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IRRIGATION DEVELOPMENT, FOOD PRODUCTION AND THE STATE IN HISTORICAL PERSPECTIVE

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INTRODUCTION

This paper deals with irrigation policy. It attempts to review the manner in which **water** is being exploited in the pursuit of development objectives. By providing necessary factual background information on trends in resource development it is possible to better identify specific policy issues. With increasing attention being given to link Environment and Development in analytic and policy terms, it is necessary for social scientists to have a basic understanding of major substantive issues in natural resources exploitation. These are policy areas where natural scientists and engineers are dominant, but where a better dialogue with social science perspectives is much needed.

In an earlier paper[1] I reviewed the process of rivers being impounded for purposes of generating hydro-power and to facilitate water diversion for irrigation (Van de Laar, 1993). The emphasis was on the major long term environmental consequences of this trend, including the implications of irrigation for public health. The present paper tries to be largely complementary[2].

In the present paper I shall first review the link between irrigation development and agricultural production. It deliberately takes a rather long time horizon of some 40 years, for irrigation development is a long term policy, and irrigation investments have long planning and gestation periods. Moreover, irrigation development decisions often imply **irreversible** actions, so that one is stuck with the consequences of earlier investment decisions, regardless of whether evidence becomes available (sometimes much) later, which would call into question the wisdom of some initial strategic decisions.

Taking a longer term perspective in analysis also allows one to see major long term trends more clearly, and the major picture which emerges from the materials in Section 1, is that of the rise and fall of the major post-Second World War irrigation development boom period. In as far as the major advances in food production employing new High Yielding varieties (HYVs) of rice and wheat were conditional upon adequate water management, there is a clear link between the future of irrigation and the future of food supplies in major parts of the world. Therefore, the terms in which the discussion about the future of the world's food production will have to be framed should be different from similar discussions in the past, because one of the major sources of past growth of agricultural production will not be available to the same degree in the future. If the rate of growth of irrigated area continues to slow down, as is expected (Mohtadullah, in Feyen, 1992) future growth of food output will have to come predominantly from yield increases. However, the very productivity of irrigated land is increasingly threatened by salinization in many of the older irrigated areas

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[1] Aart van de Laar (1993), 'Water Development for Power and Irrigation, the Environment and Sustainable Development', ISS Working Paper Series No 141, February.

[2] CPR Discussion Note Nr 14, (December 1994), deals with: 'Irrigation Evaluation, Performance Measurement and Major Trade-offs between Production, Efficiency and Equity in Irrigation Investment Strategies'.

developed since the beginning of this century, and despite major investment programmes to combat the process in the last 20 years (Rydzewski, 1992).

Irrigation is inherently a conflict-ridden subject, and there is therefore a clear need to establish an appropriate analytical framework for the study of irrigation situations, which pays attention to the multiple conflicts and the choices which have to be made in irrigation development. The recognition of ubiquitous and persistent conflicts is crucial to understand the problematic character of any significant decision in irrigation policy at any level.

The thesis of Chamber's well-known book on Canal Irrigation is:

> 'that many past attempts to improve performance have failed because of defective analysis. In the past studies and recommendations for canal irrigation have been dominated by the normal professionalism of the irrigation professions, especially irrigation engineering and agronomy.....but neither is at all equipped, nor have irrigation engineers or agronomists often been inclined to look far beyond their disciplinary boundaries' (1988, p 27).

The specification of conflicts and elements for a more synthetic and eclectic analytical framework for the study of irrigation situations, is the subject of Section 2. It is a framework which allows for many different disciplines to fruitfully contribute to the analysis, and whereby analysts can more squarely confront each other, rather than occasionally meet tangentially.

Irrigation has been of interest to scholars in a multitude of disciplines. Unfortunately their framework of analysis, the questions asked and the aspects to be dealt with differ greatly and this implies that many of the studies on particular irrigation systems do not lend themselves easily to comparative analysis.

In general, there is surprisongly little information on the history of government irrigation policy, and virtually none of Irrigation Departments charged with irrigation development in different countries. At scheme, project or village level there is more, but here too the situation is far from satisfactory.

Coward and Levine (1986) review studies on farmer-managed irrigation systems. They distinguish: colonial compilations, anthropological field studies in an irrigation setting, irrigation ethnographies, and development-oriented irrigation studies. They characterize the completed research as:

1. heavily social-science oriented, where physical components of the hydraulic works and agronomic dimensions are presented as mere background.

2. nearly all are descriptive, and very few have been analytical.

3. nearly all have focused on the internal dynamics of the system under study, but have not placed these systems in the larger regional contexts in which they operate. These studies have thus not been able to inquire about the possible impact of external environmental, social, economic or political changes on these critical internal processes.

4. nearly all studies that have been concerned with the impact of government assistance on farmer-managed systems have examined short-term effects only. All external interventions have short-term des-orienting effects, but extending the impact period may modify initial judgements reached.

5. virtually all studies fail to discuss the bureaucratic characteristics and processes of the assisting agency. Hence, they cannot be useful to suggest improving such interventions.

6. research has not included a clearly articulated concept of the role of the state and its bureaucracies in national development. (Coward and Levine, 1986, p 9-10).

A consequence of the disjointed nature of available studies in irrigation is that policy recommendations emerging along different disciplinary lines are often contradictory, inapplicable or irrelevant as several disciplinary approaches base themselves on suppositions which are not relevant in irrigation situations[3]. In addition, little comparative analysis is possible on patterns of strengths and weaknesses in irrigation systems and in improving external interventions. Yet, such agencies as the World Bank, do not refrain from giving generalized policy prescriptions to all client countries and for all sectors.

There is a need for a better understanding of the historical experience in irrigation development and irrigation policy within a better analytical framework than has been done before, to improve the relevance and potential applicability of 'lessons from history' which might be drawn.

Attempts have been made to formulate cross-cultural hypotheses in respect of irrigation. Especially, assumptions have been made about the link between irrigation development and the role of the state, associated with the work of Wittfogel and Steward. But studies in this tradition have suffered from a number of shortcomings. Therefore, a feeble attempt is made, in Section 3 of the present paper, to interpret the historical pattern of irrigation development in different parts of Asia, where irrigation is crucial for development. It identifies some of the topographical, ecological, technical and social factors involved, and it highlights apparently different roles of government in this historical experience. This review is, necessarily, based on the few comparative studies which seem to exist at the present time.

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[3] For instance, neoclassical economists analyze the outcomes of competitive forces in a market economy setting. However, the preconditions for the proper functioning of market forces under the price mechanism are not fulfilled in common pool situations, and under conflicting legal property rights for water. This is analyzed in Discussion Note No 14, 1993. In a different vein: many studies and handbooks deal with irrigation engineering and construction designs, but irrigation is primarily about water management. Alternative technical designs have different implications for water management practices, and possibilities for forging effective water users organisations.

It is shown that there is much diversity in the Asian irrigation development experience, and within Asia one cannot easily draw valid comparisons between the experiences of different countries or sub-regions.

1 TRENDS IN IRRIGATION DEVELOPMENT AND FOOD PRODUCTION

1.1 Trends in food production and population growth.

There is by now considerable evidence that the high rates of growth in global food production, experienced since the early 1950s, have slowed down considerably during the 1980s. Contributing factors to this trend reversal are sharply declining growth rates of the major agricultural resources: grain-land area, irrigated area and fertilizer use. Grains dominate the energy requirement of mankind and soybeans is the world's leading protein crop. See Table 1.

Table 1: Growth in production of principal foods and in use of agricultural resources, 1950-1992.

Commodity/Resources	Rapid growth Years.	Annual rate (%)	Slow growth Years.	Annual rates (%)
Principal foods:				
Grain production	1950-84	+2.9	1984-92	+0.7
Soybean production	1950-80	+5.1	1980-92	+2.2
Meat production	1950-86	+3.4	1986-82	+2.0
World fish catch	1950-88	+4.0	1988-92	-0.8
Principal resources:				
Grain-land area	1950-81	+0.7	1981-92	-0.5
Irrigated area	1950-78	+2.8	1978-92	+1.2
Fertilizer use	1950-84	+6.7	1984-92	+0.7

Source: Brown, State of the World (1993), p 11

This slower growth in the principal agricultural resources has several causes. While new cropland is being added in some countries, it is being lost in others from land degradation or conversion to non-farm uses. The slowing down in the rate of expansion of irrigated areas reflects the reality that the scope for easy and cheap forms of new irrigation development seems to be coming to an end. This may have far-reaching consequences, because the reach and apparent success of the green revolution agricultural technologies since the mid-1960s was limited to and conditional upon adequate water management regimes facilitated by irrigation development. The turn-around in fertilizer use reflects decreasing physical returns to greater fertilizer use in some countries. In addition, economic policy changes, such as the elimination of fertilizer subsidies under structural adjustment programmes, reduces the profitability to farmers of fertilizer applications. Political upheaval in Africa and in the former Soviet block cannot but have negative effects on the broader policy environment affecting agricultural production in the years to come.

Trends in Africa are particularly worrisome, with North Africa shaping up as a major food deficit area. The figures for Sub-Saharan Africa hide sharply deteriorating resource conditions. Reduced levels of external inputs into agriculture increases the danger of nutrient losses in the soil. For instance, Stoorvogel & Smaling (1990) have analyzed trends in the nutrient balances in **Sub-Saharan Africa**, on the basis of the latest FAO's: World Agriculture: Toward 2000 study (Alexandratos, 1988). They conclude that nutrient depletion is quite severe in almost all 38 countries in their study. Nutrient depletion rates in East Africa are more than four times the average for SSA. The FAO projections resulted in an increase in nutrient depletion in all countries, particularly in the countries which already had a high depletion rate. Even the high increase in fertilizer consumption projected for the year 2000 by FAO did not help in lowering the depletion, as it is more than offset by increased nutrient withdrawal.

In addition to these directly measurable trends in agricultural resource use, there are the as yet not clearly identifiable and measurable effects of general environmental degradation on agricultural growth and productivity. These include the effects of loss of topsoil from erosion, air pollution, ozone depletion leading, through exposure to increased ultraviolet radiation impairing photosynthesis, to stunted plant growth, increased flooding due to deforestation, the depletion of aquifers, losses in genetic diversity of various crops and the threat of global warming.

The loss of momentum in food production growth, specifically the 6-percent decline in grain output per person between 1984 and 1992, is said to be perhaps the most disturbing economic trend in the world today (Brown, 1993, p 13). This slow-down in agricultural output growth, therefore, raises new concerns about the earth's capacity to feed a growing population. Self-sufficiency ratios appear to be declining in several continents, implying a growing need for international trade/aid in food. But this creates additional problems for the design of growth strategies and balance of payments management.

Trends in the self-sufficiency ratio's, defined as gross agricultural production divided by domestic use and excluding stock changes, is given in Table 2. The effects of the decline in food production since the mid-1980s cannot as yet be disaggregated.

Table 2: Self-sufficiency ratio's in agriculture (in %).

	1961/3	69/71	79/81	83/85
Developed countries	96.7	96.7	100.0	99.9
Market economies	95.7	95.7	103.8	102.6
North America	105.5	105.2	120.1	113.5
Western Europe	86.6	87.4	92.8	95.7
Others	102.5	98.4	97.3	95.5
European Centr. Plan. Economies	98.9	98.7	92.8	94.8
Developing countries (94)	106.6	105.7	100.3	101.1
Ibid. (excluding China)	109.8	107.5	101.2	101.4
Africa (SSA)	119.8	117.0	102.9	100.8
Near East/ N.Africa	100.9	97.4	80.1	75.6
Asia	100.9	101.9	99.5	102.0
Asia (excl.China)	103.7	102.8	100.8	103.5
Latin America	119.9	115.7	113.0	113.9
Low-income countries	101.0	102.0	98.2	100.3
(excl. China)	103.9	103.0	98.4	100.3
(excl. China,India)	111.0	106.0	100.8	99.5
Middle-income countries	114.9	111.1	103.2	102.3

Source: Alexandratos (1988), p 33, 38

In interpreting these figures it should be born in mind that such aggregate figures do not incorporate aspects of income distribution and unequal access to existing agricultural produce. Aggregate balances may therefore be consistent with worsening income distribution and/or deteriorating nutrition standards of segments of the population.

