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WATER CONTROL INSTITUTIONS AND AGRICULTURE: A Comparative Perspective

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C O N T E N T S

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INTRODUCTION

Background

1. Irrigation institutions, and more specifically the relation between irrigation and general political authority, has attracted much attention from social scientists and historicans since long. More than a century back Marx had suggested that the apparent peculiarities of Oriental society, which had been noted even earlier by classical economists like Mill, may have something to do with the technical and organisational compulsions of water control.[1/] 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.[2/] This line of argument was further elaborated by Wittfogel[3/] into a general theory concerning the inherent tendency of hydraulic societies to become centralised, despotic states.

> "If irrigation farming depends on the effective handling of a large supply of water, the distinctive quality of water - its tendency to gather in bulk - becomes institutionally decisive. A large quantity of water can be channelled and kept within bounds only by the use of mass labour and this mass labour must be coordinated, disciplined and led. Thus a number of farmers eager to conquer aird lands and plains are forced to invoke organisational devices which - on the basis of pre-machine technology - offer the one chance of success; they must work in cooperation with their fellows and subordinate themselves to a directing authority....

> "The effective management of these works involves an orga-sational web which covers either the whole, or at least the dynamic core, of the country's population. In conse-quence, those who control this network are uniquely prepared to wield supreme political power" (Wittfogel, 1957: 18, 27).

2. Social anthropologists interested in exploring cross-cultural regularities and the factors underlying them were naturally attracted by this hypothesis for, at a time when "historicans of culture were emphasising differences between civilisations, Wittfogel was postulating a single basic factor that brought all these civilisations into being" (Steward, 1980) For the same reason it also provoked sharp critical reaction. The ensuing controversy stimulated a number of systematic and detailed studies of irrigation institutions in different parts of the world including Indonesia (Geertz, 1959, Jay, 1969), Ceylon (Leach, 1961 Chambers, 1977), Tanganiyaka (Gray, 1963), Iraq (Fernea, 1970), Cen America (Price, 1971), Spain (Glick, 1968, 1972), Mexico (Hunt and Hunt, 1974), Spain and US (Maas and Anderson, 1978), and Japan (Kelly, 1980); Thailand (Potter, 1971) and Taiwan (Pasternak, 1972).

3. These studies revealed that the institutional arrangements by which irrigation was set up and managed are extremely varied; that there is no systematic correlation between the existence of irrigation and the nature of the overall political authority; and that there is no general tendency for irrigation societies to be centralised, bureaucratic or authoritarian. As Steward put it recently:

> "The thirty years since Wittfogel's first publications... have produced a vast amount of field work which have thrown doubt on the universal applicability of the irri-gation hypothesis. It is clear that in many instances irrigation has been ascribed excessive importance and that in others its development seems to have been the result rather than the cause of the growth of States." (Steward, 1980:4).

4. While there is impressive evidence to cast doubt on the Wittfogel hypothesis, we do not have an alternative hypothesis regarding the determinants of the form of irrigation institutions or their relationship to political authority. Part of the difficulty arises from the ambiguities in the concept of 'centralisation' and of 'irrigation organisation' which runs through most these studies. For instance, as Hunt and Hunt have noted, there is a tendency to confuse between two distinct types of centralisation:

> "..One refers exclusively to authority in terms of the irrigation system. The other refers to generalised political authority which may involve other functions of control outside or above simple water control. In one case authority is exercised over different decisions making rights in terms, exclusively, of the social and technical needs of the irrigation system per se. In the other case authority is exercised over water as one aspect of a complex political role or of a large multi-function political machine." (Hunt and Hunt, 1976: 132).

5. This point is also emphasised by Kelly who goes on to focus on the need for greater clarity in the concept of 'irrigation organisation' itself. Irrigation, he points out, has several phases (namely control of the water source, the delivery of water, the actual application of water to crops, and drainage) each of which involves a number of distinct functions (namely, 'facility construction', operation and maintenance, water allocation and conflict resolution). In view of this it is inappropriate, and certainly misleading, to speak of 'irrigation organisation' as if it were a single unit handling all phases and functions; rather it has to be viewed in terms of arrangements for performing the various functions in each of the phases of irrigation and water control. (Kelly 1980: 14-20).

6. Moreover as already mentioned, most of the above studies view water control institutions primarily in terms of their relation to general political authority. Though they document the wide variations in internal structures and processes of these institutions (as distinct from their external form), there is hardly any attempt at examining the significance of these variations or the reasons therefor. It is of course recognised that institutions for water control have to be viewed in relation to agro-climatic conditions, the technology of water control and of agriculture, land tenure and other factors which define the context in which these institutions function and which to some extent conditions their characteristics.[4/] However, while most of the studies give some information on the physical and technological conditions of the study area, they do not always bring out the relations between them and the structure and working of water control institutions. This calls for systematic comparative studies of water control systems in different agro-climatic, technological and socio-economic contexts. Though the need for it is appreciated (Downing and Gibson 1974; Coward Jr.1980), such s are altogether rare. We however have a few studies of the evolution of water control institutions in specific regions of China (Hamashima 1980) J (Tamaki 1979; Hatate, 1979, 1981; Kelly 1980) and Taiwan (Vander Meer 1977; Pasternak 1972) which throw some light on these inter-relations.[5/]

7. In recent decades the role of water control in agricultural development has come to attract more and more attention. That expansion and improvement of water control facilities (and in particular irrigation) has a crucial role in increasing agricultural production in densely populated developing countries is by now commonplace wisdom. Most countries in Asia attach great importance to rapid development of irrigation and flood cont-

and have spent massive amounts for this purpose. However experience shows that there is great deal more to this than the construction of reservoirs and canals. The effective utilisation of these facilities is often found to be impeded by the inability to complete the construction of terminal distribution and land improvement works, and the lacunae in the organisations for proper maintenance and operation of these facilities on a continuing basis. This has stimulated much interest in the problems relating to the design of water control institutions: what the 'right' design should be; and what the impediments to implementing the right design are. We now have a sizeable literature on these questions (see for example Coward Jr. 1980, IRRI 1978, Wickham 1971).

8. Unfortunately much of this literature also tends to focus on institutions per se with what seems to be an excessive pre-occupation with differences in form, e.g., 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. Which again stresses the need for, and value of, comparative and historical studies of irrigation institutions in a variety of natural, technological and tenurial contexts so that we can have a better understanding of the nature of institutions suited to different contexts and the extent to which they can be expected to improve agricultural performance.

Objectives and Scope of Paper

9. The compexity of the task is too obvious to be stressed. Nevertheless it is worthwhile, as a beginning, to attempt at least to sort out the key elements of the physical, the technological and socio-economic environment which have a bearing on the nature of the water control problem and hence on the institutions for handling it. It is to this end that this paper is addressed. Hopefully it will help in the formulation of a omore comprehensive and better-articulated framework in which comparative studies of water control institutions, their role and evolution can be undertaken.

10. The scheme of the paper is as follows: Since the ultimate purpose of water control is to help increase agricultural production, it is appropriate to start by spelling out the relation between water control and agricultural production. This is the subject of the following section. Section 3 deals with the construction of water control and distribution systems and the role which institutions,along with other factors,play in shaping them. The subsequent section is concerned with the maintenance and the operation of water control systems. Both are aspects of continuing management usually handled by the same organisation. Nevertheless they are functionally distinct and should therefore be considered separately. main point is that while the role of institutions in managing the recurrent 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 determine the returns to irrigation. Persistent or acute conflicts within the irrigation syste

and/or a change in the returns to irrigated farming induce changes in water control procedures and eventually in system design. At all stages we draw liberally on the available descriptions of water control systems in different parts of Asia (and more particularly India, China and Japan) to illustrate the argument. The main points of the discussion which are suggestive rather than conclusive, and their implications for further studies are highlighted in the concluding section.

2. WATER CONTROL AND CROP PRODUCTION

11. Water serves two essential functions in plant growth: It maintains the plant temperature within tolerable limits and facilitates the absorption of nutrients. Plants can only use the soil/moisture available within their root zone. There is usually a certain maximum amount of water which a field of given soil type and depth can hold at a particular point of time. When the soil moisture stock falls below this level plants find it increasingly difficult to maintain the rate of transpiration necessary to regulate temperature. Upto a certain point, the plant has internal adjustment mechanisms to cope with moisture stress without any adverse consequences to its growth. But beyond that point, which varies with crop species and variety, continued stress begins to have adverse effects on the vital life processes of the plant, including its capacity for photosynthesis. These adverse effects increase as the moisture stress increases until in the extreme case the plant wilts to death. The amount of moisture available in the root zone also affects the volume of nutrients which the plant can absorb and the efficiency with which they are utilised: In general the more abundant the soil moisture, the larger the volume of nutrients which plants can absorb and the greater the efficiency of their use. Additionally, an

the case of paddy water plays an important role in regulating soil temperature and in controlling the growth of weeds.[1/]

12. From the purely agronomic viewpoint, the 'ideal' soil moisture regime can be defined as that level at which the plant is free from any moisture stress and can realise its full genetic potential (provided that other inputs are used in the required measure). Fields under crops are continually losing soil moisture on account of transpiration by the plants and evaporation from the exposed soil between them. Losses due to such evapo-transpiration (ET) must therefore be replenished promptly in order that the plants are not subject to any moisture stress. It so happens that ET (under conditions of no moisture stress) depends largely on sollar radiation, humidity and other climatic factors.[2/] Except in the case of paddy, which needs substantial amounts of water for puddling and for keeping the field submerged, the nature of the crop grown seems to make no significant differente.[3/]

13. The seasonal profile of ET is typically of the shape denoted by EE in Fig.1: It is relatively low in the winter and gradually rises to reach a peak in the summer months before falling. In the absence of irrigation the only source of soil moisture is local rainfall. If the quantum and seasonal distribution of effective rainfall (i.e., that part of the rainfall which is absorbed and retained in the soil) is such that the losses due to ET are promptly and fully replenished, year-round cropping is possible without any need for irrigation. The only limiting factor would then be the winter temperatures.

14. The above situation can obtain if the seasonal distribution of effective rainfall more or less coincides with that of ET. Such a situation is however very rare. As a rule, in most parts of Asia the distrib-

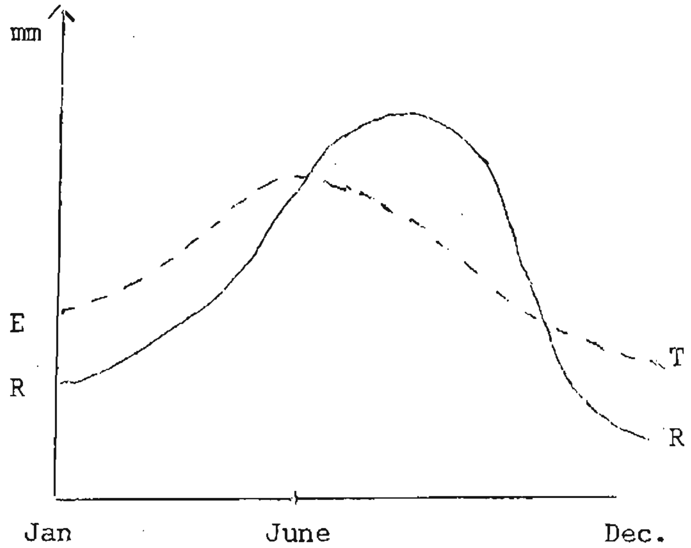


Fig.1: Seasonal pattern of Evaporation [ET] and Rainfall [RR]

of rainfall relative to ET follows the pattern shown in the above figure: Effective rainfall (RR) is less than ET in the relatively dry months and exceeds it during the rainy season. In other words, the moisture available is on the average more than adequate to meet crop-water requirements in the rainy season but falls short of it during the rest of the year. The relative positions of ET and RR, which is one important manifestation of agro climatic conditions, have a major bearing on the timing of sowings, the duration of the crop season as well as the nature of crops grown under rainfed conditions. The greater the seasonal concentration of rainfall and the larger the gap between ET and RR, the shorter is the period available for raising crops wholly on the basis of rainfall. The function of irrigation (and water control generally) is to bring the seasonal pattern of water availability more closely in line with that of ET.

15. There are several aspects of this: In the first place, even where on the average and taking a season as a whole, the amount of rainfall is adequate to meet crop water needs, its distribution within the season is

often so variable that rainfall by itself can not be trusted to ensure that soil moisture is maintained at appropriate levels throughout the growing season. The variability in the date of onset of rains and in the amount of rainfall during the early phases of the season affects the date of sowing as well as the rate of germination and establishment of the young plants all of which obviously have a significant bearing on the eventual yields. Similarly dry spells during critical stages of plant growth (which varies with crops) can reduce eventual yields considerably. Under these conditions irrigation has an important role in ensuring that the soil moisture supply is adequate especially during critical stages of crop growth irrespective of the unpredictable variations in rainfall during the growing season. The lower the total rainfall, and the greater its variability during the season, the more important the role of irrigation.

16. In many parts of Asia, especially in south Asia, the nature of crops which can be grown during the wet season is also conditioned by the unreliability of rain and by the fact that the total quantum of precipitation is low. Thus in most parts of peninsular India rainfed lands can grow only millets, pulses or oilseeds during the monsoon season. Under these conditions, irrigation works which augment the total supply of water during the rainy season enable farmers to grow crops like paddy which yield much more than other crops but require a larger volume of water. The impact is even more dramatic in arid regions like Rajasthan, Punjab and much of Pakistan where rainfall is scanty even during the monsoon season.[4/] In such cases the possibilities of rainfed agriculture are severly limited: A relatively high proportion of land is under pastures or kept fallow, and the rest of it used to grow species and varieties of crops (mostly millets and pulses) which can survive on small and precarious moisture supply and whose yield potentials are by the same token low. Introduction of irrigation

in such a context enables a significant expansion of cultivated area, an extension of the cropping season and a switch to an altogether new and more productive cropping patterns.

17. Controlling soil moisture conditions, however, does not always or exclusively depend on irrigation: In many circumstances, the problem is to protect cultivated lands from inundation and provide effective drainage in areas prone to water logging. Flooding arises from spells of heavy rainfall concentrated in a short period and is liable to be especially serious in the plains along the lower reaches of large rivers. Swamps and marshes, mostly in the estuaries of major rivers often require elaborate drainage works to remove excess water and make the land suitable for cultivation. (Extensive areas of cultivated land both in China and Japan were in fact reclaimed by this means.) Besides, in all irrigated tracts, efficient drainage is essential to prevent waterlogging and salinity arising from indiscriminate irrigation. In view of these, the concept of water control relevant from the viewpoint of agricultural production should obviously be broader than irrigation and must cover flood control and drainage as well.

18. It is clear that water control could contribute to increased agricultural production in one or more of several ways: It can raise yields of particular crops and make them more stable by facilitating planting at the optimal time and by enlarging scope for fertiliser use; it can contribute to increasing the intensity of cropping by reducing the extent of fallowing and/or by extending the effective cropping season; and it enables a greater diversity of crops to be grown permitting in the process a switch of high productivity, high value crops. However the precise magnitude of the increase in productivity per unit area (and in total production)

depends not only on the extent of the water control system and its quality, but also on several other factors notably climate, soils and the genetic characteristics of the crop varieties grown.

19. To illustrate the point let us consider the effects of water control on the productivity of a given crop variety. In figure 2 00_1 represnets the yield response curve of a given crop variety to fertilisers under rainfed conditions; 00_2 denotes the positions of the response curve at the limit of the genetic potential of the same variety under ideal soil mo conditions, (i.e., when the crop is not subjected to any moisture stress at any stage of its growth). How far apart 00_1 and 00_2 are depends in part on the reliability and seasonal distribution of the rainfall.

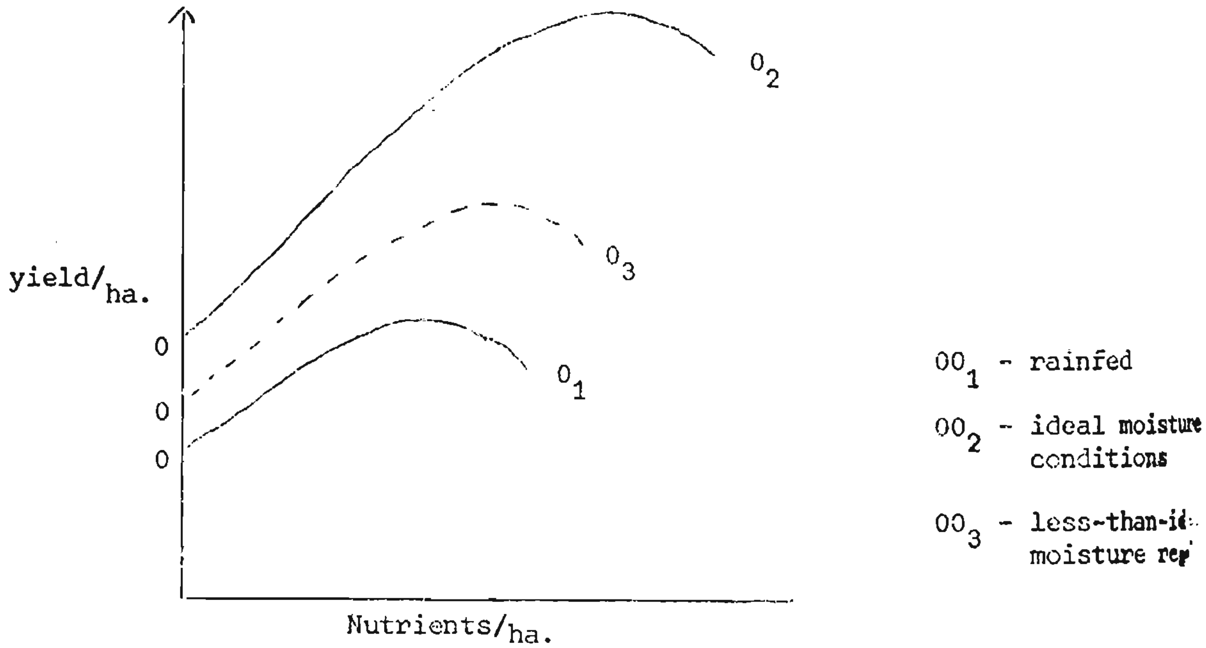


Fig.2:. Production possibilities under different moisture regimes for a given crop variety.

20. The more ample the rainfall and the more even its seasonal distributi relative to ET, the smaller is likely to be the increase in yields as a result of water control. The genetic characteristic of the crop variety

would influence the extent to which the fertiliser response curve would shift when 'no moisture stress' water control is introduced. But in general yields per hectare are likely to be higher at any given level of nutrient use and the maximum amount of nutrients which the plants can use to be also higher under ideal moisture conditions than under rainfed cultivation. (OO_2 assumes that other elements of crop husbandry such as control of weeds, pests and diseases are adjusted as necessary to realise the full potential of the variety in use).

21. The production possibilities are likely to be lower than OO_2 if the 'ideal' moisture regimes is not achieved. The possibilities under less-than-ideal water control is denoted by OO_3. (Obviously there are, in principle, an infinite number of positions between rainfed and 'ideal' water control conditions). The achievement of 'ideal' water control essentially depends on how successful the system is in regulating the timing and quantum of irrigation supplies, as well as drainage, so that the relevant soil profile is kept at or near field capacity in all stages of the crop. For this there are both physical and institutional prerequisites: Among the former are the design of the distribution network which effectively reashes all the fields and permits regulation of the flow of water to different fields; an adequate drainage network; and careful grading and levelling of fields (or alternatively, facilities like sprinklers and drip irrigation). At the institutional level it is necessary to have a set of rules and procedures for the proper maintenance of the system; determining and enforcing a schedule of distribution in the light of seasonal conditions; and for resolving the conflicts among users in relation to both maintenance and water allocation.

22. The yield nutrient relations presented in figure 2 give a stylised picture of production possibilities for a particular crop variety under at varying levels of fertiliser use, under different soil-moisture regimes. We can also look at production possibilities in terms of yield - soil moisture relation at a given level of fertiliser application. In figure 3 each curve portrays the effect of variations in soil moisture on yield, keeping the level of fertilisers constant. Take OA D_1 for instance. It implies that if total moisture available to the plant is less than A the crop will not grow maturity. Beyond that point as moisture supply increases yield will also increase but a declining rate till it reaches a maximum. Further increases in moisture may after a while depress yield. The moisture-yield curve will shift upward as the level of nutrient is increased; but again beyond some level of application, which depends on the crop and its genetic potential, increase in nutrients will not make any difference to yield. OA D_p represents has maximum yield potential of the crop.

