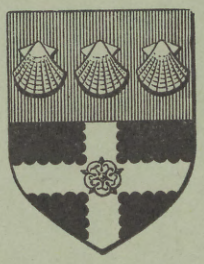
Irrigation



UNIVERSITY OF READING

DEPARTMENT OF AGRICULTURAL ECONOMICS

CONTRASTING POLICIES IN IRRIGATION DEVELOPMENT

Sudan and India

By

D. S. THORNTON

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FOREWORD

This Department is one of a number in the Faculty of Agriculture which have for many years, both through the frequent entertaining of students from overseas and by way of continuing contact with old students in overseas posts, maintained a close interest in problems of development in low-income countries. More recently, members have been acquiring first-hand experience during periods of secondment abroad. This year, a further step in the same direction has been taken in the Department of Agricultural Economics, thus matching similar moves elsewhere in the University, by setting up posts, the holders of which are specially charged with teaching and research in the field of Development.

It is planned that the teaching effort will make possible the strengthening in this respect of undergraduate and post-graduate courses already in existence as well as the institution of new course options with the specific need in mind of those students who wish to specialise in this field.

It is intended also, that a parallel research programme should be built up designed specifically to contribute to the solution of current problems in developing countries. The skills and experience of many other members of the Faculty will be of great value in this programme.

Success in expanding useful research studies will depend on a number of factors, among which may be included the active co-operation that can be achieved with those in overseas countries in which the problems lie, and the financial assistance that may be forthcoming. The study which follows has happily benefited from very favourable conditions in both these respects. Its author Dr.Thornton has recently returned to the Department after a period of secondment in the Sudan during which he was head of the Department of Rural Economy in the University of Khartoum. I feel very glad that we have been able to open with so appropriate a work this new series of departmental publications in the general field of Development.

R. H. Tuck.
Professor.

PREFACE

The author's secondment to the University of Khartoum 1962/66 afforded the opportunity for close inspection of all the main areas of irrigated agriculture in Sudan. This was greatly assisted by research funds from the Ford Foundation and from the Sudan Ministry of Agriculture. In May-July 1965 he was fortunate to be awarded a Travelling Scholarship by the Rockefeller Foundation to visit India and Pakistan to study irrigated agriculture there. He is deeply indebted to all those who have so readily provided information and stimulating discussion.

NOTE ON NOMENCLATURE

Local usage has been followed. The following relationships may be useful to readers.

	1 feddan	=	1·038 acres
Officially	£1 Sudanese	=	£1-0-6 sterling = 13·7 rupees during the period when the estimates quoted herein were made.
1 million	cubic metres	=	810·71 acre feet
	1 cumec	=	35·31 cusecs

Also:

1 milliard	=	1,000 million
1 crore	=	10 million
1 lakh	=	100,000
Kharif	=	late summer rainy season
Rabi	=	winter dry season.

CONTRASTING POLICIES IN IRRIGATION DEVELOPMENT

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INTRODUCTION

Throughout the arid tropics, irrigation for agriculture has become a major feature of economic development and is likely to remain so for many years. Within this general region, at both national and local levels, the approach to development has varied widely. To some extent this variation has been determined by the nature of the physical environment - the terrain, climate, and location and regime of the natural water carriers. In addition however, human societies have sought different objectives and used different means in trying to achieve them.

These objectives are of two kinds: on the one hand, raising incomes and material living standards; on the other, improving (or in some cases preserving) certain social and cultural characteristics of the lives of the people concerned. In practice of course, these two kinds of objectives are interdependent. Nevertheless, different societies are to some extent free to pursue that combination of material and social objectives which they or their leaders prefer. It is necessary that economists take into account these preferences when describing and assessing the success of the irrigation development which now exists. Due weight should also be given to them when examining alternative courses of further development.

The purpose of this essay is to review irrigation policies in the contrasting cases of India[1] and Sudan, countries which lie within the broad region of the arid tropics; to examine some of the characteristics of policy diversity that are to be seen in their recent history and to consider the nature of the problems they face in further development.

Sudan and that part of India with which we are chiefly concerned have broadly similar climate. The progression from complete aridity to a rainfall of some 80" concentrated in a late summer season which is experienced from the northern to southern boundaries of Sudan is broadly paralleled in India by a similar progression from the West Pakistan border eastward and south-eastward, the marked relief features of the Himalayas and the Deccan influencing the rate and local details of the progression.

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1. The more arid parts of Northwest India falling within the States of Punjab, Rajasthan, Gujarat and, to a lesser extent, Uttar Pradesh, Madhya Pradesh and Maharashtra are of particular interest in this comparison. Some of the relevant basic facts about the two countries are given in Appendix 1.

Marked contrasts occur in respect of other aspects of their physical environment, however. Sources of groundwater are very restricted in Sudan whereas in India they are plentiful; India now controls the headwaters of her major rivers whereas Sudan does not; among the irrigable soils of Sudan heavy clays predominate, whereas in Northwest India soil types vary widely from heavy clays to light porous sands.

But it is also partly as the result of differing material and social objectives that irrigation development has taken radically different courses in the two countries. The history of Indian irrigation is chiefly the development of local and, latterly, more distant sources of supply as a supplement to rain for an already settled society, the land being already owned in estates ranging widely in size and cultivated in small farms; the water has chiefly been used to increase food production for a dense and growing population. In Sudan the advent of modern irrigation has coincided for the most part with the settling of hitherto semi-nomadic people; although occasional local food shortages are by no means unknown the pressure to produce food for survival has been far less severe.

Also, the influence, in India, of Social Democratic ideals has coloured many aspects of agrarian reform and development in recent years and has influenced many decisions about irrigation. While similar ideals are not absent in Sudan, they appear to have had little influence so far on what is a predominantly commercial attitude to agricultural development inherited from the pre-independence era.

Obviously, therefore, there is no simple criterion by which irrigation development can be assessed in such dissimilar circumstances as Sudan and India. It would not be feasible, in any case, once having embarked on one pattern of development, to change it radically or quickly, even if such changes could easily be justified. It may be possible, however, by close comparison, to show more clearly the reasons why, for example, certain difficulties arise in one case and not in another and, here and there, to indicate practices currently being followed by one country which might be usefully studied and possibly adopted in the other without altering essential material and social objectives.

This essay is divided into three parts: first a description of the types of role played by the two Governments in irrigation development; second, a review of some of the underlying considerations influencing policy and related to further development; and third, brief comment on some directions in which further economic research can usefully be done with the objective of eventually increasing the effectiveness of irrigation in these and broadly similar countries.

