expected;
- The primary costs (investment and recurrent) are higher than foreseen.
  The reverse is seldom encountered.

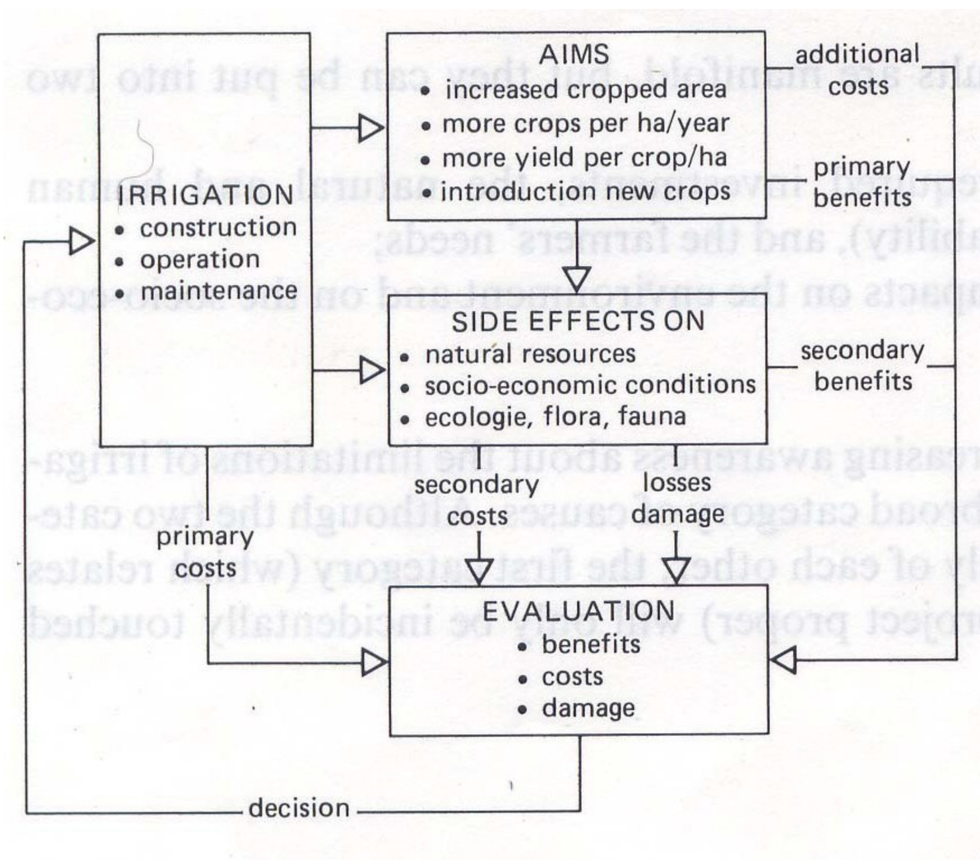

Figure 1 Irrigation effects and evaluation

The reason why the primary benefits are often less than expected is that many projects are initiated on political grounds, with little heed given to farmer's needs or motivations (*Kortenhorst* 1985). In other words, there is only a "top-down" and not a "base-up" approach during the project's conception, construction, operation, and maintenance. Further, there is a lack of project staff to bring the "top-down" approach to a good end. Hence, the scheme cannot function as desired.

Van der Klei (1988) gives a very representative example of diverging national policy aims and the needs felt the farming community. As a result, a reclamation project for rice cultivation, initiated by the government, turned out to be unsuccessful. The community concerned was not in need of rice, because its members spent log periods of time in the capital of the Country (Senegal), so there were not many mouths to be fed, nor was there sufficient labour available. The cash-crop requirements of the community were covered by the cultivation of groundnuts which, as an export product, yielded a better price than paddy, whose price is purposely kept low by the government for the benefit of the growing urban population.

The primary costs of irrigation projects are mostly much higher than predicted because, from the outset, not all the costs are adequately estimated, perhaps to avoid problems of financing. As a project nears completion, considerable complementary, unforeseen, expenditures are often necessary to attain the predicted benefits. It is then argued that the benefit/cost ratio of the additional investments remains favourable, because the initial costs are "sunken costs", and that the initial investments will be lost if the complementary expenditures are not made. This explains why many irrigation projects are constructed at excessive costs.

Besides the primary costs, irrigation projects have additional costs (those costs that relate to extra agricultural inputs required to obtain the desired irrigation benefits or to offset social and environmental damages). Very often, additional costs have to be made to achieve a sufficient production increase. In this respect we can think of farm mechanizaton, the use of modern varieties, fertilizer applications, plant protection measures (the spraying of herbicides, insecticides, fungicides), as well as the development of a marketing and industrial processing system. The additional costs for all this are often so high that, if not subsidized, farmers see their income drastically reduced. *Tillman* (1981) writes: "*In too many irrigation projects, the farmer becomes a victim of the system in which operation costs increase faster than the value of the crops*."