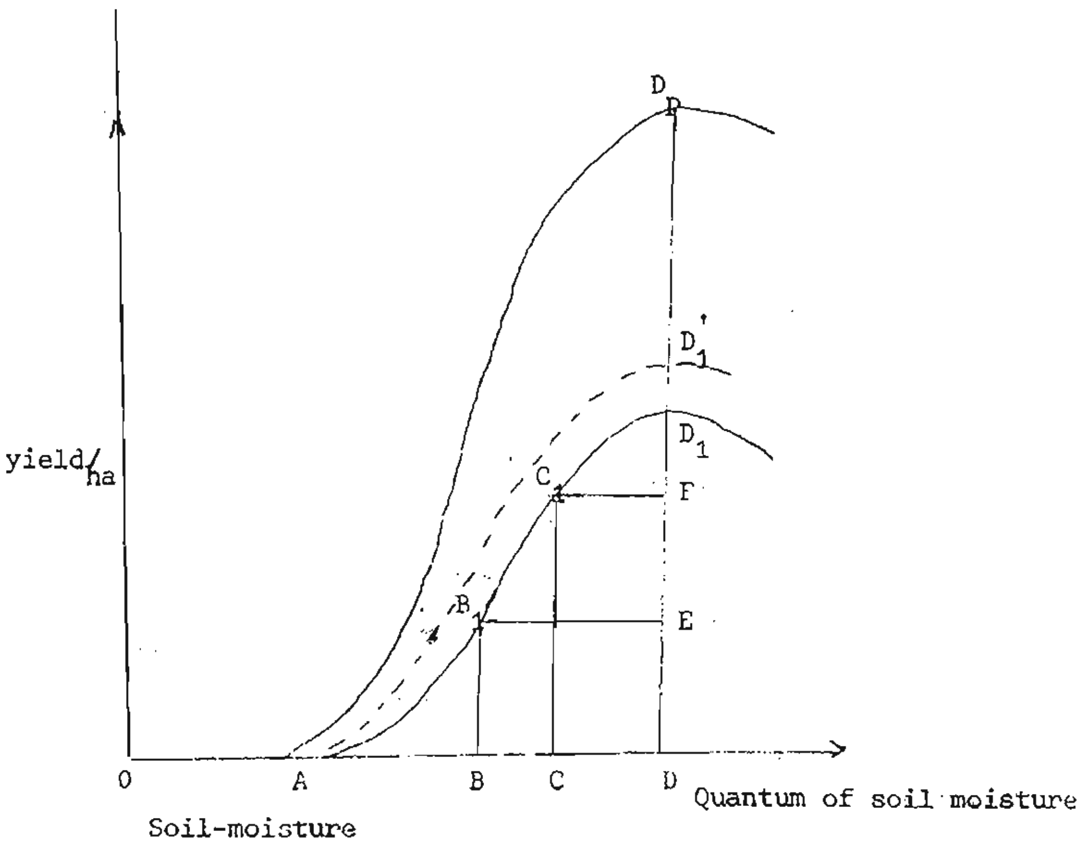


Fig.3: Yield response curves at different levels of fertilisation.

23. "Moisture Supply" in figure 3 refers to total supply of moisture during the growing period from rainfall and irrigation . Clearly, the effect of irrigation on yield depends on how much moisture is available from rainfall. The higher the rainfall relative to the crop-water need, the lower is likely to be the effect of irrigation When rainfall supplies OB of soil moisture , the marginal product of irrigation at the maximum yield D_1E/B_1E which is lower than D_1F/C_1F corresponding to a situation when rainfall contributes OC. The introduction of a more fertiliser-responsive strain of the same crop, would shift the OAD_1 upward, denoted by OAD_1', which implies that the incremental output per unit of water for any level between A and D is higher than with the old variety. Finally it is relevant to note that in figure 3 water input denotes the quantum of soil moisture supplied by irrigation which is different from the total water supplied by irrigation, the former being invariably lower. Out of the total water tapped at the source of irrigation, besides sheer waste, a part is lost in the process of conveying water to the field and another part on the field itself. The percentage losses on these accounts, which is a measure of the technical efficiency of an irrigation system, depends on a variety of factors some of which (e.g. the distance over which water has to travel) depends on the size of the irrigation system; others (like the technical specification of the distribution net work, the lay-out of the fields and the extent to which they are graded and levelled)on project design; and yet others on the quality of maintenance and techniques of water application.[5/] All this underlines the need to view water control - in a broader perspective: The effect of irrigation is not entirely a function of how will a system is designed and managed. Important as these are, they are powerfully conditioned by the larger

material and social context. In order to appreciate these inter relations we will consider first the factors which shape the character of water control systems and then proceed to a discussion of their operation.

3. CONSTRUCTION OF WATER CONTROL WORKS

24. The construction of water control works covers several distinct phases from controlling and harnessing a water source, through the laying of the distribution/drainage network reaching down to the farm level, to preparation of land for efficient irrigation. The institutional aspects concern the location of the responsibility for planning, design and construction of the facilities in each phase, for mobilising the necessary resources and resolving conflicts which arise in the process. Of particular interest in this connection is the relative roles of the State, local institutions and private effort in each of these activities and the factors which determine the particular mix of roles in different situations.

Variations in Organisation

25. There are marked differences between countries and regions in the manner in which construction of water control systems is organised. In contemporary times the State everywhere plays a prominent role in planning, regulating and assisting the development of irrigation, flood control and drainage projects. The extent of its direct involvement in the process however, varies. In India,[1/] for instance, the national and the state governments bear a much greater direct responsibility

than most other countries in Asia (including China): In the case of surface irrigation works, it is the government agencies which do the preparatory surveys, design projects and undertake the actual construction. Till some two decades back the government undertook the responsibility for constructing the main reservoir, the main and branch canals and distributaries upto a certain level (usually outlets covering about 40 ha or so); the farmers were expected to construct field channels beyond this level and also make the land improvements necessary for irrigation. However, since then there is a clear trend towards the government assuming responsibility for these works as well. For this purpose a new institutional arrangement, in the form of Command Area Development Authorities, separate from the departments responsible for the construction of the main facilities, has also been devised. The cost of all these programmes is financed initially from the budtet and to some extent through financial institutions. The departments concerned procure the necessary materials and sometimes do the construction with their own staff and labour specifically hired for the purpose. The more common practice, however, is to entrust the construction (including the task of recruiting the necessary labour and supervising it) to contractors selected by a "tendering" procedure. The farmers do not contribute any money or labour at the time of construction. The cost of works is supposed to be recovered from the beneficiaries in easy instalments over a period of several years in the form of 'betterment levies'. But little is actually collected so that in effect the beneficiaries hardly contribute anything to the cost of developing water control facilities.

26. In the case of groundwater, the states role is more limited: Apart from organising surveys of groundwater potential, providing

technical advice and some drilling equipment, and laying electricity transmission lines, its involvement in actual construction is confined to the relatively large-sized tubewells in North India. The great bulk of the work of digging/drilling, construction of channels, land levelling and installation of pumps is done by the farmers themselves, typically on an individual basis. However, the government is the principal source of finance, which is given directly (both as loans and as grants) and indirect in the forms of loans through financial institutions. This assistance is usually adequate to cover most of the initial costs and the terms are relatively soft.

27. Compared to India, the higher levels of government in China and on Japan play a much more limited role in practically every phase and the users and their organisations bear a correspondingly larger responsibility both for construction and for mobilising the necessary resources.[2/] Thus in China

> "The planning, design, a construction and operation of specific projects takes place at four different levels depending on the size of the project. The general principal is that the responsibility for a project which affects two or more units is taken up by the unit of the next higher rank. A corrollary is that each unit which benefits from a project contributes labour and investment in proportion to its share of the benefit. Thus the central government, through the project bureaus of the Ministry of Water Conservancy, takes the responsibility for 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 irrigation projects which affect more than one country or municipality. Country (or municipal) governments usually undertake the diversions or reservoirs which affect more than one commune... At the local level commune or production brigade units plan, construct and operate numerous projects of all types.: (Greer, 1979: 116-7).

28. As a matter of fact a high proportion of the water conservancy development works in China consists of projects of the last category. Government policy has consistently emphasised the importance of the people's communes and their constituent units exploiting the possibilities of such development on the basis of their own initiative and effort. These local works include projects to harness water sources within the boundaries of the commune/brigade as well as the construction of distribution/drainage networks and land improvement necessary to make effective use of opportunities opened by larger projects undertaken by higher levels of government.

29. Even more striking are the differences in the method of resource mobilisation. In China, unlike India, the beneficiaries are expected to constribute a large share of the project costs at the time of construction itself. Thus the cost of projects undertaken by communes/ brigades/production teams are to be met wholly out of their own resources. Since labour is the main resource needed for construction of these works and accounts for the bulk of the costs, the mobilisation of resources takes principally the form of labour contributions by members of the beneficiary units. The communes are also expected to mobilise labour contributions for projects undertaken by the provincial/national government which benefit their areas. During the Big Leap period such contributions were sought and obtained even for projects which did not directly or immediately benefit them. Despite controversies over the basis of labour contributions and concern over the problems of effective organisation of a highly variable labour force, the principle of beneficiaries contributing directly to construction has been maintained. And though labour contributions are now limited to units which directly

benefit from a project, the magnitude of these contributions is very large amounting in some cases to as much as 80% of the total project costs (Vermeer, 1977: 260-1). It is relevant to note that the practice of mobilising labour for both local and national projects of water control (and for public works generally) has a long tradition in Chinese history.

30. In post-war Japan[3/] the planning and construction of water control works, most of which are for the expansion and modernisation of pre-existing systems, is the responsibility of the Land Improvement Districts (LID). These LIDs of which there are 13,000 at present, are constituted under a special legislation specifically meant to improve water control by constructing new storages to augment the water supply, rationalising the layout of irrigation and drainage canals and reorganising the physical layout of plots to permit more effective water control at the field level and also facilitate mechanisation. The LIDs are associations of farmers in the service area of water control systems (usually formed out of users organisations of local systems built in the past) and managed by elected representatives of its members.

31. The prefectural and the national governments undertake designing and construction only of barrages (or storages) and canals which serve more than one LID. In all other cases the government provides technical advice (in matters of engineering and design) and financial assistance (half the cost is borne by the national government, one-fourth by the prefecture and liberal loan facilities to cover the balance). While all this gives the government considerable influence over the general conception and design of the projects, the formal responsibility for decisions on all these matters as well as the awarding of contracts rests with the LID management.

Historical antecedents

32. To some extent these variations are a reflection of differences in the historical evolution of the government's role in relation to water resource development. In India, from what little we know about irrigation history of the pre-British period, it would seem that considerable development of local irrigation works had taken place, especially in south India, under essentially local leadership even before the emergence of unified states of any significant size. (Ludden, 1973). Similar developments may have taken place in north India as well, but the state seems to have played a more direct and prominent role in developing some of the larger irrigation systems like, for example, the Jamuna and the Ganga canals and the elaborate system of flood irrigation in Bengal (Harris 1923, Habib, 1962).

33. During the early phases of British rule, the government did not take much interest in irrigation development. In south India, for instance, soon after the British take-over, the government assumed responsibility for rehabilitating tanks which had been damaged by war and neglect as well as for their subsequent upkeep.[4/] In the first half of the 19th century, the State spent substantial sum on reconstructing old systems of surface irrigation, some of them very large by even modern standards. New projects were then taken up as commercial ventures. But since they were not profitable, progress was slow till the end of the 19th century. Thereafter public irrigation construction increased rapidly possibly as a response to recurrent famines and partly for strategic considerations.[5/] Almost all the new projects were for surface irrigation; not only were they large in terms of cost and area covered, but many of them involved construction of reservoirs of a size altogether new to the subcontinent. By all

accounts, there was no attempt to extract contributions whether in money or labour, from the potential beneficiaries or to involve them in any way in the conception or implementation of the projects. The post-independence period witnessed a massive expansion in the scale of development in all types of irrigation and flood control projects; but the composition has shifted markedly in favour of ground water. Though groundwater development is largely in the private sector, it depends heavily on technical and financial support from the State. Surface irrigation works continue to be dominated by large storage works.

34. Both in China and Japan, by contrast, have had a long and sustained tradition of water conservancy development through local effort, and of requiring beneficiaries to contribute labour and materials for construction even when the government undertook projects. In China huge projects to control floods of the Yellow and the Hwai rivers, and to divert river flows to irrigate extensive areas, were taken up as fair back as 500 BC or even earlier, and the practice of using corvee labour established then has continued through out subsequent centuries. The role of such undertakings in shaping Chinese history and their significance for the nature and organisation of government in China has attracted much attention. (Chi, 1936; Wittfogel, 1957).[6/] The fact remains however that these large projects account for but a fraction of the total effort which has gone into the development of water conservancy and in particular irrigation. Not only was there a great deal of construction (smaller dykes, distribution networks and land development) at the local level essential before the benefits of the large projects could be realised, but a good part of irrigation was in any case derived from essentially local works, which seem to have been conceived, planned and constructed by, or under the leadership of, local landlords, clan leaders, and the

Gentry using local resources (mostly labour) with occasional help and support from the government and from merchants. Even in the case of large projects mobilisation of corvee labour, which on occasion could reach staggering dimensions, was widely used in project construction by both provincial and national governments.[7/] Despite the far reaching changes in other aspects of economic, political and administrative organisation of Chinese society after the Revolution, one can thus see a certain continuity in regard to the organisation and financing of water conservancy construction.

35. The Japanese experience shows an unmistakable trend towards growing government involvement not so much in construction, but in guiding and financing water control development. (Tamaki 1977, Hatate 1978). Historically early development of irrigation consisted, almost exclusively, of small localised developments organised by feudal chieftains and large land owners with the help of local labour. As the limits to such works were reached and/or significant improvements in techniques of water control became available, larger projects requiring support of and intervention from supra- local political authority were taken up. This was sometimes the result of pressures from below but often they also reflected the effort of ambitious local rulers to enlarge their revenues and extend the domain of their power. Regional and national governments took a particularly active part in water conservancy during the 17th and 18th centuries and financed part of the costs, but the local participation continued to be very important. Even during the 19th century when the role of national government increased significantly, the government generally insisted that the beneficiaries bear the bulk of the costs of new projects. It was only in the 1920s that the government, under pressure of growing food shortages, substantially liberalised the scale

and terms of assistance for water control projects.[8/] For a variety of reasons the process has been carried considerably further in the post-war period. But a high degree of user involvement in and control of the developmental activities has been maintained.

Scale and complexity of Projects

36. To a considerable extent, the difference in the role of the government reflects difference in the scale and complexity of the works involved. This is of course the central point of the Wittfogel thesis on the role of the State in hydraulic society. The argument simply is that large scale, technically complex water control works call for mobilisation of resources and organisational capacity on a scale far beyond the capability of local communities or private enterprises and can only be handled by the government. This implies that where projects of large size and/or complexity figure more prominently in the mix of water conservancy works, one may expect to find the State playing a more prominent role in the planning and construction of these works. Such an association in fact seems to exist in the three countries just discuss-

37. Thus in India about two thirds of the total irrigated area is estimated to be under surface water irrigation the great bulk of it from canals as distinct from tanks[9/] and other small, local sources. The canal systems ,consisting of both diversion works and storage based projects, are typically large by the standards of the rest Asia (except perhaps Pakistan). Projects irrigating 100,000 ha. or more are common and account for about half of the area served by surface irrigation sources; there are as many as 10 systems serving 500,000 ha. or more and the largest (the Bhakra-Nangal)' irrigates some 1.3 million ha. Reservoirs with a storage capacity of more than 500 million cubic meters each

which there are some 50, account for 80 per cent of the total storage capacity (147 billion cubic meters), while tanks and small ponds are estimated to account for less than 10 per cent (Rao, 1979). Large scale canal irrigation projects dominated irrigation development during the British rule; in the post-Independence era, the absolute scale of activity has risen steeply even though in relative terms their importance had declined as a result of an even more rapid expansion of groundwater development.10/

38. In China, during the mid-fifties (the latest period for which the relevant information is available), surface irrigation accounted for over 80 per cent of the irrigated area most of it (over 90 per cent) consisting of 'farm ponds and weirs' and 'gravity systems based on small ditches and aqueducts'. Large gravity canals, which would include the bigger river diversion works (some of them of ancient origin) serve less than one tenths of the country's irrigated area.11/ This brings out the dominance of relatively small, essentially local projects in Chinese irrigation system. And as mentioned earlier, the construction of such projects together with the improvement of existing local systems through communal effort has been the highlight of the post-revolution period as well.

39. It is in the case of flood control and drainage works that the government played and continues to play the major role. Many of the classic examples of massive public works in ancient Chinese history are in fact works of flood control (especially in the Yellow and the Hawai river basins) and in navigation canals (like the Grand canal). In recent times too this has been the pattern: besides the construction

of new embankments and improving existing ones along the major rivers, there has been a large programme for construction of reservoirs. The number of reservoirs with a capacity of 100 million cubic meters or more (most of which were meant for flood control rather than irrigation) rose from 10 in 1949 to 300 in the later seventies (Nickum, 1981:6). The government necessarily had to play a leading role in the design and construction of these works which were not only huge but also required coordinated planning of entire river basins cutting across provincial boundaries. That even in these projects a large part of the cost was met by labour contributions from the areas benefitted by them remains a distinct feature and one which cannot be explained in terms of the scale and complexity of the projects.

40. In Japan, as in China, the bulk (75 per cent) of irrigated area is served by river diversions and ponds. Even now reservoir based systems are estimated to serve barely one sixths of the irrigated area (Fukuda, 1976:88).[12/] The Japanese irrigation systems are large in number and their average size is quite small. If we consider each Land Improvement District as one project (or system), the average size of an irrigation project is barely 250 ha; there are hardly any systems serving more than 20,000 ha.[13/] Flood control and drainage were of course essential for expansion of paddy cultivation and in some areas (like the Kanto plain) involved relatively large scale construction and high level of technique. But nowhere did these works reach the scale found in China. Much of it could be and was handled by local rulers well before the emergence of a unified national government. The relatively more prominent role of the government in the post-war period is consistent with the programme for construction of new storages, involving integration of

pre-existing irrigation communities and LIDs. But there were also other factors behind the enormous increase in the volume of financial assistance given by the state.

41. Given that the scale of projects has some bearing on the nature and extent of state involvement, the question arises as to what determines the type of projects which are undertaken. The nature of water control needed for agriculture depends on agro-climatic conditions, while what is feasible is conditioned by topography, geological conditions and the state of the arts in hydraulic engineering; and what gets actually selected from the feasible set is a function of yet other, essentially socio-economic, factors.

Agro climatic factors

42. We have already explained at some length (see Section 2) how rainfall and evaporation are the two basic climatic variables which determine the nature of the water control needed for efficient agriculture. Different configurations of these variables imply different problems in the attainment and maintenance of appropriate soil moisture conditions. Consider for instance the two different configurations portrayed in figure 4.

43. In A - which is a stylised picture of the climatic pattern characteristic of much of south Asia - temperatures are throughout much higher than in B - which approximates to the climate characteristic of much of east Asia. Consequently A has a higher evapo-transpiration (ET) in practically all seasons and certainly over the year as a whole compared to B. On the other hand the average rainfall in A is lower and its

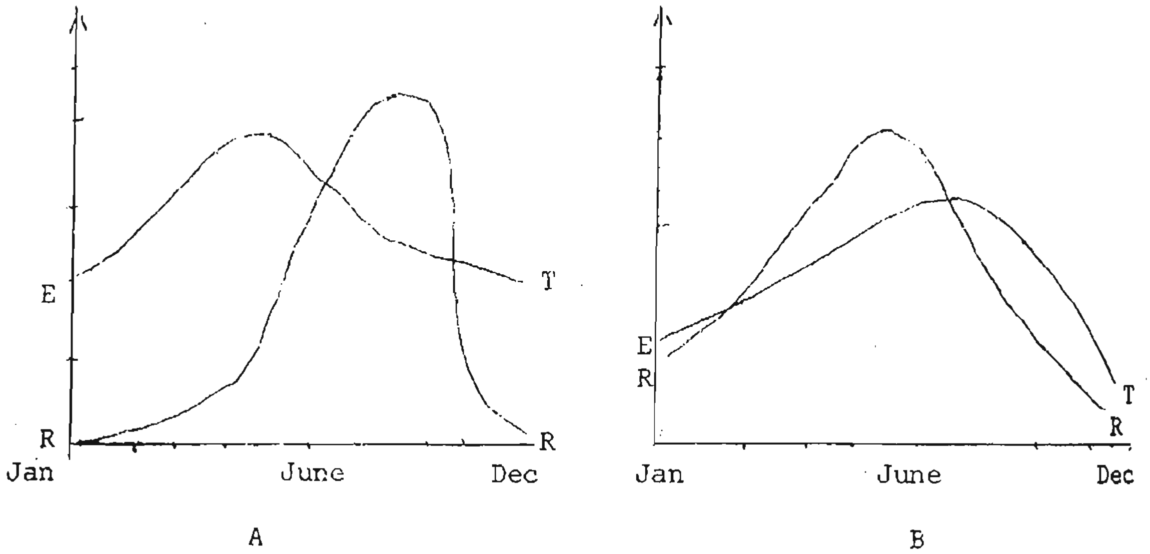


Figure 4: Climatic patterns typical of South and East Asia

seasonal concentration much more pronounced. The combined result of these difference is that the 'dry' season in A is not only longer but, the moisture deficit (i.e., the excess of ET over effective rainfall) is also larger. (See Table 1). 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 or underground for use in the dry season. Which of these possibilities is in fact available however depends on topography and geology.