I. TYPES OF PARTICIPATION BY GOVERNMENT IN IRRIGATION DEVELOPMENT

The types of Government activity which are particularly relevant to irrigation development may be broadly classified as follows:-

1. Regulating by licence and other laws the method by which, and the extent to which, private developers may utilise surface and underground waters;
2. Assisting private developers by means of loans and grants;
3. Directly investing in irrigation development by providing water for purchase by private users (linked, perhaps with the provision of benefits to others in the forms of Hydro-Electric Power (H.E.P.), flood control, fishing and navigation);
4. Comprehensive developing of irrigated agriculture, whereby the Government not only takes responsibility for the provision of irrigation supplies but also determines their use by controlling cropping patterns, the size of production units, the nature of tenurial rights etc.. In effect the Government becomes a partner and entrepreneur in the business of productive irrigated agriculture.

Types of Government participation are by no means as clear-cut as this classification might suggest. For instance, policies of more than one type may be followed which impinge on farmers at the same time. Policies of, say, type 3 may be preceded by land reforms and followed by an extension policy, which together make a Government's total role far more than that of merely providing a public utility.

Nevertheless, these categories may serve as a basis of discussion of the countries selected, partly because they provide a convenient method of subdivision and partly because there is often in practice a degree of independence between the policies pursued under these heads. In order to facilitate comparison between Sudan and India, the extent to which each type of policy is employed will be examined in turn, dealing first with the control and then the assistance of private developers, before passing on to direct Government participation in irrigation.

A. CONTROL OF PRIVATE USERS THROUGH LICENCES AND OTHER LAWS

It is a primary function of Government to regulate relationships between community members, not least with respect to scarce resources. The purposes are generally two-fold, namely to prevent resource wastage and to prevent monopolisation by one or a few individuals. Controls of this kind are necessary where water supplies are scarce yet capable of development by small entrepreneurs. These conditions obtain in Sudan chiefly along the banks of the Blue, White and Main Niles, where it has been necessary to contain private users within the national water budget determined by a series

of international Agreements. In India a parallel situation arises. One main concern there is the rational development of minor works using chiefly well water and stored rain water, and their effective integrating with supplies derived from rivers and, in the case of well water, their integrating one with another in the light of limited supplies of ground water.

In Sudan a major irrigation development in the last twenty years has been in pump schemes which have largely replaced and extended the Sagias (Persian Wheels) and Shadufs (manually operated bucket-lifts) which before this century provided the only forms of irrigation in the country. These pump schemes now water more than one third of the gross irrigated area of nearly 4 million acres. With the exception of a few large pump schemes set up by the Government for the alleviation of local food and fodder shortage, these schemes are in private hands, either individually owned or organised as companies or co-operatives. The licensing procedure amounts to a deep intervention by government in pump scheme development. Not only is the season of pumping controlled by this means; prior approval must also be obtained of the pumpsite, the layout and the acreage of each Scheme.

Along the Blue and White Niles, where the primary objective of the entrepreneurs has been to grow long-staple cotton, the Ministry of Agriculture dictates through the licence the rotation to be followed in the interests of fertility maintenance and cotton disease control, and lays down the form of the agreement between pump owners and cultivators. As a supplement to the licensing procedure, compulsory auditing of accounts is designed to ensure smooth working of the crop-sharing which underlies this relationship. The Ministry Inspector may even insist on the removal of an inefficient manager in some cases.

On the Main Nile between Khartoum and the Egyptian frontier the pattern of farming is less uniform. Nevertheless control of water use is again imposed and rotational principles are prescribed though in practice not rigidly enforced.

Both here and in the cotton growing areas further south, effectiveness of control depends on the efficiency of Ministry officials; pump scheme licences are not a major source of government revenue and their cost can have little influence on the decision to develop. Overall control is vested in the Nile Pumps Control Board, the administration of licensing however being done by Inspectors of the Ministry of Agriculture among their many other duties.

While licensing has provided fairly effective control of water uptake, less attention has been paid to the optimisation of the water-land combination. The amount of suitable land is strictly limited; surveys have been started to assess further development possibilities of irrigable land and pump sites. Rationalisation of scheme layouts as a whole may prove

necessary if waste of valuable irrigable land is to be avoided.

In India, minor works make a large contribution to the irrigated acreage.[1] In Northwest India these are particularly wells, lined or unlined and mostly dug to a shallow depth; a high proportion are privately owned. In a random survey carried out by the Programme Evaluation Organisation[2] frequent complaint was recorded of inadequate water supplies limiting production. At least one reason for this water shortage and for sub-optimal use of existing facilities appears to be the absence of control of siting, thus leading both to bad choices in location and to interference between installations. At the same time, and linked with the uncertainties of supplies, there are reports in some areas of lack of maintenance of existing installations and a high rate of dereliction.

These problems are probably inevitable where, with increasing overcrowding and with excessive working time available, farmers become convinced that another well is the only way to solve their own food problems. But such activity adds little or nothing to the social product; more wells mean less reliable supplies and higher lifts in wells already existing. The only complete solution is probably a reduction of population, but it is to be expected that as government financial assistance is increasingly sought for financing minor works, and as extension programmes become more effective, a measure of control, both of well-siting and of cropping patterns, will be introduced resulting in the more orderly exploitation of groundwater.[3]

B. ASSISTANCE BY GRANTS AND LOANS TO PRIVATE DEVELOPERS

It is part of the declared policy of both India and Sudan to assist, where practicable and economic, the growth of private enterprise. The two countries are also similar in that though it is the declared policy to assist small investors, this has so far proved extremely difficult.

In Sudan, financial assistance from Government is virtually confined to the pump scheme owners; little assistance is available either for Sagias and Shadufs or directly to cultivators within the pump schemes. Besides funds from the commercial banks, since 1958 the Agricultural Bank of Sudan has provided a variety of loan services.

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1. See Appendix 1.
2. Programme Evaluation Organisation (1) p.65.
3. The serious need for rationalisation of groundwater use was stressed by Rao when outlining the future emphasis to be placed, in the Fourth Five Year Plan, on the energising of pumps in the rural electrification programme (2) p.8.

In the Blue and White Nile cotton schemes there have been loans for pump and canal installations as well as to cover production expenses, marketing costs and advances to cultivators. As a result of a decline in cotton prices and an increase in production difficulties which have resulted in falling yields, heavy liability has been incurred by the Bank on more than one third of the 700 schemes.

In the Northern Province there has been some lending for Scheme installation but more as fertiliser loans (the fertiliser being directly distributed by the Bank to scheme owners who in turn distribute to the cultivators and act as the Bank's agents in collecting repayment). In this Province the Agricultural Bank has specifically encouraged co-operative schemes with reduced rates of interest.[1]

Wherever the Bank's services are sought it is now trying to ensure sensible use of funds and timely repayment by insisting on good initial planning, regular supervision and, where possible, loans in kind.[2]

In India the Government has, in all its Five Year Plans, set aside large sums to assist private developers of minor works such as wells, tanks, tube-wells and lift schemes. The advantages claimed for this policy, as compared with investment in major irrigation, are (i) their lower initial investment cost per unit of water provided (ii) quicker results because of quicker uptake by users (iii) a wide spread of benefits (iv) opportunity for the exercise of local initiative.[3] Assistance is mainly through loans rather than grants.