Further, an increased competition amongst the farmers, reduces the prices, often to levels lower than before the project.

Apart from the primary and additional costs, irrigation projects have secondary (indirect, environmental) costs which do not stand in direct relation to the techniques and objectives of the project (figure 1), but which become apparent when one compares:

- The socio-economic conditions with and without project, considering:
    * The groups of people who take part in the project;
    * The groups of people outside or ousted from the project area;
- The value of the natural resources with and without project;
- The quality of the natural resources before and (long) after the project, both:
    * Inside the project area
    * Outside the project area.

Examples of the disregard of socio-economic aspects of water-management projects were given in a review of six case studies by *Oosterbaan* (1985), of which a summary is given in table 2.

Table 2. Summary of case studies reviewed by *Oosterbaan* (1985)

Project No. and	Name	Type of organization	Type of organization intended
I	Pilot cattle station with irrigated fodder crops (Middle East)	State enterprise	State enterprise
II	Village schemes for irrigated rice (w. Africa)	Utility system (government)	Cooperative society (communal)
III	Pilot scheme for sprinkler irrigated vegetables (E. Africa)	Utility system (government)	Cooperative society (communal)
IV	Small dams for water resources (Central Africa)	State enterprise	State enterprise (farmer involvement)
V	Swamp reclamation (Caribbean)	State enterprise	State enterprise
VI	Rehabilitation large-scale irrigation scheme (S.E. Asia)	Utility system (government)	Utility system (farmer participation)

C O N C L U S I O N S

* All projects started by government initiative (urban-based, top-down);
* None of the projects started with cooperative action by farmers;
* All projects failed in many respects, only project II holds slight promise;
* Projects intended for cooperation of farmers did not reach their objectives;
* All projects lacked adequate staff;
* Farmers' objectives, social, natural, soil, and environmental constraints were considered problems of 2nd order (to be solved in the course of time) instead of points of departure, but they proved to present obstacles without remedy.

Well known, but often neglected, cases of physical damage to the environment or the loss of natural resources due to the establishment of irrigation projects are the following:

A – At the dam sites and downstream of off-take structures;
B – Around groundwater wells;
C – In the irrigated area itself;
D – To the "beneficiaries".

A - At the dam sites and downstream of off-take structures

The creation of storage reservoirs causes the loss of forest and of grazing and agricultural lands, and it dislodges people.

The High Aswan Dam (Egypt) displaced 120.000 persons, the Akosombo Dam (Ghana) 78.000 (*Kassas* 1980). The affected people are generally very poorly compensated.

The Manantali Reservoir (Mali) will intersect the migration route of nomadic pastoralists and will destroy 43.000 ha of savannah, probably leading to overgrazing and erosion elsewhere. The Kainji Reservoir in Nigeria drowned 15.00 ha of cultivated flood-plain.

The off-take and diversion structures often deprive downstream users of their water (Oosterbaan 1982). After the closure of the Kainji Dam, 50 to 70 per cent of the downstream area of flood-recession cropping was lost (*Drijver and Marchand* 1985). Further, reduced downstream river discharges and sedimentation often cause:

- Increased salt water intrusion in deltas and estuaries (e.g. the Nile Delta with large tracts of salinized land along the Mediterranean sea coast).;
- Increased coastal erosion (e.g. in Ghana as described by Timberlake 1985, Mississippi Delta);
- Reduced fishing opportunities;
- Jeopardized shipping routes (e.g. Ganges River);
- Disappearance of ecologically and economically important wetlands or flood forests.

B – Around the groundwater wells

, Very often, groundwater is used for irrigation. In many regions, more groundwater is pumped than is naturally replenished. As a result, the groundwater levels drop and the cost of lifting the water becomes more and more expensive. Population groups who used to make modest use of the groundwater are being deprived of this resource and are left in a state of misery. Oases – places of natural groundwater supply in deserts – dry up.

Another disadvantage of excessive groundwater extraction is the subsidence of the land, as has occurred in the USA at a rate of 1 m for each 13 m that the water-table has been lowered (*Todd* 1980).

C - In the irrigated area itself

One of the most common negative side-effects of irrigation is soil degradation through water-logging and salinity. These problems are the cause of reduced yields, loss of land, and a higher incidence of water-borne diseases (malaria, bilharzias, filariasis; WHO 1983).

The problems of water-logging and salinity will be discussed in more detail in the following section of this article.

D – To the "beneficiaries"

Very often, irrigation projects are not beneficial to the people in the project area. Carruthers (1982) described a study of Philippine small-scale irrigation in which an increase of agricultural production is correlated with reduced farm incomes and impoverishment. The reason is that the enforced irrigation of high-yielding crops needs high inputs from the farming communities, which are not offset by an increase in farm income. Further, the intensification of irrigated farming requires so much labour from the farmer's family that they no longer have time for the traditional off-farm jobs that used to generate additional farm income.