44. Thus in the Indo-gangetic plain, though the general climatic pattern follows the pattern A, the rivers flowing through the plains have unusually large catchments which includes the Himalayas. The contribution of snow melts from these mountains is an important factor in making all the major rivers in this region perennial. The topography

Table 1

Dependable precipitation, Potential Evapo transpiration and moisture deficits at different locations in Asia

(mm)

ry -Centre	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec
saka	22	28	69	94	88	132	84	61	107	62	48	3
	37	42	68	100	131	137	167	167	117	81	58	3
	15	14	-1	6	43	6	83	112	10	19	5	[illegible]
okyo	28	51	69	97	92	97	71	66	163	145	63	2
	38	43	66	94	123	121	148	153	100	71	48	4
	11	-8	-3	-3	31	24	76	87	-63	-74	-15	2
igata	151	102	82	87	70	72	120	54	120	106	128	19
	0	0	51	88	121	135	153	166	105	67	37	2
	-151	-102	-37	1	51	63	34	112	-15	-39	-90	-17
usan	9	23	57	70	89	89	131	92	109	21	25	1
	0	45	73	102	134	133	144	160	113	90	57	4
	-9	22	15	31	45	45	13	68	3	69	31	3
Taipeh	50	76	102	96	106	221	173	153	123	54	36	-
	64	66	95	116	142	148	165	159	134	105	79	
	14	-10	-7	20	36	-73	-8	-8	11	51	42	2
pins-Legaspi	250	128	116	94	136	110	149	169	155	227	352	30
	115	117	143	148	157	152	153	151	141	135	117	11
	-135	-11	27	54	21	42	+4	-18	-14	-92	-235	-19
nd-Bangkok	0	2	10	43	122	122	112	141	235	166	25	[illegible]
	158	157	191	189	186	155	143	147	133	152	152	15
	158	155	181	14[illegible]	64	23	31	6	-102	-14	128	15
sia-Djakarta												
	210	127	156	76	55	42	24	7	31	47	96	11
	147	134	152	141	134	124	135	150	160	168	154	15
	-63	7	-4	64	79	82	111	143	130	122	58	41
ka-Colombo	33	46	63	147	241	156	64	46	68	246	226	7
	149	142	164	157	157	147	155	161	157	148	135	14
	116	96	101	10	-84	-9	90	115	89	-99	-91	6
esh-Jessore	0	1	4	31	100	185	247	196	145	66	0	[illegible]
	93	110	165	191	190	164	159	146	130	124	101	8
	92	109	162	160	91	-21	-88	-50	-15	57	101	8
alcutta	0	4	4	12	61	184	212	230	200	93	0	[illegible]
	111	123	172	191	203	148	132	133	134	143	123	10
	111	119	168	180	142	-36	-80	-97	-66	50	123	10
adras	1	0	0	2	0	26	47	77	70	153	153	2
	149	158	197	207	216	178	154	170	166	157	132	13
	148	158	197	205	216	152	106	94	96	4	-21	10
egumpet	0	0	0	6	7	59	121	86	91	30	0	[illegible]
	120	135	185	20[illegible]	229	185	161	156	141	142	121	11
	120	135	185	200	222	126	40	70	50	12	121	11
oona	13	1	0	21	3	5	0	0	1	108	201	8
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Table 1

Dependable precipitation, Potential Evapo transpiration and moisture deficits at different locations in Asia

(mm)

-Centre	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec
ka	22	28	69	94	88	132	84	61	107	62	48	3
	37	42	68	100	131	137	167	167	117	81	58	3
	15	14	-1	6	43	6	83	112	10	19	5	5
kyo	28	51	69	97	92	97	71	66	163	145	63	2
	38	43	66	94	123	121	148	153	100	71	48	4
	11	-8	-3	-3	31	24	76	87	-63	-74	-15	2
ta	151	102	82	87	70	72	120	54	120	106	128	19
	0	0	51	88	121	135	153	166	105	67	37	2
	-151	-102	-37	1	51	63	34	112	-15	-39	-90	-17
	9	23	57	70	89	89	131	92	109	21	25	1
	0	45	73	102	134	133	144	160	113	90	57	4
	-9	22	15	31	45	45	13	68	3	69	31	3
aipeh	50	76	102	96	106	221	173	153	123	54	36	
	64	66	95	116	142	148	165	159	134	105	79	
	14	-10	-7	20	36	-73	-8	-8	11	51	42	2
a-Legaspi	250	128	116	94	136	110	149	169	155	227	352	30
	115	117	143	148	157	152	153	151	141	135	117	11
	-135	-11	27	54	21	42	+4	-18	-14	-92	-235	-19
Bangkok	0	2	10	43	122	122	112	141	235	166	25	0
	158	157	191	189	186	155	143	147	133	152	152	15
	158	155	181	146	64	23	31	6	-102	-14	128	15
a-Djakarta												
	210	127	156	76	55	42	24	7	31	47	96	11
	147	134	152	141	134	124	135	150	160	168	154	15
	-63	7	-4	64	79	82	111	143	130	122	58	4
a-Colombo	33	46	63	147	241	156	64	46	68	246	226	7
	149	142	164	157	157	147	155	161	157	148	135	141
	116	96	101	10	-84	-9	90	115	89	-99	-91	6
h-Jessore	0	1	4	31	100	185	247	196	145	66	0	0
	93	110	165	191	190	164	159	146	130	124	101	8
	92	109	162	160	91	-21	-88	-50	-15	57	101	8
lcutta	0	4	4	12	61	184	212	230	200	93	0	0
	111	123	172	191	203	148	132	133	134	143	123	10
	111	119	168	180	142	-36	-80	-97	-66	50	123	10
dras	1	0	0	2	0	26	47	77	70	153	153	2
	149	158	197	207	216	178	154	170	166	157	132	13
	148	158	197	205	216	152	106	94	96	4	-21	10
umpet	0	0	0	6	7	59	121	86	91	30	0	0
	120	135	185	206	229	185	161	156	141	142	121	11
	120	135	185	200	222	126	40	70	50	12	121	11
	13	1	0	21	3	0	0	0	1	108	201	8
	134	138	171	172	178	166	169	171	162	155	132	127
	120	137	171	151	175	166	169	171	161	47	-71	4

Contn. of Table 1

abad	0	0	0	0	0	28	151	100	33	0	0	0
	119	133	176	211	245	20[illegible]	149	132	156	171	135	117
	119	133	176	211	245	180	-1	32	123	171	135	117
	13	5	7	2	1	17	132	109	17	1	0	0
	62	73	131	187	246	244	203	175	155	129	86	62
	49	68	124	185	246	227	71	66	137	129	86	62
derabad	0	0	0	0	0	0	17	2	0	0	0	0
	94	112	168	207	236	222	209	192	171	159	116	93
	94	112	168	207	236	222	192	190	171	159	116	93

Source: Hargreaves (1977)

Note.: The first row against each centre gives Dependable precipitation at 75% probability, the second row denotes Potential Evapotranspiration and the third row gives the Moisture deficit.

of the plains also permits irrigation by diverting the river flow to feed canal systems some of which are quite large.[14/] Apart from the Indus valley systems of antiquity, several large canal systems based on run-of- the-river have been constructed in this region both before and during British rule. But as the possibilities of river diversion got exhausted, further expansion has increasingly depended on storage.[15/] The geology of the plains is exceptionally favourable for groundwater storage but the intensive exploitation of this resource had to wait the introduction of energised pumpsets (which reduced the cost of lifting water) and the availability of techniques for tubewell construction (which made it possible to tap deeper strata of the sub-surface storage).[16/]

45. In south India, by contrast, 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. Irrigation development in this area was traditionally based on using local topographic variations to impound rainfall in small ponds for seasonal irrigation which also served as a means of improving groundwater recharge in their command area.[17/] Barring diversion works in the deltaic regions of the major rivers (the Krishna, the Godhavari and the Cauvery and to a limited extent in the smaller river basins) the bulk of the irrigation in south India in pre-Independence period was from ponds and wells.[18/] The development of tanks irrigation seems to have reached a point of saturation even before the British came. Further significant expansion of storage irrigation in this tract required the construction of large storages upstreadm and/or cheaper techniques for lifting groundwater. The technology required for storage dams did not develop indigenously and became available only in the last century or so. Economical techniques for exploiting ground water did not become available until much later.

46. By contrast in east Asia (Pattern E) precipitation is higher and at any rate better distributed relative to ET; the duration of the season when there is a soil moisture deficit (under conditions of rainfed farming) is shorter; and the magnitude of the deficit relative to crop water needs is smaller.[19] Rainfall being more evenly distributed most of the rivers are perennial. In China given the enormous extent of the catchment area and the fact that the rainy season in the upper parts of the catchment trends to be somewhat earlier than in the lower part of the river basin (where most of the agriculture is concentra probably means smaller seasonal variations in river flow in lower reaches Under this conjunction of 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, despite the dominance of paddy, which is water-intensive, large canal irrigation systems, and in particular those based on storage, are relatively recent phenomena.

47. By the same token, the relative abundance of water in these countries makes floods a more serious problem. Effective measures to regulate seasonal floods and ensure proper drainage of excess water is essential especially in the lower reaches of river basins and the esturaine areas. These works tend to be relatively large in terms of both size and the extent of area benefitted compared to irrigation products. The flood protection works of north China are among the largest water control works in the world.

Technology of water control

48. The constraints imposed by the state of hydraulic engineering and construction technology have been greatly relaxed in modern times because a large accumulation of proven techniques is available and has become more easily accessible. But these constraints were quite important in earlier times. The level of engineering and construction skills required for local ponds and shallow wells is of an altogether different order compared to what is involved in the construction of larger reservoirs and extensive canals. For reasons which are far from clear, significant progress in technology took place in some situations and at certain times but not in others.

49. Thus in China sustained efforts to control her major rivers led to major advanced in techniques of flood control occurred fairly early and this made it possible to implement massive works even in the pre christian era. (Needham, 1971). 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. That the technology of storage based systems did not develop indigenously in India and did not become available till recently must have been one of the factotrs which arrested the growth of irrigation in that country.

50. The relevant technology of water control from the viewpoint of agriculture of course extends for beyond what is used for harnessing water sources; it comprehends techniques for regulating conveyance of water and its efficient application to crops, Here perhaps more than

anywhere else, one can see the close interconnection between, the physical and the organisational aspects of water control. Efficiency of water management is crucially dependent on the working of institutio operating the system and within limits may even make up for defects in system design. But the physical design of the system (embodied in the structures through which the flow of water to different parts of the system are regulated; the specifications, design and layout of the irrigation-drainage channel network; the quality of land preparation; and the irrigation technique used at the field level) set definite limits within which the institutions have to operate. And it is also relevant to note that notions of 'efficient' water use are themselves conditioned by the state of knowledge regarding water-yield responses again has been constantly changing. There is a striking difference in this respect also between east and south Asia. Most of the Japanese and Taiwanese systems, and some at least of the Chinese have been "modernised" and achieved a level of sophistication in the design of distribution networks and control devices, as well as the management of water deliveries which stands in marked contrast to South Asian systems.

<u>Economic and Social factors</u>

51. Whether and to what extent technically feasible opportunities for water control are exploited, and how sophisticated to systems one, of course depend on economic considerations, i.e., by the magnitude of potential benefits from these works relative to the costs of developing them and by the returns to alternative use of available resourc The economic calculation may not always be explicit; in fact there is little evidence of such calculation behind much of water conservancy

development at any rate until recently. Nor is the calculus independent of the social and political context. Nevertheless there must have been some economic rationale understood in a broad sense even if it is only implicit:[21/] For instance the intensification of agriculture through irrigation rather than extension of rainfed farming probably reflects the dwindling scope for (or, equivalently, rising costs of) extending the area under cultivation and/or the possibility, under the prevailing agro-climatic and technological conditions, of realising a larger volume of total production with given resources under irrigated farming. It is also economically rational that improvements in the technology of water control (e.g., energised pumping, tube wells) which reduce the cost of water, and innovations in cultivation (like the introduction of new crop species and varieties, or of newer and cheaper source of plant nutrients) which increase the potential returns to irrigated agriculture should stimulate larger investments in water control.

52. The economic calculation is relatively straightforward when the investments are undertaken by an individual landowner for his own benefit. But when the investment is made for the collective benefit of several individuals, the calculus is affected by the way the necessary resources are mobilised; the basis on which costs and benefits of such investments are apportioned among the beneficiaries; and on the way the system is expected to be managed (especially in the matter of water allocation).

53. These problems arise even in situations where private property in land does not exist and where the use of land and other productive resources as well as the distribution of their product are decided communally. The experience of the Chinese communes, which come closest to this type in modern times, suggests that agreements over the distri-

bution of produce and the basis on which members are to contribute labour for capital formation are not easy to reach and their enforcement is not without difficulties. (Anon 1950 ; Nickum 1981: Crook $ Crook 1962). The difficulties are greater in the more common situation characterised by private ownership of land and unequal distribution of that resource resulting in an uneven distribution of output and a relatively high degree of concentration of 'surplus' in the hands of larger land owners. At one extreme, when the bulk of land is owned and cultivated by a small group, it is the interest of this group which is decisive in determining whether or not water control investment will be carried out and on what scale. In some situations the land owners had at their command 'serfs' whose labour they could use for constructing irrigation works, or for land improvement. But this is not a necessary condition.

54. The typical situation is one in which control over land is not so absolute and owners do not cultivate all their lands directly. When ownership of land is widely distributed and/or when a substantial part of land is cultivated by tenants, agreement over whether to invest in water control and how much is to be contributed by various beneficiaries must necessarily confront the question of how the benefits will be distributed. The decision could in principle be made by a consensus among all the parties involved but this seems rare. In any event it is the configuration of interest and power in the community which will determine whether and what kind of 'enforceable' compromise is feasible in a given situation.

55. The task becomes more difficult when the scope of water control works extends beyond individual communities and when villages lose their isolation and become more and more integrated with the economy and polity of larger territorial complexes. The former means that coordination and resource mobilisation have necessarily to be managed by a supre-village authority. The latter has the effect of loosening the connection between mobilisation of 'surplus' and its use for water control, making the connection less and less direct. The extent and manner of mobilisation as well as its disposition is increasingly influenced by the configurations of interests and power over a much wider area and further away from the village.

56. Historically investments in water control were promoted or undertaken by supra village authorities, eager to extend their command over territory, resources (by way of rent and taxation) and hence, power. In some cases, like China, these authorities had the power to enforce mobilisation of corvee labour and the capacity to organise them for the construction of large scale works. But often they also offered encouragements (by way of concessional taxation for instance) to merchants and large landowners (or their retainers) to invest in agriculture (including the construction of water control works). Examples of this can be found in practically all countries (see for example, Kelly, 1980; Ludden, 1978; Takaya, 1975).

57. Interestingly, however, there are also several instances of reluctance on the part of these rulers to use their resources (collected mostly through rent and taxes) for water control works: Thus, in the Aka river system (the subject of Kelly's study), the domain rulers

were remarkably reluctant to commit any resources of their own for this purpose even when it could have helped to reduce conflicts and make the existing system more effective. They preferred to let the local lan[illegible] and merchants do much of the investment and even encouraged them to [illegible] This way the rulers were able to use their resources for purposes which were more important in their priorities. Similarly, in south Asia than a large proportion of farm output was appropriated as rent by the landlo and as land revenue by the State, investment in water control was limit[illegible] Evidently consumption of the rulers, tribute to higher powers, defence and other uses commanded a higher priority in deciding the disposition o this "surplus". During the British rule it was only in the later 19th century when a succession of famines and concern for securing the strate gically important areas in north west India altered the priorities that significant new investments in irrigation began to take place.

58. The nature of the land revenue system, land tenures, the composit[illegible] and interests of the ruling groups, and the extent to which agriculturis[illegible] could make their interests felt are all clearly important factors in determining how much surplus was extracted, by whom and for what purposes it was used. There are also interesting questions (raised by Wittfogel others) as to the extent to which water control itself affected the [illegible] of political authority and whether the choice of projects in any given situation was dictated wholly by techno-economic considerations and whe[illegible] it was influenced by the interest of the ruling groups in extending the power by controlling a critical resource like water. These issues are considerable historical interest but need not concern us here. In any case in contemporary times the role of government in promoting develo[illegible] has become important everywhere (and dominant in some) and the necessi[illegible]

for large scale public investment in water conservancy is widely accepted.

59. While the role of governments has become important, significant differences persist in the relative roles of government in mobilising resources and channelling their use. In the Chinese system the responsibility for constructing water control works and for mobilising the necessary resources for the purpose is more widely diffused among different levels of government and the potential beneficiaries; there is also greater congruence in the location of these functions especially at the commune level and below. It is noteworthy that in some essential respects the current practices are a continuation of a long tradition. This is obviously so in respect of the form, and possibly the scale, on which local resources are mobilised. Its enforcement continues to depend on a strong centre of political power at the local level - a role which used to be played by landlords/gentry/bureaucracy is now played by the party cadres. There is however a major difference in the distribution of costs relative to benefits among the beneficiaries and this change is directly related to the change in the control over land and the distribution of its produce. In Japan too there was a long tradition of local construction and despite a big rise in the extent of national government involvement the tradition of autonomous organisations managed by users continues to be strong.

60. In India, as already noted, local institutions play a far less important role in water conservancy development. Even in regions (like south India) where they had, the advent of British rule invariably weakened them and increased the role of the government bureaucracy. Such limited investments as were made in irrigation works was mostly preempted for relatively large projects in areas which were strategically important or were liable to famine.22/ While technical compulsions

no doubt dictated a larger role for government, there was much that local effort could do. But the trend towards weakening of local institutions was if anything intensified in the post independence period.

61. At present the farmers/village institutions play hardly any role either in planning, resource mobilisation or construction.[22a]. All these functions are highly centralised in the hands of the state and the national governments. One consequence of this has to shift the responsibility for solving conflicts between farmers and the rest of the community as well as between farmers from different regions to higher levels of government. Since the route to power is through the electoral process and since farmers are numerically one of the largest segments of the electorate, the government has been remarkably reluctant to make the farmers contribute to the cost of water control development and enforce collection of such contributions (in the form of betterment levies) which are part of declared policy. Indeed the trend towards a general reduction in the burden of taxation on farmers,which had set in even during the British period,has been greatly intensified since Independence. The farmers as a class have been able to exert pressure and succeeded in winning a variety of concessions relative to the rest of the economy.

62. On the other hand the demand for extension of irrigation facilities has been consistently greater than could be met by the resources available to the government and this despite large increases in the allocation for water control projects. For the ruling party, public spending is also a means of providing patronage to constituents thereby securing or enlarging their power base. Consequently there has been a tendency to 'spread' the patronage as widely as possible by allowing projects to be launched without sufficient preparatory investigation and appraisal; by spreading

available resources over a large number of projects at the risk of delaying the completion of all; and by succumbing to pressures for extending the canal network in particular projects far beyond the level which can be served with the available water supply in each. That construction contracts are a lucrative source of political funds has undoubtedly contributed to laxity in matter of cost control.

63. While the above factors place the Indian farmer at a relative advantage in terms of getting the government to bear a relatively high proportion of the cost of water resource development, they cannot explain why collective effort by beneficiaries to expand and improve essentially local resources of water has been so limited in relation to the opportunities. Opportunities in this category include modernisation and improvement of existing tanks; expansion and integration of existing local systems; construction of field level distribution channels; and land consolidation and improvement. Some of these augment water supply, others can reduce losses in conveyance and application thereby facilitating more effective use of water. In all these cases individual farmers can go only a limited way; but combined action by groups of beneficiaries could be more productive for everyone.

64. That such action has not taken place more widely than it has cannot be due to difficulties of finding resources because the government has been providing liberal assistance by way of subsidies and low interest loans. It could be that the potential returns of such investments are not attractive enough; but this goes against the weight of expert opinion. While recognising that 'expert' opinion may not always be correct, it seems more probable that the real difficulty lies in the allocation of costs relative to the distribution of expected benefits among the potential beneficiaries.

65. The difficulty arises partly because the total potential benefits to the collective investment are uncertain.[23] Even greater uncertain attaches to the benefits which any particular beneficiary can hope to obtain with reasonably assurance because it is contingent on the manner in which improved facilities are managed and on the access to and costs of complementary inputs. In so far as 'uncertainty' regarding total benefits arises from inadequate knowledge, it can be reduced by education, demonstration and, failing both, by actual experience. Uncertainty regarding the benefits accruing to particular beneficiaries is more difficult to take care of because it depends on the location and the initial quality of the land. The more important difficulty is that the actual increse in productivity of a particular piece of land depends, in the case of irrigation, on how the improved conditions of irrigation supply resulting from the collective effort is allocated on a continuing basis.[24]

66. The mere enunciation or legislation of a set of rules for guiding these allocations is not enough; it is essential that the beneficiaries are agreed about the fairness of the allocations and that they are reasonably confident that the rules will in fact be implemented. The beneficiaries' view of the fairness of the rules as well as their confidence in the ability of the operational organisation to enforce them are therefore likely to influence the prospects of their participation in the initial collective investment. The possibility of overcoming the vagaries of the state-run canals by developing supplementary well irrigation on an individual basis weakens whatever compulsion there may be for coope tive action. The uncertainty about distribution of benefits arising from collective effort in flood control and drainage would seem to be a somewhat less serious problem in as much as they do not involve a continuing problem of water allocation which characterise irrigation.

67. If the above line of reasoning is correct, one should expect greater willingness to join a collective effort in the case of flood control and drainage than in irrigation; and in the case of irrigation, when the project augments water supply and makes its more assured; where the crop patterns are homogeneous; and there are strong local institutions which can be trusted to manage the allocations fairly. One should also expect that a change in seed varieties or other similar technological improvements which increases the production potential for a given amount of water and hence the potential returns to collective investment, would stimulate greater interest in such effort.

68. The few available studies of irrigation institutions do not provide sufficient information to judge how far these expectation are borne out by experience. Nevertheless we would venture to suggest that the stronger tradition of collective local effort in east Asia may have atleast to some extent been shaped by the following circumstances: Compared to south Asia, rainfall in east Asia is more ample and better distributed relative to crop water needs. In Japan and the major paddy growing tracts of China, shortage of arable land rather than lack of water seems to be the more important constraint on production; and flood control and drainage were essential first steps to water control and extending paddy cultivation and continue to be integral constituents of water control systems. It is significant that despite these 'advantages' the process of expansion and improvement of water control systems was far from being smooth or conflict free. Nor did it gather significant momentum until other conditions were favourable: Thus in Japan rapid progress took place only after the Meiji restoration when land reform and inflation brought about a significant reduction in the incidence of land taxation, and the introduction of new agricultural

techniques which, in conjuction with the rise in paddy prices, significantly increased the returns to investment in better water control. (See Hatate 1981, Kelly 1980, Shimpo, 1976).[25] State intervention through legislation to facilitate these improvements and by offering liberal financial assistance were also important contributory factors. But in the case of land consolidation progress was much slower despite the fact that owners of land were permitted to raise rents to appropriate a part of the increased productivity due to consolidation and improvement, and also enabled consolidation to be done without having to obtain unanimous agreement.[26] Again significant progress had to wait till after the war under the powerful and growing compulsions to mechanise agriculture (aris from the dwindling supply of, and rising costs of, labour for agriculture) reinforced by liberal financial support from the government.