1.2 Trends in food production and irrigation development in Asia

The link between food production and irrigation development is of greatest importance for Asia. Asia accounts for 63 percent of the world's irrigated area as against 5 percent for Africa, and 4 percent in Latin America (Rosegrant and Svendsen, 1993, p 17, and Field, 1990). The proportion of cropped areas under irrigation, at some 34 percent in Asia, is three times as high as in North America and Europe, and one also finds large concentrations of the world's population in Asia (Field, 1990).

Irrigation contributes to agricultural production in basically three ways. First is the stabilization of harvest fluctuations, with attendant improvements in average yields, brought about through the provision of dependable water throughout the growing season. Second, in some circumstances improved control over available water resources may make a second or even a third crop possible. Finally, the availability of reliable water supplies makes it possible to use improved seeds, to introduce new farming techniques and to increase the use of chemical fertilizer, all of which require adequate water to supply large relative increases in productivity.

Trends in annual growth rates of area, production and yields for rice and wheat, the dominant irrigated crops in Asia, are shown in Table 3.

Table 3: Annual growth rates of area, production and yield for rice and wheat, Asia, 1957/59-1988/90

	1957/59-1965/67	1965/67-1973/75	1973/75-1981/83	1981/83-1988/90
RICE				
Area	0.85	1.09	0.24	0.25
Production	2.60	3.37	3.09	2.16
Yield	1.74	2.27	2.86	1.91
WHEAT				
Area	0.02	2.41	1.58	0.29
Production	6.24	6.46	5.99	2.96
Yield	6.22	4.07	4.41	2.69

Source: Rosegrant and Svendsen (1993), p 14.

Area expansion for **rice** virtually halted since the mid-1970s. Yield increases peaked in the late 1970s but fell sharply in the 1980s, to levels only slightly higher than those obtained before the introduction of the HYVs. The extraordinary yield growth for **wheat**, from the mid-1950s to the mid-1960s, could not be sustained and, here too, yield growth trends fell sharply in the 1980s, to levels less than half those obtained before the introduction of the HYVs.

More disaggregated data by country (groups) are given in Table 4. The contrasts between China and India in respect of rice are noteworthy.

In discussing these trends, Rosegrant and Svendsen note that sharp declines in world rice and wheat prices and increasing capital costs have resulted in reduced rates of investment for irrigation infrastructure; have led to a shift of land out of rice and wheat and into other crops; and have reduced the rates of increase in input use. At the same time, increased intensity of farming, particularly in irrigated areas, has led to diminishing marginal returns to increased input use, and has caused degradation of land in some areas.

Table 4: **Annual growth rates of area and yield for rice and wheat, Asian country groups, 1957/59-1988/90**

	1957/59-1965/67	1965/67-1973/75	1973/75-1981/83	1981/83-1988/90
RICE				
Southeast Asia				
Area	1.73	0.35	1.51	0.72
Yield	1.46	2.94	3.22	1.57
South Asia				
Area	1.26	0.61	0.88	0.25
Yield	1.89	1.02	1.71	2.03
China				
Area	-0.58	2.25	-1.07	-0.38
Yield	3.21	1.68	4.06	1.63
India				
Area	1.21	0.74	0.46	0.34
Yield	0.74	2.15	1.57	3.23
WHEAT				
Southeast Asia				
Area	7.93	-3.72	4.48	2.04
Yield	0.36	4.63	-0.77	2.79
South Asia				
Area	1.88	1.65	3.36	1.03
Yield	-0.35	5.03	3.19	1.06
China				
Area	0.24	1.19	0.62	0.31
Yield	11.49	4.25	5.66	2.88
India				
Area	-0.93	5.26	2.56	0.13
Yield	0.97	4.89	3.47	2.92

Source: Rosegrant and Svendsen (1993), p 14

For instance. Although individual projects vary widely, the range of capital costs per hectare irrigated by new large surface water projects for Asian countries for which data are available

(India, Bangladesh, Pakistan, Thailand, Indonesia, Nepal, and the Philippines) in the mid-1980s, is $1,500 to $4,000 per hectare. In other countries, capital cost tend to be considerably higher: in the vicinity of $10,000 in Mexico, South Korea, and much of Sub-Saharan Africa. These figures typically do not include the costs of mitigating or avoiding environmental hazards; resettling displaced communities and providing adequate drainage, in particular, can add very substantially to project costs.

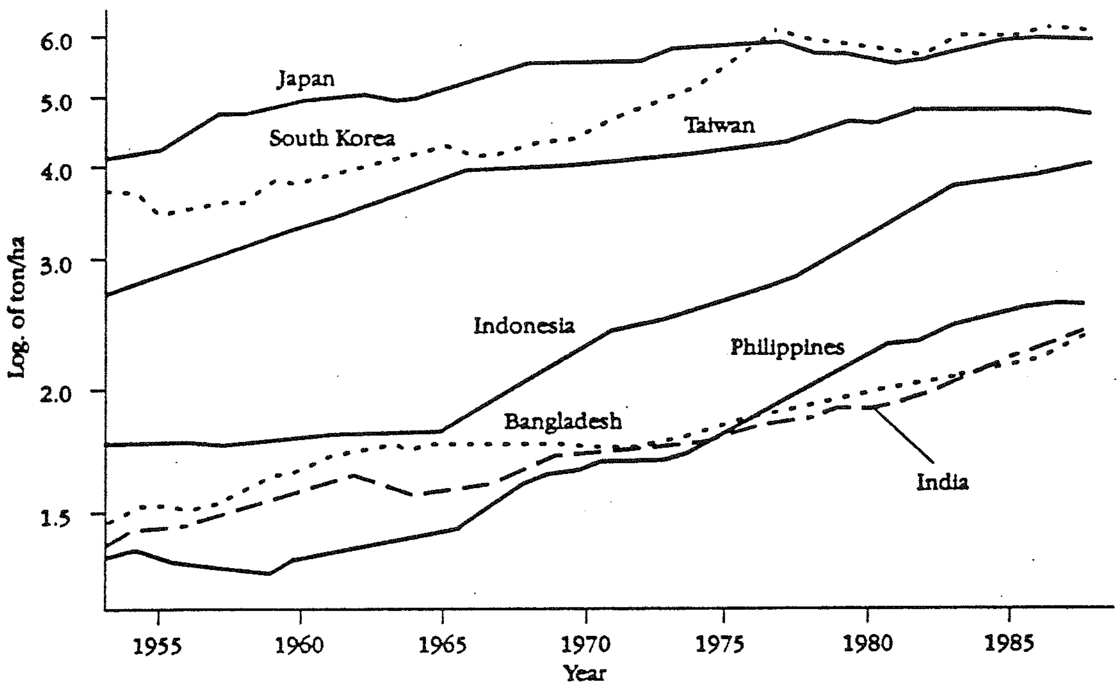
With these price tags, investments in irrigation are difficult to justify if benefits are projected on the basis of current experience. The high cereals prices of the early 1970s, which were incorporated into future price projections that inflated estimated benefits, have fallen since by 50 percent in real terms. At mid-1980 prices, simulations of typical irrigation projects in rice-growing Asia show that to provide a 10-percent discounted rate of return on investment costs of $3,000 per hectare, production increases of over 3 tons per hectare are needed. This is well in excess of what has been achieved, on average, in most large public irrigation systems in Asia (Repetto, 1986, p 7).

What are the implications of the changes in productivity growth for rice and wheat and parallel changes in irrigation investment patterns for future irrigation investment and management policies? As could be expected there are sharp differences of opinion as to the relative importance of the various factors which have contributed to the slow down in productivity growth in many parts of Asia, with quite different implications for irrigation investment policies.

The **optimistic scenario** assumes that rapid crop productivity growth is still possible. It ascribes the recent slow down as appropriate responses to changes in relative prices and government reforms, and assumes that growth in food grain production can be sustained through normal technological improvements. Adherents point at good performance in some countries, such as India or Bangladesh or to fast growing regions within countries as indicating apparently still existing and exploitable yield gaps (Byerlee, 1992. p 485-6)
Yield trends for rice are given in Fig 1, and on yield gaps within the Punjab and in India in Fig 2.

Fig. 1 : Rice Yields per hectare, select Asian countries

Rice Yields per Hectare Harvested for Selected Asian Countries, Five-Year Moving Averages, 1953-88



Source: IRRI 1990.

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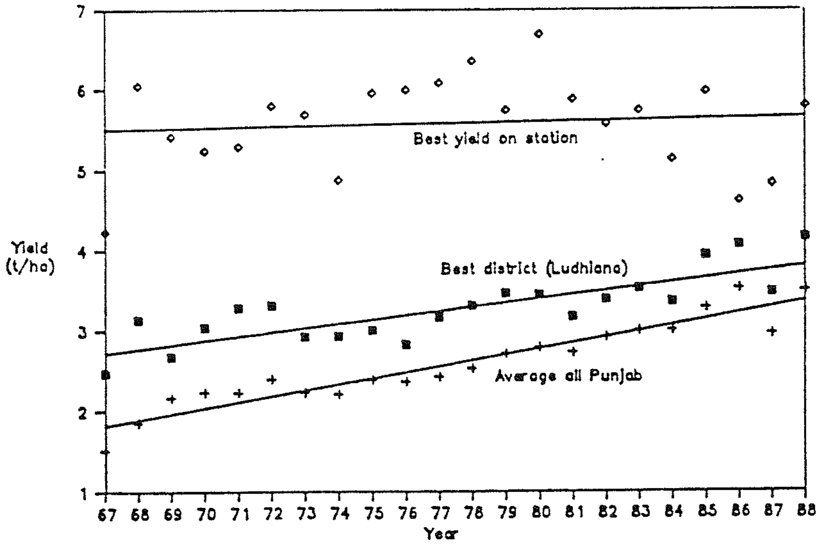
Fig. 2 : Farmer yields and potential yield of wheat, Punjab, India.



Source: Punjab Agricultural University

The **pessimistic scenario** foresees only slow productivity growth. The sharp drop in irrigation investments, together with other technological constraints, raises serious questions whether desired levels of food grain production can be maintained. The full impact of the slow down in the rate of irrigation investment in the 1980s will be felt most strongly in the 1990s, further exacerbating the slow down in irrigated area development and yield growth. Adherents of this view have less faith in the possibility to accelerate yield through agricultural technology-based growth, and point at the long gestation periods for new irrigation investments to come to fruition as a source for new agricultural output growth.

1.3 Trends in irrigation development and investment

It has been estimated that by 1900 the area under irrigation in the world was some 40 million ha, five times that a century earlier. By 1950 the area had extended to about 100 million ha and in 1986, it is estimated that the gross area under irrigation amounted to 253 million ha. Almost two thirds of this area (162 million ha) is located in just five countries: India (56 mln ha), China (46 mln ha), USA (23 mln ha), USSR (21 mln ha) and Pakistan (16 mln ha). Next, we find countries: Indonesia, Iran, Mexico, Iraq, Spain, Turkey, Thailand, Egypt, Italy, Rumania and Japan, with irrigated areas ranging from 7.3 to 3 million ha. A further 17 countries have irrigated areas of between 2.7 and 1 million ha. This group includes the country with the largest irrigated area in Sub-saharan Africa: Sudan, with 2.2 million ha (Field, 1990).

The pattern of growth in **irrigated area** within **Asia** since 1960 is shown in Table 5. It shows a sharp decline in the 1980s.

Table 5: Average annual growth rate (%) of irrigated agricultural area in Asia, **1960-88**

	Total	S.Asia	S.E.Asia	E.Asia
1960-88	1.7	1.9	2.7	1.1
1960-65	2.0	1.8	1.6	2.2
1965-70	2.5	2.9	1.2	2.4
1970-75	2.0	1.8	2.8	2.1
1975-80	2.0	2.8	3.6	1.2
1980-85	1.2	1.8	4.1	-0.3
1985-88	0.4	0.1	1.5	0.3

Source: Rosegrant and Svendsen (1993), p 18.