Similar developments were the reason for *Barnett* (1977) to write his book on irrigation in Sudan: "Gezira, an illusion of Development", and for *Lipton* (1977) to write the book "Why poor people stay poor", an account of farmland incomes being drained to the cities.

Kortenhorst (1984) reports that land and water developments for one socio-cultural group can be at the expense of the farming system of another. *Oosterbaan* (1982) described how modern interferences in water resources (e.g. by the development of tube-wells or small dams) can be at the expense of the original farming communities or nomadic groups, sometimes giving rise to fierce tribal disputes.

3. Water-logging and Salinity

Causes of water-logging

Water-logging can be an acute problem, not only in flat land, but also in land with considerable topographic differences.

In flat lands, water-logging is the result of local losses of irrigation water, due to leakage from canals and above all of percolation from the irrigated fields in the absence of sufficient natural drainage capacity of the aquifer. These waters add to the groundwater reservoir, thereby raising the water-table (Figure 2).

In the Indus Plains in Pakistan, more than 3 million of water-logged lands have been provided with tube-wells and drains at the cost of billions of rupees, but the reclamation objectives were only partially achieved (*Bhatti* 1987).

In the Nile Delta of Egypt, drainage is being installed in millions of hectares to combat the water-logging resulting from the introduction of massive perennial irrigation after completion of the High Dam at Assuan (*Abdel-Dayem* 1987).

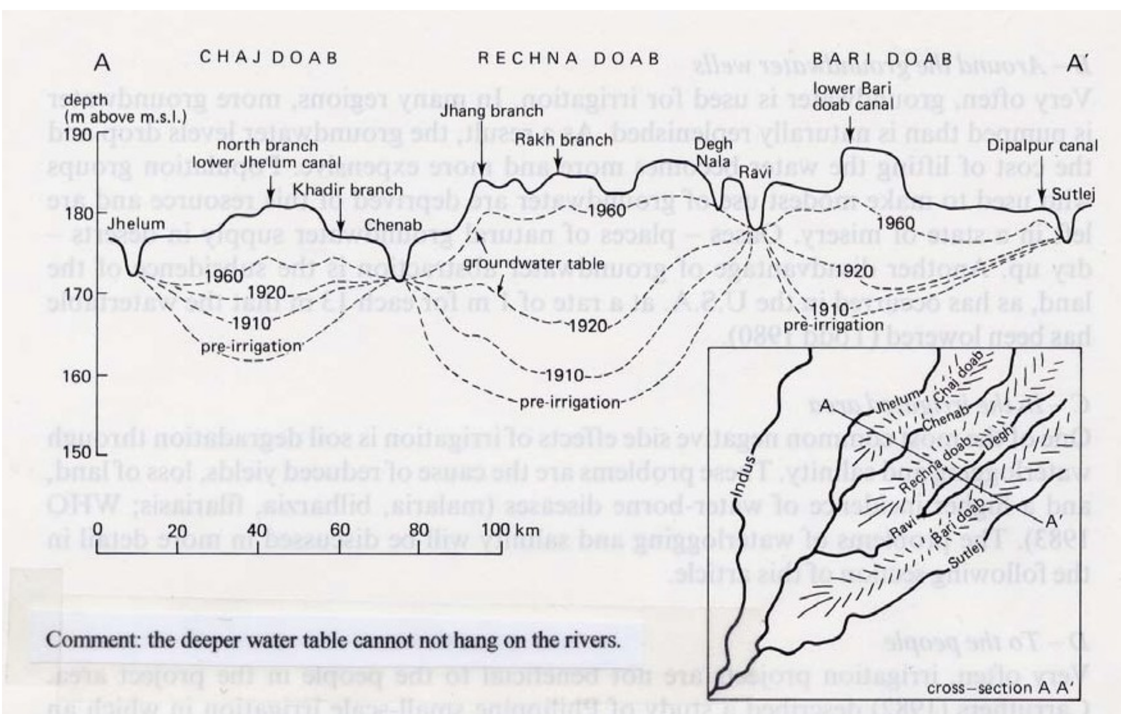

Figure 2 Groundwatertable profiles in Punjab, north-east Pakistan (Bhatti 1987)

(Comment in the figure by Oosterbaan)

In lands with considerable topographic differences, water-logging occurs mainly in the depressions, valley bottoms, or at the foot of slopes. It is caused by the inflow of groundwater resulting from irrigation losses in higher-lying areas.

This occurs for example in the Nile Delta where it borders the higher desert sand irrigated from the West Nubariya, Nasser, and Ismailiya Canals.

Similarly, in the many river valleys and deltas at the western foot of the Andes along the coast of the Pacific Ocean, more than 30% of the agricultural land is affected by water-logging and salinity due to irrigation of the higher-lying lands (*de la Torre* 1987).

Causes of salinity

Salinity develops in (semi)arid regions, simultaneously with water-logging. As long as the water-table remains deep, the salts, imported with the irrigation water (in the order of 0.5 to 2 tons per ha per year), are washed down to the deeper soils with the percolation losses of irrigation water. If the water-table becomes shallow, however, excess irrigation can no longer take place, otherwise the land would become flooded with stagnant water. Hence, salt leaching no longer occurs, and the salts brought in with the irrigation water accumulate in the root-zone.