Conflicts in Construction

69. A common source of conflict in the construction phase arises from objections by farmers and communities who are served by a pre-exist' system based on the same source of supply as the proposed new project. Such objections are based on the fear that the new project may adversely affect the quantum, timeliness or reliability of water supplies to users of existing systems; it could also arise because the new projects creates or aggrages flood or drainage problems outside its command.

70. Disputes of this category arise when attempts are made to construct a barrage or reservoir upstream of an existing system on that river. Japanese irrigation history is replete with such instances.[27] Typically, those already drawing water from the same source are extremely

zealoud of their rights and newcomers usually had to concede superior fights to the former before the new project could go ahead. This concession could take several forms such as first claim to pre-existing users over available supplies in the new system; assurance of a minimum supply equivalent to earlier use; higher priority in times when rotation is introduced. Another way of reconsiling conflicts was to expand the system but this invariably required mediation by a higher level authority and preferably combined with financial support. An expansion programme usually involved integration of pre-existing systems into the larger network and again the former's concurrence was essential. Here again agreements over the allocation of water in the enlarged system had to protect the rights of pre-existing users before the project could proceed. These agreements are a common feature in Japanese irrigation systems and though not always reduced to a formal written document were legally recognised and were justiciable (see e.g. Hatate 1979). There are some reported instances of similar conflicts in India (Jayaraman, 1961; GOI, COPP). But no detailed histories comparable to what is available in Japan.

71. Disputes of a bigger scale between different regions, and even countries, are triggered by proposals to construct large new projects to tap rivers which flow through several distinct administrative and political units. Disputes over division of water supplies in respect of river basins has been prominent in India and also other countries. Practically every major river in India is, or has been, the subject of disputes between the riparian states. Some of these disputes have been quite protracted and have adversely affected the water resource development programmes. Attempts to evolve 'objective and rational' basis for allocations on the basis of integrated river basin planning have not been conspicuously successful and the matter continues to be handled through judicial and, more often,

political mediation.[28/]

72. A second category of disputes arise the area and/or particular communities or farmers who would be served by a new projects and over regulations as to the types of crops which can be grown. In principle it is possible to avoid such conflicts by limiting the coverage to areas which can be served by the available water supply consistent with optimum use of resources. But there are always pressures for extending the coverage of the systems. Given the difficulties of determining the optimum coverage (the state of the arts in this area is still too rudimentary) these pressures are difficult to resist. The more so in countries like India where water is potentially very productive and the political pressures to extend irrigation as widely as possible are great. However in the process canals are often over-extended in relation to available water supplied and only succeed in shifting the difficult problems to the operational stage. (For a further discussion see para 132 to136).

73. Third, beneficiaries can, and invariably do, disagree about the extent of the investment costs they are, as a group, expected to bear, how this obligation is to distributed among them, and the terms on which it is to be recovered. There is clearly great diversity in the way this is handled in different countries. In China the basis on which these issues are settled seem quite clear and in that beneficiaries are expected to contribute directly the bulk of the costs at the time of construction roughly in proportion to the extent of benefit. (more precise information on these aspects is difficult to come by.) This principles also seems to be effectively enforced. Japan too has well defined rules to decide the extent of beneficiary liability and the mechanisms to enforce them. But in India, notwithstanding legislations requiring farmers to pay a betterment levy, the farmers have sufficient political power to thwart any attempt at enforcing their liability.

4. OPERATION OF WATER CONTROL SYSTEM

74. Unlike the construction of water control works, which is essentially an once-for-all or, at best ,intermittent activity, their operation involves tasks of a continuing nature. Basically these tasks are to make sure that the physical facilities (dams, canals, field channeks, control structures) of the system are maintained in good working condition and to regulate access to and use of the facilities provided by it. The latter function, in an irrigation system, involves allocating water available in the system among different uses and users. The mechanisms and procedures by which the decisions relevant to these tasks are made and implemented defines the "Irrigation Organisation". They can differ in one or more of the following structural characteristics, namely: The distribution of tasks between different parts and layers of the organisation; the locus and the modalities of decision making; the manner in which functionaries are appointed and controlled; and the relation between irrigation organisation and the wider socio-political framework.[1/]

Structure of Irrigation Organisations

75. The simplest situation is one in which a water source is harnessed and used by a single farmer for cultivating his own land. Here the farmer has only to decide how best the available water is to be allocated between different uses (crops/seasons) in relation to his objectives. The question of allocation between users does not arise . And, subject only to technical constraints, he is fully in control of implementing the decisions. The problem remains fairly simple even when the irrigation source supplies water to several users-whether because the supplies

are in excess of the owner's need or because the source is developed purely as a business proposition - so long as the owner has unfettered right over the disposition of the water. The best examples of such a system are -individually owned wells or tubewells. Some large cultivators had, and still do, have ponds and small diversion works for use on their own lands.[2/] However given the relatively small size of cultivation holdings in most parts of Asia, development of surface irrigation works and even large sized tubewells require some form of collective effort or, more commonly, the initiative and resources of the State. In these cases, typically, even small systems have to serve several farmers; no one has over-riding rights over the management of the system; and the allocation of both maintenance obligations and water is subject to the rights and responsibilities of different segments of the system and/or users. In other words, the problem of allocation between users is as important as that of allocation between uses (crops and seasons). It is this which makes irrigation organisation a rather unique and interesting subject of study.

76. Organisations for management of water control systems tend to be differentiated in terms of the role of bureaucrats (as distinct from users) in management and the extent of centralisation of authority: "Bureaucracy" refers to the corpus of paid professional staff hired to carry out specified tasks in an organisation within the framework of certain recognised rules of procedure. Small localised systems serving a few farmers can make do with a simple organisation and manage all the tasks with the help of their own members. This is in fact the case in most parts of Asia. Such systems traditionally did not use any hired personnel; and policy makers and the administrators

were chosen from within the community by selection, election or rotation. That the personnel are not professionally trained however, does not mean that they are not skilled. In fact considerable knowledge and experience in handling both technical and social problems of water management are essential for smooth functioning of even small systems, and the functionaries are expected to have these attributes.

77. Larger, multi-community systems require more skilled and specialised personnel for managing the technical tasks and also personnel who can give more continuous attention to the day-to-day tasks of running the system. Consequently as the size and complexity of the system increases the need for paid, full time staff to handle both technical and routine administrative tasks also increases. But there are situations in which the bureaucracy's role goes beyond technical and administrative functions to comprehend making and enforcing policy. Therefore it is not so much the reliance on paid, full-time personnel as the role they play together with the manner in which they are appointed and controlled which forms a meaningful basis for distinguishing different classes of irrigation organisation. In this respect again there is a marked contrast between the patterns prevailing in East Asia and South Asia.

78. Thus in Japan because of the way irrigation systems evolved and the predominance of small, localised systems,user control over the management (in respect of policy formulation, day-to-day administration as well as appointment and control of operating personal) is very strong. As mentioned earlier, irrigation works in Japan developed by extending and improving small diversion wiers and ponds. It was only in the 1930s that the higher levels of government (prefectural and national) came to play any significant role in the modernisation of the systems.

Neverthelessthe average size of the systems remains quite small when compared to canal irrigation systems of South Asia. The greater complexity of the systems and the growing difficulty in getting members to contribute to system management along traditional lines, had led to greater reliance on paid professional staff. But with few exceptions, all the staff are effectively under the control of the LID which are managed by representative of users. Apart from laying down the general legal framework governing LIDs and, in rare instances, managing of reservoirs and canals serving more than one LID, the state plays a relatively marginal role in the operation of irrigation systems.3/

79. In China,4/ though from ancient times the State bureaucracy was supposed to be responsible for managing water control works, in actual fact its role was limited to supervising the maintenance and operation of large projects constructed by the State and that too to the central reservoirs, canals and embankments. Lower levels of large systems, as well as smaller systems mostly constructed with local resources and initiative, were managed locally with their own personnel. Currently, for purposes of operational management water control systems are organised into Irrigation Districts of varying sizes ranging from a few villages to several communes or even prefectures. All these organisations have a corpus of paid professional and administrative personnel some of whom are appointed and controlled by the Irrigation District while others (usually those at the top level) are officials from the concerned professional cadres of the government (Prefecture, Province of the Centre). The latter are not fully under the control of the District Organisation. By virtue of their technical expertise and being responsible to ensure that the District is managed in accordance with general policy guidelines issued by the Party, this category of personnel play a significant role

in making of policy. But they play this role as members of a management committee in which the representatives of users and key Party functionaries are also members. The Committee's decisions are then expected to be implemented by the officials. At lower levels, the representatives of users and party officials play a much more important role in policy and reliance on paid officials progressively declines as one moves towards the basic user unit (namely the team). The personnel of the committees as well as the personnel for actually carrying out the tasks are drawn mostly from within the jurisdiction of each level. The operating personnel at each level are controlled by the management committee at that level.

30. The Indian systems, by contrast, are dominated by and dependent on the State bureaucracy. Indian canal systems (which serve 40 per cent of the country's irrigated area) tend to be large compared to those of East Asia; most of them, as pointed out in Section 3, were constructed under state auspices and using state resources with very little participation by beneficiaries. Nor did the beneficiaries have any role in designing the management system. The pattern of organisation, the rules and procedures to be followed and the staffing were decided by the State (usually the provincial governments) with hardly any consultation with users. This continues to be the case even now. The system does not provide for participation by users in making or implementing decisions even at lower levels. Matters of system-wide policy are left to be decided by the State irrigation department; elaborate formal regulations (Acts of legislations, rules, and operational manners) exist to guide the managers of individual systems. These managers, as indeed practically the entire technical and administrative staff down to the lowest level,

are appointed by the State Government and answerable to it.[5]

81. That many of the canal projects during the last century happened to be built by the State in areas with no prior tradition or experience in irrigation may have been a contributory factor. However there are instances where large scale canal irrigation was introduced in areas which had already developed locally built and managed irrigation works on an extensive scale, but no attempt seems to have been made to integrate the new system with the pre-existing works either physically or institutionally. The Sarada canal in UP is a case in point. The introduction of the government canal displaced the local systems which already existed in the area and the traditional institutional arrangements associated with the letter seems to have disintegrated.[6] In South India and in Sri Lanka the state showed a marked prediliction in favour of assuming a direct role in administration of even small scale and essentially local irrigation ponds by replacing traditional irrigation functions with state appointed personnel and by enacting formal regulations on the management of such works.[7]

82. Some of this may have been dictated by objective conditions. Thus, the substitution of canals for older local systems in the Sarada canal area may be due to the relative cheapness of canal water and the fact that, under the conditions then prevailing in the area, introduction of the canal did not significantly increase the returns to irrigated agriculture.[8] In South India, state intervention was at least in part a response to the disintegration of the traditional social order - itself a direct consequence of the changes in land tenure system introduced by the British - andthe resulting deterioration of tanks which affected production and Government revenues.[9] However, it should be noted that

this basic pattern of management through a state bureaucracy with minimal participation by users has continued down to present times although vast changes have take place in the techniques of production and in market conditions. Whatever the reasons, the management of the Indian (and generally South Asian) canal systems represent a high degree of centralisation in the sense that the authority to make and implement policy and to resolve conflicts vests in a state controlled bureaucracy.

83. It seems useful for the sake of clarity to make a distinction between two aspects of centralisation of irrigation management: One might be called the "functional" and the other the "political" aspect. The former reflects the technical characteristics of the system which dictate the locus of decision and the distribution of decision-making powers between different levels. For instance, compare a system which is entirely based on canals fed by a single source (say a diversion work or a reservoir) with one in which, besides the central source, there are smaller storages/wells distributed over the command area. In the first case, smooth working of the system requires centralised coordination of the operation of canals and outlets. And once the operational schedule of the canals are determined, the amount and timing of water available at each outlet is more or less fixed. The management organ at the outlet level can protest against upstream users taking too much or can try to take more than they are entitled to. But in either case, the extent to which they can manipulate either the timing or quantum of supply is limited. Their main function would be to distribute supplies available at the outlet as between different parts of the area covered by that outlet. By contrast, in a system with supplementary local storage/wells, the intermediate level organs have much greater flexibility

in manipulating the quantum, timing and allocation of water which also means that potentially the intermediate management levels have a wider range of decisions to make and implement. The extent to which this potential is in fact used however depends on several factors including the degree of adequacy of irrigation water supply relative to requirement of the command.

84. The "political" aspect concerns the question of who among the various groups interested in the system makes the allocation decisions, on what basis and for whose benefit. The allocation decision has to be derived from certain objectives (which may or may not be explicit) to be achieved by the system. Since every allocation decision in a multi-user system implies a certain distribution of costs and benefits among the users, its smooth functioning requires a clarity regarding the goals (which must necessarily comprehend both the overall level of output and its distribution among different parts of the system), definition of allocation rules consistent with these goals, and the capacity to enforce them. It is conceivable that these matters can be settled by mu agreement among the users or their representatives. But when there is no consensus among the users or between the users and the management on these matters, or if the consensus is fragile, it will be difficult to enforce the allocation rules and smooth functioning of the system requires that there be some higher authority to resolve the conflicts.

85. This kind of centralisation of authority exists even in traditional user-managed systems.[10/] The most obvious case is when the dominant land holders are also the managers. But it is not necessary for the dominant landowners to be directly involved in water management; they may exercise authority through managers who are their nominees or subs

their interests. They may also choose to interfere only when the conflicts threaten to get out of hand. Traditionally the authority of large landowners seems to have played an important role, at any rate as an authority of last resort, in the functioning of local systems. When the composition of this group changed, as it did from time to time, the working of the irrigation organisations were also affected. There are cases, of which the Vel Vidanes of Sri Lanka is an excellent instance, where the overriding authority was formally vested with a functionary backed by the State but they again seem to have been drawn from, or into, the ranks of the well-to-do.

86. In multi-community systems the large landowners per se seem less likely to play the role of "ultimate arbiter" because there are so many more of them and conflicts of interest among them are apt to be greater. And where, as in modern Japan, China, and Taiwan, land reforms have resulted in a relatively even distribution of land, land ownership is much less important. Multi-community systems rely more on rules and adjudication procedures and on entrusting the implementation to persons recognised by the community to be knowledgeable, skilled and fair. However this cannot be effective unless the users and the managers are broadly in agreement over the system objectives and its regulations.[11/] Even then, there is need for a clear locus of authority for resolving disputes which the organisation cannot handle in the normal course. In several systems, the top level functionaries are people who command respect and influence in the region on the basis of wealth or political influence.[12/] In the case of China, a strong and active involvement of Communist Party cadres performs the same function.[13/] On the other hand, one cannot assume that merely because the management of irrigation organisation is centralised

and vested with wide powers, the central authority is in fact, or can be, effective. Thus, as we shall see later, in the Indian canal systems the irrigation bureaucracy is not free to exercise its very considerable formal authority because the rules do not reflect or derive from goals on which both users and managers are broadly agreed. Attempts on the part of the bureaucracy to enforce its rules are thwarted in myriad ways.

87. Since there are so many dimensions to irrigation organisation, it is difficult to find a classification which is simple and at the same time meaningful. In any case, the form of the organisation tells us relatively little about how they in fact work and how they adapt themsel to changing circumstances. These questions are best examined in relatio to the way specific tasks of management in irrigation works - namely maint of physical facilities and regulation of water allocation - are handled concrete situations. Partly for convenience, and partly because of the limited material available, our discussion will for the most part focus on the contrast between the traditional, local systems (relatively small in size, with a high degree of user involvement) and the large state-ru canal systems in India.

Maintenance of Irrigation Systems

88. The purpose of "maintenance" is to make sure that physical facili- ties (dams, control structures, distribution networks) function smoothly and at the level of performance for which they were designed. Typically in a surface water system, this involves periodic inspection of the facilities to identify any deterioration (such as leaks in embankments, erosion, silting of canal beds, growth of weeds, malfunction of slui etc.) and execute the necessary repairs. Besides, the organisation nee

to be alert in identifying major mal-functions as they arise and have the capacity to correct them promptly.

89. Inefficient maintenance could adversely affect the water deliveries by reducing the volume of water carried by the canals; slowing down the speed of water flows; increased waste due to leakage and spills; and in the extreme case a partial or total breakdown. All of these reduce the volume of water made available to the field; and hence the feasible level of production compared to the potential of the system (given the design). The quality of maintenance affects the interest of both the organization as a whole (which is presumably interested in getting the maximum production with the available water) and the users (whose output and incomes are directly affected by it).

90. The strength of this common interest is however variable depending as it does on the size of the system; the nature and extent of users' involvement in its development; the productivity of water control in a given situation; and the distribution of costs relating to benefits between different users and/or parts of the system. The sense of common interest seems likely to be strongest and most widely shared in a relatively small system which has been set up by the community of users who have also made a substantial contribution to the cost of developing it; in systems where irrigation leads to relatively big increase in productivity of land (or when the potential loss of output on account of poor maintenance is high); and when there is adequate supply of water to meet the needs of the entire service area. On the other hand the larger and the more extensive a system, the more difficult it is for users to appreciate their common interests in proper maintenance of facilities at all levels. The importance of

maintaining the main canal is not so obvious to the tailenders of a system serving 100,000 ha. as in one serving 100 ha. The interest will naturally be weaker when the users have not contributed any of their own resources to developing the system and when the returns to irrigation in terms of increased output is relatively small or uncertain. And if all parts of the system are not supplied the promised quantities or if the supplies are irregular and uncertain, not only will the affected segments have less interest in contributing to systems maintenance, but they may actively resist such contributions as being "unfair".

91. Traditional community irrigation systems of Asia fall in the first category: For the most part they are the product of local initiative and resources; higher levels of government were seldom involved to any significant extent in organising or financing their construction; and typically they serve but a few villages. Available accounts of a number of these systems suggest that most of them have evolved mechanisms and procedures for maintenance which work quite smoothly.[14/] However it would be erroneous to suppose that they work entirely on the strength of "mutual interest" or that the process is free of conflict. In a small, close-knit community the force of custom and social pressure no doubt plays an important role in ensuring that users fulfil their obligations. But these are invariably combined with explicit penalties ranging from fines to loss of waterrights for non-compliance![15/]

92. The irrigation organisation in all cases has the formal authority to apply the sanctions but may not always be able to exercise it. For instance, it cannot do anything which goes contrary to the interests of other important centres of power in the community of which the dominant

land owners are perhaps the most important. Because of this, and the fact that control over irrigation is itself an important additional source of power, there is potential for centralisation of authority in local irrigation organisation. Whether in fact this takes places depends, however, on the extent of concentration of land ownership and on the land tenure. It seems likely, that extent of land-lord dominance over irrigation management would be greater when a large portion of the land is controlled by a single family than when there are a number of relatively large land owners belonging to different family groups or castes.

93. The land owners themselves are likely to have a direct interest in maintenance and operation of irrigation when their own incomes are significantly affected by the way it is managed: The active interest taken by large landlords of Japan in water control management may have something to do with the fact that they lived in the village and cultivated a part of the land directly.16/ In South India the traditional land tenure system earmarked a certain percentage of produce for maintenance of tanks and the land controlles took active interest in this task. In other parts of this region, a large number of tanks were owned by landlords. So long as these tenure systems continued and the State's revenue itself was determined as a share of produce, there was strong interest in both local and supra-local centres of power in ensuring proper maintenance of tanks. Apart from wars, the introduction of tenurial reforms early under the British rule weakened these traditional centres of village authority. This undoubtedly contributed to the deterioration of irrigation tanks during the 19th century. Under the new tenure land control, and hence the power derived from it, was perhaps more diffused. Though the government took over responsibility for maintenance, its functionaries clea were unable to get the work done.17/ In Bihar too the traditional zamindars

who had taken active interest in maintaining local irrigation works lost interest once the share rent system was replaced by a fixed rent system. (Sen Gupta, 1980). Clearly there is a close connection between land tenure and the management of local water control systems.18/

94. In larger systems, the responsibilities are of necessity more diffused and the perception of common interest in the maintenance of the system as a whole tends to be weaker. Consequently the penalties and sanctions also tend to be more formalised and impersonal. The mobilisation of labour contributions become more difficult. It is perhaps for this reason that some of the larger multi-community systems combine a labour contribution by beneficiaries for maintenance of local facilities with a levy to meet the cost of maintaining facilities which fall in the jurisdiction of higher levels.19/ Where, as in China, maintenance was sought to be done with labour contribution, a degree of cohesion was necessary. The scope for differences over the performance of the tasks and the sharing of costs also increase with the size of the system. For all these reasons the role of the central management in maintaining internal cohesion and enforcing the regulation is apt to increase with the size of the system. Further more, the larger the system the greater the influence of the higher political authority in its functioning especially when the latter is involved in setting them up.

95. Involvement of the higher level political authority (be it the regional or the national government) in maintenance and operation of water control has been and remains quite limited in Japan; it is considerable in China and most striking in India. In China the maintenance of relatively large irrigation and flood control works has been traditionally the responsibility of the state bureaucracy who were expected to mobilise

corvee labour to carry out periodical repairs. But they needed the help and support of landowners, the Gentry and other centres of local power to effect the mobilisation.[20/] The quality of maintenance was apt to suffer when government as a whole was weak and/or there were serious conflicts of interest at the local level: We have an account of the lower Yangtze delta where the maintenance system broke down as a result of disputes over sharing of maintenance costs following a change in the pattern of land ownership and the state was unable to resolve it satisfactorily for several decades. Though the account pertains to 16th and 17th centuries, it does highlight the inter-relation between water control maintenance, land tenure and bureaucracy, as well as the inter-play of interests at different levels. (Hamashima, 1980).