A common basis for support of wells, pumpsets and tubewells is 25% subsidy, 75% loan repayable with 6-7% interest, over 10 years. The functions of subsidies here are to encourage developmental efforts in new directions and to encourage new investment by reducing net cost and risk.

Loans are being increasingly channelled through co-operatives the further growth of which it is national policy to foster. In Rajasthan, for instance, the State Government is making loans to co-operatives direct, especially for wells.[4] The State Government lends at $3\frac{1}{2}\%$ interest and the co-operative lends to the ultimate borrower at $7\frac{1}{2}\%$, 2% going to the co-operative society, 1% to the Central Co-operative Bank and 1% to a fund at the Central Co-operative Bank level.

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1. Loans to Co-operatives for more than 5 years are made at 6% rather than 8% interest.
2. On the cotton schemes administrative and advisory charges are deducted from the licensee's cotton income on a scale which varies with the level of cotton yield. A further 1% is deducted if the Bank markets the cotton on behalf of the Scheme.
3. Planning Commission, India (3) p.307.
4. Registrar of Co-operatives Rajasthan (4).

The emphasis given to minor works development varies widely between the States but it appears to be generally true that the past policy of encouraging individuals is being increasingly supplemented by organised schemes of minor works development. Both methods, however, are encountering difficulties arising in particular from the shortage of trained personnel in administration and extension, and from the complexity of the administrative set-up.[1]

Moreover, while it is the intention to encourage local initiative and co-ordination through co-operatives and village councils (panchayats), dearth, not only of technical knowledge but also of experienced leadership, have made progress slow. As in Sudan, the problem is primarily one of education of small entrepreneurs in the use of funds for capital investment; the old-established attitudes to wealth and the habits of mind associated with local lending and borrowing have not yet been replaced by a less personal and more strictly commercial attitude. Under present circumstances direct assistance to small entrepreneurs in the form of loans and grants too often results in heavy losses of funds which are unwisely invested or diverted to non-productive uses, together with excessively high expenses in administration. To rely on local voluntary organisations of farmers to reduce these expenses may raise other problems. There is much evidence to suggest for instance, that it is a relatively small number of members within a co-operative who benefit from the loan facilities made available by its creation and that these are the larger and more wealthy farmers.

It has now become the custom, in many Indian States, to lay down norms against which claims for assistance will be assessed. These may be in terms of the increases in acreage, cropping intensity or crop yields that can be expected to result from the investment. Alternatively certain limits to the level of investment approved may be set in rupees per acre.[2] Cropping plans are taken into account in the assessment, but with the exception of crops like sugar cane which have unusual water requirements, the seasonal pattern of water provision in practice leaves the Indian cultivator with considerable freedom of cropping.

C. DIRECT ACTION IN DEVELOPING IRRIGATION

Both countries' governments are heavily committed to a programme of direct investment in medium and large scale irrigation. These include

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1. Programme Evaluation Organisation (1) p.119
2. For instance, in the Co-operative Lift Scheme in Maharashtra, loans were restricted to Rs.300 per acre for schemes up to 500 acres and Rs.250 per acre for larger schemes at the time of the P.E.O. study. Programme Evaluation Organisation (1) p.92.

Government pump schemes in Sudan, tube wells in India and canal irrigation in both countries.[1]

Only those organisations in which the users purchase their water direct from the Government are dealt with here; those areas of Sudan where the Government is a partner in production are considered later. Special attention is given to the structure of organisation in each case.

(a) Government Pump Schemes in Sudan

Nine Government Pump schemes (covering 34,000 acres) have been set up at various times since 1917 to ensure food and fodder supplies to over-populated areas of the Northern Province.[2] The cultivators are a mixture of owner-occupiers and tenants whose holdings vary in size up to about 20 feddans within and between schemes. They are allowed a measure of freedom of cropping within broad rotations which determine the season when the land will be cropped. Water is charged by the Government at a rate per crop which closely reflects the amount of water normally required.[3]

The Government provides water channels to all holdings while the cultivators are responsible for making and maintaining field channels. The frequency of watering, variable as between summer and winter and between crops is controlled by managers provided by the Ministry of Agriculture. In the collection of water rates, the managers are assisted by Sheikhs and local leaders. Complaints by cultivators of water shortage are attributable to occasional technical difficulties in pumpsites and canals. (Only in one scheme do heavy rains and river flooding sometimes complicate a system which is wholly dependent on river water.) On the whole the system works well and is highly regarded by cultivators on the private pumpschemes in the neighbourhood.

(b) Tube Wells in India

A programme for the development of State tube wells was begun in India during the 1940's, when hydro-electric power became available. It was

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1. India is also committed, particularly in Punjab, to large-scale reclamation of land already irrigated, which is the direct outcome of errors in past irrigation methods.
2. Four others (covering 14,000 acres) have been set up on the White Nile in order to accommodate those people disturbed by the construction in 1937 of the Jebel Aulya Dam to assist Nile water control in Egypt, but their type of organisation falls more properly in Category D.
3. In some of the schemes the level of this rate is now barely sufficient to cover operating expenses and the income from the Government schemes taken as a whole is insufficient to cover depreciation and modernisation costs.

concentrated particularly in the States of Uttar Pradesh and Punjab and also to a lesser extent in Bihar and Bombay (Maharashtra - Gujarat). In terms of the culturable commanded area (C.C.A.)[1] it had, by 1961, reached a coverage of some four million acres though the intensity of irrigation, taking Kharif and Rabi seasons together appears to be only 35-40%. The rate of development reached a peak in the mid 1950's, the objective being in part to tap aquafers for supplementary irrigation (for instance in Bihar) but also in part to assist in the reduction of waterlogging (especially in Punjab).

The method adopted has been to spread tube well water widely through lined channels. Beyond a specified distance from the well, which varies from State to State and with soil conditions,[2] the cultivators continue leading the water in unlined channels. Until 1958 it was the practice to construct wells and lined channels without regard to the placing and timing of the cultivators' channels. In 1958 however, steps were taken in the Punjab to revise the Northern India Canal and Drainage Act, and in that State the irrigation authorities now plan and supervise the erection of the cultivators' channels, carrying out the work and charging the beneficiaries in cases of default. In this way a considerable saving in time and water is being effected. Hitherto some five to seven years had elapsed before the potentiality of wells was fully utilised.

Water is charged to users by volume in Uttar Pradesh and by the quantity of electricity required in Punjab (the cultivators thus carrying the increasing costs of a falling water table). A rotational system of distribution to farmers is followed which theoretically ensures equitable sharing though, in practice, this is not always easy to achieve. In Uttar Pradesh the 'Osarabandi System' of distribution is commonly used where the irrigated area is divided into 8-12 convenient blocks or 'thoks' each in charge of a thokdar who is responsible for distribution of water between users.