It should not be assumed that all these irrigated and thus high potential areas are also productive agricultural lands. Estimates of annual global losses of agricultural land due to waterlogging and salinization range from lower estimates in the range of 160-300 000 ha to high estimates of 1.5 million ha. Global estimates of the total area affected by salinity but still in production also vary considerably: from 20-30 million seriously affected to 30-46 million affected by salinity in the late 1980s[4].

Surface water quality varies enormously. For instance, salinity levels in rivers supplying irrigation waters vary but tend to increase over time, as rivers are important 'sewers' for riverain development: total Dissolved Salts (TDS) in mg/l ranges from 60-80 for the Niger, 174 for the White Nile to 250-300 for the Indus. Water having TDS-values above 500 are classified as saline water. Bringing already saline water onto the land will lead to further salinization in the irrigated cropping areas.

Corrective action through the provision of drainage facilities is possible, but these investments pass the economic viability test only when crop yields, though reduced, are at a high level (e.g. cereal: 6-8 tons/ha). With much lower yields typical of developing countries, social and environmental (sustainability) criteria have to be invoked in their defense (Rydzewski, 1992, p 25).

Estimates of irrigated land damaged by salinization are given in Table 6.

Table 6: **Irrigated land damaged by salinization, top five irrigators in the world, estimate mid-1980s.**

Country	Area Damaged (million hectares)	Share of irrigated land damaged (%).
India	20.0	36
China	7.0	15
United States	5.2	27
Pakistan	3.2	20
Soviet Union	2.5	12
Total	**37.9**	**24**
World	60.2	24

Source: Rydzewski (1992), p 25.

Hence a three-pronged long term effort is needed: to increase water application efficiency at field level, reduce drainage costs and a major effort in plant breeding for salt resistance, in addition to such traditional criteria as yields, taste, pest and disease resistance.

Reductions in **irrigation investment** have been dramatic. Aggregate lending and assistance for irrigation by the four major donor agencies (World Bank, Asian Development Bank, USAID and the Overseas Economic Cooperation Fund of Japan) in Asia and the Middle East/North Africa in the 1970s and 1980s reached its peak in real terms in 1977-79, and by the mid-1980s it was less than 50 percent of the 1977/79 level. Total domestic and foreign irrigation investment expenditures for individual countries in Asia showed similar declines

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[4] For more information on environmental effects in irrigated agriculture, see Van de Laar (1993).

in rates of investment in irrigation during the period (Bhuiyan, 1989 based on Levine et.al. 1988; Barker et.al.,1984, Rosegrant and Svendsen, 1993).

The decline in irrigation investments, no doubt, also reflects the impact of a series of evaluative reports of past irrigation investments. As is so often the case with evaluation studies -- which came to be widely introduced for development assistance efforts since the early 1970s -- many of these reports tended to be rather critical of irrigation investments, though the analysis in these reports is often rather general, and often do not extend much beyond the investment stage of irrigation projects[5].

Early examples of published evaluation studies on the irrigation sector are contained in Widstrand (1978) for UNEP, Carruthers (1983) for the OECD countries, Steinberg et.al (1983) for USAID, Van Steekelenburg and Zijlstra (1985) for the EDF. More recently studies have appeared concerning irrigation in **Africa**, which repeat many of the earlier general criticisms: Moris and Thom (1990) for USAID, Aviron Violet et.al. (1991) for the OECD/Club du Sahel, Barghouti and LeMoigne of the World Bank (1990).

According to Harrison (1987, p 157), the expansion of irrigation in Africa has now probably reached a standstill, where new land coming under irrigation barely balances the losses of irrigated lands through deterioration.

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[5] More on this in Discussion Note no 13 [under preparation].

2 CONFLICTS IN IRRIGATION AND THE NEED FOR AN APPROPRIATE ANALYTICAL FRAMEWORK.

2.1 Water development and irrigation as an arena of multiple conflicts

There is a vast gap between the development of irrigation technology and the real world. Ever more complex hydraulic systems are being designed in research laboratories, with elaborate control structures, regulatory devices and complex cybernetic feedback systems to manipulate the flow of water through conveyance systems from the initial source to the plant root zone. With laser technology land levelling can be made near perfect such as to minimize the amount of water that is needed in irrigation. Crop-water requirements in different stages of the growing season can be calculated from controlled experiments, and seepage coefficients and evaporation losses can also be derived from experimental studies. Water use can be precisely regulated in drip irrigation and sprinkler systems. Computer technology is increasingly employed to design structures and to calculate complex water delivery scheduling rosters.

But two questions arise: (i) how do these technical advances relate to the reality of irrigation in the great majority of irrigation system existing in developing countries; and (ii) what is the contribution of the undoubted technological advances to the improvement in overall irrigation system efficiency in practice?

Levine (1977, 1980) has noted that:

1. Our knowledge of the interrelationships between water and plant growth far exceeds our knowledge of the interrelations between water and the human element in delivery and utilization.

2. The efficiency concepts used in irrigation system design tend to underemphasize the human component as a factor in water-use crop production.

3. Irrigation systems, on the one hand, and the farmers they serve, on the other, have criteria of optimal efficiencies of water use which may not coincide. When they are far apart there is friction between the system and the farmers and/or among farmers.

4. Within the resources available to the farmers and to the system, the operational optima can be brought closer together by effective liaison, e.g. feed-back and response mechanisms.

The developments in irrigation engineering theory as sketched above, seem to be inspired by what is technologically possible. The sophistication in technical designs and water scheduling, however, require also highly centralized control systems, as variations in water use in some parts have immediate repercussions everywhere in the integrated water system.

In irrigation practice, the amount of water to be delivered by an irrigation system to the 'outlet' exceeds by far the amounts calculated to be needed for land preparation, percolation and seepage, and evapotranspiration. Using examples from Southeast Asia, Philippines, Malaysia and Taiwan, Levine finds figures as stylized in Fig. 3. These differences reflect differences in technical irrigation designs, but the greater part of the differences reflect the impact of the human factor, not as a machine operator in an automated factory following the operating instructions for the 'irrigation machine', but as an independent decision maker in respect of water use in irrigation. To reduce that gap between actual water use and theoretical irrigation water requirements seems to be the central question in improving irrigation system performance under field conditions.

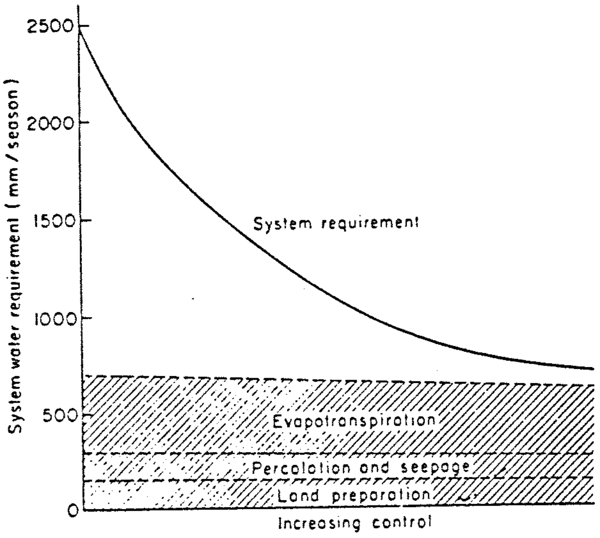

Figure 3. Irrigation water requirement for lowland rice as affected by the level of control inputs.

This paper is not concerned with advances in irrigation engineering (such as Rydzewski, 1987, Rydzewski and Ward, 1989, Feyen et.al. 1992), but attempts to look at the real world of irrigation in developing countries. This reality of water resources and irrigation development inevitable is a multifaceted and very complex process, extending over long time periods. Criticisms of the outcome can be directed at every stage of the process from initial planning, to design, construction and system operation. Criticisms can also be formulated from different disciplinary and ideological perspectives.

It is not always clear ,whether the 'fault' lies: in the irrigation design process, in the responsible irrigation department, or in the external social, economic or political environment. Consider the following range of common criticisms from field visits, levied at irrigation development and performance, and from the perspective of an Irrigation Department which only has responsibility for the main canal system[6]:

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[6] See Ali (1981) on the situation in Andra Pradesh. Many of the same points can be found in most of the critical irrigation evaluations cited above.

(a) **Engineering.** Defects in outlets (pipes): Not fixed, fixed in wrong place, or defunct; water flowing below the vent; unauthorised pipes, broken pipes, or open cuts widened by upper end farmers.

(b) **Insufficient supplies**: high seepage in the canals; silting; minors incapable of drawing design discharge; design discharge not released due to weak bunds.

(c) **Insufficient controls**: no control structures for nearly all minors and many majors in the canal system; measurement devices not used; wrong creation of minor off-takes; insufficient capacities at off-takes; irregular and untimely supplies.

(d) **Field channels**: Not excavated, or not fully extended over the command area; open cuts without structures or drops; no culverts over field channels crossing cart tracks; constructed but damaged; inadequately dimensioned channels; rapid flows causing erosion; ramps at crossings not provided; improper alignments; insufficient drops and distribution boxes.

(e) **Lands not getting water**: uncommandable areas localised; unauthorised cropping patterns; leaking systems; weeds in canals and desilting not done; majors and minors inadequately excavated to take design discharges.

(f) **Water logging**: due to heavy seepage. or due to unauthorised conversions of dry to wet crops in the upper reaches.

Only the shortcomings in categories (a) to (c) would seem to be under the direct responsibility of the Irrigation Department. The other categories of problems would seem to fall within the domain of farmers responsibilities and action, on government policies or on changing market processes. Moreover, different disciplines would look at select aspects of irrigation development within their direct professional interest (see below).

Criticisms of irrigation can also be seen from different scales, leading to sometimes different judgements. For instance, irrigation hydrologists frequently point at low water efficiencies at project or scheme level, where only a small proportions of the gross water supplied from source reaches the plant root zone. To illustrate the effects of a change in the scale of evaluation, consider the following:

The overall or project water efficiency (Ep) is defined as follows:

$$Ep = Ec * Ed * Ea$$

in which: Ec = conveyance efficiency,
Ed = distribution efficiency (within tertiary unit),
Ea = field application efficiency.

The coefficients are to be seen as the ratio between the water volume which reaches the end of the stage (output), relative to the volume of water supplied at the beginning of the system phase (input). Empirical values for the coefficients have been established in a world wide survey in the early 1970s (Bos and Nugteren, 1974, 2nd ed.1982), with variations depending upon soil conditions and on such factors as whether canals are lined or not. In general, low values were found for the coefficients, and such figures are often used to criticize irrigation performance.

However, it should not be assumed that increasing water use efficiencies is either cheap or organizationally easy, and major changes may not be technically and economically feasible. Moreover, the analysis of irrigation efficiencies is usually limited to individual irrigation projects. More recently, one tends to look at water losses in the wider river basin context, with the result that overall efficiencies are judged to be much higher, as downstream users usually rely on the return flows from upstream diverters for their operations (Frederiksen, 1992a, p 27-29, 33). Consequently, water use efficiencies show different values when different measuring points are observed, and the differences are less dramatic than initially asserted.