96. The growing difficulties of enforcing corvee labour gradually led to abolition of the system. By the 19th century the cost of maintaining public works was supposed to be met out of the general budget. However the bureaucracy was not allotted sufficient funds to carry out the works for which they were supposed to be responsible. In some areas officials resorted, with the help of local leaders, to extra-legal labour contribution; there were attempts to narrow down the state's responsibility for maintenace; in many cases officials simply neglected this task. The general decline of the authority of the central government undoubtedly was an important factor contributing to the relative neglect of maintenance of water control facilities under state control during the decades preceeding the Revolution.[21/]

97. With the reorganisation of water control management in the post revolution period, labour contribution for maintenance have again become important.[22/] Almost all the labour needed for maintenance and

repair throughout the system is contributed by the beneficiaries. The requirements of items other than labour, as well as the cost of the administration, are recovered in the form of water fees. While the responsibility for planning and executing maintenance works is distributed between different levels, and local leadership is encouraged, the available accounts (mostly relating to models of successful management) highlight the key role of the party leadership at all levels of the organisation through a combination of propaganda, political education and even compulsion, in ensuring smooth working of the arrangements. There are indications that when the party leadership is not strong or, as it happened after the 1979 reforms, the Party involvement is reduced, the functioning of the water control organisations is adversely affected.

98. In India (and South Asia generally) the state has direct responsibility for maintenance of practically all surface irrigation systems, including ponds and other local systems which historically used to be managed either privately or by the village community. Recently, some of the smaller village ponds have been turned over to panchayats (which are supposed to be autonomous and representative with institutions of local government but are in fact neither). They depend mostly on subventions from the state governments and do not seem to take much interest to tank maintenance. In all other cases the state public works departments are wholly responsible for maintenance, the costs of which are met out of allocations in the general budget of the State government.23/

99. Users of state canals pay a water fees (which is sometimes merged in land revenue) which are supposed to cover operational costs (including maintenance and interest on capital) but are almost invariably

quite inadequate for the purpose. Moreover, unlike in China, such fees are not earmarked for use by the system managers but get merged in the general pool of resources. If the PWD has to compete with other departments for allocations from this pool, the managers of different systems have to compete with each other and with claims of other activities of the department. Maintenance of irrigation systems does not seem to command a high priority in deciding budgetary allocations at the State level or within the PWD.

100. The complaint of inadequate allocation is long standing and there is stark evidence of the deterioration in the condition of important segments of the irrigation system.[24/] And yet there has been hardly any pressure either from the PWD officials or from the users to remedy the situation. The lack of concern among officials is perhaps understandable for they are not committed to serving as managers of any particular irrigation system, nor do their careers depend on how well this job is done.[25/] The apparent passivity of users is more difficult to explain: The sheer size of the systems, the weakening of collective interest due to the development of independent supplementary source of irrigation (especially wells and tube wells) and the fact that they have no role at all in the management may have all contributed.

Management of Water Allocation

The nature of the Problem

101. The other major task of irrigation organisation is to decide the principles on which the available water is to be allocated among alternative uses and between different segments of the service area; and

device effective mechanisms and procedures for making sure that the allocations in fact conform to these principles. On the face of it this would seem a straight-forward problem in resource allocation which can be handled with the help of standard, though by no means simple, techniques of economic analysis.

102. This is quite a reasonable view in the case of a system which is owned and operated by a single entity (which could be an individual or a cooperative) exclusively for its own 'benefit' defined in clear and unambiguous terms: Consider a farmer with his own tube well, who wants to use the water from that well along with his other resources (land, labour, equipment and working capital) to secure the maximum net income. The available water can be used to grow different crops, the feasible set of which is determined by the soil conditions, elevation, topography, climate and other elements which go to make up the agro-climatic environment. Within the limits set by the environment, the farmer has to choose the crops to be grown and the area to be sown to each crop. Each crop has different water requirements, responds differently to variations in the amount of water and of other inputs. Taken together they define the "production function" of different crops. Given this information, the prices of each crop and each input, and the volume of water and other inputs available, the farmer can work out the optimum allocation of all inputs (including water) as between crops.

103. This is of course a rather simplified view of the problem in as much as soil and topography varies even within a farm; the effect of irrigation on crop yields depends not only on the total quantum of water applied but also on when it is applied; response to water is not

independent of fertilisers and genetic potential of the crop varieties. In principle, however, it is possible to allow for these in the calculation of the optimum provided of course the necessary knowledge and data are available.[26/] Quite sophisticated calculations, using models and computers, are in fact made by large irrigated farms in countries like the U.S. An Indian farmer deciding on how to use his tubewell may not go in for such sophistication. While he may simplify the problem and focus on a narrower range of choice variables than may be available, the optimation calculus is well-defined. Moreover whenver the user is wholly in control of the irrigation source, he should have no difficulty (other than the constraints imposed by the system design and the availability of relevant data) to regulate quantum and timing of water deliveries to different parts of the farm and to different crops.

104. But in multi-user systems, the problem is to allocate available water not only between different crops (and seasons) but also between users. One of the obvious institutional mechanisms for solving this problem is the "market". A well-functioning market is supposed to ensure "efficient" allocation in the sense that the marginal productivity of irrigation water between uses and users is equalised. In the process the "right price" of water is also determined. There are of course well known general questions whether markets do in fact work all that well and whether the income distribution which results from it is socially "just". But the more relevant point here is that the market or even allocation through pre-determined prices is so little used in irrigation management. These are several reasons for thi$

105. First since its effect on productivity depends not only on the quantity of water applied but also its timing we need to differentiate between time-specific inputs of irrigation. Second, the productivity of irrigation is not independent of the amount and the seasonal distribution of rainfall both of which are highly variable and unpredictable. Third, the eventual yield being the cumulative result of moisture status at different stages of crop growth, it is difficult to evaluate the contribution of a given amount of irrigation at a given point of time without specifying the levels of input at other points in the season. Fourth, the response to irrigation is also conditioned by soil and other physical conditions which can vary between different parts of the system. Finally, the supply of water and its productivity to particular users is not independent of the actions of other users. Whether or not a particular plot gets a given amount of water depends not only on the seller (the system) but also on the behaviour of people holding other plots. Since the seller cannot control the amount of water he can supply a particular plot at a particular time and the buyer cannot assess its marginal productivity, it is not possible to have a 'well-functioning' market. Allocat has to be done by other means.[27/]

106. In order to appreciate the nature of the problems involved, consider a multi-user system meant to irrigate a single variety of a particular crop. Given the total amount of water available, the question of how large an area is to be equipped for irrigation has to be decided even at the stage of design and construction. For this the designer needs to know the relation between the moisture requirements and crop yields. Leaving aside, for the sake of simplifying the argument, the question of time-distribution of moisture supply, let us focus on the

relation between total moisture available to the plants and the yields per unit area (given the level of other inputs). This relation is typically of the shape shown in figure 3. Suppose that from a purely technical view point - soil, topography and elevation - the system could serve a certain area, say X. Suppose further that the losses in conveyance and application are also given. Now if the expected supply of water in the system (net of losses) together with rainfall per unit of the potential service area can ensure OD or more, there is no problem. When the available supply is less than OD there is a choice between planning on the basis of providing OC to a part of the potential service area or less than OD to the entire potential area and hence fewer users thereby benefitting a larger number of users. The total output attainable in the two cases are unlikely to be the same.

107. The problem is essentially similar when several crops with different water requirements are to be grown. In figure 5, OAC represents the moisture-yield response cause at a given level of fertilizer use of sorghum/millet and OA'D for rice. Sorghum needs less water but it yield potential is also less. Rice needs very much more water, but it also yields much more. Let us suppose that rice yields more both in absolute terms and relative to irrigation water used. In this case the problem is to decide how the irrigation water is to be allocated between sorghum and rice. Given water supply this decision determines both the total area irrigated and the total production. More area under rice means a smaller total irrigated area but, under our assumption, a larger output. But favouring sorghum more area, and possibly more farmers, are benefitted, but total output may be less.

108. In principle the irrigation organisation could design the system geared wholly to ensuring the "efficient" use of water (and other resources) from the social view point. The optimum design should then be the basis for determining the total area to be irrigated, the crop pattern, the amount of water to be allocated to different uses as well as the economic price of water. If users were charged the economic price of water so determined, the desired allocation of water between crops and users could be ensured.[28/] However, this logic is frustrated by several factors, some general and some peculiar to irrigation.

109. In the first place, optimisation exercises, no matter how sophisticated, cannot be any more solid or reliable than the concrete knowledge and information which goes into it. In point of fact, in most parts of Asia, designers do not have adequate or reliable information on water supply, yield response to irrigation, irrigation efficiencies, soild conditions and other relevant aspects to permit such calculations. Systems are designed on the basis of relatively crude data and rules-of-thumb.[29/] Secondly, where the valuation of inputs and outputs underlying the design differs from the prices actually facing farmers, and there is no effective attempt to bring them in line, the crop pattern and water use which is "optimal" for the individual farmer may diverge from the pattern prescribed by the system managers from an overall efficiency viewpoint. Third, even if the design were right, the system has to cope with the problem of how shortages in water (which are inevitable from time to time because of the variations in rainfall) are to be shared among the eligible users. Fourth, in systems with mixed cropping patterns, the allocation of the total acreage under relatively water-intensive, but lucrative, crops as between different parts of the system and among different users could become contentious matter. Furthermore in a

surface water system serving several users, the mere fact that water has to first pass the fields at the upper level of the canal network before reaching those situated lower down gives the former an opportunity to intefere with the allocation.

110. Under these conditions it is difficult to decide the configuration of the "efficient" system, and even more to ensure "efficient" water allocation on the basis of the prices alone. At any rate most surface water systems are set up by the user community with its own resources or by the State using public funds. In either case consideration of distribution cannot be kept out of project design or operation, both of which represent some sort of a compromise or consensus regarding the balance between 'efficiency' and 'equity'. Here the potential for conflict in the course of operation even greater and price-based allocation is an even less effective basis for allocation. Hence the necessity for physical rationing of area irrigated, (both total and by crop) and of the amount of water supplied to particular crop in the light of available total supplies. The allocation procedures in practically all multi-user system have to define the basis on which these decisions will be made and also the mechanisms and procedures by which they will be enforced.

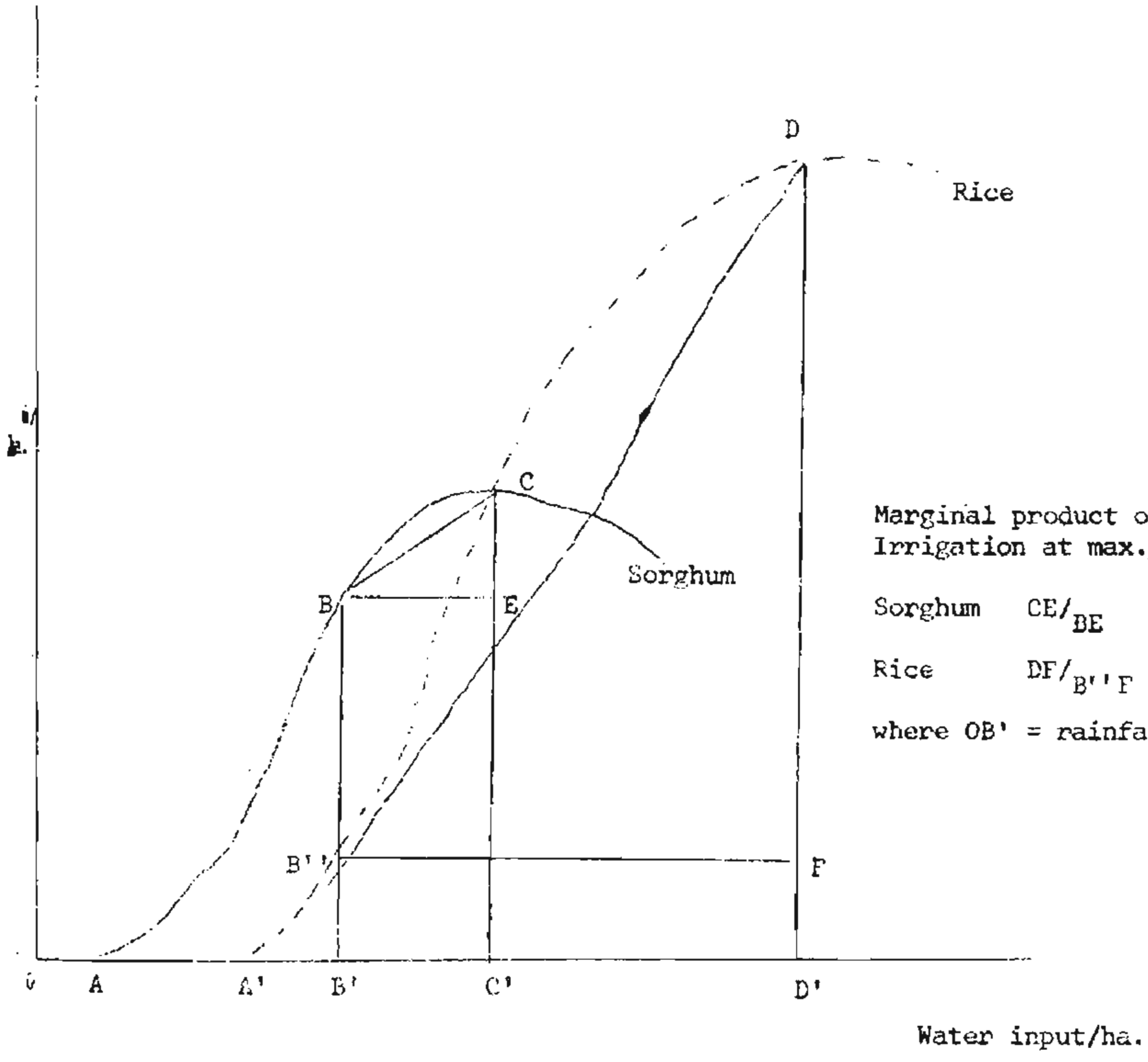
111. We have descriptions of how these tasks are managed in several systems from all parts of Asia. Though these accounts leave much to be desired - most of them are not sufficiently detailed, often the distinction between which is supposed to be and what is gets blurred; and they reflect different concerns and perspectives of the authors - they do help focus on the significant differences in practice between

different types of systems across Asia.[39/]

Traditional Community Systems

112. Descriptions of the water allocation procedure in traditional community - based systems (which represent an important, and in some countries the dominant, type of irrigation in Asia) are relatively more numerous and some of them quite detailed. These systems vary from fairly small ones serving a single village or a part of it (like the Pul Eliya tank in Sri Lanka described by Leach, 1961) to moderate sized multi-community systems like those of Bali and Japan. They include irrigation based on storage ponds, diversion of river flow, or a combination of the two. Most of them are used essentially for paddy cultivation, which again is the dominant characteristic of irrigation systems in most parts of south east and east Asia, and of traditional systems in south India and Sri Lanka. They are generally relatively old systems (some are in fact several countries old). Their current management practices are the result of a process of adaptation to changes in the land tenure, prices, technology and the system itself. Many of the systems have in fact undergone significant transformations sometimes for the better (thr extension and improvement) and sometimes for the worse (through neglect and consequent deterioration).

113. The water allocation problem as we have seen, consists in delimiting the area to be irrigated and deciding the amount of water to be given to different segments of the area entitled to irrigation. The limits of service area more or less well defined (partly by topography and partly by the amount of water available) but variable: The area which can be effectively irrigated in any given season depends on the



Marginal product of Irrigation at max.yiel

Sorghum $CE/_{BE}$

Rice $DF/_{B''F}$

where OB' = rainfall.

Fig.5 : Illustrate Moisture yield response curves for Sorghum and Rice.

supply available in the pond or river. Moreover, the area sought to be irrigated as well as the supply of water may show secular change: the service area may be extended (on account of under demographic pressure or as a matter of policy) and the effective supply of water can be changed for better (by extending and/or improving the system) or for worse (on account of negligent maintenance, damages from war or natural events and, possibly, long term climate changes).

114. The extent of area to be cultivated as well as the timing of the start of irrigation in a particular season seems to be generally decided by the irrigation community as a whole in the light of available water supply and rainfall at the beginning of the season. Where the entire service area cannot be irrigated, there is the problem of deciding how to the reduction is to be distributed. The basis seems to vary widely: Some systems have worked out quite elaborate and ingeneous arrangements to ensure equitable sharing of the reduction among all users: For instance in the case of the Pul Eliya tank (Sri Lanka) the irrigable area is divided into three segments according to distance from the tank and the wetland holdings of every farmer are equally distributed between these parts, because of this:

> "If the villagers are to cultivate rice in the old field during the Yala season, they will decide from the start either to cultivate the whole of the field or (the upper two thirds of the field or just (the uppermost) one third.... No pooling of proceeds or reallocation of holdings is necessary since the land is already divided up in such a way that each landholder works the whole or two thirds or one third of his total holdings as the case may be..." (Leach, 1961).

115. Chambers (1977) cites instances where the rationing of area is done on different criteria: In one case each user was guaranteed full irrigation for a limited acreage; any additional area would be given water only if there is any surplus. In another, the farmers were left free to decide how much they would sow. Thus rationing is not always on the base of a proportionate reduction in acreage of all users. This is particularly true when differential rights to water are recognised. In many systems (e.g., the Balinese subak, the Japanese systems as well as in Thailand and Taiwan) it is established custom that some sections of the service area have superior rights and hence first claim over available supplies.[31/] In general this differentiation is based on location: upstream lands and communities have priority over those downstream. While this is partly a formal recognition of the inherent advantages of upstream users, if often happens that they were also among the first to develop the irrigation source.[32/]

116. Acreage rationing is itself a way of rationing water but not always sufficient and has to be combined with rationing actual water supply. The latter is in any case essential when unexpected shortages de in the course of a season. Even in normal season, these systems have both physical devices and operational procedures (which can be quite elaborate and ingenious) to divide the available supplies among different plots on some recognised basis.[32/] In times of shortage, besides rationing acreage, the water allocation is also rationed even more strictly. The basis and procedures vary. Some times (as in Pul Eliya) the physical design of the system is such that it is possible to make sure that the reduction in both area and water supply is shared in more or less of the same proportion by all users. But this seems exceptional: The area of each land holding is not usually distributed in such a systematic way

across lands with different grades of water rights. In such cases, only rationing as between different sections of the command is attempted. Rotation by canals or distributories or outlets or a combination thereof seems common. Not infrequently this is subject to differential water rights of different segments of the command area. There are a few cases where supply of water for relatively water intensive crops is rotated from year to year. These are usually in areas where crops other than paddy or more than one crop of paddy is raised in a year and the available supply of water even in a normal year is not sufficient to permit all users to grow the water intensive and dry season crops.[33/]

117. Coordination of irrigation schedules with crop-water needs is facilitated in some cases by collective agreement on the schedule of cultivation operation in each season. Thus in Pul Eliya, traditionally, the villagers take a collective decision at the beginning of each season regarding which lands and how much is to be cultivated as well as the schedule regarding "the dates on which the sluices will be open, the date at which sowing will be completed, the varieties of rice which will be sown and the date by which it is planned to have the harvest ready" (Leach 1961: 108).[34/] In some Japanese systems also the fact that the date of releasing water for puddling and transplantation is decided by the irrigation community as a whole implies a certain coordination in the timing of operations. Where the system is relatively extensive and the seasonal distribution of water supply does not permit synchronised operations over the entire command, cultivation is staggered. Sometimes, as in Bali, this staggering is elaborate and carefully coordinated in an institutionalised way.[35/] Staggering of operations of a less controlled character is reported in several cases.[36/] There are a few examples of systems (e.g., some of the Japanese pond-cum-canal systems and the Meichuan

project of China) which operate flexible delivery schedules which are varied according to the crop-water needs in different segments during the crop season.

118. The individuals or groups responsible for the overall management of the system make the allocation decisions within the framework of prim established by convention (or in some cases like the Sri Lankan tanks, by state law) and supervise its implementation. In multi-community systems the function has to be distributed between different layers, each layer being responsible for allocation within its jurisdiction subject to the limits set by the higher level. The basic unit at the field level is usually a group of farmers served by the same outlet. While users and other representatives participate at all levels. knowledge, experien and skills in water management are given considerable weight in the choice of functionaries.37/ In larger multi-community systems, where a higher order of expertise is needed, specialists are hired by the organisation. In this way technical expertise and users' interests are combined in arriving at decisions.

119. Where the system is fed by single pond or barrage, the top level decisions on canal operation largely determine the amount and timing of supplies at lower levels. The main task of the latter is to make sure that the supplies made available at that level are put to effective use and distributed "fairly" among its consituents. Systems with multiple sources and/or intermediate storages permit greater flexibility of allocation at all levels, but the managerial task is much more demand- in terms of the volume and quality of information required; alertness of the operating personnel; speed of communications, and coordination of decisions. All this also calls for far greater rapport between operators users. Meichuan is an excellent case in point.38/

120. Policing of the system, which is essential to ensure enforcement of the water allocation, especially in times of shortage, is provided for at all levels through a system of guards and watchmen who are either appointed as regular paid employees (this practice being usually restricted to the higher levels of relatively large system) or by assigning some of the farmers (sometimes for long periods and sometimes by rotation) to do this duty. The latter practice is common at the lowest level of multi-community systems.39/ In either case guards are selected for their reliability and fairness, and remunerated by the members of the group either directly or through a levy paid to the central organisation.

121. Conflicts occur both between constituent units of the system and among members of each unit over the way allocations are managed and over attempts to violate the allocations. There seem to be well-established conventions as to how such situations are to be handled: The leaders of a particular constituent group are expected to mediate disputes among its members and at the same time to represent the interests of their members as a whole in relation to other units of the system. Disputes which cannot be resolved at one level are referred to the next higher level. Conflicts which cannot be resolved by the irrigation organisation may have to be referred to higher centres of power. But it does not follow that the latter will always intervene decisively. Unfortunately there are few detailed accounts of the nature and incidence of actual conflicts over water allocations in such systems or about how they are resolved. The general impression that one gathers is that while conflicts are quite common and sometimes violent, there are counter-vailing forces which keep the organisation from breaking down.40/

122. Persistent conflicts which cannot be resolved satisfactorily within the existing framework, is one of the factors which could trigger modifications in the organisational framework and, failing that, a redesign of the system itself. This is brought out by the experience of several concrete projects in Japan (e.g. Aka river system, Azusa river, 12 Go Can) China (Meichuan project) and Taiwan (Nan Hung). These cases show that however the intensification of conflicts in a system is only a signal that changes in its operational procedures and perhaps physical design are needed. Whether and when the changes, and in particular system redesign, in fact take place depends on the potential returns to the investment on system improvement as against other means of raising output; the ability to mobilise resources to finance such investment and on the manner in which the costs and benefits from modification will be distributed. Even in Japan major system improvements took place in stages spread over several decades in spite of the fact that these improvements meant more abundant and assured water supply and hence a significant reduction in conflicts among users. Much the same was the case in the Nan Hung project of Taiwan. In MEIchuan on the other hand such improvements seem to have been brought about in a sh period, and the necessary resources mobilised wholly from the irrigation community because the combination of the commune system and strong local political leadership made it possible to secure an enforceable solution.