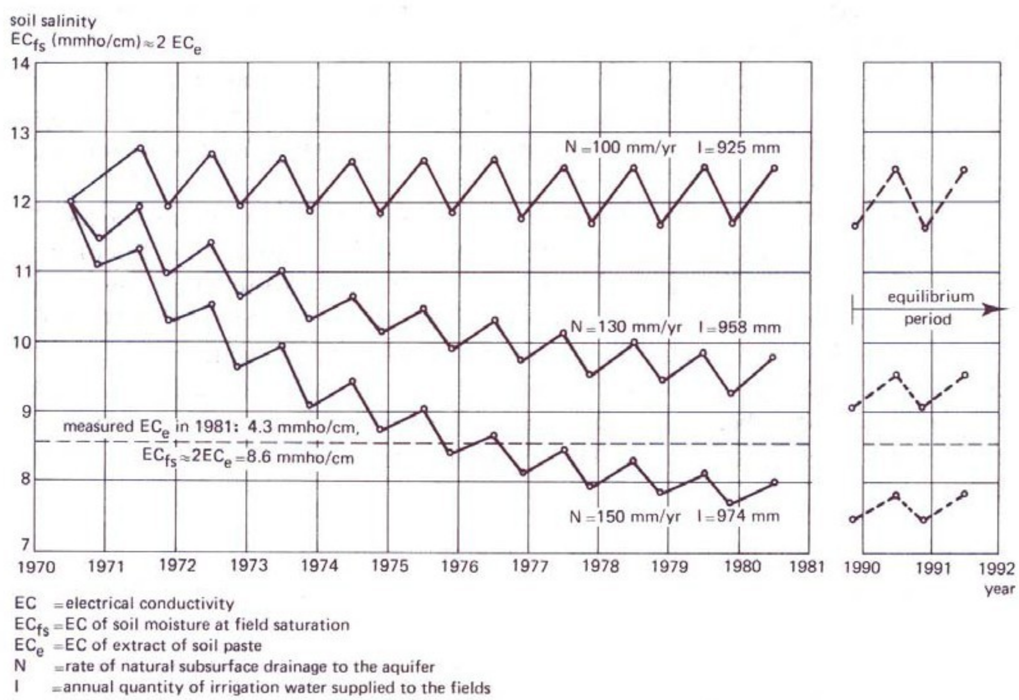

Figure 3 Simulation of soil salinity as a function of time and rate of natural drainage to the aquifer in a pilot area in the Nile Delta

Figure 3 shows the results of the simulation of a situation encountered in the Nile Delta of Egypt. The simulation was done with a predictive salinity model, SaltMod, currently being developed at ILRI. It shows that even if the natural subsurface drainage to the aquifer is in the order of 100 mm/year, the salt balance of the topsoil cannot be maintained at a low enough level to be safe for crop production. The figure also shows that, at low rates of natural drainage to the underground, the quantity of applied irrigation water is reduced, otherwise the water-table becomes too shallow. Hence, the amount of irrigation water is insufficient for proper leaching of the soil.

A salinity problem becomes worse when irrigation losses from elsewhere are entering lower lying areas as groundwater flow (figure 4, right-hand side). The already salty percolation water in the higher land picks up more salts on the way, and the groundwater, upon reaching the topsoil in the lower land, evaporates leaving the salts behind.

Groundwater flow also plays a role in the salinization of flat land by redistributing the salts from irrigated to un-irrigated field (Figure 4, left-hand side). Submerged rice fields in relatively permeable soils aggravate the problem of excess groundwater (figure 4).

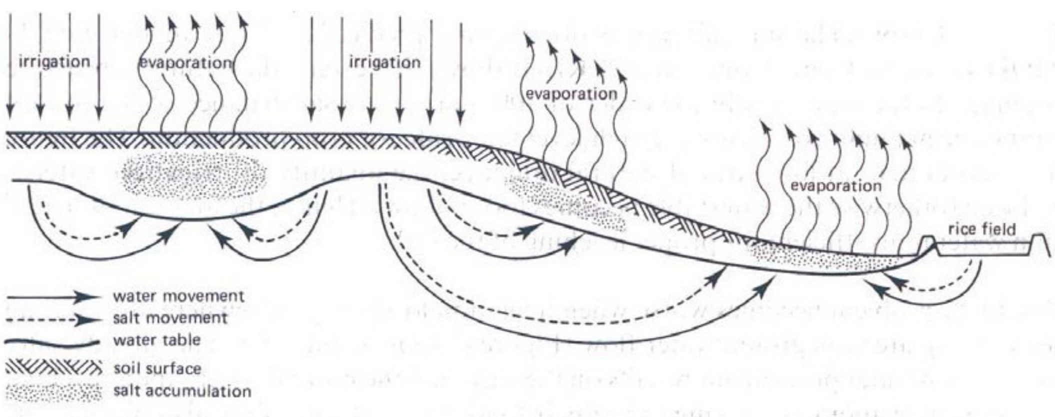

Figure 4 Water and salt movement in irrigated and surrounding lands

FAO has estimated that by 1990 about 52 x 106 ha of irrigated land will need to have improved drainage systems installed, much of it subsurface drainage to control salinity (United Nations 1977). Thus, the additional costs for salinity control in irrigation projects are considerable. In new irrigation developments, it is better to take these costs into account from the outset.