Table 7: Water-use efficiencies, in the USA and developing countries

					Point of evaluation			
Category	User		Delivery		Scheme		Sector	
of use	US	DevC	US	DevC	US	DevC	US	DevC
Irrigation	53	40	78	68	41	28	87	85
Urban	15	60	85	40	13	25 60	45- 70	30- ...
Industrial	16	na	na	na	na	na	na	na

Source: Frederiksen (1992a), p 33

Agronomists see low cropping intensities and lower than anticipated yields. Economists complain about cost overruns and disappointing rates of return on irrigation investments. Social scientists see social and economic inequities inherent in irrigation development, depending upon whether farmers have access to irrigation or not, and see differences enhanced by the locational position of farmers along the canal system. Some judge the provision of irrigation as a means to overcome other forms of inequity arising from inequity in land ownership, but such objectives may have been incompatible with the original design criteria (See for instance the rebuttal of Malhotra (1982) to the original criticism of Reidinger (1974, 1980 of the *warabandi* system of water distribution in Northern India). Others, such as geographers, point at the effects of using water in concentrated form in compact irrigated areas, for the displacement of people upstream in the dam lake area (often indigenous, tribal peoples) and/or downstream where the land previously intensively used by local populations loses its productivity (Van de Laar, 1993, p 58 for examples). Public administrators and management experts are surprised by the lack of accountability of those in charge of irrigation development. Political economists see irrigation as the vehicle for the expansion of state influence and the imposition of state power over autonomous and self-reliant rural communities. Others, such as political scientists see the contracts for large schemes in public sector irrigation investment projects as a major 'pork barrel' to be plundered to enhance local political and economic power. Though 'improvements' or 'changes' in each one of these areas might be possible in principle, each proposal will have its own associated costs and benefits -- in the technical, economic, social and political sense -- and moreover may only be brought about by different institutional arrangements.

Faced with such a vast array of criticisms, how can anything in irrigation possibly go right? What would be an appropriate evaluation framework for the assessment of irrigation projects? Do the social and political aspects overwhelm irrigation engineering?

The utilization of surface water resources in irrigation development involves finding workable and thereby sustainable solutions to a whole range of actual or potential conflicts. Water is perhaps the most typical common pool natural resource. Individual actions affect all other water users and thus effective collective action is required for the management of water resources[7]. It may therefore be useful to first spell out the many types of conflicts.

Conflicts surrounding water and water development policies through irrigation can be classified in a **hierarchical setting** (Widstrand, 1980).

(a) Conflicts over international rivers.

A United Nations inventory of river basins shared by two or more countries showed that there are 214 such basins. The complexities which this entail may be indicated by the following Table.

Table 8. **International rivers distributed in terms of number of countries sharing the same river basin.**

Nr. of riparian countries.	Total nr of rivers.	Name of rivers shared by 5 or more countries
2	155	
3	36	
4	10	
5	3	La Plata, Elbe, Ganges and Brahmaputra.
6	3	Volta, Nelson, Amazon,
7	1	Lake Chad.
8	2	Zambezi, Rhine.
9	2	Nile, Congo.
10	1	Niger.
12	1	Danube.

Source: Widstrand (1980), p 125.

The exploitation of many river basins requires cooperation between states, and it can be expected that the problems of finding mutually acceptable solutions may be directly related to the number of parties involved. Inequality in the strength of some states in the bargaining

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[7] For a general theoretical discussion of concepts, problems and issues for the management of common pool natural resources, see Van de Laar (1990). The joint-use characteristics of irrigation below the outlet in the tertiary fields are not explicitly discussed there. Though there is a growing literature on water users associations, much of this literature does not explicitly link their scope and roles to alternative irrigation technical designs, or to contexts where different joint-uses for different water sources are simultaneously possible. See Van de Laar (1993) section 3.1.2 and CPR Note Nr 14, Section 3.1.

process may lead to impositions by the stronger parties. Many international basins are already stressed under normal conditions, but have no water rights agreements agreed by the states involved. Fewer still have a detailed agreement linked to a drought management plan (Frederiksen, 1992a, p 11). The need for such a drought management plan will be increasingly necessary if sudden water shortages are not to have more serious consequences than would have been necessary. A drought management plan is a fully worked out 'stand-by' facility with clear monitoring, analysis and defining conditions, specific drought management measures and firm and clear implementation criteria. The situation in the Middle East is already very serious because many countries there face considerable water stress, and several of the key countries derive a sizeable share of their water from international rivers (Van de Laar, 1993, p 53-5).

There are two principally different aspects in problem solution: problem solving in advance, as part of a joint river-planning and development process, and ex-post, when the damage of some action has already developed. The general tool for prospective action is an International River-basin Commission in which countries act jointly in a more or less constructive process based on joint treaties and agreements. The tool for retrospective remedy action is decisions in international appellate courts, based on principles of international law.

Both tools would be strengthened if there were clear legal principles guiding water use[8]. International practice, as summarized by Widstrand, demonstrates that the basic principle of absolute territorial sovereignty is not adhered to. This doctrine has been modified by the other extreme expressed in Roman law which prescribes the use of one's own property as not to injure your neighbour. The resulting doctrine is a 'fair share concept' of **equitable apportionment** of the water resource, implying that benefits are balanced by cost and damage incurred on other co-basin states. The ideal of this equitable utilization principle is that the resource should be utilized to satisfy the needs of the co-basin states to the greatest extent possible, thereby maximizing benefits and minimizing detriments to each. This doctrine is expressed by the **Helsinki rules**, which constitute general guidelines accepted by the **International Law Association** in 1965 after ten years of preparation.

The practice of applying this principle of equitable shares on a continuous basis points at a number of key problems:

- **Vagueness**. The content of the concepts is disturbingly vague, and the status of the basic principles is no more than a set of recommendations from a non-governmental scientific organisation.

- **Time aspect**. The distribution of benefits and damages to the countries involved in an upstream-downstream relation changes over time, and so, therefore, do the implications of the equitable share concept, see Table 9.

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[8] See Caponera (1992) for a comprehensive review of competing legal regimes for water in the world. See also CPR Note 14, Section 3.1.

Table 9. Benefit-damage relation at different times.

Zero situation.	Intended change.	Benefit to	Damage to
natural	upstream exploitation	upstream	downstream
exploitation already realized	reduce damage in downstream country by limitations to upstream country	downstream	upstream

Source: Widstrand (1980).

Such time effects would, in fact, strengthen the incentive of the upstream country to avoid entering into negotiations at a too early stage. The fait accompli is a much more favourable starting point. Also, technological change contributes to a more or less continuous change of the mutual situation and the implication of the equitable share concept.

* **Persuasion rather than coercion.** As decision-making always stays with the individual governments, the role of river basin commissions is persuasive rather than coercive. The power to persuade has to be backed by detailed knowledge, which is often highly inadequate, but the possibility to persuade depends heavily on the patterns of (des)incentives of specific actions.

* **International code of conduct.** There clearly is a need for an international code of conduct to persuade governments to act in line with the equitable share principle. This inevitable will be a long process. In a world with resurgent nationalism and open conflicts, the prospects that such a code can come into operation do not look good.

(b) Ecological conflicts

Ecological conflicts centre on weighing the short term benefits to the long term deterioration of the water resource base. At the political level short run perspectives often seem to carry the day, while at the margins of survival the population cannot afford the luxury of thinking about long term perspectives. Poverty shortens time horizons. The general environmental effects of large dams and irrigation development need not be gone into at this juncture as they have been dealt with elsewhere[9].

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[9] For a general discussion of the major environmental effects of large dams and irrigation see Van de Laar (1993), Petts (1984), and Oomen et.al (1988, 1990).

(c) Administrative conflicts

There are many types of what are here called administrative conflicts, in the wider sense of governance related conflicts. They operate at different levels and involve different configurations of actors.

- **Between major administrative divisions, between policy makers and bureaucrats, between executive and parliament.**

Classical conflicts in irrigation administration are caused by the division of the irrigated area into one section under the Ministry of Irrigation or some such authority: the head works and the main canal system, and another section, at field and farm level, under the Ministry of Agriculture. Irrigation Departments wield direct power in the design and operation of the main irrigation system, but the Ministry of Agriculture has mostly advisory and research/extension functions relative to farmers. Moreover, responsibility for surface water is often separated from authority over ground water resources. Conflicts can be exacerbated when some functions are exercised at the central level, while other departments function at lower levels of administrative authority, either in a Federal/State structure as in India and Pakistan, or at National/Provincial levels in unitary states. For historical and professional reasons collaboration between different administrative units has been difficult or non-existent in the past, though some attempts are being made to increase cooperation.

- **Upstream-downstream conflicts**

Conflicts at the international level among riverine countries do occur in similar fashion along any stream flow being exploited within a country. The fact that top-enders in irrigation schemes have first access to available stream flow brings with it the danger, and in many cases also the practice, that top-enders take too much, and leave too little for tail-enders. Where rainfed agriculture is not, or only barely viable, access to irrigation water and thus location tends to be a stronger determinant of economic power in rural areas than size of holdings.

- **Conflicting end-uses**

Along the course of rivers different claims for limited water resources conflict with each other for priority treatment. Within agriculture, smallholders may compete with agricultural estates and agriculturists with the water needs of pastoral peoples. Agricultural uses may compete with the needs for clean and safe drinking water of urban populations and of industries. Both agriculture and industry will pollute water, and pollutants accumulate downstream and cause problems there. This competes with the needs of the tourist industry in estuaries and along shorelines for clean water. Where river delta's are at the same time major agricultural production centres and the location for major urban centres conflicts about water priorities are acute and the implications of the choices made are often dangerous in political and economic terms.

(d) Conflicts between 'governments' and farmers.

In many cases government agricultural or planning policy does not coincide with farmers' perceptions or wishes. These conflicts can take various forms.

* Farmers' wish for food crops for survival vs governments' preferences for cash crops, marketable surplus and exports.

* Government agricultural schemes and nomads, where such schemes preempt traditional access by nomads to grazing and valuable water points.

* The lure of the pilot projects whereby existing landholdings are realigned and consolidated to meet the requirements of efficient water allocation, and whereby often some land users loose their historical access to land and/or outsiders may acquire the newly allotted land and associated water rights. If applied on a wider scale this will lead to massive upheaval in rural areas.

* Conflicts in water administration can cover a wide range of issues: **(i)** Water restrictions in time and place may be imposed by climatic fluctuations. Other forms of control include restriction on certain types of crops, or size of holdings under one crop; **(ii)** Conflicts about the use of communal labour for irrigation construction and maintenance; **(iii)** The imposition of sanctions for unauthorized water use; **(iv)** Administrative corruption at the interface between gate operators and farmers to influence water allocation processes.

(e) Conflicts between farmers.

These covers two categories of conflicts:

* Farmers as individuals. Rich and poor farmers. Conflicts may be between large and small farmers, good and bad, in the sense of water wasting farmers when supplies are limited, patron-client relationships, and the conflicts in the whole microcosms of rural social and economic differentiation. Where irrigation systems have to be designed on 'averages' in a number of key variables, such as water needed, cropping patterns and labour availability, such averages may suit very few farmers in a concrete micro-level irrigation environments. The irrigation design will then please very few farmers and the design itself will be a major source of conflicts between farmers.

* Conflicts in farmers' organizations. These covers such issues as whether irrigation communities should be stream - based or field-based, whether they should coincide with traditional village political institutions or not; whether irrigation associations only have narrow irrigation maintenance and operations functions or engage in wider tasks such as the provision of agricultural inputs or fulfilling marketing roles.

(f) Conflicts between Donor agencies and government/local groups.

Again, there are two types of problems:

* Expatriate expertise. Irrigation development attracts many professionals in different disciplines and from different irrigation traditions[10]. Many of the irrigation professionals in developing countries have also been trained in the irrigation traditions in major donor countries. To what extent are the type of training and expertise aiding or inhibiting the design and construction of irrigation systems appropriate to the reality of farming in the developing countries, and relevant to the people who have to survive by the manner in which they have access to and can make use of scarce water resources?

* Conflicts between donors. Not only do donors attempt to influence recipient governments in not necessarily similar directions, but in the last decades a range of Non-Governmental Organisations have been getting involved in irrigation in developing countries and have chosen to champion interests of farmers and of farmers' groups.

2.2 Some definitions and terminology

Irrigation development may be **defined** as the acquisition, allocation and distribution of water resources to meet the water needs of agricultural production in the wider sense of the production of foods and of agricultural production for industry.

This rather wide definition thus includes:

(a) the investment decision and the investment phase in irrigation development: to build the irrigation head works and the canal systems;

(b) the Operations & Maintenance activities for effective water conveyance;

(c) the allocation and acquisition, or the ex ante and ex post distribution of irrigation water;

Different terms are used in the irrigation literature and in different countries. A glossary of different terms in the physical lay-out of irrigation schemes is given in Meyer (1993)

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[10] Different irrigation traditions exist in the United States, the UK, the Netherlands and in France. The Western European countries basically learned about, or rather reinvented, irrigation from their colonial experience and from the mid-19th century. Old 'irrigation civilisations', like those in the Euphrates Basin and in Sri Lanka, had developed irrigation systems centuries before the West did (Diemer and Slabbers, 1992, p 3).