(c) Large and Medium Gravity-fed Irrigation in India.

By far the greater direct participation by Government in irrigation in India, organised mainly at the State level, is in the provision of canal irrigation.

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1. Measures used in the calculation of water application in India are commonly in terms of
   (a) intensity of irrigation - the area irrigated as a percentage of total culturable commandable area (C.C.A.)
   (b) capacity factor - the ratio of actual flow in canals to the maximum design capacity
   (c) water allowance - volume available for irrigating per unit of commandable area (in cusecs per 1000 acres C.C.A.).
2. For instance, in Punjab, one mile in light soils, half a mile in heavy soils.

The growth of this policy has a long history. Irrigation, not only by wells, tanks and artificial lakes but also by diversion into canals, was already taking place on a large scale in the 1830's and 40's. Private ventures were later followed by large-scale State enterprises in the Punjab and the Ganges basin. The first dam was built at Khadakwasla (Maharashtra) as early as 1869-79 but canals were mainly filled by diversion from rivers. By Independence in 1947 some 21 million acres were already being irrigated in large and medium schemes.

A pattern of policy had been firmly established, with three main characteristics:-

1. Use of barrages as the dominant method of water control.
2. The practice of distributing water widely and thinly.
3. Sale of water to independent users.

Since 1947 these main characteristics have persisted with the difference that the techniques of water control have become more sophisticated and storage dams have become a common feature. Moreover irrigation has ceased to be the only motive for water control, being linked in multi-purpose works with H.E.P. generation, flood control and navigation.

The need for investment has received recognition in each of the Government Five Year Plans[1] to such an extent that over the fifteen year period 1950-65 it was planned almost to double the existing gravity fed area which had taken the previous 120 years to create.

(1) Increasing importance of multi-purpose projects

Indian rivers are characterised by marked seasonality of flow. The development of barrages which began in the Nineteenth Century took control a stage further than mere diversion into inundation canals. Nevertheless there was still uncertainty in the period of flow and in the number of waterings that could be applied to a given acreage. Moreover abundant flow was often coincident with heavy local rains; consequently periods of drought tended to alternate with periods of surplus, the latter made worse by the absence of adequate storm drains. Although this situation still exists over much of Indian irrigation today, the additional control made possible by the building of more dams has been a step forward. The rapidly rising demand for electricity,

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1. Outlay in the Public Sector on new irrigation (including carry-over of unfinished Schemes) increased from Rs.300 Cr. in the First Plan to 370 and 600 respectively in the Second and Third. It is estimated that a further Rs.414 Cr. will be required in the 4th Plan.(Planning Commission India (3) p.384). Rs.600 Cr. represents 7·4% of the total planned outlay during 1961-65 a substantial drop from the first plan (16%) when many major schemes were started.

which appears to have been consistently underestimated in the planning process, has also to some extent been satisfied at the same time.

Water control has therefore increased in scale, complexity and cost and resulted in complications in planning and administration. Of the 41 schemes listed as under active preparation during the period 1960-65 no less than eleven were multi-purpose schemes based on dam construction, eight eventually to irrigate more than one million acres each. Of outstanding importance in Northwest India is the Bhakra-Nangal project,[1] consisting of two dams on the Sutlej river. The plans have undergone a sequence of revisions since the original in 1919 (in 1942, 1948 and 1953) as the potentialities of the sites, the markets for irrigation water and H.E.P., and techniques of construction have developed. By 1965 the C.C.A. was calculated at 3·6 million acres and installed H.E.P. capacity 371,000 KWs.

(2) Widespread distribution of water

A method of water distribution was adopted from the earliest times which always left the area commanded substantially larger than the area for which, even in plentiful seasons, there were sufficient irrigation supplies. A primary objective was to provide the water required to assure adequate food supplies to the largest possible number of cultivators. While such a policy made allowance for the lack of interest of some cultivators in using irrigation water on all or some of their land and assured as many as possible of minimum water for food, it could be criticised as a system requiring relatively heavy capital investment, subject to large losses from seepage and evaporation, and restricting the cultivators receiving it to a low level of farming intensity.[2] Insofar as intensification would imply fewer farmers using more water, the system adopted also meant higher administration costs in the allocation of water and the collection of dues.

While the principles followed in water distribution have remained unchanged since Independence they have frequently been criticised in recent years. The Bhakra-Nangal Project, for instance, which was designed to provide water to areas differing substantially in rainfall and water-table level, makes its biggest contribution in the South Punjab districts of Hissar and Rohtak and in Rajasthan, where rains are poor and uncertain. For these areas 'perennial' (i.e. two seasons) irrigation is provided but the intensity of irrigation is only 62%, 31% in Kharif, 31% in Rabi. The water allowance is only 2·4 cusecs per 1000 acres[3] (with 10·6 cusecs allocated to gardens). While

1. For details of development projects specifically mentioned, see Appendix 2.
2. This is not to deny that intensity could be greatly increased by adding other inputs.
3. Statistic provided by Executive Engineer Hissar District, at variance with planned 2·75 cusecs. At 278 full supply days this gives 18" irrigation water. Owing to heavy distribution losses this may be sufficient for wheat and oilseeds but insufficient for cotton and other more demanding crops. (I.C.A.R. (5) pp.16-17). At a great distance from the Main Line, losses may make this amount inadequate even for wheat unless applications can be made at the most effective points in the plant's life.

this irrigation has allowed increase of population, partly of immigrants from water logged areas further north, the increase in success of those villages taking irrigation water compared with those who had not was rather modest over the first ten years of operation.[1] The main change in cropping pattern has been from the traditional emphasis on rainfed bajra to rabi wheat and gram; the amount of cash crops introduced was very small. Improvement in the reliability of crops caused some addition to the value of output.

The main criticisms made by K.N.Raj[2] of the irrigation aspects of this multi-purpose project include first the heavy losses in water which the system entails - he estimates that only some 44% of the flow at point of diversion will be taken up by plants; and second the laying-down in advance of water provision without thorough examination of existing crop requirements or alternative and more economic combinations, bearing in mind likely future cultural changes, such as increases in fertilisers.

A third criticism might be that the water regime devised is similar to that which has reduced other porous Punjab soils to an unproductive water-logged and saline condition in the past hundred years.

The present distribution of water and the results achieved are to some extent the inevitable outcome of the sequence of events occurring in the setting up of most projects, in which first the irrigation authorities discover and recommend a site for water control; second, the irrigable area commanded is calculated (which may be subject to political considerations especially when more than one State is involved); third, difficult conflicts of interest as between irrigation, H.E.P. and flood control are resolved; fourth, water distribution is conditioned by what irrigation engineers can provide in any one season; and fifth, estimates are then based on what use cultivators are expected to make of the water available, generally on the basis of current practices in neighbouring irrigated areas.