123. That a high level of conflict or increasing conflict does not necessarily lead to such improvements is highlighted by the state of tank irrigation systems of South India and Sri Lanka. In both these regions, irrigation supplies relative to needs ARE much scarcer than in east Asia

and given the low and variable rainfall relative to crop water needs, one would expect the potential returns to irrigation to be greater. It is true that the supply of water in these systems is much less reliable, and therefore the returns are more uncertain than in say Japan. Also the process of breeeding superior crop strains and improving cultivation practices had started much earlier in Japan. Major changes in bio-chemical technology have been slower to develop in south Asia. But this does not seem to be an adequate explanation for the continued neglect of tank maintenance and the inability to contain encroachment of cultivation into tank beds and to other 'prohibited' areas, which have led to a progressive reduction in storage capacity and hence water supply.

124. In more recent times despite the rising prices of paddy and the introduction of HYV, no major change seems to have occurred in the management of tank irrigation in south Asia. Any attempt to change the existing scheme understandably generates resistance because the users cannot be sure in advance about the overall benefits from a change, and are in fact likely to be apprehensive about how it will affect each one of them. The organisation and the leadership needed to allay the users' legitimate fears and to convince them that their interests will be protected - both of which involve a sustained process of education, persuasion and pressure - evidently does not exist and has been slow to develop. These difficulties are apparently being side-stepped by recourse to groundwater pumping on an individual basis - a phenomenon which by all accounts has become widespread even in tank irrigated areas.41/ However, all this is based on "casual observation" and not on any systematic studies of the adaptation of systems to changing situations. Hardly any study of irrigation from this perspective is available in south Asia.

Large State-managed Systems

125. At the other extreme, and in sharp contrast to the above category of systems, are the large canal irrigation projects of India (and south Asia). The management of water allocation in the latter is conditioned by the following characteristics: They serve extensive areas; until recent times, most of them were fed by a single source (usually a reservoir unlike in most parts of south east and east Asia, they cater to a wide variety of crops with different growing seasons and growth periods; and the allocations are sought to be decided by the system managers without consulting the users. In large systems with numerous users communication is more difficult; changes in any particular segment could have ramifications over a wide area; and the task of coordination becomes more complex. As a result, there is a preference for relatively simple operational principles which necessarily involve a certain rigidity in schedules and procedures. The scope for flexibility is further reduced when the system receives all or the bulk of its supply from a single barrage or reservoir. The diversity of irrigated crops makes coordination of water deliveries with crop-water needs more complex than in systems which use irrigation mostly for paddy.

126. Throughout India, the operation of canal systems and other control structures upto the "outlet" [which irrigates anywhere upto 40 ha] is wholly the governments' responsibility.[42/] The responsibility for overall management of the system is vested with a senior government official who is invariably from a permanent cadre of engineers. The entire project command is then divided into a hierarchy of smaller operational units and sub units (usually by sections of main canal, branch canals, groups of distributors, etc.) under officials subordinate to the system manager. The officials in charge of the intermediate

levels are usually from the engineers cadre; the supporting staff as well as those responsible for supervising the operation and policing at the lower levels are all employers of the state. Each system is supposed to be governed by codified operational procedures derived partly from general legislation and partly from the design of the project. Users or their representatives are not directly involved at any stage of the management (except below the outlet) and major changes in water distribution policy usually require approval at higher levels of government. They have formal power to enforce compliance and to punish offenders. And in case of serious violations which create law and order problems they can take the support of the state's police force. Below the outlet, the management of allocations, as of maintenance is entirely with the users.

127. In general the Indian canal system[43/] is geared to a certain crop pattern (in terms of area under paddy and other seasonal crops and perennials by major crop season) which is supposed to be decided and incorporated into project design on the basis of a careful evaluation of the quantum and seasonal distribution of rainfall; likely water supply in the reservoir; the water requirements of different crops under different soil conditions; and the policy regarding how the benefits are to be distributed. The extent of area which can be sown to certain water intensive crops (like paddy and sugarcane) is also specified with provision for penalties (penal water rates and even denial of water) in the case of violations. In some cases, annual rotation of supplies between different distributaries fed by a main canal is incorporated into the design to prevent excessive concentration of water intensive crops in the command. In general the systems are designed for continuous operation of the main canals except during the closure period which varies

depending on the needs of maintenance and on the crop pattern. The operation of branch canals and distributaries are continuous in some systems, rotated in others.

128. There are, however important differences in the way the canal supplies are regulated in any particular year or season. In south India, on the basis of the supply in the reservoir, water is released to the command area from a fixed date at the beginning of the crop season till the maturity of the main crop. "... the main canal runs continuously and the distributaries may be rotated in some projects with limited control structures. In this system no effort is made to ascertain the demand of the farmers on a weekly or fortnightly basis which may vary due to rainfall and the staggering of crop sowing from distributary to distributary and year to year" (Kathpalia, 1980:6). The focus of equitable distribution in south Indian system seems to be more on the regulation of crop patterns, particularly in respect of water intensive crops, both overall and in different segments of the command.[44/]

129. The annual operation of the systems in West India are also decided on the basis of the supply position in the reservoir, but deliveries in different branches and distributaries are regulated on the basis of the extent of area under different crops (especially the water intensive crops) in different parts of the command sanctioned by the canal management on the application by farmers at the beginning of each season. In these regions, the water supply in the winter season is rotated by distributaries as well as within each distributary.

130. In north Indian system while "the supply of water to different distributaries and minors is worked out in advance depending on the forecast of available water every season" the procedures are meant to give "flexibility to adjust the supply in the course of the season". (Kathpalia, ibid.) This is done on the basis of "demands" received from farmers, screened by the successive levels of canal officials and channelled up to the authority controlling releases in the main canal. This process is supposed to be done at frequent intervals during each season, for each minor and distributary, taking into account "the rainfall in the area, the stage of crop growth and the area under different crops at the particular time" care being taken "... to limit these demands within the available water in the particular crop season of the year". (ibid.). Rotation of supply usually by multiples of a week, between branches, distributaries and minors is common especially during the winter season. There is reportedly no rotation between outlets located on a given distributary. The procedure of the north Indian systems would seem to have a built-in method of handling situations of shortage. The fact that water is supposed to be released on the basis of farmers' demand subject to official review in the light of overall water supply provides a potential means for enforcing an "equitable" rationing of water in periods of shortage. Other systems do not seem to have any well defined procedure for handling shortages. The reactions of the canal management seem to be more or less adhoc.

131. But in point of fact even in north Indian systems scheduling is much less flexible than the above description would suggest. A detailed study of the working of the allocation procedures in the Bhakra canal system shows that (in the late sixties) while the rotation schedules as between the distributary channels enabled farmers served by each channel to be reasonably certain as to the date when they

might expect to get supplies, it gave no guarantee as to the amounts they would get. The latter depended on the amount of water released in the system which was highly variable. The uncertainty of timing and volume of supplies at the individual farmer level, which is determined by a further rotation system below the channel outlets, is considerably greater. (Reidinger, 1974). Where rotational scheduling is not in vogue, as is typically the case in south India, and there are no codified procedures for managing drought situations, there is not even the pretense of attemtping to assure predictability of supplies and equitable distribution of water to each outlet. In effect the areas close to the head of the distribution channels have greater assurance of supply, the degree of certainty falls sharply as one moves towards the tail end. The experience of one canal system during a recent drought highlights how slow the management is in reacting to water shortage, the ad hoc manner in which it tries to cope with the situation, and also the kind of pressures under which it has to operate. (Wade, 1980).

132. More generally, few systems seem to be able to conform to allocations visualised in the original design. The planned allocations are based on assumptions regarding (a) the likely availability of water in the system, its seasonal distribution, and variability; (b) the losses in conveyance, distribution and field application of water which together determine the "technical efficiency" of the system; (c) the water requirements of different crops; and (d) the pattern of cropping in different sections of the common area. Many of these turn out to be either erroneous or mutually inconsistent. The available information on rainfall, st flow and crop water needs are often inadequate or unreliable. With the best of intention the project design calculation can and often do go wrong.[45/] In the post-independence period inadequacy of time and staff

devoted to surveys and design in relation to the volume of work involved along with laxity in the technical and economical scrutiny of projects before approval have contributed to a significant lowering in the quality of designs. That there is political pressure to make it appear that project benefits are to be widely distributed is an aggravating factor. Under these circumstances it would be difficult to ensure that the availability of water, the size of irrigable area, crop pattern and the water allocation plan, are at least mutually consistent, not to speak of "efficient" of "optimal".

133. Such defects in design are compounded by difficulties in enforcing the planned crop patterns (in terms of both extent of area under different crops and their location). Most Indian canal systems are characterised by a shortage of water relative to irrigable land. The rainfall relative to crop water needs is typically low over the larger part of the year. Consequently the potential return to irrigation by way of increased yield of particular crops and, even more, through shifts to high value crops is large. This offers a powerful incentive to violate both the crop pattern and the irrigation quotas. The incentives are not - and perhaps cannot be - neutralised by appropriate differential pricing of water by use. The physical control devices are too crude to permit effective regulation of the volume of water delivered to particular locations necessary for proper rationing of water supply. The canal bureaucracy has in principle a variety of ways to enforce desired crop patterns some of which (like localisation, regulating canal supplies, and policing) have to do with operational procedures and others involve invoking sanction. But they do not seen to have been used to much effect.[46]

134. Since the available supplies are inadequate to meet the needs of the entire service area, and since the timing of supplies is highly uncertain, one naturally expects conflicts over water allocation to be relatively intense and widespread in the Indian canal systems. Conflicts among different segments of the command (upto the outlet level) one supposed to be mediated by the canal bureaucracy. There is no mechanism, in the formal framework by which users interests and operational constr. can be made to confront each other and compromises evolved. When authori fail or users are disaffected, extra-institutional channels of influence pressure are involved.

135. Reduction in the area effectively irrigated is one way by which the conflicts over water allocation seem to be contained. This happens not so much by design as by the head-reachers exploiting their advantageous location. We have one instance where the canal managers sought to involve penalties over such violations but gave up because the latter could muster the necessary support at higher levels of government to thwart the enforcement of regulations.47/ It is rather surprising that this has not led those at the periphery and the tail end to mount a sustained and organised effort to seek redress.48/

136. The reduction in irrigated area does not of course eliminate the "conflicts" over water. Again not much is known about their nature and magnitude, where they occur, how they manifest themselves and how they get resolved. All we know, in a general way, is that water is diverted from canals and channels in violation of rules. Some times with the connivance of officials, sometimes due to other negligence and, on occasion, despite their efforts to enforce the regulations. Apart from the location of the channels (upstream channels can get away with "violation" more easily than tail enders), the ability of a group or

to influence the officials through persuasion, for a consideration or by "political" pressure, seems quite important.

137. We know even less about the way allocations below the outlet are managed. In North India, a system of rotational supply according to cropped area to be managed by users, but backed by legislative and administrative support, was introduced in the late 19th century and seemsto have become a general practice in all systems. In other parts of the country they have been slow to develop. The field channels are not constructed, and the distribution below the outlet seems anarchic. During the last decade or so, a conscious effort has been made, as part of the Command Area Development Programmes, to improve the field distribution system both in its physical and organisational aspects. The introduction of a rotational system within the Command area of each outlet in all parts of the country is receiving serious attention. This has largely been at the initiative of the State though more spontaneous forms of community effort have also been reported (Haskim Ali, 1980 , Jayaraman/1981, Singh 1980). It has been suggested that the allocation at this level are biassed in favour of the larger and more powerful land owners (Thorner)[49/] But a detailed study of one outlet in the Bhakra system (Vander Velde, 1970) suggests that when water available at an outlet is inadequate in relation to its command area, rationing seems to take place eventually in the basis of the location of plots : Those closer to the outlet got more water and more assured water than those at the tail end. However, the present state of knowledge on the management of allocations and conflicts at the field level is too rudimentory to permit any generalisation.

138. In all these respects the situation is far from static. Significant changes have taken place both in the organisation and techniques of water management. We have already referred to the example of the Sarada canal where the introduction of the government canal seems to have displaced pre-existing local systems and the institutions associated with them. The canal system of the Deccan, which were originally designed for protective irrigation but then altered to support sugarcane cultivation is another case in point. The consolidation of land holdings in the north west India (especially west UP, Haryana and Punjab) and the abolition of zamindari may also have induced some changes, but there are hardly any studies documenting them. Several changes in both the organisation and in techniques of water management are currently in process.

139. In recent times awareness of the need for improved water control has increased possibly as a result of the spread of HYVs (whose high potential cannot be realised without adequate and timely supply of water To some extent the high and rising costs of new irrigation development and the fact that in some areas the scope for extending irrigated area is reaching the limit, have perhaps helped to shift attention towards more effective use of available supplies. The encouragement of ground water use in the command area of canals - which was earlier prohibited - is a major change. It has enabled the effective supply of water in the canal irrigated areas to be increased and at the same time given farmers greater control over timing and volume of application. The other important development is the establishment of the Command Area Development Programmes aimed at increasing the efficiency of water use by improving the physical facilities, planning of crop pattern and water deliveries on the basis of more careful studies of soil

conditions, irrigation efficiency and crop water need, and introduction of new systems of water distribution both between different parts of the canal system and among farmers served by a particular outlet.50/

140. These programmes have not accomplished all that they set out to: Major changes in the basis of regulating distribution of canal water has proved difficult even where they have been shown to facilitate wider sharing of available supplies without reducing yields. (see Wade, 1980) Attempts to bring about improvements at the user level by construction of field channels, consolidation of holdings and land levelling have not made much headway. The uncertainty of returns to the required improvements which involve substantial investment, the fact that the efforts are almost wholly conceived and implemented by state agencies with little user involvement, and the organisational weakness of the state apparatus are all important constraints. Given these constraints, it is perhaps not very surprising that the response to higher returns to irrigated agriculture has taken the form of expanding conjunctive use of ground water with canal supplies. The necessary investment for this purpose is made mostly by the better-off farmers with the smaller, less-rich, cultivators buying water from the former. While the distributional consequences of these changes are a matter of legitimate concern, the relevant point in the context of the present ... is that they provide strong evidence of adaptation to changing circumstances.

5. SUMMARY

139. This paper is concerned with the manner in which the principal functions of water control are organised, the reasons for variation in the form and structure of these organisations and their relationship to agricultural productivity and growth. These issues are examined in relation to agro-climatic conditions, technology, and the socio-economic environment which are also among the important determinants of agricultural production and which at the same time define the context in which water control organisations function. It draws liberally on the available material on water control organisations in different parts of Asia to highlight some of the crucial inter-relationships among these aspects.

140. Basically the need for water control arises because rainfall, which in the absence of irrigation is practically the only source of soil moisture, may exceed or fall short of crop water requirements in aggregate terms. More importantly their relative distribution over the growing season may not coincide. The function of water control is to make the two coverage and also to make for greater assurance in water supply. This involves irrigation to make up for moisture deficits in most cases but in some situations flood control and drainage to remove excess moisture is just as important.

141. Water control facilities help increase production by making it possible to make more intensive use of arable land, permitting a wider range of crops to be grown and enabling plants to use a larger volume of nutrients more efficiently. The quality of water control relevant from the agricultural viewpoint consists essentially in the capacity to regulate water application in accordance with soil moisture status and

crops' requirements. This is only partly a function of management which has to operate within the limits set by the physical design of the system and the way cultivation is organised. Neither of these is amenable to easy or rapid modification. Moreover, the magnitude of production depends not only on the quality of water control but is conditioned to an important degree by climate, soil conditions, genetic potential of the seeds and the amount of nutrients actually applied. Economic factors and land tenure are clearly relevant here.

142. Water control involves two distinct, though related, functions: one has to do with planning, design and construction of the system and the other with its operation. The organisations for carrying out these functions differ in several respects of which the relative roles of users as distinct from the State, the extent of reliance on bureaucracy and the degree of centralisation have attracted most attention. These differences in form however seem to be largely conditioned by system characteristics and by the manner in which they evolved. Thus all over Asia community involvement in, and contributions to, system construction has been most noticeable in small, relatively simple local systems. It has been high also in the extension and improvement of pre-existing local systems. But large systems covering extensive areas tend to attract a high degree of State involvement. One important reason for the relatively prominent role of the State in setting up water control systems in south Asia compared to east Asia seems to be that large storage systems figure more prominently in the former even as relatively small, local systems do in the latter. This cannot however explain why China has been and continuous to be able to get beneficiaries to contribute directly a major part of project costs while in India almost the entire cost is met by the State.

143. Differences in the size and character of systems are the cumulative result of varying agro-climatic conditions (which have a bearing on the kind of works needed and also the range of options available); the evolution of technology of design and construction (which affects both the kind of works which are technologically feasible at a given time and their cost); as well as the scope for and returns to investment in different kinds of water control along with other means of raising production. Thus in east Asia, the frontier of extensive cultivation seems to have been reached much earlier than in south Asia and increasing yields of paddy, the dominant crop, was contingent on wa· control. Agro-climatic conditions favoured the construction of local works, and much of the expansion in water control came by way of exten and integration of pre-existing local systems. Improvements in biochemical technology, which raise returns to irrigated farming and call for improved water control, seem to have occurred earlier and proceeded further in east Asia. In south Asia, until recently the cultivated area continued to expand more or less in step with population. Significant expansion of irrigated area had to wait till the necessary technology for construction of large storages and reducing the costs of pumping ground water became available. The advent of large storages also meant a high degree of State involvement in construction and financing.

144. The operation of water control systems involves maintenance of physical facilities and regulating the allocation of water among use and users in such a way that water deliveries at particular location can be made to match water requirements of crops at that location. Again organisational form is to some extent determined by size and complexity of the system and its evolution: Small systems generally tend to be managed by users without usual outside intervention. User participatio

remains high even in moderate sized multi-community systems when they have grown out of pre-existing local systems. In larger canal osystems, bureaucracy is inevitable and a high degree of centralisation is necessary for purely functional reasons, especially when several sources of water have to be operated in a coordinated fashion. The Indian canal systems being very extensive in scale and having been set up by the government, has resulted in a centralised organisation manned by the State bureaucracy. There are instances, mostly in east of Asia, where complex forms of multi-tieredorganisation which combine a high degree of central coordination with active user involvement in management. But these systems are in general much smaller than in India and usercommunities had been actively involved in setting them up.

145. All multi-user systems have to face the problem of conflicts among users which arise over the contribution each one has to make toward system maintainence and, more requently, over the allocation of water. Partly because of the complexity and uncertainty about yield response to irrigation, and partly because they directly affect income distribution among user, wate allocations are seldom determined by the market mechanism or through prices. Physical rationing of area and water are nearly universal. In the case of traditional local systems the basis of allocation, having evolved by a process of accommodation and compromise among the users, commands fairly general acceptance in the community. Even then, there are conflicts among users in times of shortage. These are handled partly by applying accepted principles such as differential water rights, rotational supplies and area adjustments, supported by sanctions against violation. These are also well established procedures for settling disputes. But the implied consensus and force of custom are

not always sufficient to ensure smooth functioning of such systems. There are occasions when the help of other centres of authority is ess Traditionally there seems to have been a close connection between the land tenure system and water control management in local systems with dominant landowners in the community playing a key role. But land own is not the only basis of such authority in irrigation organisation. P of wealth and influence in the community concerned may be involved dir or indirectly in the irrigation organisation, or their authority can be invoked when necessary. When the allocation rules of a system are se to be changed significantly intervention by outside authority is often essential during the transition. This may be a juridical authority su the organisation or intervention by a higher political authority. We have well documented instances of the latter in China where successful modernisation is seen to require active involvement and strong leaders of the Party Cadres.

146. In large canal systems, of the kind seen in India, the system design and water allocation rules are often decided by the project aut without consulting the users. The design itself is based on certain ptions of extent and location of area under different crops, and within limits set by the design (canal capacities, central structures etc.), the operational rules seek to coordinate water deliveries with crop water needs. Quite apart from the problems posed by defective design, which are quite common, such situations give use to a double conflict one between users and the management and the other among the users. The conflict potential is increased when the available water is inadequate to meet the requirements, and ... crops of very different water needs and productivities are grown. The Indian canal systems ha

sought to manage this problem through centralised management by officials armed with elaborate sanctions. But in reality this "centralisation" has been largely ineffective: The canal officers are unable to exercise their authority and enforce the regulation against head-reachers who exploit their advantageous location with virtual impunity at the expenses of the tail-enders. Nor, interestingly, have the tail-enders been able to do much by way of organising counter pressures. The question of how irrigation organisations relate to users, and how both are "articulated" with the wider political authority is therefore an important issue.

147. The "effectiveness" of irrigation organisation, and in particular of water allocation procedures, obviously cannot be judged by its form: There is no necessary connection between bureaucracy and centralisation on the one hand and system performance in the other. Organisational characteristics are themselves conditioned by the nature and scale of the system. The quality of water management in any case depends not only on how well it is organised, but also on the physical design of the system. Moreover, the connection between water management and yield being determined by a complex of factors, including rainfall, bio-chemical technology and land tenure, is not easy to disentangle. The more so because all these elements are variable over time.