Also in other respects terminology is not uniform, and this leads to confusion, especially in attempting to compare different irrigation projects and experiences. For instance, one can have water rotation systems among canals and operated by the Irrigation Department, and within the tertiary unit and therefore organised by farmers. In the influential American literature farms are often so large as to encompass what elsewhere would be a geographical area with many individual farmers, with obvious implications for cropping patterns, water distribution and decision making processes at that level. On-farm water management in the US would then be quite different from water management within a tertiary unit amongst a group of farmers.

In some circles 'water distribution' is restricted to the distribution over individual farms within the tertiary unit. Primary and secondary canals are then called conveyance canals.This is illogical as conveyance and distribution takes place at all levels, from main canal to the farm plot and over the whole command area.

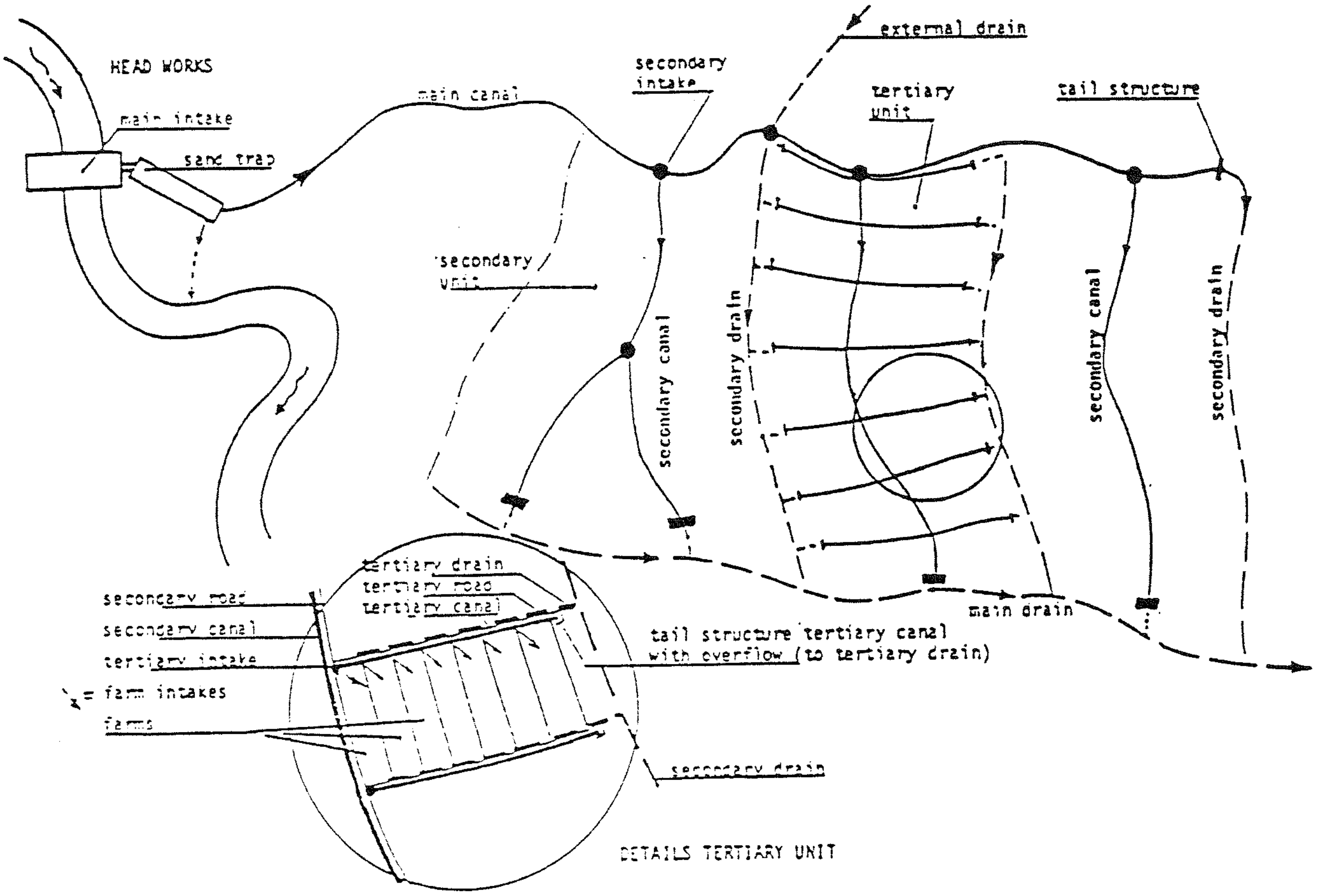
The term outlet/inlet usually denotes the point where the responsibility for water is transferred from the Irrigation Department (ID) to (groups of) farmers. Consequently, the ID will talk about the 'outlet', while the farmers would talk about their 'inlet'. In estate schemes, or in some African schemes such as Gezira in Sudan and Mwea in Kenya, scheme management is deeply involved within the tertiary unit, including water distribution, maintenance and land preparation. In such situations the tertiary unit should be defined within the water system rather than from the responsibility point of view.

O&M can mean two different things: in the early 1970s it denoted Operation & Maintenance, after the design and construction phases in irrigation development. Later on O&M was replaced by the concept of Organisation & Management which is a much broader concept. (see Jurriens and de Jong, 1989, Chapter 2. A helpful discussion about a range of concepts is Chambers, 1988, Chapter 2).

2.3 Useful analytic tools

In the Introduction it was noted that the study of irrigation systems is highly fragmented, reducing the scope for comparative analysis and for learning from inputs from different disciplines. It is therefore important to pre-define an appropriate analytical framework for the analysis of irrigation situations, be they for the study of the historical irrigation experience as well as for problem analysis in the contemporary setting. Such a framework should include the following three elements: (i) who is responsible; (ii) an ecological perspective; and (iii) analysis of irrigation functions and roles at different levels.

GLOSSARY



The names given to canals and structures differ from one region to another.

Main canals are also termed:	feeder/conveyance/trunk canals,
secondary canals:	branch/lateral/distributary canals,
tertiary canals:	supply/delivery/farm/terminal/sector canals or water courses,
tertiary unit:	farm block/users' unit/chak/sector,
intake structure:	turn-out/head structure.

Often irrigation schemes are divided into *major* (or *main*) *systems* and *minor systems*.

Major systems include:	main and secondary irrigation canals + structures, including tertiary intakes, main and secondary roads (not shown) + structures, main and secondary drains + structures.
Minor systems include:	tertiary irrigation canals, roads and drains + structures (no tertiary intakes).

Normally an Irrigation Authority is responsible for the operation and maintenance (O+M) of the main system while the farmers in a tertiary unit are responsible for the operation and maintenance in their unit.

Note that in americanized publications (World Bank, FAO, ADB, etc.) the term *on-farm development* is often used. This, however, refers to the development of tertiary units and not at all to the development of the smallholdings included in these units. Similarly, *farm canals, farm intakes* or *farm structures* actually are tertiary canals, tertiary intakes or structures in tertiary canals.

Who is responsible

From the point of view of the **responsibility** for irrigation, it is useful to distinguish the following possibilities (from Chambers, 1977, adapted by Coward, 1980):

(a) Government or bureaucratic schemes;

(b) Communal schemes, built and operated by the farmers themselves;

(c) Jointly managed schemes, whereby the various responsibilities are shared between government agencies and the farmers;

The **relative size** of these segments in the irrigation sector has not been known but recent information does indicate that the share of communal schemes in total irrigation is quite large. In the Philippines communal schemes comprise some 48 percent of the nations's irrigated area (Svendsen, 1992); Nepal mostly has communal systems (Chambers,1988, p 17); on the other hand, in Indonesia the proportion of communal schemes by now is much smaller at 15 percent (Schrevel, 1993, p 8). FAO data for Africa and based on weak data indicate that small scale/traditional irrigation may account for some 47 percent of all irrigation areas in a 40 country study (Adams, 1992, p 72-5).

One finds many other classifications of irrigation systems, but these are mostly descriptive, and often not helpful for analytical purposes, and could be misleading in some respects.

For instance, the distinction between **large** and **small** irrigation schemes involves arbitrary judgements on the sizes chosen which can be different in different countries. FAO (1986, p 12, 15) classifies large projects as usually greater than 200 ha and/or more than 500 farm units, and **defines** them as projects which require a substantial professional staff to manage them. Medium-sized projects are then **defined** as those which are too small to allow consideration of unified or multi-purpose projects agencies (owing to their relatively high administrative costs) but which nevertheless require a substantial input of professional staff to operate and maintain them. Here we see a mixture of size and assumed organizational requirements, but it is not made clear to whom the professional staff is accountable. FAO does not consider communal systems which are constructed and operated by the farmers themselves. This in itself is revealing of how FAO conceptualizes the irrigation sector, in disregard of the important role which communal schemes have in many countries.

It cannot be assumed that communal, farmers' self-managed schemes are mostly small units, in either area irrigated from the same water source or number of farmers involved. The classification as between **traditional** and **modern** implies prior value judgements, and is unhelpful in characterizing the nature of the schemes, nor on how they function. Traditional, old, communal systems can be quite sophisticated such as the ***subak*** in Bali or tank systems such as Pul Eliya in Sri Lanka (in Coward, 1980), may be working well, while modern, recently constructed schemes may be non-functioning in practice. In Indonesia, the distinction used is between **technical**, **semi-technical** and **non-technical** irrigation. This is an administrative classification indicating whether or nor government has undertaken technical works in irrigation systems, often under rehabilitation programmes. It does not denote whether water availability and water management have materially improved comparing the 'before' and 'after' situation, and between short term and medium term effects. A distinction between **gravity** and **pump or lift** schemes could be significant if the pumps would enable more stable and more timely flows to be provided which gravity systems are often incapable of supplying. The capacity of farmers to secure effective water supply in a pump scheme may be a powerful incentive for them to organise for effective collective action in water management and for pump maintenance. These incentives may be absent in gravity-based river-flow systems.

An important distinction in irrigation systems is between **supply-based** and **demand-oriented** irrigation systems. Supply based systems distribute existing water as and when it becomes available. Fluctuations in water availability from rivers may or may not be dampened through intermediate storage in the canal system. This distinction has important implications for system design, control structures and system operations, and often serious problems arise to accommodate or reconcile conflicting water demands from different sections in the system and in different times of the season. Further complications arise in situations where irrigation systems are initially designed as supply-based systems, but are operated as demand-driven systems: where farmers' actions negate the intention of system designers and manipulate the system physically or through interaction with the appointed system operators to change the rules of operation. Such cases are common when cropping patterns begin to deviate from designed cropping patterns, or by top-enders depriving tail-enders. The conflict between design parameters and farmers demands puts system operators in a very difficult managerial role and dilemma.

Need for an ecological perspective.

The mismatch between the location specific availability of water, suitable lands for agriculture and population distribution is a basic feature of development. The technical possibility, by means of irrigation development, to change the spatial patterns of water distribution is thus, **by definition** a source of open or more latent (in longer term perspective) conflicts between societies, or segments therein.

An **ecological perspective** for analyzing irrigation situations is needed because this perspective emphasises the role of physical-environmental factors, in shaping, limiting or determining forms of human behaviour.

For instance, the small scale, communal schemes, which more or less spontaneously developed along the Senegal River have been judged a success by the LUW team (Diemer and Huibers, 1991). These schemes seem to relate to small pump schemes with short and direct supply channels to avoid interference by others; they involve small and homogenous farmers groups, implying that the scaling down of technical scheme size is downgraded to the largest homogeneous group, to reduce the scope for internal conflicts, and the schemes seem to be laid out (though this is unclear from the information available) in confined, 'closed', geographical areas, thus avoiding open-ended situations when irrigation is to be provided later to newcomers, and additional areas are to be supplied with irrigation from the same source. Such a technical and environmental setting is conducive to effective collective action on the part of farmers' groups. In many respects the topography of hill side irrigation (whether gravity or pump based) is similar. But such systems are incomparable to irrigation in the open plains, where area expansion and new-comers will have to be accommodated over time. Unfortunately, in many case studies these physical, environmental preconditions for effective collective action are not sufficiently specified and this limits the lessons one might learn from comparative analysis.