An attempt is now made to reduce errors and improve co-ordination by the Central Water and Power Commission which acts as adjudicator on all development plans. Further improvements in allocation, assuming Indian policy continues to be of the kind where water is provided as a utility, await advances in knowledge and calculating skill, a topic which will be discussed in Part III of this essay.

(3) Supplier-user Relationships

The bulk of irrigation water in India is sold by the States to autonomous cultivators. A distinct break therefore occurs in the chain of responsibility for water use, generally at the end of canals of one cusec

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1. Punjab Board of Economic Inquiry (6)Ch.III.
2. Raj. K.N. (7) p.92

capacity. The results too often seem to have been slowness on the part of users to take up irrigation water and often rather small improvements in users' incomes. Only in a few areas has the arrival of irrigation water resulted in a major break-through to highly productive and profitable agriculture. In certain environments, long-term deterioration in production conditions have occurred leading to dereliction and loss to everybody.

Consideration is here devoted to three aspects of the system

(a) local organisation of water distribution
(b) control of water use
(c) recoupment

(a) Local organisation of water distribution

The difficulties of laying out irrigation channels in an already settled area, which has applied to almost all Indian situations in the past,[1] are immense even when the community is wholly disposed to accept an imposed plan. The Indian practice, which to a large extent leaves this process to existing rural communities, suffers even greater difficulties.

The technical problems include the survey of levels, the assessment of soil potentialities, and the design and location of outlets from the main canal system. While it is sometimes claimed that "the local farmer is the best surveyor" it seems unlikely that even he is always very capable. It has often also been observed that distributaries are badly sited in relation to land suitable for receiving irrigation water.[2] Though the relocation of outlets is relatively inexpensive it seems an unnecessarily confusing factor that they should be sited in the first instance on a hit-and-miss basis.

There are additional social problems. Unless the area to be irrigated exactly corresponds to a well-organised community ready for joint action, leaders capable of enlisting support must be found; land requisition and compensation for canal construction must be agreed; works must be constructed and maintained; inequities of distribution must be avoided (which is less easy when the intensity of irrigation is low and the benefits obvious). It is,therefore, salutary that the Government is giving increased attention to stimulating the growth of local organisations for various types of community development and that the Public Works Department is increasingly intervening in the planning and execution of small-canal construction. For instance, under the Punjab and Uttar Pradesh Consolidation Acts, Government consolidation officers, surveying staff etc. co-operate with village Panchayats to classify land, consolidate holdings in relation to existing minor irrigation, plan, and set aside land for irrigation channels and roads, all of which are reorganised at the same time.[3]

1. It was not true of the Doab Settlements in the Punjab in the 1920's nor will it be true of much of the major extension of irrigated agriculture dependent on the Rajasthan Canal.
2. Ansari N. (8) p.33.
3. In the case of tubewells land may now be compulsorily purchased and canals imposed after consultation with village Panchayats.

Even so the radical nature of the change to irrigated agriculture, particularly when the water supplies are uncertain and not directly under the farmer's control, cannot be overestimated. Too often it appears that farmers have not been sufficiently instructed and psychologically adjusted to make the change. Non-rational habits of thought frequently persist during the transition from subsistence agriculture to commercial agriculture, such as retaining unirrigated land to produce food crops while limited irrigation is adopted to grow cash crops to pay taxes. Progress however, now seems to be growing in those selected Districts being subjected to intensive extension.[1]

(b) Control of Water Use

Typically, these irrigation systems are operated by the Executive Divisional Engineers of the Ministry of Irrigation who are each responsible for water control on a specified acreage. Each carries a water rotation register and his canal inspectors assisted by crop measurers (each covering some 500 acres) keep records of crops grown. The function of the Executive Engineer is to prepare weekly indents for the engineer 'upstream' who in turn passes indents towards the point of water release. Adjustments to requirements may be made according to weather conditions; periodic modifications to flows are made to compensate for short/falls in designed flows (especially to ensure adequate water to as many as possible at planting time), and to allow for canal maintenance; canals on the other hand, may be left open in the Monsoon in order to spread flooding risks. The possibility of both shortage and surplus therefore persists.

The farmer, who himself applies the water allocated him must take his turn in the local rota, the periodicity of which is affected by the seasonal flow. While the farmer always tends to overwater if he is given the chance,his eagerness is to some extent understandable in view of the element of uncertainty in most Indian systems.[2]

Irrigation clerks prepare demand statements which go to Revenue Officers for collection of water rates together with land taxes. A clearance certificate may be necessary showing freedom from debt before the farmer can apply for water the following year. Heavy penalties are imposed for contravention of canal regulations by the cultivator.

(c) Recoupment

Recoupment for water supplies is obtained in two forms (i) by

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1. Ministry of Food and Agriculture, India (9).
2. Experiments currently in hand in Pusa Research Station and Ludhiana University are beginning to throw new light on the optimal periodicity and quantity of water required for some of the main crops (for instance, see Prashar C.R.K. and Mukhtar Singh (10) p.91.).

water rates levied annually on single crops or rotational blocks, and (ii) by supplementary charges.

Water rates may be classified,[1] varying in their suitability for different situations, into:-

1. Volumetric rates, which are subject to difficulties of measurement and supervision in canal irrigation but which have clear advantages in instilling an economical attitude in the user;
2. Occupier's rates, a widely used method, relating the charge to the crop grown and area irrigated, the charge being based on the amount of water normally required per acre of crop; a system which may lead to wastefulness;
3. Agreement rates, found especially in wetter areas (e.g. in West Bengal, Bihar, Orissa), the rates being agreed over a long period and thereafter compulsory albeit low;
4. Consolidated rates common in the older works in South India, in which water charges are consolidated with a land tax assessment and fixed as a settlement; a system where collection is easy but alteration difficult;
5. Differential rates, tried in Andra Pradesh but being replaced; the differences between wet and dry land assessments being proportional to crop yields but needing detailed land classification to be effective.

Supplementary Charges commonly met, include

1. Betterment levies; once-for-all payments designed sometimes to appropriate some of the unearned increment in land value, and sometimes to recoup some or all of the capital outlay on the irrigation project.
2. Irrigation cesses, designed to recoup the working expenses of canal operation and applicable to irrigable land irrespective of whether it is actually watered.

Practices vary between States; in some only a water rate is applied, in others a combination of water rate and supplementary charge. In Bombay (Maharashtra-Gujarat), for instance, the 1879 Irrigation Act was amended in 1950 to introduce both betterment levy and irrigation cess.[2]

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1. Based on private communications from Mr. B.A.Desai, University of Bombay.
2. The values used in the calculation of the Betterment Levy also vary. Variations may occur at each of three stages:- the assessment of increment to annual product, the conversion of this to capital value and the share prescribed for the State.

The readiness with which water is taken up and the economy with which it is used obviously depend on the nature and level of these charges. Water is readily taken up in the low-price block-lease systems common in the higher rainfall areas, and where supplied fairly regularly from dams and mountains. In Maharashtra the block lease system, where it is applicable to a rotation containing sugar and cereal crops, works well. In Gujarat there are cases of 'phad' where water is sold in blocks to a community. When charges are optional, uptake being dependent on the annual or seasonal decision of the cultivator, and where charges are relatively high, more inefficiency occurs.