148. A more fruitful line of approach would seem to be to view irrigation organisation (which of course includes its water allocation procedures) and the physical design of the system as being in a state of mutual interaction both being subject to the influence of changes in agricultural technique, land tenure and prices. The way a system is designed in effect reflects the state of knowledge, techniques skills, and prices as well as the interests of the various groups involved at that time (the latter

including not only the potential users of the system but also those which organise and finance the construction). Since designs are based on limited and often erroneous understanding and facts, the planned allocations are at best approximate and, not infrequently, defective. The effective command area, the crop pattern, as well as the operational rules get modified in fact, even if not always formally, in the light of actual experience regarding water availability and its seasonal distribution, crop water needs and the effects of varying water (under prevailing agricultural technique) on crop yields until a certain "equilibrium" is established. At this stage any hiatus between the system authority's objectives and the users interests have also to be sorted out whether by consensusor fiat or by users in the upper reaches asserting their locational advantage.

149. This position can be disturbed for any of a number of reasons: Other groups may begin to tap the same source (by extending existing canals or by taking out new ones from the same river) thus leading sooner or later to shortages and conflicts. Neglecting to maintain system facilities may reduce effective supplies and aggrevate conflicts. Expansion of the market for crops, introduction of new crop species and varieties, improvements in cultivating technique (including new techniques of irrigation), a shift in the prices of crops relative to inputs - all these may individually and collectively increase the potential returns to irrigated agriculture. Changes in land tenure and taxation may alter the returns which the actual cultivators gets from irrigated farming. If there is no change the system or allocation procedures, these changes, in so far as they increase the potential returns to water, could aggrevate conflicts over allocation.

150. It would seem natural that when conflicts over water in a given system increases, whether as a result of over-extension of the command relative to supplies or because water is becoming more valuable, attempts will be made to change operational procedures and to make minor modifications in the physical facilities with a view to reduce waste and facilitate a more equitable sharing of available supplies. But this process has definite limits beyond which further improvements in the technical efficiency of irrigation and in the regulation of the volume and timing of irrigation requires major modifications in system design (involving such works as integration, of intakes, increasing water supply by constructing new storage and/or tapping groundwater, redesign of canal and drainage networks, and land improvement) or introduction of improvements (such as land consolidation and levelling, better techniques of water application) which raise irrigation efficiency. All of this involves additional investments. The willingness of beneficiaries to undertake these investments or to contribute to the cost depends as much on the overall productivity of these investments relative to the costs involved as on their perception of how the changes in system and its operational rules will affect their individual interests.

151. In so far as changes in organisation and its operational procedures are essential to get the most out of these system changes (in terms of additional output), the two cannot be dissociated. At this point again a difficult and time consuming process of securing - through persuasion or pressure - the users to accept the organisational changes is invariably involved. Even as procedural changes cannot go beyond a point without system modification, institutional changes must sooner or later accompany system changes.

152. The few studies of the evolution of irrigation systems and their organisation which we have broadly fits the above view. Most of them however relate to the relatively small irrigation systems of east Asia which have grown by combining expanding and improving pre-existing local systems. The pace and character of these changes however vary a great deal, and not much can be said with confidence on the reasons for these variations. Further, there are hardly any studies of the changes which have occurred, and are occurring, in the very different and much more varied, irrigation systems of south Asia: The reasons for the apparent failure of traditional tank irrigation systems to respond to changes in cultivation techniques and prices; the difference in response between users (in terms of community organi-sations to maintain local facilities and allocate water within the community) to introduction of canal irrigation in areas which already had local systems, and those which had no prior tradition of irrigation; the manner and speed with which users in different segments of a large canal system respond organisationally to deal with the allocation probl- the differences in response between areas with ground water and those without as well as between areas experiencing high rate of technical improvement and those which have experienced little - these seem are some of the issues which seem highly promising subjects for systematic investi-gation.

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Part 1

1/ Marx had suggested that "climate and territorial conditions" made artificial irrigation by canals and water works the basis of Oriental agriculture. And "this prime necessity of an economical and common use of water which, in the occident drove private enterprise to voluntary association as in Flanders and Italy, necessitated in the orient where civilisation was too low and the territorial extent too vast to call into life voluntary association, the interference of the centralising power of the Government" (Marx, 1853 cited by Wittfogel, 1957 and Chi,1936). In relation to China, Chi interpreted the comment about the 'low level of civilisation in the orient' in terms of the tendency of the ruling 'landlord bureaucracy' to nip the growth of merchant capital in the bud by declaring 'every important profitable enterprise as a state monopoly and absorbed the embryonic merchant class into their ranks if it were felt it would be unsafe to disregard it' (Chi, 1936:71).

2/ Weber argued "...in the cultural evolution of Egypt, west Asia, India, and China, the question of irrigation was crucial. The water question conditioned the existence of the bureaucracy, the compulsory service of the dependent classes, and the dependence of the subject classes upon the functioning of the bureaucracy of the King" (Weber, 1927 cited by Chi, 1936:73).

3/ His ideas are set out in a series of works the first of which appeared in 1926 and culminated in the book entitled 'Oriental Despotism: A comparative study of total power' (1957). The latter volume provides a resume of the evolution of Wittfogel's ideas on the subject and also their antecedents.

4/ Leach (1961) formulated the perspective thus: The material context of societies "... is not merely a passive backcloth to life; the context itself is a social product and is itself structured the people who live in it must conform to a wide range of rules and limitations in order to survive at all. Ever anthropoligist needs to start out by considering just how much of the culture with which he is faced can most readily be under as a direct adaptation to the environmental context inclduing that part of the context which is man made" (Leach, 1961:306). But the perspective is not universally accepted and as Leach goes on to point out "While every social anthropologist recognises that societies exist within a material context... too many authors treat such things as nothing more than a context useful only for a introductory chapter." (Ibid.)

5/ Of these, Kelly's study of the evolution of the Aka river system in north Japan spanning a period of nearly 3 centuries (from its inception in 1600 to 1870) is perhaps the most detailed. For a more general treatment of history of irrigation in Japan, and its relation to evolution of land tenure, see Hatate (1978).

Section 2

1/ For a useful and non-technical summary of the present state of knowledge on the role of water in plant growth see Dakshinamurti et.al. (1973) and Carruthers and Clark (1980·Ch.2).

2/ The determinants of ET and its relationship to crop water needs are ofcourse more complex than this. There are also many controversial and unresolved questions. However, for our purpose it is appropriate to focus on two basic propositions which are more or less generally accepted, namely, that maximum crop-water needs are a function of evapo-transpiration and that they do not vary much over a wide range of field crops. For an idea of the nature of the other influences on crop water needs see Wiesner (1970) Carruthers and Clark (1980) and Dakshinamurti et.al (1973). For a discussion of the determinants of ET and the problems of measurement see Weisner (1970) and Olivier (1961).

3/ In the subsequent discussion we do not always distinguish paddy from other crops. Paddy is unique among field crops in that it needs substantial amounts of water over and above ET for keeping the field submerged and for puddling and transplantation. Percolation losses from paddy fields also tend to be relatively high. This does not pose a serious difficulty when comparisons are made between countries/ systems where paddy is the dominant crop. But in comparing systems/ regions where paddy is grown along with other crops in irrigated tracts and this is quite common; in south Asia these differences in water nee of paddy and other crops become important and need to be explicitly taken into account.

4/ The pattern in peninsular India is broadly similar to the pattern shown in fig.1. However the rainfall even during the monsoon is inadequate to sustain paddy cultivation whose water requirements, for reasons cited, far exceed ET. In 'arid' regions (like Rajasthan and N.W.India) rainfall is uniformly below ET.

5/ See for instance Levine (1972:53-54). He cites concrete examples from the south east asia to show the wide variability in 'overall irrigation efficiency' (measured by the ratio of the actual amount of water needed by the crop on the field to the amount of water diverted at the source of the system). This ratio ranged between 25 and 90%. These differences, Levine points out, are partly a matter of the way the system is designed, and the soil and topographic conditions in the command, but institutions (or what Levine calls 'the human element in water management')is also an important factor. Levine emphasises that we know far too little about the relative importance of these two factors.

Section 3

1/ This account of the main features of the organisation of water-conservancy planning and construction in India is based on a variety of sources including the various five year plans and the report of the Irrigation Commission (197).

2/ For a comprehensive and detailed discussion of the evolution of Chinese policy in the post-revolutionary period see Nishimura (1971) ; Vermeer (1977). Greer (1979) provides a detailed account of developments in the Yellow river basin. We have drawn heavily on these sources.

3/ A number of descriptions of the post-war land improvement programmes are available. see for instance Ogura et.al (1963: Chs.12 and 20) Nishikawa (1971).

4/ Sarada Raju (1941: 113-120) gives a brief review of the situation immediately before the advent of British rule and thereafter upto.the end of the 19th century.

5/ For a recent historical account see Whitcombe (1983).

6/ Several books/papers dealing with water conservancy from a historical perspective are available in English. Notable among these are Chi (1936); Wittfogel (1957); Needham (1971); and Hamashima (1980). But except Hamashima and Needham, these works are not concerned with water conservancy per se but its relation with other issues like the extent to which water control development affected the shifting locus of political power (Chi) and the relation between water control and the nature of the state (Wittfogel). Needham's focus is on the evolution of technology of water control but provides some information on the organisational aspects also. These works generally tend to concentrate on larger works. There are no detailed accounts of the construction and operation of small systems: We have pieced together this information from works relating to local government in the 18th and 19th centuries (Hsiao 1960; Chu 1962; and Chi, 1936); Hamas' is one of the few works in English which is concerned with water control and its relation to the wider political context. For an comprehensive review of the historical evolution and contemporary situation in respect of construction and management of water control works in China see the author's 'Organisation and Management of Water Control in China (to be published by IDE, Tokyo, 1983).

7/ See for instance the following account of the construction of the Grand Canal cited by Chi (1936: 123). "All men between the ages of fifteen and fifty were ordered to assemble by royal edict. All who tried to hide were punishable by decapitation... The labourers thus assumbled numbered 3,600,000. Then each family was required to contribute a child or an old man or woman, to prepare meals for the workers. Five thousand young and brave soldiers were ordered to be armed with sticks (to maintain discipline).. Together with section chiefs and other administrators, the whole number of people employed in the canal amountéd to 5,430,000.... "At the beginning of the eighth month of the fifth year of Ta-yeh's reign (609 AD) baskets and shovels put to work; the workers were spread over several thousand li in a west-east direction. After a certain sector of the work was done, when the workers were counted, two million and a half labourers and twenty-three thousand soliders had been lost".

8/ For a description of the historical evolution of particular Japanese irrigation systems and the role of government in it, see Tamaki (1979). Hatate (1981), Kelly (1980), Shimpo (1976).

9/ Out of a total irrigated area of 43.3 million ha. 26.7 million ha. were served by surface sources consisting of canals (19 million ha.) tanks (4.1 million ha.) and other surface sources (3.5 million ha.) (Rao, 1979:59). Canals thus account for nearly 70% of the total area under surface irrigation.

10/ Thus the effective storage capacity rose from an estimated 12.3 billion cubic meters in 1951 to 61.7 billion cubic meters in 1966. The complet' of irrigation projects on land as of 1965 was estimated to raise the total storage to 120 billion cubic meters (Framji and Mahajan, 1969, vol.1: 420).

11/ Chao (1970:129) gives the following figures based on Chinese sources

Types of irrigation in selected years in China

(Million mou of land irrigated)

Type of irrigation	1949	1952	1956	1964
Gravity - large canals	23.5	31.9	43.2	278.
Gravity - small ditches and aqueducts	261.6	289.2	182.	
Farm ponds and ditches			216.5	82.
Pumping with electric or mechanical power	4.2	5.	11.9	86.
Wells and other subterranean sources	14.6	24.5	86.4	34.
Total	303.9	350.6	540.	480.

Gustaffon (1983:15) gives the following information on the distribution of storage capacity built during 1949-1980 by size and unito of responsibility.

Reservoir size	$10^6 m^3$	Numbers	capacity km^3	Responsible unit
Large	> 100	300		Min.of water conservan & Power
Medium	100 - 10	2200	113	Provincial government
Small	10 - .1		115	Country for commune
Ponds	< .1		na	Brigade
Flood Retention basis			212	Ministry of water conservancy & Power

2/ In the mid fifties, there were some 41 multi-purpose storage dams with a total storage capacity of 1.4 billion cubic meters (billion = 10^9) and 50,000 small and medium reservoirs with an aggregate capacity of 1.64 billion cubic meters. (Sasaki, nd:13-14).

/ In the early 1970's, there were some 10,000 land improvement districts irrigating 1.4 million ha. The average LID thus covered about 150 ha. About a third of them served less than 50 ha.; only 2 per cent served more than 3,000 ha. There were only 17 systems serving more than 10,000 ha. (Takeuchi nd 87).

4/ At the time of independence most of the canal irrigation in the Indo-Gangetic plain consisted of diversion works. Among the prominent ones are the Sirhind canal (0.6 million ha.) Upper Bari doab (0.33 million ha.) the Son canal (0.35 million ha.) Jumuna canals (0.68 million ha.) and the Upper Ganga canal (0.7 million ha.) (Rao,1979:241). It should be noted however that the overall level of irrigation development was low and the bulk of irrigated area was under small local works and wells. See Sengupta (1981) for a description of some of the local systems in south Bihar and Whitcombe (1972) for a description of their role in Uttar Pradesh.

15/ The largest of which is the Bhakra Nangal reservoir (capacity 7.4 billion cubic meters). As of 1979, total storage capacity in the Indus and Ganges basins (including multi purpose reservoirs) is estimated at 48 billion cubic meters representing nearly a third of the total storage capacity of all reservoirs in the country (147 billion cubic meters). Practically all the reservoirs in the Indo-gangetic basin were constructed since Independence (Rao, 1979:239-240).

16/ Nearly half the irrigated area in the Ganges basin (8.9 million ha. out of 19.5 million ha.) and about two fifths in the Indus basin (2.4 million ha. out of 6.3 million ha.) is estimated to be served by ground water. More than half the area irrigated by groundwater sources is currently under tube wells which is entirely a post-independence phenomenon. (Rao, 1979:59).

17/ There are an estimated 127,000 tanks in the area covered by the present States of Andhra pradesh, Karnataka and Tamil Nadu irrigating an estimated million ha. (GOI, COPP,). Besides topography, the fact that these tracts have a rainfall pattern marked by two distinct seasonal peaks (one during May-July and the other in October-December) is an important factor facilitating tank irrigation.

18/ The four river basins of south India (Godhavari, Krishna, Cauvery and Pennar) where groundwater resources are not as abundant as in the northern plains, only 25% of the irrigated area is served by this sources and that too mostly from shallow wells. Of the area served by surface water, over one fifth is under tanks the comparable proportion for the rest of the country being 10% (Rao: Ibid.). It is noteworthy that while the Cauvery system is of ancient origin, similar developments did not take place in the Godhavari and the Krishna deltas until the mid-nineteenth century.

19/ There is obviously great variation in the climatic patterns within each Asia. But our interest here is to focus on the gross differences between east and south Asia. These differences seem to us to be very striking and have an important bearing on the nature of the water control problem. A somewhat more refined comparison would be between the paddy growing tracts in the two regions and between their respective wheat belts. Our essential point would however still remain.
Note that ET in the diagram relates to consumptive use of water; non-consumptive uses in the case of paddy would in effect shift the water requirements curve upwards (but not in the same proportion in all parts of the season). Thus basic argument however is not likely to be affected.

20/ The annual distribution of run-off in some major rivers are given below:

tion	Percent of Annual flow by months												High rate		Low rate	
	1	2	3	4	5	6	7	8	9	10	11	12	Months	%	Months	%
[illegible]OW	2.3	3.9	3.4	5.6	4.8	6.2	13.1	19.9	16.2	13.1	7.8	3.7	7-9	49.2	1-3	9
UKOW	3.1	3.1	4.3	4.3	8.5	10.9	13.6	15.6	13.2	11.7	7.8	3.9	7-9	42.4	12-2	10
TICKG	2.2	1.6	1.3	1.2	1.9	7.2	13.5	21.9	23.7	14.9	7.	3.6	8-10	60.5	2-4	4
[illegible]HE	2.1	1.4	1.2	1.5	2.	8.2	22.8	22.4	20.4	11.9	4.6	2.5	7-9	65.4	2-4	4
RAKAH	2.	1.7	1.4	1.2	1.4	3.	14.	30.4	25.7	11.9	4.6	2.7	7-9	70.1	3-5	4
[illegible]-BAHADU-RIBAD	2.3	1.9	2.	3.1	7.8	14.1	17.5	19.1	15.4	9.3	4.6	2.9	7-9	50.	1-3	6
[illegible]UR	1.3	.6	1.	3.2	7.	12.3	22.7	30.7	14.6	4.3	1.2	1.1	7-9	68.	1-3	2

Source: UNESCO 1978:229.

21/ Kikuchi and Hayami (1979) have tried to show, empirically, how the differences in timing and scale of different kinds of investments (opening new land, investment in new irrigation, improvement of irrigation) in Japan, Taiwan, Korea and Philippines were conditioned by their relative costs and returns, the latter being in turn a function of technical possibilities for extending cultivation and for irrigation; changes in complementary aspects of agricultural technique; and the demand for agricultural products. See also Levin (1977) observation on the timing of irrigation improvements in Philippins and Taiwan.

22/ This does not mean that nothing was done in other areas. Substantial work was done in the south (the construction of the Krishna and the Godhavari delta systems, the reconstruction of the cauvery system and the renovation of tanks being the major ones). But the fact remains that the volume of investments in the north-west India were far greater than anywhere else in the country. (see Paustian, 1930, also Whitecombe 1983).

22a/ Private initiative did play an important role in developing groundwater but this is almost oalways on an individual basis. Group activity by farmers or by village institutions to develop irrigation sources of any kind for the benefit of several farmers is altogether rare. A survey in the 1950s (GOI, PEO, 1961) reported four out of every 5 private tanks and half the " pucca wells" as being jointly owned. Details on the nature of the joint ownership are not available but it seems likely that such joint ownership is limited to small groups of kinsmen.

23/ Thus if farmers served by a government outlet do not have reasonable assurance of the volume of water they can expect to get at that outlet - and this could happen due to over-extended canal systems or defects in the estimation of irrigation efficiency or inability to enforce the planned crop patterns - they cannot be sure of the returns to constructing field channels or making land improvements.

24/ Thus if the water supply available at an outlet is inadequate to meet the requirements of the entire area under its command, those nearer the outlet are surer of meeting their needs than those further away. Reidinger (1974) has shown this to be actually the case in one north Indian village. Clearly under these conditions, all farmers in the command cannot be expected to be equally enthusiastic about joint effort involved in constructing field channels. While the reluctance of tail enders to participate in such effort is understandable, one would expect those nearer the outlet to be more interested. Whether this is in fact so is a matter which remains to be investigated.

25/ To quote Kelly (1980:518) "... in the decades following the domain period changes in land tenure and taxation (stricter surveying and assessment and fixed cash taxes) created pressures on paddy land owners in the basin, including the large landholders previously enjoying near immunity from tax demands. At the same time the relaxation of administrative restraints on production and marketings and land transfers, and an increased market for rice promised expanded opportunities for profit from rice cultivation; the new Meiji methods offered the possibility of increasing and stabilising land productivity. Water was the key then; if problems which had plagued all four phases of irrigation during the domain period could be addressed, rice cultivation could. viable for the small bolder and profitable for the large landlord. "It was in this context and for these reasons that a more centralised organisation of basin irrigation tasks emerged in these decades. The cooperatives on several levels carried out directly important technical and procedural changes in source control delivery and drainage and facilitated the major adjustments of fields and field ditching which accompanied a shift in water application practices."

26/ For a brief review of the Japanese land improvement Programme, see Nishikawa, 1971. In the Meiji era ..."The replotment work brought an advantage in double ways to the landlords as enterprisers, on the one hand they could claim for raising the amount of rent on the pretext of yield increase per hectare and on the other hand they could have usually more registered area of paddy field to be rented out them before". The latter possibility arose becanse "...the area concerned before the works had been estimated in many cases about 10 to 20 per cent less than an actual state, and because the whole area through the replotment after surveying could increase owing to the decrease of le ees area and often to additional paddy field making" (ibid: 17). At the peak, replotment was 60,000 ha.per -year. But the process suffered a severe set back after the first would war and the surge of tenancy disputes. Another phase started in the 1930's and by the end of the Second World War about a quarter of the paddy land had been replotted. For a micro-view see Imamura, 1980.

27/ See Kelly (1980:Ch.9) on some of these aspects as manifest in the Aka river system; Hatate (1981) in relation to Azusa river; and Shimpo (1976) concerning the Iwate area. Kelly also refers to a number of such studies concerning other systems (Kelly, 1980a).

28/ For a brief account of inter state river disputes in India see Rao (197

Section 4

1/ See Maas and Anderson (1978. Ch.1) Coward Jr.(1980:Ch.1) Chambers (1977) for a generalised discussion on functions of irrigation organisation and of the conceptual framework appropriate for studying its structure and working.

2/ In Japan 10 per cent of the irrigated area is reported to be under individual management (Takeuchi, nd:87). These systems are presumably also owned by individuals. In India, a survey conducted in the 1950's reported 30% of the tanks is being privately owned, a large majority of them jointly. (GOI, PEO, 1961).

3/ See Sasaki (1959).

4/ For details see Vaidyanathan 1983: 30-56.

5/ For a general description of organisational structure see Framji and Mahajan (1969) and Govt. of Andhra Pradesh (1982: 78-87); GOI, PEO 1965 gives some, albeit sketchy, idea of management organisation for selected projects.

6/ See Baljit Singh and Sreedhar Mishra (1962: 123-127).