The *subaks* in Bali (Geertz, 1980 p 72), for all the important social and cultural features stressed in the literature, appear to consist of relatively small and closed agricultural systems, each with their own supply channel to the river. This limits water distribution problems to those with direct stakes within the subak, and this makes the problems arising more manageable than in the much larger universe of several subaks in a village. There is no indication of the aggregation effects on total water availability, and on how this affects inter-subak tensions and behaviour in periods of water shortages.

The study by Leach (1980, p 112) of village irrigation in the dry zone of Sri Lanka shows that proportional dividers are used for water distribution. This does imply that variations in aggregate water supply are proportionally shared by all farmers in the irrigated area. This could be an important factor in bringing farmers to act together in jointly deciding on a course of action to meet the water supply and cropping pattern implications arising from variable water availability.

The transformation in the National Irrigation Authority in the Philippines has received much attention and the process has been well documented (Korten and Siy, 1988). But the study (de los Reyes and Jopillo, 1988) on the impact of farmers' participation, does not provide information on the inter linkages between topography, group size and communal irrigation scheme, on possibly significant preconditions for collective action in water management. Further, the one case study presented in detail, the Taisan project, and presumably included to present a typical case of the approach taken to participation by NIA and the problems to be overcome (Illo, 1988, p 37, 56), raises at least two problems which might be crucial for sustainability of institutional coherence within the irrigation group: A large and powerful farmer did not want to participate, and this seems to have been the decisive factor to change the initial trajectory of the distributary, as he did not want to give 'right of way' for the canal. What will that farmer do after the canal is constructed, and still in small part over his land? Moreover, it is mentioned that in future the distributary may be extended to new areas, which raises immediate problems of to be expected conflicts between head and tails and between senior and junior water rights.

Taking an ecological perspective for the analysis of irrigation situation forces the analyst to consider the physical-environmental factors as well as the spatial aspects of development in their possible interaction with organizational form and cohesion within irrigation societies. Topography and some technical features of irrigation designs have important implications for the preconditions for effective collective action by water users in water management, e.g. they determine the collective interest in water management and they could be inspired to act if there were clear objective indications of action needed and when easy options for evading collective action are foreclosed.

Where social cohesion amongst farmers is very weak, it may still be possible to exploit pervasive social distrust by a particular design of the irrigation system. In fact, the *warabandi* system in Northern India is an example of irrigation based on mutual distrust between irrigators. The system (Reidinger, 1980, Malhotra, 1982) allocates time slots for uncertain water supplies. This has the effect that each irrigator acts as the policeman on actions being taken by his predecessor in the turns. He cannot tolerate that his neighbouring predecessor takes more time to irrigate his land, because he in turn will be pressurized by his successor. The system is thus self-policing and based on distrust. The outcome would seem orderly, though factual information is not available on how the system reacts to modernization employing high-yielding varieties. It seems more or less effective because irrigation water is the lifeline to survival where rainfall is too low to make rainfed agriculture viable (Berkoff, 1990). Because physical and environmental factors have also important time perspectives, a longer term perspective for the study of rural development in irrigation situations is also necessary. Apparently, the 'waribandi solution' to social strife was historically born out of field experience: the irrigation engineers and colonial administrators facing too many complaints and conflicts when they built their canals in the late 19th century (Stone, 1984). A rigid administrative rule in water allocation, and the use of force in enforcement by government power did enable this novel system of 'settling' in and gaining acceptance in practice. But towards the Eastern side in the Indo-Gangetic plains the same system cannot work, because of the reality of the conjunctive use of irrigation water and rainfall. (Berkoff, 1990).

A prior question in irrigation system design may thus be an assessment whether effective collective action might be possible or not, and, depending on the outcome of this social investigation, the technical design of the irrigation may be able to respond to these social realities. To neglect this aspect, and to merely design a system on the basis of technical water, and water-crop parameters, seems to be inadequate to realize appropriate water management practices, which are sustainable.

To many social scientists such a more integrated analysis and a much closer interaction with natural scientists does not come easy, for it does imply that social scientists have to learn quite a bit about various natural sciences to be able to effectively interact with natural scientists and, in this case, with irrigation engineers. Moreover, it requires pronouncements on projected social action to technological innovations, and most social scientists rather look backwards rather than forwards. But also in the field of technical irrigation professional contacts between irrigation engineers, who often have a background in civil engineering and a strong professional interest in the head works design have historically not related well with agronomists who tend know too little about irrigation (Rydzewski, 1987, Chambers, 1988, Stone, 1984).

For too many social scientists studying rural development the natural environment is merely the passive backdrop to human interaction. Points of connection between the broad rural development literature and the natural environment are few and rarely are these made the staring point for the analysis (Blaikie and Brookfield, 1987, xviii). Specifically for irrigation studies by social scientists, Coward and Levine (1986) have made the same point, as noted in the Introduction.

Analysis of irrigation functions and roles

Against the background of the classifications by responsibility and in ecological perspective, a useful framework for analyzing irrigation situations is the one proposed by Coward (1980). Though Coward developed the framework initially for the analysis of mostly small communal irrigation communities, the framework can also be applied to the wider definition of irrigation as given above, and for state and jointly managed systems. In Coward (1991) he has expanded the framework by 'adding a column' on water acquisition, and this recognises the separate role of the main system and those responsible for it.

The chosen framework locates goals and objectives in different institutional rather than professional and mono-disciplinary groups. It also enables the irrigation process to be conceptualised as the arena where various objectives are articulated and come into conflict with each other. The outcome shows whose interests will prevail.

For instance, in such a framework the **irrigation engineering profession** can be located as a function of who's interests they help impose. When irrigation engineers are employed by governments they will in effect have to reflect to a large extent the goals and objectives of governments. Where they are to be employed by farmers' groups they inevitably will have to contend much more with farmers' wishes in the design process. Similarly, agronomists may either serve the needs of governments for marketable surplus and exports, or the subsistence and survival needs of rural populations. Apparently, it is not 'what you know' which determines what you do, but rather 'where you stand'.

It is not unusual for irrigation engineers to think that proper irrigation designs are largely determined by technical parameters. It is then argued that water availability and topography determine the size and shape of the scheme. Compact schemes are to be preferred to minimize channel excavation and control structures, and the functions of conveyance, distribution and drainage have to be separated with their own channels and drains. The farmers then have to adjust themselves to such technical imperatives. However, water is too important for survival and food production, to have its utilization prescribed by temporary outside visitors laying down a 'new and modern' irrigation system. The study of indigenous irrigation systems has shown that such ancient systems rarely are organised and operated in a similar fashion. Similarly, after 'modernisation', farmers actual behaviour tends to differ from expected or prescribed behaviour (Schrevel, 1993; Roth, 1993; Jaspers and Jurriens, 1993 for different Indonesian experiences).

Such a purely technocratic approach might be valid in situations where there are no people living in the proposed area, and where people are brought in **after** the designs have been made and the systems is constructed. In most cases, however, people already live in the area and the designs have to take account of the then existing realities. These considerations should be the starting point in rehabilitation projects.

If irrigation water is quintessentially a common pool natural resource, conflicts about its use are inevitable, and thereby the need for having effective mechanisms which deal with conflict resolution, and to avoid anarchy. Therefore, in the scheme of Coward the **emphasis on rules for conflict management** is fully recognized and highlighted to play a role at all levels.

Table 10. Irrigation system activities, by institutional and organizational elements.

Institutional and organizational element	*Task*				
	Water acquisition	*Water allocation*	*System maintenance*	*Resource mobilization*	*Conflict management*
Key rules	Rules for acquiring extra water supplies for the systems	Rules for allocating water between subunits of system, farms, and so on	Rules for what repairs need to be done, where, and by whom	Rules for mobilizing labour, materials, money, or other resources needed to perform system tasks and for responding to shortfalls in resources	Rules for avoiding or resolving disputes between systems, zones of a system, or individuals
Important roles	Roles for planning and implementing water acquisition activities	Roles for establishing and implementing water allocation policies	Roles for identifying maintenance jobs and supervising repairs	Roles for implementing and monitoring the resource mobilization process	Roles for mediating disputes, making judgments, and enforcing sanctions
Significant social groups	Groups that seek additional water supplies	Groups that influence water allocation policies and implement water distribution	Groups that provide routine or emergency repairs to system	Groups that collect specific resources	Groups that participate in settling disputes and in enforcing sanctions

Source: Coward (1991, in Cernea, 1991).

3 IRRIGATION DEVELOPMENT IN HISTORICAL PERSPECTIVE

3.1 Is there a direct link between irrigation development, irrigation based societies and the nature of the state?

The relation between irrigation and general political authority has long attracted attention from social scientists and historians. Marx had suggested that the apparent peculiarities of oriental society may have something to do with the technical and organisational compulsions of water control. Weber had also postulated a similar connection between the necessity for irrigation and the important role of the bureaucracy in ancient Egypt, West Asia, India and China. But it is Wittfogel who in the 1930s formulated the cross-cultural hypothesis that the early civilized states of both the eastern and western hemispheres were integrated by the managerial controls required to construct and maintain the irrigation - and more broadly hydraulic - systems. His views culminated in the 1950s and had much wider impact through his book with the revealing title : *Oriental Despotism. A Comparative Study of Total Power* (1957)

As water was brought to arid lands, food production and population increased and became the basis for class-structured states and the achievements of civilization. While historians of culture were emphasizing differences between civilizations, Wittfogel was thus postulating a single basic factor that brought all of these civilizations into being (Steward, 1978).

The four elements of Wittfogel's theory are (a) a particular form of resource: arid land, large water resource, and potential for large irrigated agricultural works; (b) for preindustrial regimes a sociological imperative for its exploitation through massive, centrally organized and controlled labour demands; as a consequence: (c) a particular kind of state system (managerial), with (d) a particular distribution of power (despotism), (Hunt and Hunt, 1976).

This stark hypothesis has inspired a host of empirical studies which has thrown doubt upon the universality of the thesis, and thus clarifications and hence modifications are needed. A number of issues needed to be more clearly defined. For instance: the value of irrigation to pre-industrial civilizations has been overemphasized as the all-important factor in creating the state. Sometimes irrigation development seems to have been the result rather than the cause of the growth of states. Both states and irrigation societies may not only grow but also decline over time (Widstrand, 1980). The time frame of irrigation systems development is important. Most systems were not built in one gigantic effort, but systems grow from humble and small scale origins to expand over time and become interlinked as population expanded and food requirements increased (Mitchell, 1973). Thus, one has to look at the relation between the evolution of the state and the role of irrigation. Further, distinctions need to be made between construction and maintenance in irrigation systems. While large irrigation structures such as dams or major flood protection embankments require mass organization in a disciplined joint effort, subsequent maintenance and/or derivatives of such major public works through irrigation systems could well be decentralised. Important questions thus arise about how a centralised state in some areas interacts with apparent decentralised power in the running of irrigation systems.

These are questions of central organizations, local organizations and inter linkages. However, those who study irrigation institutions often do so by focusing excessively on forms, such as community- managed vs. bureaucratic systems; and centralised vs. decentralised systems. Not only is there no necessary correlation between form and effectiveness, but the appropriateness of institutional forms cannot be decided independently of the agro-climatic, technological and land-tenure conditions (Vaidyanathan, 1984). Thus, a more precise and integrated analytical frame work needs to be specified encompassing these three major formative ingredients of evolving irrigation situations, to enable more meaningful cross cultural comparisons to be made.

This new approach to the cross cultural study of irrigation situations again stresses the need for, and value of, comparative and historical studies of irrigation institutions in a variety of situations, but with a more sharply defined terminology and in an interdisciplinary context, as distinct from the many existing disciplinary and thus only partly useful studies prevailing (Hunt and Hunt, 1976; Coward and Levine, 1986, Mitchell, 1973).