Increasingly the general approach seems to be to regard water rate payments as based on the short-term costs of water provision and to assign to the Betterment Levy the role of recouping capital outlay (the major item of cost in gravity-type irrigation works). The argument against concentrating all charges in a water rate is that the annual cash payment which results represents a heavy burden and has a disincentive effect. The arguments against a Betterment Levy based on increased land value are the difficulties of estimation (especially following the dwindling of the free market in land with recent land reforms) and of collection (which often has political repercussions). During the second Five Year Plan period only Rs.3·5 Cr. out of a planned Rs.47 Cr. were successfully collected.

The level at which charges should be set in relation to cost of provision is also subject to continuous discussion. To set rates below the true cost of provision would be to subsidise irrigation; to seek to take the whole of the product increment would remove from the cultivator any incentive to utilise water. In the past, the objective in India has been rather to recover the true cost than to treat the investment as a profit-making venture. Even so, The States have often failed to obtain full recoupment partly due to slowness of cultivators to take up water[1] and partly due to a failure to revise rates to keep pace with rising maintenance costs.[2]

D. DIRECT PARTICIPATION IN IRRIGATED AGRICULTURE

Large and Medium gravity-fed irrigation in Sudan forms a class of development distinct from those already described. The works included here in total constitute some 65% of the whole of Sudan's present irrigable area. All this development has been directly sponsored by Government, and Government participation in its operation continues. In the future, such schemes are likely to play an increasingly important part.

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1. Which may arise in some areas through failure on the part of the irrigating authorities to understand the cultivator's preference to wait for the chance of rain or, in some cases, failure to assess accurately the importance of existing minor works.
2. Ansari N. (8) p.34.

The history of Government participation is confined to the Twentieth Century. Early development was notable for the major part played by foreign capital, though organisation was never of the standard plantation type. The main enterprise was the Gezira Scheme, until now entirely dependent on the Sennar Dam for its diverted and stored-water consumption.

After preliminary trials and limited development with pumps, the Sennar reservoir supply became available in 1925. Two British Companies, The Sudan Plantation Syndicate Ltd. and the Kassala Cotton Co.Ltd. provided the capital required for housing of staff, ginneries, light railway, field machinery and advances to tenants for operational expenses, and also provided personnel for the management of the production and marketing of the cotton crop. The Sudan Government provided the land and the capital for irrigation works. Tenants provided the labour. A tripartite 'partnership' was thus formed, sharing the proceeds of the cotton crop (the main purpose of the enterprise) after deduction of certain joint costs.

These arrangements continued until 1950 during which time there were extensions of area[1] and some minor changes in working arrangements (for instance, a reduction of cotton in the rotation to reduce cotton disease problems). The Companies concessions were not renewed in 1950 and the functions they had performed were taken over by the Sudan Gezira Board, the directors of which were drawn both from public life and the Civil Service (ex officio). The S.G.B. has maintained some degree of independence from direct Government control; and the method of husbandry together with the share cropping system has continued.

The system has some similarities to crop sharing practices long followed in the sagias along the Nile, the cultivators providing their own family labour and any they wished to hire, another party or parties providing land, water wheels and bulls. In the case of the Gezira the arrangement is different in a number of ways, however: the farmer is a tenant allocated an annual tenancy[2] by Government who acquired it on lease from original right-holders; he receives free water for subsistence food and fodder crops; he is strictly regulated in his use of land and water and is supervised in the all-important operations of the cotton crop.[3]

The Scheme is organised into Blocks, each consisting on the average of some 20,000 acres. The Block Inspector and his small staff are responsible not only for supervision of the cotton but also for water control. It is they who prepare weekly indents for the water they consider necessary, and pass them to the Ministry of Irrigation who regulate the flow from Sennar.

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1. By 1942 the total scheme had reached some 980,000 feddans of which 874,000 were in rotation. Tothill,J.D.(11) p.768. It remained substantially unchanged until 1958.
2. The standard tenancy was originally 40 feddans but many subdivisions have since occurred.
3. For a fuller description of the organisation of the Gezira Scheme, see Thornton, D.S. (12) p.290.

As in India (after 1947), Independence in Sudan (1956) brought an upsurge of enthusiasm to expand agricultural production through irrigation. Of the two major developments which have taken place in the last ten years, the first was the Managil Extension to the Gezira which has nearly doubled the total area of the scheme and, due to a rather more intensive rotation, more than doubled the area of cotton.

Contemporaneous with Gezira development, the Government was more directly engaged in other smaller areas of flush irrigation in the internal Gash and Tokar deltas. Early steps to control the very seasonal and variable Gash flood were taken by the Government through the Provincial administration and Ministry of Agriculture. In 1924 management was taken over by the Kassala Cotton Co. but its function was replaced by the setting up of the Gash Board in 1927. Steps were also taken to control flush irrigation in the Tokar delta but here the Government retained its control directly through the Provincial staff.

The areas cultivated in these deltas vary widely from year to year but 40,000 feddans in the Gash and 80,000 feddans in Tokar may be taken as typical. Tokar has been producing long-staple cotton continuously since the beginning, though, since World War II, more water has been devoted to food crops. The Gash has been similarly used, with areas of poorer soils around the edges of the delta allocated for sorghum. While in Tokar the Government helped by distributing cotton seed, experimenting with loan schemes and supervising cotton-auctions, in the Gash the Board has been responsible for a complex system of water control, the annual allocation of flooded land for cropping, and subsequent supervision and sale of the cotton crop. In the Gash the tenants are charged for their seed, and are responsible for cultivations. A system of share cropping similar to that practised in Gezira was set up.[1]

Owing to the difficulties of water control, production in these deltas has always been much more variable, less intensive and poorer yielding than in Gezira, (though the latter is noted for its extreme yield variations). The land allocations per tenant are also smaller and the income to all parties is less. A policy of replacing cotton with castor in the Gash has failed to raise income sufficiently to meet rising administrative costs. Most of the local people who take part in these schemes are still semi-nomadic, though recent estimates do not indicate that cattle are a source of any considerable wealth to more than a few.[2]

The only other Government enterprises sponsored before Independence were on the Alternative Livelihood Schemes,[3] taking the place of lands flooded by

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1. After deduction of joint expenses, 50% of cotton proceeds was allocated to the tenants, 30% to the Board and 20% to the Government, now modified to 57: 25: 12 and 6% to other funds.
2. Tewfig Hashim Ahmed (13) p.296.
3. Four pumpschemes and a northerly extension of the Gezira (Abdel Magid Scheme).

the Jebel Aulya Dam. The pattern of administration followed is very similar to that followed in Gezira though the sharing of the cotton crop differs slightly.