7/ In South India this intervention seems to have been limited to maintenance which was taken over by the PWD. The State apparently made no attempt to take over management of water allocations. In Sri Lanka the coloniel government appointed an official (the Vel Vidane) in the village specifically to manage both maintenance and water allocation from public tanks (to be distinguished from private and temple tanks). Regulations were also introduced to ensure fair distribution of water (See Leach 1961 and Roberts 1967).

8/ Baljit Singh and S.Mishra (Ibid.)

9/ In Sri Lanka too. Roberts (1967) refers to the decline in the "spirit of practice of mutual obligation which was so important a feature of peasant agriculture was being undermined by forces of individualism, litigousness and apathy" and the consequent decline of the tanks as being "...partly, if not largely,...of the British rulers' own making. In abolishing forced services... and in creating minor courts, they had deprived vel vidanes ... and gamsabhawas ... of the only effective means of compelling obedience to village agricultural customs". These changes were part of a more general change in the land tenure and land revenue systems.

10/ See "Hunt and Hunt (1976) and comments thereon. Also Kelly (1980). Both have drawn attention to the need to distinguish centralisation of authority within the irrigation organisation from control of irrigation organisation by centers of power and authority outside of, and in some sense higher than, the irrigation organisation.

11/ It has been pointed out by Coward Jr. (1980:25-27) that in community systems the role of the water user and that of water authority "are highly integrated because they are guided by similar socio-cultural roles and because of the temporal circulation of individuals between the two configarations or the simultaneous occupancy roles in both configurations or the simultaneous occupancy roles in both configarations". (This does not of course mean "harmony" in as much as the interests of managers as water users may be in conflict with those of other users). As water authorities become more specialised and differentiated from users, integration through the same individuals bei involved in both roles is more difficult. The possibility of disso and between the rules orienting the users and the authority also increases.

12/ The following are a few examples:

In the northern Thailand systems studied by Potter (1972:89) the h d-man of the system is "chosen by the three...heads of the three communes served by the irrigation system. The present head... has been head for about two decades. He is one of the richest and highest status men in this part of Saraphi district and owner of an enormous traditional Thai house...and a large private lake for fish. His granary...is as large as most village h ses... ..."The assistant heads of the system, of whom there are two, are respectively head of one commune and head of an important village. The village irrigation headman, chosen, by the farmers in each village served by the system, are usually also village headmen and hold office for long.

In the 12 go canal (Beardsley et.al., 1959:150). "The mayor of Kamo is fairly prominent in the councils of the board of the twelve-go organisation because by tradition he is the chief administrator of the Iwasaki water gate located near Kamo village office. The fact that Kamo is furthest upstream and the oldest participant in the six-go canal system also gives him seniority". In one of the Zangjeros (irrigation coops) of Ilocos, Philippines, "leadership of the federation is elective and the president of the group is an important and influenctial man in the Baccara politics. He is a member of 2 [illegible] and president of still another". (Lewis, 1971:155).

13/ For details see Vaidyanathan, 1983.

14/ Descriptions of the way these tasks are decided and implemented are available for several systems. They show that most systems have established conventions regarding the timing of repairs, the manner in which works to be taken up are decided, the responsibilities of different functionaries and levels of the organisation, and the ob tions of the users. The following are two typical cases.

In a local system of north Thailand a meeting of the leaders of the system is held at the end of each rainy season to decide on the dates when the canals will be cleaned and wiers rebuilt. The cleaning of the minor canals and distributories, which has to be done several times in a year, is organised at the village level. All farmers are expected to contribute labour for the maintenance of the main canal in such a way that tail-enders have to contribute relatively more than those at the head of the system. At the village level contributions are generally proportional to the area irrigated. The actual work is distributed among the irrigation headmen, of whom there is one in every village, who enforces the mobilisation of labour from each household and organised and supervises the conduct of the work. (Potter 1972:91-96).

In a multi-community system of north China, before the Revolution, the chief supervisors of the system decided on the repairs to be undertaken at the beginning of each season and indicated to this subordinates, of whom there were approximate one for every 20 households, the number of labourers required from his group as well as the time and place where they would be needed. The subordinate was then responsible for mobilising the workers from his group (each member household being expected to send an able bodied person) and for ensuring that the assigned work was completed. (Myers, 1975:201-2).

The users obligations generally involve the supply of labour for carrying out the works, with supplementary payments for other (usually material) costs. The basis for allocating the labour contributions are varied: while sharing in proportion to area benefitted seems common it by no means universal: In the Thailand case, cited above, tail-enders had to bear a heavier burden. Similar practice is reported to have been in vogue in the Aka River system of Japan (Kelly 1980: 292-3). For a similar case in China see Nickum,ed(1981: Reading 5). There are instances of communities setting apart some land the produce of which were used to meet the costs of maintenance.

15/ We have details regarding the penalties only for some systems in the Philippins. In one case, (Bacadayan, 1974: 174-6) the fines are reported to take several forms: "money (one peso), rice (5 bundles) or a good drink and a meal for the group". Lewis (1971:165) cites a case where "repeated failure to attend work sessions can result in a loss of water" and another where "fines are levied for work absences and, if the absence continues, the loss of land may result".

16/ For a discussion of the changing role of landlords in Japanese context see Hatate: (1978).

17/ This is evident from the data and observations presented in GOI, COPP (1959, 1960) and GOI, PEO (1961, 1965).

18/ The decay of traditional maintenance in Sri Lanka is also connected with the changes in land tenure and consequent changes in the village polity. It is of some interest in this connection to note that in the case of the "Crown tanks", which were taken over by the State, the maintenance seems to have been better than in the temple tanks. (Leach 1961) points to the stark difference between the state of the Crown tank and the temple tank in the same village. This raise several questions: Why did the temples lose interest in their tanks? why did the farmers using the tank, or alternatively the State, fail to step in? Why are two tanks in the same village treated so differently?

19/ This practice is reported in the Twelve-go canal of Japan, the Balinese Subak as well as in some Philippine systems.

20/ For a more detailed discussion see Vaidyanathan 1983: 48-53.

21/ Ibid.

22/ For details see Nickum 1982 UN, ESCAP, 1978. The available material is summarised in Vaidyanathan 1983:53-7.

23/ The maintenance of all tanks is divided between the PWD and the Revenue departments and, in some cases, local authorities (Panchayats There is an elaborate (but variable) procedure for inspection and formulation of concrete proposals for maintenance/repair by lower level officials. These proposals are reviewed by the district offic' in the light of available resources and priorities assigned. Before the abolition of zaminari and Inamdari tenures, this system did not cover private tanks, of which there were 13,000 in Andhra Pradesh alone. The owners were responsible for their maintenance. Many of them were neglected and the survey showed a large number to be sub-standard in design and in a poor state of repair. But even in respect of tanks which were under the government care, maintenance was far from satisfactory. While in some cases this was attributed to weaknesses in administration, it is significant that even in Madras state, judged to be the best organised in this respect, most tanks were found to have silted and their storage capacity reduced: In hal the tanks surveyed in the state, the capacity had been reduced by 50 or more since the late nineteenth century (GOI, PEO, 1961:98).

24/ The evidence of deterioration of tanks, has been already cited. Complaints about poor maintenance in Canal projects is widespread. (See for example, GOI, PEO, 1965); the papers presented at the 1981 Seminar on Warabandi held at Hyderabad; and Singh (ed), 1982. The following examples are illustrative:

"Based on the experience in 350 minor canals in which was introduced over a period of 3 years, it can be said that no minor was capable of discharging the design discharge unless it was either improved or brought to it original design standard..." This was estimated to cost Rs.10,000 per minor. In a quick survey of the Nagarjunasagar Right canal command area taken up in July 1979"... 557 defects were found in the canal system serving 232 villages".

"A study of 105 distributaries in .... 1980-81 showed that more than 50% of the control and cross structures needed replacement or repairs. The canal banks were eroded, canals were silted up or had vegetative growth, siphons were choked and there were a large number of unauthorised offtakes in practically every distributary and minor" Hashim Ali, in Singh ed (1982:41-42).

25/ This account concerns the responses of officials and users in respect of particular osystems. There is however a growing concern over this problem at the general policy level - a concern which is reflected in the establishment of numerous committees and commissions to study the problems of effective use of irrigation potential. See e.g. GOI, Irrigation Commission (1972); Govt.of Andhra Pradesh (1982);Singh ed. (1982). However none of these reports deal with the problems of ensuring proper maintenance in any depth; they seem to view it essentially in terms of allocating more money!

26/ A number of attempts at modelling optimum water allocations have been made in the Indian Context. See for example Minhas et.al. (1974) and GOI (1970).

27/ In the case of wells and ordinary tube wells many of these limitations are mitigated by the fact that the service area is typically quite small; that the buyers are usually relatively few in number and lands for which the water is intended are contiguous to the well; and that the seller has much greater control over how much water he delivers, to which plot and when. It is therefore not surprising that "markets', in the sense of purchase and sale of irrigation water, are much better developed in the case of ground water than in surface water systems.

28/ Note however that since there is synergy in the response of water and fertilisers, and irrigation contributes only a part of the water supply, the marginal product of irrigation depends on the level of fertilizer supply (which is more amenable to variation than the irrigation supplies once the system is in place) and on rainfall. Any change in the responsiveness of yields to fertilisers under actual farm conditions (be it due to better seed, better fertilisers, or better skills acquired through experience) will also affect the productivity of water and hence its "efficiency" price.

29/ See 46 below.

30/ Similar studies are available for other parts of the world e.g. Glick (1968, 1972). Hunt and Hunt (1974) and Maassand Anderson (1978). We have not made any attempt to bring them into our discussion largely became they relate to altogether different agro-climatic, technolgical and socio-economic environments compared to Asia. The dominance of paddy and small-scale farming are two distinctive features which the irrigation communities of Asia have in common, and which marks them out from those of Europe and America.

31/ The tradition of unequal water rights is well documented in the case of Japanese and Taiwanese systems: Thus in the case of the 12 Go canal system, "In time of drought the villages on the reclaimed land in Kojima bay get shortchanged, according to their view. Their claim to this water goes back only a century at most and they are at the tail end of the canal. Hence the older villages upstream claim prior right to the water. In any case they have first access to it and it is their own people who decide, , as water guards, how much to let

through ... At a still higher level, the Eight-go organisation has gone to court against the Twelve-go organisation in a dispute over the division of the Takahahshi river water. The dispute concerned the question of how high the Twelve-go organisation ought to be allowed to build its diversionary dam." (Beardsley et.al 1959).
See also Hatate, 1981.
In the Shiwa study, Shimpo (1976: 5-7) reports:

"The closer the water intake of a canal to the junction of the river the more advantageous were the water rights of the canal group that used it." And in the case of canals further way from the stream, as water became scarcer, "the allocation rules became fairer and the equipment used to measure the quantity of water more exact".

Vander Meer (1977: 233) cites an instance from Taiwan where prior to modernisation:

"The customary water rights of irrigable fields within the Nan-hung system concerned the amount of water which could be applied and the seasons during which they could receive water. All irrigable land is divided into three classes: Class A land had primary rights, assuring it of sufficient water to produce rice during the first and the second rice crop seasons. Class B land could take only that water not needed by Class A land. ...Class C land received water from the irrigation system only during the second crop season ... This aspect of water rights seems to have been based upon the dates on which the fields first received water from the canal and the amount of water which flows in the canal during the cropping season" But some lands "located near and taking water from the middle portion of the canals received primary rights" by virtue of the location even though they could not have been irrigated by the river water at the time the first canal was constructed.

Similar instances have been reported from in India
See for instance Jayaraman, (1981), and GOI, COPP (1961).

32/ For discriptions of such devices see (Leach 1961, Kelly 1980, and Beardsley et.al 1959).

Ingenious as these devices may be, they are not always based on any careful calculation. By modern standards they are often crude Many of them were set up long ago, and few people now can even recall the basis on which they were designed. And yet they are considered to be extremely important by users:

On the Pul Eliya system Leach (1961) 121-2 remarks:

"It must be understood that from the Vel Vidane's point of view the ratios are established by tradition; ...in 1954, several of the Karahankota were missing but these that existed were consistent with the possibility that some recent velvidance had worked to the above numerical formula or at least copied older Karahankota which were constituted on this principle...

"...Although the present generation of Pul Eliya Villagers are not at all clear about the inner logic at all, they are keenly aware that the numerical formulae handed down from ancient times are very important. The general view seems to be that we don't understand why things are arranged linked this; but this is how they are and we had better leave them as they are".

"The recent great extension of 'ane land' cultivation... has reduced the crucial importance of the old field holdings... Nevertheless it is quite clear that working or tapping a neighbour's water channel is still by far the most common cause of village quarrel and inter-compound litigation". // In the 12 Go canal, "Enroute between the two gates, sections of concrete or rock retaining walls alternate with heavy piles or stakes interwoven with bamboo strips to support the banks. Some diversion ditches that water the field in the vicinity are no more than holes in the bank. At other places there are crude diversion devices made of submerged rocks and pine trunks laid across the canal, of calculated thickness and depth beneath the surface to control the amount of water delivered. These simple arrangements are readily displaced by accident or high water and their reinstallation becomes a matter of sometimes acrimonious arbitration, it is difficult to replace them with more precesily measured modern devices... because of jealous fear that one side or other will come out on the short end" (Beardsley et.al 1959: 148-9).

33/ See Vander Meer (1968) and Parternak (1972) for a description of two such systems in Taiwan.

34/ Similar procedures are reported in the traditional systems of South Bihar (Sen gupta 1980) and of Maharashtra (Kulkarni & Lele 1980).

35/ See Geertz 1967 for a detailed description.

36/ For instance, Nan Hung project area of Taiwan, prior to modernisation when all parts of the command could not get puddling and transplanting water at the same time, planting used to be spread over as many as 8 weeks and transplanting over 4 weeks. Harvest however took place at about the same time (June) everywhere. (Vander Meer 1968). This implies that part of the adjustment had to be made by choosing different varieties and/or accepting sizeable yield variation between the head reaches and the tail end of the system.

37/ The following are some examples:

Myers discussing the system in North China says: "The Lao-ren (the managers) were middle aged and elderly peasants who were very experienced in water management. "The Xi ao-jin (the subordinates responsible for a group of 20 households) 'were selected on the basis of demonstrated leadership and skill in supervising other families, mediating disputes and loyalty" (Myers, 1975:200).

In the Philippine irrigation communities studied by Bacedayan, water distributors are uniformly selected by the people on the basis of dependability, diligence and fairness, (Bacedayan, 1974:176) Pasternak (1972:28) reports that in the Taiwanese system he studied "to every pumping station the irrigation association assigns a watchman usually on the basis of recommendations provided by pump group owners."

38/ See Nickum 1982: Reading 5 for a description of the complexity and sophistication of flexible scheduling in a multi-storage system. Many of the systems in south west Japan (especially around Osaka-Kyoto and in Kyushu) are also multi-source systems. We could not get any detailed description of these systems in English. But the author has visited some of them.

39/ In this connection mention may be made of an interesting custom in south Indian tanks (Chambers 1977) where the responsibility for operating the sluice and distribution of water from village tanks is entrusted invariably to a member of the "untouchable" caste: since he has no land and a very low social status, he can never use his office to act arbitrarily. A similar custom said to have existed in parts of Japan as well.

40/ Kelly (1980:365-67) discussing the reasons why despite its losseness, the Aka river system organisation did not break down suggests that the following countervailing factors tended to limit conflict among water users and 'prevent disputes from deteriorating into serious destruction':(1) The irrigation relations were such that 'shifting lines of shared and conflicting interests created complex situational patterns of cooperation and conflict'; (2) conflicts was probably mitigated by the disjunction of land tenure and irrigation;, i.e. the distribution of cultivators and land owners over the water channel line. (3) 'Promotion of paddy land expansion through special concessions in surveying and registration resulted in wide disparities in tax burden; the undersurveyed, undertaxed lands in the tail end did not press their complaints of water shortage too forcefully"; (4) "there was a fit between irrigation conflicts and administrative units." Conflicts increased when the dissonance between land holding, cultivation and residence increased.

41/ For some idea of changes in particular ovillage see Mizushima and Nara (nd) and Guhan and Mencher (1982).

42/ For a more detailed description of organisational structure and regulations in one state, see Government of Andhra Pradesh (1982:78-87).

43/ The following description is largely based on Kathpalia, 1980.

44/ This is generally known as "localisation" and intended to ensure "equitable" distribution of the benefits of water intensive crops (subject to soil and topography) within the command, especially between upper reaches and tail enders. For a discussion of the system and its working see for example GOI, PEO (1965); Govt. of Andhra Pradesh (1982:53-65); and Govt. of Maharashtra (1962).

45/ Numerous examples can be cited. Thus in the Kosi project (Bihar) as against an estimated discharge of 15,000 cusecs during the Kharif season, the actual discharge over an eight year period averaged 8,000 cusecs and the maximum was 10,700 cusecs. (Pant, 1981:A81).

On the other hand in the Lower Bhavani project, the total amount of water utilised was far higher than assumed in the project design. (GOI, PEO, 1965). This report also gives information on 8 other major irrigation projects which brings out the large differences between design assumptions and actuals in several important respects.

A recent study of irrigation management in Andhra Pradesh (Govt. of Andhra Pradesh, 1982: 16-7) has the following observation on planning of systems:

"...The initial planning did not take into account the area occupied by field bund, field channel, field drains etc. and the area planned for irrigation wasz not based on any scientific or rational analysis of parameters like water requirements of crops, the system efficiency for conveyance and operation and application of water to crops etc..."

As regards the assumption about water "duties" underlying project design, "None of the engineers examined by the Commission were able to give the actual basis for the duties adopted... There is no evidence of taking into account the difference in climate, topography, soils, etc. from one project to another located in different agricultural zone of the state or the variation in the length of the distributary system..." Seepage losses were infact found to be far in excess of design assumptions (often by a factor of 3 or 4).

"... There is no correspondence between the design cropping pattern and dates of sowing as assumed at the stage of planning and the actual cropping pattern adopted by the farmers with varying dates of sowing. The projects therefore deliver water at the offtakes and outlets with little relevance to the actual water requirement of crops sown and their stage of growth at any given point of time..."

46/ The divergence between planned and actual crop pattern, and between planned "localisations" and actual distribution of water intensive crops within the command, is a widespread phenomenon. For example see GOI, PEO (1965); Wade (1978); Hasham Ali (1980); Govt. of Andhra Pradesh, 1982.

47/ The difficulty in enforcing crop patterns and localisation envisaged in the project is illustrated by the following account of the Lower Bhavani project in Tamilnadu: The design envisaged 5% of area to be under paddy; 47% under cotton and the balance under 'other irrigated dry crops'. But the farmers did not favour this pattern and 'the first five years of the working of the project . showed that the planned cropping pattern was a failure'. Due to greater profitability of paddy and technical problems (due to soil conditions among other things) of raising irrigated cotton, more than half the area was brought under paddy. And "when the divergency between the preference of the cultivators and the plan was so wide, it is obvious that there should be unauthorised allocation in spite of penal provisions. When penalties were demanded of the ryots, the ryots protested; and the government found it necessary to intervene and stop the levy of penalties. The revenue department, responsible for maintaining 'all dry' character of the project could not do anything" (GOI, PEO, 1965:207).

Again, the government had laid down regulations regarding the use of seepage from the canals for irrigation directly or through tanks and pumps. "Government had banned the construction of wells within a distance of two furlongs from the main canal and one furlong from the distributaries. It is however observed that well even outside this limit were benefitted by percolation. In spite the fact that construction of new wells was not allowed, in actual practice wells and tanks were dug and pumpsets installed. In fact there was a great demand for installing pumpsets in the area, and pressure was being exercised... to remove the ban on the construction of new wells and tanks. It is understood that the ban has now been removed." (Ibid.: 212).

Wade (1978, 1980) reports one instance from Andhra Pradesh where rotational irrigation between different parts of the Command was successfully introduced at the initiative of the system manager in a drought year enabling much wider distribution of supplies and apparently without any significant reduction in yield. In another the cultivation of paddy in unauthorised blocks was checked. These cases are interesting for two reasons: it shows that the experiment worked despite strong protests and resistence of upper reaches, because the system managers not only showed extra-ordinary initiative but also because they were willing and able to muster the powers of the State to overcome the resistance. This seems difficult to achieve in all systems and sustained on a continuing basis. On the tail ender question see also Hart (1978) and Pant (1981).

48/ Though the dominance of upper reaches, by virtue of their location, cannot be altered by the tail-enders, it is intriguing that they do not oseem to use political channels to exert pressure on government for improving the distribution. (At any rate no instance of this has been reported). This does not however mean that the tail-enders are totally passive: There are reported instances where users who do not get enough water combine and try to persuade the canal officials, at considerable expense, to deliver them more water; or to distribute the available supplies among themselves in a fair manner. Where they get no water at all, their option is often only to agitate for withdrawal of water cess and betterment levy demanded of them. (Wade 1980 and Hashim Ali 1980).

49/ In this context the distinction between unequal distribution between fields at different locations and between different users is important. In a gravity irrigation system it is the physical location of the field which has an important bearing on the ease of access to available supply. It seems unlikely that in systems covering several thousand hectares large farmers throughout, or even in a major part of the command, will be concentrated in more favourable locations along the canal network. The probability of this happening in the normal course is very low. It seems difficult to manoevre the design of the system even at the distributary level to favour large owners systematically. It is of course possible that after the system has been constructed large farmers shuffle their holdings through purchase and sale with the explicit purpose of securing favourable locations:

This however needs to be established.

The importance of the size of landholding however is likely to be more, and may even be decisive in deciding how water is shared among farmers served by a particular outlet. This is probably what Thorner had in mind. It is noteworthy that unlike in canals where field location is more important, in the case of wells, the size of holding has a much more direct bearing on access to ground water.

50/ See for instance the papers presented at the All India Workshop on Warabandhi held at Administrative Staff College, Hyderabad in 1980. Also Singh (ed) 1982.

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