It may be pointed out that Vaidyanathan's framework as comparatively applied to irrigation experiences in Asia (more particularly India, China and Japan) comes close to Coward's model of roles and functions in an ecological setting approach and presented above.

The main point of Vaidyanathan's analysis is that while the role of institutions in managing the recurrent and continuing tasks of maintenance, water allocation and conflict resolution is much more crucial to the effectiveness of water control than during construction, this role is conditioned by the physical characteristics of the system and by factors other than water which determines the returns to irrigation (1984, p 29).

The new emphasis on water management and on institutions is much overdue, but its implications have not yet been fully realized, certainly not by most irrigation engineers. It is noted that the investment phase rather than the operations and maintenance phase is the level which receives most attention at the present time (Tiffen, 1987b, 1989). This is to be expected in a project cycle in irrigation capital investment planning, where the irrigation **design** is defined as the output by planners and irrigation engineers, and not even construction as that is being farmed out to contractors implementing the designs. Ascertaining a high *ex ante* probability of irrigation maintenance after investment completion, does not seem to be a major concern in irrigation designs.

3.2 Characterization of historical irrigation development in Asia.

Because of the importance of irrigation development in Asia, it may be of some use to broadly sketch the **diversity** in irrigation development in different parts of Asia, and the dynamic characteristics over time. Liberal use will be made of Barker, et.al. 1984; Vaidyanathan, 1984, Sengupta, 1991, Stone, 1984, also Chambers, 1988 is quite useful from an analytical perspective, and for a summary of much of the water management literature on

India). This sketch could be seen as a further orientation on and introduction to major issues which currently dominate international irrigation discussions[11].

There are several reasons for such a brief sketch, however eclectic. In many publications, generalizations are made on the basis of a very narrow geographical and limited analytic and professional perspective and experience. Few analysts have had the opportunity to work in depth in more than one location. As already pointed out, existing irrigation studies are mostly not comparable due to different analytical frameworks used, different questions asked and different disciplinary perspectives taken, making helpful generalizations not feasible anyway. Because fieldwork in irrigation research is expensive, opportunities for social science research in irrigation is often only possible under the aegis of major donor funded, and construction oriented irrigation investment projects[12]. In such a context there is often no room for studying water management for several years after construction is completed. It appears that irrigation research by social scientists follow the shifts in donor support for country irrigation assistance. With the decline in donor funded irrigation expenditures, opportunities for social science research, at least by 'westerners', may also dry up. At any rate, the gravity point in studies on irrigation is inevitably shifting from Northerners to Southerners, from donors to the developing countries themselves.

The pace of irrigation development in the post-World War II period has been so rapid that little attention has been devoted to long term issues, such as system management and efficient utilization of existing resources. Now that these issues have come to the fore, dealing with these issues has become very complicated, precisely because of the manner in which the irrigation projects and water management institutions have been undertaken. This track record embodies a number of irreversible decisions which complicates present problems.

The historical sketch is, of course, only of limited use for tackling future policy problems, largely because the rate of population growth, and thus the increase in the demands on water resources are historically unprecedented, and as such exert tremendous pressures to come up with answers and solutions in the short run. Limits to available water resources are increasingly becoming in evidence in some countries (Van de Laar, 1993) While major current policy concerns are with improving better use of irrigation potentials created, some planners, for instance in the World Bank, are already beginning to be deeply concerned about the capacity of current systems for flexibility in use to meet the near certain prospects of medium term periods, say 5-8 years, of substantially below historical averages in rainfall and thus water availability in irrigation systems. Flexibility in water use among alternative priorities is also substantially and increasingly constrained by the fact that clean and polluted

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[11] Major trade-offs in investment strategies, between production, efficiency and equity are taken up in CPR Discussion Note No 14, December 1993.

[12] See for instance the striking similarities in the problems encountered by the Cornell Irrigation Group and those of the irrigation department in Wageningen University. In addition, social scientists, as adjuncts to irrigation technical projects are often forced to stay within the framework of the different irrigation schools existing (Diemer and Slabbers, 1992).

waters cannot be mixed in alternative end-uses (Frederiksen, 1992). Thus the priority policy agenda for the future has to be different from that in the past.

Timing differences

Prior to World War II, irrigation facilities in East, South and Southeast Asia were at very different levels. Nearly all of Japan's rice area was already irrigated by the end of the Tokugawa period (1868). By 1940, approximately two-third of the rice area in Taiwan and Korea was irrigated. National rice yields were at an average of two metric tons per hectare. Crop intensification had begun, but modern inputs, such as fertilizer, were not widely used. China was in a similar position, with advanced irrigation facilities and high cropping intensities in the rice producing region of South China. In Southeast Asia, prior to World War II, the most significant developments occurred in Java. In 1880, the irrigated rice land in Java and Madoera exceeded one million hectares, accounting for approximately 50 percent of the total rice area (Booth, 1977).

In contrast to East Asia, most of South and Southeast Asia had barely begun to develop irrigation facilities in the lowland flood plains where rice is commonly grown. By the end of World War II, the bulk of the rice area was still unirrigated, and national yields were only about 1.5 metric tons per hectare, one-half ton below average Japanese yields in 1880 (Barker, et.al., 1984, p 3, 10-11).

The orderly development of irrigation in successive stages as occurred in East Asia has not happened in South and Southeast Asia. Given well developed irrigation systems and entrenched water management practices and institutions, the development of storage irrigation and the expansion of multiple cropping continued to grow slowly in East Asia after 1945.

In South Asia, the rapid expansion of irrigated area, crop intensification, and the introduction of modern inputs all occurred almost simultaneously in the period following World War II. This has had serious equity implications for those who do not have access to irrigated areas and the attendant improvements in land productivity. Thus, access to irrigation has, in most cases, become a precondition for the use of modern inputs. Even today, rainfed areas of Asia have largely been bypassed by the benefits of modern technology (Barker, et.al, 1984, p 3).

Determinants of scale

Major determinants of scale, and thereby of the complexity of irrigation works are agro-climatic factors and topography. In turn, these factors have major implications for the relative roles of government in resource mobilization and realizations of potentials are further conditioned upon technologies in civil engineering becoming available.

Stylized facts of climatic patterns characteristic for South and East Asia show that temperatures and evapotranspiration in South Asia are higher than in East Asia. The average rainfall in South Asia is lower and seasonally more pronounced. The combined result of these differences is that the 'dry' season in South Asia is not only longer, but the moisture deficit is also larger. Under these conditions irrigation needs of the dry season, being relatively large in relation to crop-water needs, can be met only if the surplus water from the monsoon season is stored, either on the surface behind large dams, or underground for use in the dry season. (Vaidyanathan, 1984, 42-4).

In combination with topography, it is easy to understand that early irrigation development in **East Asia** developed in proximity to flowing streams, most of which were perennial. These systems required little more than simple diversion structures, usually of a temporary character. Management and distribution were also simple, with the main focus on the timely repair of temporary structures and diversion channels. With high population densities labour resources were available for bringing about irrigation works using simple technologies. Consequently, the local population acquired access to water rights from their labour inputs. In China, given the enormous extent of the catchment area and the fact that the rainy season in the upper parts of the catchment is somewhat earlier than in the lower part of the river basin (where most agriculture is concentrated) probably means smaller seasonal variations in river flow in lower reaches. Under these circumstances, it is possible for China to meet the dry season moisture deficits with the help of diversion works, ponds and surface water lifts. Both in China and in Japan large canal irrigation systems, and in particular those based on storage, are relatively recent phenomena (Vaidyanathan, 1984, p 44). Currently, the Three Gorges Project receives most attention. Its links with Hydro Quebec of Canada has given the international environmental movement a handle to raise its objections.

As the area served by these simple systems increased, the normal variation in river flow and natural rainfall prevented adequate supplies of irrigation for all lands. Furthermore, since these systems could irrigate only a small fraction of the dry season crop, the potential benefits from increased solar radiation and reduced incidence of insects and disease that typically characterize the dry season were largely unavailable (Barker, et.al 1984, p 9). Since the 1950s investment in surface storage and in tube wells allowed dry season cropping to expand, thereby increasing cropping intensities.

In **South Asia** (South India and Sri Lanka), the rivers are mostly seasonal; there are no extensive plains along the course of the major rivers, and geology is not favourable for groundwater storage. Hence, local topographic variations have been effectively exploited to impound rainfall in an extensive system of tanks, which are used to grow irrigated paddy and simultaneously serve as a means of improving groundwater recharge in their command areas. The outcome is again a smaller scale and rather decentralised system where local participants built stakes in water rights through their labour input in tank construction and maintenance. There are only few large works in South India, most noteworthy the massive weir on the Kaveri River, known as the Grand Anicut.

The development of tank irrigation seems to have reached a point of saturation even before the British came (Vaidyanathan, 1984, p 43). Further significant expansion of storage irrigation in this area required the construction of large storages upstream and/or cheaper techniques for lifting groundwater. In recent times tank irrigation seems to be on the decline for a variety of reasons: lowering water tables reducing recharge, encroachments into the catchment areas, and perhaps longer term effects from building upstream storages (Madduma Bandara, 1977, Palanisami and Easter, 1984).

In **North India (and Pakistan)** the situation is quite different. Consider the sharply different conditions in the Indo-Gangetic plain. The rivers have vast catchment areas, are in part recharged through snow-melt from the Hymalaya's and are thus perennial. The flat topography of the plain allows large areas to be covered by diverting river flows in canal systems of hundreds of miles in length. Such systems were constructed both before and during British Rule. But as the possibilities of river diversion were exhausted, further expansion increasingly depended on storage. The division of the Indus waters to accommodate the split-up of British India between India and Pakistan, resulted in the construction of link-canals between the Indus tributaries and of storage facilities.

Storage was needed to meet the long period of moisture stress in that part of South Asia. But the construction of large storage dams in the rivers had to await the development of appropriate technology in engineering, and this became possible from the latter part of the 19th century. The size and the complexity of the structures required also was in excess of the capacity of local population groups to supply and hence the state played an important role in irrigation development from a centralised perspective. It has become clear later on that the geology of the Indo-Gangetic plain is also exceptionally favourable for groundwater storage, but the intensive exploitation of this resource had to await the introduction of energised pump sets (which reduced the costs of lifting water), and the availability of techniques for tubewell construction to tap the deeper strata. This technology began to be applied on a large scale from the 1960s. In addition, this latter development was also facilitated by the long term rise in ground water levels, itself associated with long periods of (over)irrigation from surface sources (Johnson, 1988, Van de Laar, 1993).

The scale of the schemes in Northern India (and in Pakistan) is therefore gigantic, in absolute standards as well as relative to schemes elsewhere in Asia. Projects irrigating 100,000 hectares are common, and account for about half of the area served by surface irrigation sources. There are 10 systems serving 500,000 hectares or more and the largest, the Bhakra-Nangal, irrigates some 1.3 million hectares. Some 50 reservoirs with a storage capacity of more than 500 million cubic meters account for 80 percent of the total storage capacity, while tanks and small ponds account for less than 10 percent (Vaidyanathan, 1984, p 40).

The question whether an alternative, and much more decentralised development path might have been feasible in North India has received attention in the sparse literature which exists on the history of irrigation. Stone (1984, Chapter 3) has noted, with respect to the situation in Uttar Pradesh, that the rapidly expanding canal system from the late 19th century frequently encroached upon tracts with long-established systems of (shallow) well irrigation. The overlapping of facilities, and the subsequent widespread substitution of the canal for wells, has been condemned as undesirable by both contemporary and latter-day critics. The conclusion, however, which Stone reached is that, for all its disadvantages -- such as the inflexible cash outlays associated with the use of canal water, the uncertain nature of the water supply, and the observed tendency for the yields of sugar cane, opium, tobacco and garden crops in general to be lower where grown with canal water -- the canal provided more nearly for the needs of most farmers. The canal was an innovation which met their requirements, and it did so because it slotted into the productive aspects of the peasant system in a way which made it generally more advantageous than even the most favourable well irrigation (Stone, 1984, p 70).