After Independence and following on the completion of the Managil Extension, the Khasm-el-Girba scheme was begun on the Atbara River. Its first phase served the double purpose of providing a place of refuge for those migrating from the Wadi Halfa area, now inundated by the lake of the High Aswan Dam, and of developing the River Atbara's potential. When the second phase (now in hand) and the third phase (now in the planning stage) are complete, the whole will cover rather more than 400,000 feddans.

In addition there have been other small enterprises. Of particular interest are two sugar schemes each of about 30,000 feddans and designed to produce 60,000 tons of sugar a year, one based on pump irrigation, and one attached to the first phase of the Khasm-el-Girba development.

In Sudan, the approach to development since Independence has remained unchanged in general with the Government playing the leading role. The details differ with each new venture however.

The responsibility for the Managil Extension has been assumed by an enlarged S.G.B. Administration; long staple cotton is still the main interest, though grown in a modified rotation. The standard 15 feddan tenancy is smaller, though not dissimilar from the half tenancy which has, over the years, become common in the original Gezira area. The Gezira's crop-sharing arrangements have been extended to include Managil.

In Khasm-el-Girba, tenancies are similar in size to Managil. They will be supplemented, in due course, by freehold land distributed in proportion to that previously owned in Wadi Halfa (but this will not add greatly to the total area cultivated). An even tighter rotation is being followed; medium staple cotton has been introduced instead of long staple cotton and wheat has taken the place of the Gezira tenant's staple sorghum. Groundnuts form a second cash crop. Crop sharing arrangements for cotton will be accompanied by a water charge on wheat[1] but none on groundnuts.

In the new projects to take advantage of the Roseires Dam the first phase of which is to be completed in 1966, the continuing role of Government is taken for granted, but new thinking is taking place on the desirability of continuing the crop-sharing principle.

In the sugar schemes, an attempt was first made at Guneid to develop sugar production on the basis of a tenancy system which had already been

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1. This charge has not been collected in the first two seasons of operation.

designed for cotton production. Difficulties in applying this system emerged however; these consisted partly of finding satisfactory incentives to persuade the tenants to attain the degree of cultural efficiency required and partly of devising a system of management which ensured small losses and high harvesting and processing productivity in what is a very heavily capitalised venture. In the second scheme, similar in size and general method, the Government is employing a plantation design, with direct labour directed by imported (temporary) management.[1]

In the main areas of Government gravity-fed irrigation in Sudan, it may seem that arrangements have remained fairly static over the years. But it should not, therefore, be assumed that these systems have always worked smoothly, or that the relationships between authority and cultivators have undergone no change, or that no changes in organisation are to be expected in future. None of these assumptions would be justified. In the first place the economic environment has undergone changes, helping to cause depression in the early thirties and bringing about a relative decline in the attractiveness of long staple cotton since the 'high water mark' of the 1951 Korean War boom. Secondly the intentions, stated as early as 1929,[2] to devolve increasing responsibility on to the tenants or their organised communities, have not materialised. Rather, a relationship has grown up which bears many similarities to modern industry in which the Board plays the part of employer and the tenants that of foreman employees. The latter have a highly organised Union which represents the tenant's interests and whose chief objective has been, by various means, to divert an increasing share of the net-product of the Scheme from the Government to the tenants. While it has long been the practice to devote 2% of the net proceeds from cotton to Social Development, Local Government expenses and Tenant's Reserve Fund respectively, increasing political pressure has been successfully applied in recent years to obtain an increased allocation of the net proceeds from cotton to the tenant,[3] and to place further items of the tenant's expenditure on the Joint Cost Account.

A critical stage has now been reached. It is intended that in 1967 some of the Roseires water shall be used to effect intensified cropping in the Gezira Scheme. New cash crops - groundnuts and wheat - are already being introduced. The matter of how these shall be integrated into the organisation of the Scheme has however still not been solved.[4] It is therefore clear that very soon, major decisions about the pattern of organisation will be required, which will have widespread repercussions on the relationship between cultivators and authority elsewhere in Sudan, in Government and private irrigation schemes alike.

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1. It is noteworthy that in India, quite high standards of efficiency in sugar production have been achieved with small growers and enlightened co-operative organisations. Gadgil D.R. (14)
2. Gaitskell A. (15) p.198.
3. In Feb.1964 the tenant's share of net proceeds from cotton rose to 44% and the intention of raising it still further was announced in June,1965. Even the Tenant's Reserve Fund has been subjected to manipulation following political pressure. (See Sulieman A.A. & Shaw D.J.(16) p.13.)
4. At present certain tenants are being allowed to grow these crops free of water charge, the wheat being sold to Government at a fixed price, the groundnuts being sold privately or through Co-operatives.

II. DEVELOPMENT PROBLEMS AND THE DESIGN OF POLICIES

The foregoing cursory review of the policies followed by India and Sudan in irrigated areas prompts consideration of some of the problems facing policy makers. The following, and their significance in further development will be critically discussed:-

A. The criteria used in deciding the scale and kind of irrigation development.
B. The ways in which a Government can effectively contribute to this development.
C. Where a distinction exists between supplier and user, the factors to be taken into account in establishing the relationship between them.
D. The difficulties arising in achieving planned targets.

A. SCALE AND KIND OF IRRIGATION DEVELOPMENT

The way in which irrigation development is decided must necessarily be complex because there are a number of related questions. For instance

"How much irrigation?"

"For what purposes should the available water be used, bearing in mind possible uses other than irrigation?"

"How should it be distributed through the year (again bearing in mind non-irrigation considerations)?"

"How should it be distributed spatially?"

These questions can hardly be separated. Moreover, as a group, they are embodied in even broader questions of national objectives. These will be considered first.

(1) National Policy Objectives

Sudan. The published evidence of Sudan's national policy objectives is mainly contained in the one Ten Year Plan 1961/2 - 1970/1.[1] Prepared by a small secretariat staffed mainly by expatriates and sponsored by the military government of the time, its emphasis was very much on economic growth objectives. The five main targets were

(i) an appreciable increase in real income per head;
(ii) a broadening of the economic structure including some diversification of production as a measure of insurance against wide fluctuations in the international cotton trade;[2]
(iii) the promotion of exports and of import substitution, in support of objectives (i) and (ii);

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1. Economic Planning Secretariat. Min. of Finance and Economics. (17)
2. Some geographical dispersal was visualised but this was incidental to the choice of projects rather than part of a conscious policy of regional development dictated by political and social pressures.

(iv) further improvement in social conditions and services - health, housing and education being treated partly as ends in themselves but also as contributory to increased productivity; and

(v) maintenance of a relatively stable price level, a condition for the successful pursuit of the other objectives.