Disposal of saline drainage water

The artificial or natural discharge of saline groundwater – if not transported to the ocean – increases the salt load of the environment. The Colorado River in California (USA.), for example, has become so salty that expensive measures have to be taken to prevent brackish water from entering Mexico (*El-Ashry* 1980). Another example is the salt concentration in the Murray River (Victoria, Australia) which, as a result of irrigated agriculture, has increased from less than 0.2 g/l at its upstream end to almost 0.8 g/l (EC= 1.3 mmho/cm or dS/m) downstream (*O'Brien* 1983).

An example of ecological damage due to drainage water is found in the Ketterson Reservoir, San Joaquim Valley, California, USA. There, selenium carried by drains into the reservoir causes a high incidence of mortality among waterfowl (*Ohlendorf* et al. as quoted by *Westcot* 1987).

In Pakistan, the huge, recently constructed left-bank outfall drain (Sindh Province) has started discharging the salty water from the inland into the Arabian Sea. I contrast, the State of Haryana (India) has only a limited outlet for its drainage water so that a solution to the ever increasing salinity problem is difficult to find (*HSMITC* 1984). The Haryana authorities are considering the re-use of drainage water, which will be mixed with fresh irrigation water. Such practices, however, will not resolve the salinity problem in the long run, because the imprt of salt with the irrigation water continues, whereas export does not take place. One can say: "*Dilution is no solution to pollution.*"

4. Problems in the Management of Irrigation Water

In many irrigation projects, the timely provision of adequate quantities of irrigation water to the farm or to groups of farms (the tertiary unit) leaves much to be desired, causing impoverishment of part of the farming population. Figure 5 shows the inequitable water distribution to branches of El-Mansuriyah Canal in Egypt's Nile Delta. It is seen that some branches receive only 1000 m^3 of water per *feddan* (1 *feddan* is 0.4 ha) over 5 months (March to July), whereas other branches receive 3 times as much. One branch even gets 4500 m^3 (*EWUP* 1984).

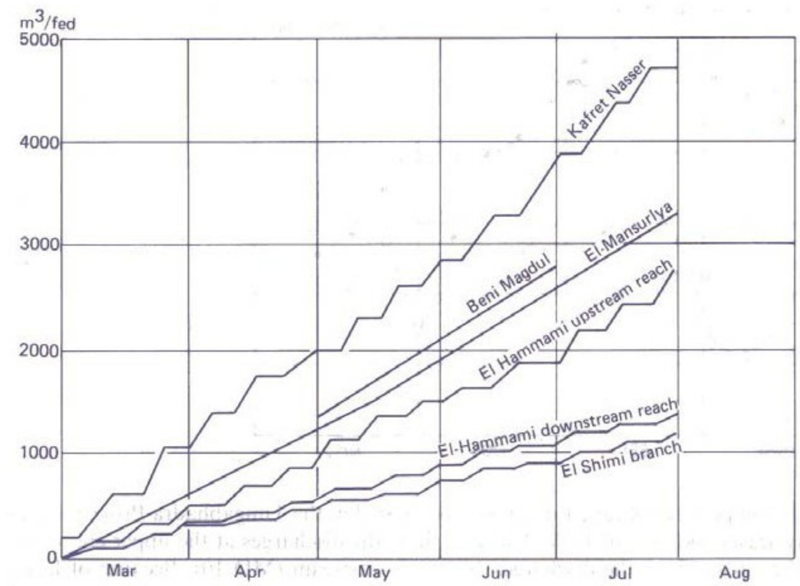

Figure 5 Inequitable water distribution to branches of El-Mansuriya Irrigation Canal, Nile Delta, Egypt (EWUP 1984)

Another example, stemming from the large Tungabhadra Irrigation Project in Karnataka, India, shows the unequal distribution of water along the D36 Distributary Canal which is 40 km long and serves 18.000 ha (Figure 6). There is apparently a great head-tail distribution problem, despite the official policy of "protective irrigation". This policy stipulates that, when the amount of irrigation water available is not sufficient to irrigate 100 per cent of the project area, the water must be so distributed that each farmer can irrigate part of his land.