Changing roles of government

In the post war era the state plays everywhere plays a prominent role in planning, regulating and assisting the development of irrigation, flood control and drainage projects. Interplays are complex: socialist government saw a clear role for establishing or extending their power and influence. Electoral politics put pressures on governments to deliver the fruits of concrete development, also in rural areas. One of the most effective ways of doing so was seen to be the accelerated provision of irrigation services. Farmers played there role in that when governments could be persuaded to undertake the construction and financing of basic infrastructure from which clearly individualised and private gains could be gained, so much the better from a private perspective point of view.

Despite these general and universal type of pressures which one can postulate to condition government roles in general, major differences in the outcome of these interplays can be observed. The extent of governments' direct involvement varies greatly. **In India,** for instance, the national and the state governments bear a much greater direct responsibility than most countries in Asia (including China). In **India**, irrigation has become a state responsibility since the provincialisation from the national level in the 1930s (Sengupta, 1991). As each state has full autonomy it is nearly impossible to generalise on an All-India basis, either in terms of information and statistics and in terms of irrigation policies and practices (Chambers, 1988, Dhawan, 1988). The general practice had developed that government would construct facilities and canal systems up to the outlet points, from where farmers were expected to undertake to construct the field channels and do the necessary land preparation. As farmers' development proved to be slower than expected the government assumed greater responsibility for these works as well, through the setting up of Command Area Development Authorities (Ali, 1980, 1984). These CADA's were set up separate from the departments responsible for the construction of the main facilities. In this way, the already existing distance and lack of professional interaction between civil engineers concerned with head works and main conveyance systems, and agronomists concerned to use water for the promotion of crop production was consolidated, posing further obstacles to the desirable and necessary professional interaction needed for more integrated water development and agricultural intensification policies and programmes to be designed. In its turn, CADA increasingly entrusted the construction tasks 'below the outlet' to contractors who were also put in charge of labour recruitment. To the extent that labour could and was/is recruited from elsewhere, and from ranks other than the farmers of the area to be served by new irrigation, the links between farmers acquiring stakes to water rights through their own labour was weakened, and the power position of existing land owners tends to be strengthened. Though the costs of the field level construction activities were expected to be recovered from the beneficiaries, no serious efforts were made to collect irrigation fees. Consequently the 'free hand-outs' to land-owners lucky enough to have first benefitted from government action which brought them within the reach of canal systems being developed, increased further through having (part of) their field development investments taken care of by government as well.

The consequence of this approach to irrigation development, of course, is a trend of rising government deficits in its irrigation related accounts, or, in the absence of public corporation-type irrigation authorities, in the general government budget accounts (O'Mara, 1989). In retrospect, massive foreign aid on an inter-government basis may have weakened incentives for the Indian government to mobilize resources from the direct irrigation beneficiaries, and to show greater accountability to its people.

Compared to India, the higher levels of government in **China** and **Japan** play a much more limited role in practically every phase and the direct users and their organisations bear a correspondingly larger responsibility both for construction and for mobilising the necessary resources. Decisions get taken at four levels depending upon the size of the project. The general principle is that the responsibility for a project which affects two or more administrative units is taken up by the unit of the next higher rank. Thus, each unit which benefits from a project contributes labour and investment in proportion to its share of the benefit. The central government takes responsibility for the major dams and power station projects, and labour to supplement state investment funds is contributed by all provinces that will benefit. Provincial governments are responsible for projects affecting more than one county or municipality, and county governments usually undertake the works affecting more than one commune (Vaidyanathan, 1984, p 35).

A corollary of this method of resource mobilisation is that in China, much more than in India, the beneficiaries are expected to contribute a large share of the project cost at the time of construction itself. The mobilisation of resources takes principally the form of labour contributions by members of the beneficiary units. In turn, this may imply that accountability is more direct and therefore more effective, in blocking grandiose and non-viable projects which may be, and in India apparently have been concocted, by distant project offices or, when consultants are given too free a hand to cook up large and complex schemes which also did appeal to major foreign donors. Further, where local level organisations are weak, conflict-ridden and/or face serious land tenure conflicts such lower level institutions cannot provide their share in a newly suggested project, and hence matching contributions of higher level organisations will not be forthcoming. It implies that the land and water rights issues are resolved before a project can start, rather than have to be sorted out after the irrigation infrastructure construction is done.

In post-war **Japan**, the planning and construction of water control works, most of which are for the expansion and modernization of pre-existing systems, is the responsibility of Land Improvement Districts (LID): associations of farmers of which there are some 13,000. These are managed by elected representatives of its members. The Japanese state supplies much of the finance and the legislative framework, but leaving much of the actual decisions and implementation to the rather autonomous irrigation organisations. Prefectural and the national government undertake to design and construct barrages and canals which serve more than one LID.

Thus, in Chinese society after the Revolution, and in spite of other aspects of economic, political and administrative organisation, one sees continuity in regard to the organization and financing of water conveyance structures. Irrigation development remains decentralised as much as possible, and continues historical patterns, in an evolutionary pattern of gradual enlargement and intensification of scales in irrigation developments. The Japanese experience shows un unmistakable trend towards growing government involvement, not so much in construction, but in guiding and financing water control development (Vaidyanathan, 1984, p 38).

Elsewhere in Asia, substantial amounts of irrigation is under local, as opposed to state or federal government control. However, in contrast to the historical experience in East Asia where the development of irrigation was based on the mobilization of community resources, the bulk of new investment in irrigation in the post war era is being made by the national governments, and an increasing proportion of grain is being produced in government-maintained irrigated areas. In Malaysia, for example, the proportion of the rice crop in government-maintained areas increased from less than one-third in 1949, to over two-thirds in 1966. In the Philippines, communal irrigation systems declined in area relative to other irrigation systems by 70 percent between 1955 and 1975, and in Indonesia the percentage of government maintained systems may be of the order of 85 percent and this trend is said likely to continue (Barker, et.al. 1984, p 21).

As investment alternatives for the development of large-scale government systems are fully exploited, national governments and expatriate donor agencies are nowadays giving more attention to investments in regions traditionally dominated by small-scale, communal systems. In this process it remains to be seen whether this new wave of external interventions will be carried out in a manner to either strengthen or weaken community action or the necessary preconditions for effective collective action. As it is so much easier for external agents to enter into the investment and construction stage of such processes, the danger is real that local beneficiaries cannot build greater personal stakes in their systems during modernization. But if effective local organisations are crucial to the operation and maintenance phase of the water management process, local social cohesion may be weakened rather than strengthened.

Irrigation in much of Asia has been highly distorted by the process of state concentration of investments and governance, and the concomitant demise of local rights and initiatives. Central control is organised around a series of principles, including the state's ownership of water, its right to taxation of surplus, its responsibility to invest in water control, and its right to management authority through a technical bureaucracy. This pattern was established in the colonial era and has been continued by new states, and by most of the influential aid agencies. This seems to be a result of viewing irrigation development largely (perhaps exclusively) as a technical engineering problem. From this it follows that scarce technical expertise is best located in a powerful state bureaucracy, where it can be effectively dispensed. The technical staff of donor agencies find this locus of expertise helpful in the fulfilment of programme objectives. This model may become increasingly ill-fitted to contemporary needs (Barker, et.al. 1984, p 26).

Water management and technology

The level of engineering and construction skills required for large reservoirs and extensive canal systems is of an altogether different order compared to what is involved in the construction of local ponds, and shallow wells. Vaidyanathan notes that in **China** sustained efforts to control her major rivers led to major advances in techniques of flood control fairly early, even in the pre-christian era, but corresponding improvements in storage dam construction and groundwater exploitation did not come about even in situations where the potential for such works existed, and the limits to development on the basis of simpler techniques had been reached. In **India** the technology of storage based systems did not develop indigenously, but came through and under British Rule. As Britain had limited irrigation experience, military engineers, with limited practical experience to guide them experimented with designs and modes of operation within the tight and fluctuating bounds of 'ordinary expenditures', charged against the revenue of each year (Stone, 1984, Sengupta, 1991).

Efficiency of water management is crucially dependent on the working of institutions operating the system, and within limits may even make up for defects in system design. A striking difference between East and South Asia is that East Asian systems have been modernized and reached a level of sophistication in the design of distribution networks and control devices, as well as in the management of water deliveries which stand in market contrast to South Asian systems. Apparently, in East Asia the various waves of irrigation investments seem to have strengthened the links with locality-based groups in their efforts to build and expand their stakes in irrigation. By contrast, the various irrigation investment waves in South Asian irrigation seem to have had the effect to loosen the direct links with irrigation beneficiaries, as more of the costs could be effectively shifted from the beneficiary groups to the government. In such a setting it will prove to be increasingly difficult to reverse the historical trend, by now attempting to (re)build more effective and responsible irrigation communities, necessary to make irrigation development and water management more sustainable in organisational as well as financial terms.

Similarly, where institutions for water management and for maintenance have substantially been locally funded and constructed, staff appointed to run such systems are elected by and accountable to these local organisations. In contrast, where systems have been externally designed and constructed, appointed officials to run the system are not elected by the direct beneficiaries, and their task is to try to implement the externally designed operational manual left behind by the external (government or foreign) consultant, regardless of whether the system as supplied meet locally specific needs and requirements. In such a context, the likelihood that such externally supplied and imposed systems will not be well maintained by the direct beneficiaries are not great, unless the system can be formally or informally modified to meet local realities. There were equity considerations are incorporated in irrigation designs, through water management rules and/or through the fixation of cropping patterns and corresponding water requirements (waribandi and localization, in India), increasing local power and autonomy in water management to local beneficiary groups, necessary for sustainability may well clash with the designed equity rules, especially when seen in the wider context of the whole irrigation system, where there are no shared goals between head and tail-enders in large schemes, and the scale of operations is too large for effective user interest reconciliation.

It must be realised that in the reality of existing irrigation many large canal based systems are in place and hence inter-dependencies between farmers and farmer groups between different sections of such systems are paramount and very real. When such systems are to be rehabilitated or modernized the fundamental issue will have to be faced whether the aim and/or result of the exercise will be to enhance and deepen the role of the state to enforce greater equity between the different segments in larger irrigation systems, or to enhance the role and scope of autonomy of farmers' groups, even if this would mean that tail-enders will be permanently deprived, as head-enders take all the water they need and may also switch from 'dry' to 'wet' crops, and increase cropping intensities beyond planned patterns.

CONCLUDING REMARKS

This paper has drawn attention, in Section 1, to post-Second World War trends in irrigation and its links with changes in the rates of growth of agricultural production and yields. Because the success of many high-yielding varieties of rice and wheat in raising food production is conditional upon adequate water management, the sharp decline in irrigation investment in the 1980s cannot but have major significance for future trends in agricultural production and for agricultural policies.

In a world with growing populations, increasingly scarce fresh water resources and rising aspirations for development, it is inevitable that irrigation should be conceptualised as an inherently conflict-ridden subject. Conflicts over irrigation have spatial, class, economic sector, and inter-temporal dimensions, and in all these aspects conflicts are likely to intensify in the future. These realities have implications for situating irrigation studies in a suitable analytical framework to incorporate these conflicts. This is necessary to understand the socio-political realities, as well as to forge better inter-linkages between the contributions of different categories of professionals working in this sector. This is the message of section 2 of this paper.

The complexity of irrigation as a phenomenon is such that nearly all studies of irrigation have major shortcomings, usually both in descriptive as in analytical terms. Though some historians, notably Wittfogel (1957), have argued that the hydraulic logic of irrigation development has features which would have far-reaching consequences for the nature of the state and society, this thesis is overblown. By specifying a number of key variables in irrigation development, relative to timing,, scale, role of government, water management and technology, it has been possible to illustrate significant patterns of diversity in irrigation development in Asia in recent times, where irrigation is most important and where more, though still quite inadequate information is available.

When such variables are interpreted as policy variables, it may be possible to explore the nature of and scope for modifications in irrigation policies which would seem to be required for future-oriented agricultural policies for the future.

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