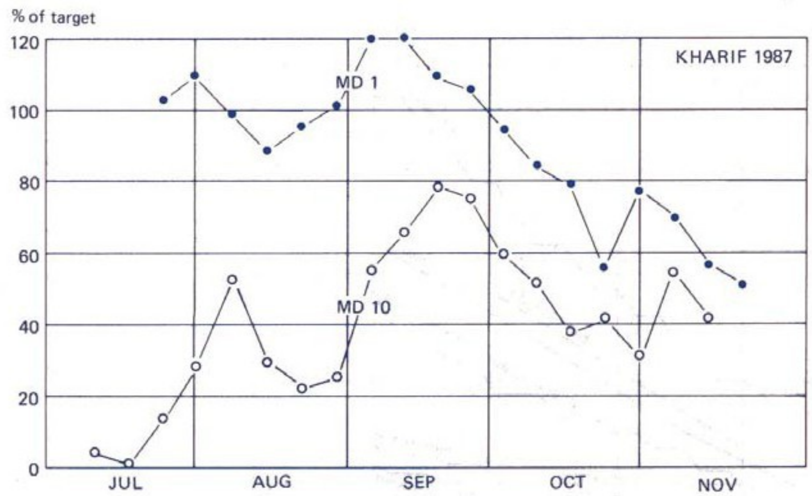

Figure 6 Actual discharges (in per cent of target discharge) of a canal in the Tungabhadra Project, India, during the rainy season (*Kharif*) of 1987. The dots show the discharges at the upper end of the canal (MD1); the circles show the discharges 10 km downstream (MD 10). Because of larger off-takes than intended in the upper part of the canal, the lower part of the canal carries much less water than intended, which results in tail-end scarcity of irrigation water (Jurriëns and Ramaiah 1989)

A deficient water supply in tube-well irrigation schemes in India is reported by the Center for Development Studies (*CDS* 1988). Funded by the World Bank, the hundreds of tube-wells installed in the State of Uttar Pradesh have operating periods varying from 1.4 to 4.7 hours a day, whereas they had been designed to operate 16 hours a day. Consequently the net irrigated area and the number of irrigations per field are much less than has been intended. CDS noted that the schemes follow a top-down approach, but that the irrigation engineers give little management support to the farmers. An atmosphere of hostility has developed. The report states: "*It is clearly shown that the delivery of water from the World Bank tube-well schemes has been both inadequate and irregular and the coverage in terms of net irrigated area has been rather depressing*". The report goes on to say that …. "*technological solutions without due regard being given to their organizational aspects is to indulge in rituals rather than work on a problem-solving strategy*".

It is without doubt that some authorities and constructors of the tube-well project, contrary to most farmers, did indeed collect a financial gain from the project.

In world literature, few data exist on the actual distribution of irrigation water over an area compared with the designed distribution. Even fewer data exist on the timeliness of the irrigation. In India and Pakistan, many farmers use too much irrigation water at the beginning of the season, because they are not sure whether they will get the necessary second and third irrigations. Often, crops have to be abandoned because the follow-up irrigations are not received on time. This signifies a waste of effort and inputs for them. It is clear that farmers facing insecure water supplies cannot afford any sizeable investments in their land or in their crops. Hence, not being able to contribute to the national economy, they remain in a deplorable state.

5. Example of Impact Assessment of and Irrigation and Flood-Control Project

In the lower Tana River Delta (Kenya) a large-scale flood-control and irrigation project (10.000 ha) has been prepared at feasibility level. It was the intention to establish a state enterprise for the highly mechanized production of rice at 175 per cent cropping intensity
75 yields per ha per year, almost double cropping). The area is currently used as rangeland, but there are also important bush-lands, riverain and flood-plain forests, as well as small-scale agricultural lands.

The decision to undertake the feasibility study was typically made "top-down". This meant that the problem analysis started from the national economy and government policies, from which it was concluded that rice production in Kenya had to be increased, that the Tana Delta offered possibilities for this national target, and that the project should be of the **state-enterprise type**: only one proprietor of both land and water under hierarchical management and with contracted labour.

On the matrix of interrelations between principal disciplines of irrigation projects (figure 7), the "to-down" approach looks like this:

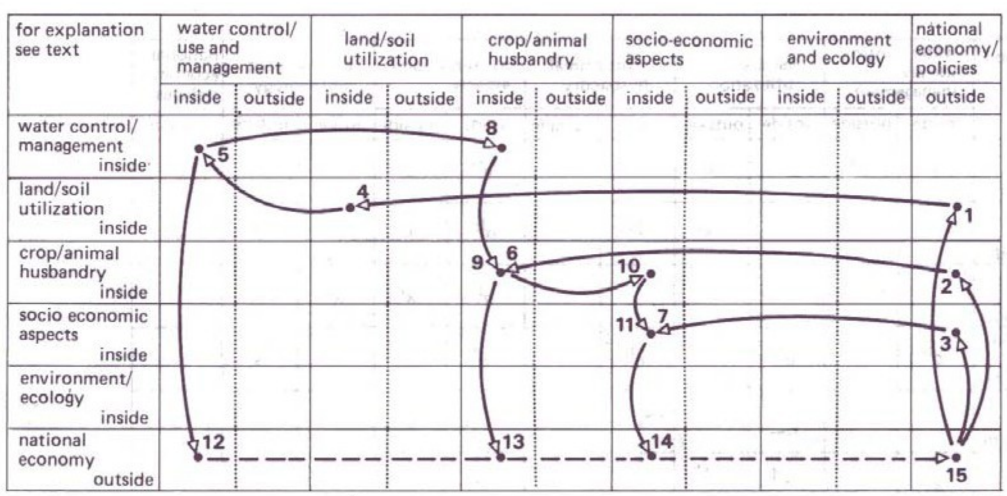

Figure 7 Example of a technocratic (top-down) approach to an irrigation project. The arrows indicate the sequence of actions and decisions

- The national policy decision fully determines the land/soil utilization type inside the project (Path 1: rice), as well as crop husbandry techniques (Path 2: double cropping), and the socio-economic management (Path 3: state enterprise);
- Starting from the desired land utilization type (Path 4), one studies the requirements of water control, use and management (Path 5);

- At the same time, detailed studies are made on crop husbandry and socio-economic needs (Paths 6 and 7 respectively);
- The interrelations between water management and cropping techniques are checked (Paths 8 and 9), and the later is also checked against the socio-economic management (Paths 10 and 11);
- The investments and recurring costs of the water management system, the benefits and recurring costs of the cropping system, and the socio-economic costs are evaluated in terms of national economic objectives and limitations (Paths 12, 13, and 14 respectively);
- Finally, the feasibility is evaluated at national policy level and decisions are made whether the proposed investments should be made or not (Path 15), or whether alternatives should be sought (Paths 1, 2, 3 etc.).

In contrast to the limited number of interrelations employed in the feasibility study, *EcoSystems* (1983) studied many more aspects of the proposed project, including its impacts on the outside environment.

Although EcoSystems did not study all the possible interrelations in Figure 7 (see Figure 8), the additional information they provided was sufficient to show that many present values of the Tana Delta (i.e. without the project) were high, but would be lost if the project were implemented. The losses to be expected (including those inflicted on the population currently utilizing the land but not gaining access to the project after its construction) considerably reduce the feasibility of the project and remedial measures would need to be taken into account. But also the feasibility of the project in a strict sense would be less than expected because of questionable data on the topography (and hence the hydrology) of the area, and probably an overestimate of the ability of the sate enterprise to obtain the predicted yields, as well as an under estimate of the management costs and constraints.

Further, EcoSystems makes a comparison between the Tana Delta Project and the Rajad Irrigation Scheme (Sudan), where the production costs (due to large-scale mechanization and frequent aerial spraying of pesticides) exceeded the returns from crop sales, leaving both the Rajad Corporation and its tenants in a poor financial state.

for explanation see text	water control/ use and management		land/soil utilization		crop/animal husbandry		socio-economic aspects		environment and ecology		national economy/ policies
	inside	outside	inside	outside	inside	outside	inside	outside	inside	outside	outside
water control/ management inside	x[a]	x[a]		x[c]			o[b]	x[c]		x[c]	x[d]
land/soil utilization inside				x[c]	x[e]		o[b]	x		x[c]	x[d]
crop/animal husbandry inside			x[e]				o[b]	x[e]	x[e]	x[e]	
socio economic aspects inside	o[b]		o[b]		o[b]		o[b]	o[f]		x	
environment/ ecology inside					x[e]			o[f]			o[f]
national economy outside	x[d]		x[d]						o[f]		

Figure 8 Interdisciplinary relations in the Tana Delta Project studied by Ecosystems (1983) in addition to those in Figure 7

x = studied in detail o = studied coarsely

(*Comment to figure 8: a study coming in the same category at the left hand and at the top concerns the relations within the category only*).

Some of the interdisciplinary relations indicated in Figure 8 have been given a reference letter (a to f) for further discussion below.

a - Impact of the water control measures on the hydrology of the environment

EcoSystems gave a great deal of attention to the reliability of the topographic data and the predicted hydrological situation after the implementation of the project. They question the reliability of the data and expect that, if the topographic data prove to be erroneous, the already high project costs would have to be even higher.

Further they fear that the intake structures for irrigation on the Tana River may cause a change in the course of the river. Other structures will perhaps not function as designed.

They also suggest that the omission of the designed large central drain would have no serious negative effects, but would represent a substantial saving in the development costs and would assist in the conservation of substantial areas of flood-plain forest.

Further they recommend the construction of a new embankment to avoid major changes in the course of the Tana River, because such changes would have widespread and severe effects on many of the human settlements in the delta, most of which depend on the river for their livelihood.

Finally they propose that the flood-drain inlet structures be reappraised to maintain and control "bank-full" conditions in the Tana River, which are of importance to traditional agricultural practices in the delta.

b - Managerial and socio-economic requirements of the project

The report of *EcoSystems* devotes relatively little attention to the managerial and socio-economic needs of the Tana Delta Project, but it does refer to the scarcity of qualified and motivated managers and technicians in the country, so that doubt arises about the efficient operation of the project as a state enterprise.

The report recommends the thorough investigation of alternative farming systems leading to ecologically well-balanced and sustainable agriculture, manageable by the locals.

c - Impact of water control measures on land-use opportunities and social economics

The Ecosystems report gives a detailed description of the reduction of grazing and fishing opportunities as a result of the project. The livestock pressure on the remaining lands will increase considerably, because the ousted traditional pastoralist tribes will have to see to their subsistence and existence elsewhere. It is feared that overgrazing will the increase, followed by serious erosion and the loss of natural resources.

The report also signals the loss of 1350 ha of forest, about half the delta's total. Consequently, the remaining forest will be overexploited to cover the fuel-wood and timber needs of the population.. It is foreseen that deforestation and erosion will follow, causing a further reduction of valuable natural resources.

A number of villages will suffer loss of agricultural lands and are at risk from agrochemicals that will be used in the project.

The report concludes that careful consideration should be given to the relocation of settlements and to the provision of new agricultural and grazing resources. Also fuel-wood plantations will have to be provided.

The water control structures as such are reported to be an impediment to the traditional canoe transport of the river and to fish migration. *EcoSystems* therefore suggests the construction of additional structures (e.g. small ship-locks and fish ladders) to overcome the impediments. These, of course, would add to the already high costs of the project.

d - The influence of the project on the national economy

The *EcoSystems* report gives limited attention to the excessive costs of the project in relation to other rice development opportunities in the country. Since the original feasibility report had already taken into account the livestock production lost by project implementation, the *EcoSystems* report only added losses from livestock production as a result of heavier grazing outside the project area. The costs and impact of additional measures deemed necessary to mitigate environmental impacts are not discussed extensively in the report. They are a politically sensitive issue.

e - The secondary effects of the crop husbandry inside the project

The intensive use of the land for mechanized rice cultivation (large-scale mono-culture) requires special cultivation techniques, including the application of biocides. EcoSystems fears negative side-effects of the biocides (especially herbicides, pesticides, and insecticides) on the water quality, on human health (both inside and outside the project), and on wildlife.

They are also worried about the development of biocide-resistant herbs and insects and the necessity of yearly intensification of the biocide spraying programs. A financial analysis of such secondary effects is not given in the report, but comparisons are made with similar problems elsewhere in the world where biocide treatments have increased ten-fold in the course of time. This leads to increased recurrent costs and a strong dependence on import of chemicals.

f - The relation between socio-economic aspects and national policies

The *EcoSystems* report pays relatively little attention to the technical organization of the Tana Delta Project and the participation of the local population within it. No relationships have been developed between the national responsibilities, the limitations of the natural resources, the negative environmental effects, and health care. The need of health care is felt because of expected bilharzia problems. Conclusions in these field have apparently been left to the government.

Impact of the impact assessment

As a result of the *EcoSystem*'s impact assessment study, it was decided that the original project plan would not be executed as designed. Perhaps the disappointing experiences with other irrigation projects in Kenya were also conducive to a more careful approach. (According to the *Kenya Times* of 22 January 1986, President Moi called the Bura Irrigation Scheme, further upstream of the Tana River, a "*disgrace*").

6. Summary, Conclusions, and Recommendations

The foregoing allows the following conclusions to be drawn:

- Many new irrigation projects have disappointing results;
- The disappointing results stem from overestimates of the benefits and underestimates of the costs, losses, and damages, in the light of the ever decreasing availability of good quality land and water resources;
- The benefits are often less than expected because many projects are initiated, implemented, and operated "top-down" without regard for:
  * Farmers' needs and motivations;
  * The discrepancy between national (urban) and rural development targets;
  * The scarcity of well-qualified and motivated managerial and technical staff;
- The direct costs are often higher than expected because:
  * The direct costs are underestimated for reasons of financing;
  * Not all direct costs are recognized or foreseen
  * The prevention of negative secondary effects requires unforeseen additional measures, which increase the direct costs;
- The secondary (environmental) costs, losses, and damages are higher than expected because they were not foreseen or taken into account.

Despite the many disappointing results, irrigation can be a central component in producing food for the world's growing population and in sustaining the livelihood of farmers. In the past many positive examples have been created. It is therefore vital that engineers and economists rehabilitate the reputation of irrigation by embarking on more effective irrigation projects - projects in which the give due attention to long-term social and environmental impacts.

Such an attitude requires a change in the current investment appraisal rules that make use of the notion "*net present value*", by which future costs and benefits are reduced by a discounting procedure. It can be argued that such discounting is only valid if the next generation is expected to be wealthier than the present (*Carruthers* 1988) and if the natural resources are yet unlimited (*Oosterbaan* 1985). Otherwise, the economic practice of regarding present income as being worth much more than future income leads to an over-exploitation of natural resources at the expense of later generations.

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