Water for irrigation is such an all-important resource in Sudan which is in general poor in natural resources, and the irrigated Gezira Scheme had been such a vital contributor to earlier development, that it was assured of a major role in terms of investment proposals. Out of a planned gross fixed investment over the ten years of £565 million, investments of £90 million and £30 million in the public and private sectors respectively were planned for agriculture and irrigation, 75% of which was allocated to irrigation. The fact that a high proportion of irrigated agriculture was directly under Government control allowed fairly precise decisions to be made on the import substitution programme in respect particularly of sugar and wheat, and to diversify the future pattern of exports by increasing groundnut production and reducing the relative importance of long-staple cotton.

India

India's Third Plan 1961/2 - 1965/6 contains a full statement of national policy objectives, confirming those set out in earlier plans. By contrast with Sudan there is much more emphasis on social and socialist objectives. The immediate problem recognised was "to combat the curse of poverty.....by social and economic advance".[1] But progress must be achieved, "not by private profit but social gain" ..... "Economic activity must, therefore, be so organised that the tests of production and growth and those of equitable distribution are equally met."[2] Though the economic objectives were then spelled out at length the social emphasis was everywhere implicit. Transposed into targets at the national, state, district and village levels the main aims of the Plan included

(i) a national income increase of more than 5% per annum during and beyond the period of the Plan,
(ii) self sufficiency in food grains and a level of farm production sufficient to meet the needs of industry and to provide exports,
(iii) expansion of basic industries,
(iv) expansion of employment opportunities and maximisation of the use of manpower and
(v) greater equality of opportunity and a reduction of disparities in wealth and economic power.

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1. Planning Commission (3) p.4.
2. Ibid. p.9.

Comparing the two plans, there is close similarity in the degree of emphasis on agriculture and irrigation in terms of overall investment. In the public sectors overall investment on these items is also similar though in Sudan the proportion of the total devoted to irrigation was greater.(Table 1). But it is particularly noticeable that, in the Indian Third Plan, to a much

Table 1

Planned investment in Agriculture and Irrigation. Sudan 1961/2 - 70/1
India 1956/7 - 1960/1 and 1961/2 - 1965/6.

	% of total investment in agriculture & irrigation	% of public investment in	
		Agriculture	Irrigation
Sudan	21	6	18
India 2nd Plan	18	11	9
India 3rd Plan	20	14	9

Sources: The Ten Year Plan of Economic & Social Development Ministry of Finance and Economics, Republic of Sudan. The Third Five Year Plan. Govt. of India Planning Commission.

greater extent than in the Sudanese Plan, irrigation is seen as only part of a plan of general expansion and intensification of agriculture. (In this respect the Planners have sought to correct imbalance in earlier Plans in which irrigation development had been pursued vigorously but other stimulants to agricultural productivity - increased inputs of improved seeds and fertilisers, community development, co-operative organisation etc. - had been relatively neglected).

The agricultural plan is primarily orientated towards overcoming existing malnutrition and the threat of continuing chronic food shortage. The case for concentration of effort on the solution of the food problem is indeed strong. While statistical evidence is subject to many uncertainties the low level of calorie intake per head of the population[1] and the high proportion of starchy foods in the diet are not in doubt. The three Plans so far published and the preliminary announcements relating to the Fourth have, moreover, all emphasised the desirability of self-sufficiency in food. The available estimates of food grain production and population suggest an improving trend.(Table 2).

1. Clark C. & Haswell M.R. (18) pp.16-17.

Table 2

Estimates of Foodgrain Production and Population 1950/1 - 1970/1

	1950/1	1960/1	1965/6*	1970/1**
Foodgrains (M.tons)	50·0***	79·7	100	120
Population (M's)	360	439	492	560
Foodgrain (oz)per head per day after deduction of 15% for seed and wastage.	11·6	15·1	16·8	17·8

Sources: Indian Reference Annual, (48) 3rd Five Year Plan (3) V.K.R.V.Rao (2). N.C.A.E.R. (19)

Notes: * 3rd Plan target, ** 4th Plan target, *** Clark and Haswell suggest this figure may be an underestimate (18) p.15.

Nevertheless, serious shortfalls below target figure for 1965/6 together with the possibility that population by 1970/1 may exceed even the most recent revised expectations, suggest that the target, which in any case is modest by world food consumption standards, may not be achieved.

The question remains of how much irrigation can be expected to contribute to the increase of food production in future. The architects of the Third and Fourth Plans underline the ineffectiveness of irrigation investment alone and stress the importance of combining irrigation water with other inputs. It is likely that the Fourth Plan will include far less emphasis on Large and Medium Irrigation Works though this will be balanced to some extent by increased expenditures on minor irrigation. In calculations made by the National Council of Applied Economic Research[1] who assumed that 18% of planned investment would be in the combined field of agriculture, irrigation and rural public works during 1966/7 - 1970/1, increases in food grain production attributable to irrigation alone was estimated at only 5% of the total. By far the greatest increment (45%) was expected from fertilisers.[2]

This greater emphasis on increasing other inputs in association with irrigation water has no parallel in the Sudanese Ten Year Plan. Sudanese agriculturalists are becoming more and more aware of the static position of yields in nearly all crops and of the great improvements that are possible.

1. National Council for Applied Economic Research (19) Table 15 p.37.
2. The effectiveness of other inputs will of course be increased by increased availability of irrigation water and greater certainty of crop maturity.

To summarise, therefore, the physical environments and past social philosophies of the two countries have been such that their approaches to expansion of production have been radically different. Sudan continues to plan the expansion of commercial irrigated agriculture, incorporating increasing numbers of people from its subsistence sector,[1] to which it has so far given little attention. India, on the other hand, seeks, with irrigation, and increasingly with other agricultural policies, to lift, as a whole, the general level of rural living.

(2) Criteria in Project Selection, particularly for new public irrigation works.

In practice there are always more projects under consideration than can be financed at any one time. Under these circumstances the criteria of choice between projects become of primary importance. It may be expected that the development of water resources will be studied in relation to the utilisation of capital and labour either or both of which are likely to be limiting, and to influence the scale of overall development as well as detailed choice. These are examined here in turn:

(a) The importance of capital

(i) Methods of Measurement

India's long history of irrigation has provided the opportunity for considerable development in thinking about the capital problems involved. As early as 1879 it was laid down by the House of Commons Select Committee on Indian Public Works that all public works in British India must be sufficiently productive to pay the cost of the capital employed, a principle which was made more precise in respect of major and medium irrigation works by the Indian Irrigation Commission 1901-3.[2] This principle applied to all major and medium irrigation enterprises with the exception of those 'protective works' which were financed from the Famine Fund.[3] The position was modified by the 1921 Montague Chelmsford reforms which permitted provincial governments to raise loans on their own credit, but the principle still remained, the productivity rate varying from time to time and between States.

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1. The contribution of the Commercial and Subsistence Sectors to Gross Domestic Product are separately calculated in the Ten Year Plan, e.g. Economic Planning Secretariat, Min.of Finance and Economics (17) Table 24 p.42.
2. Minor works were charged to general revenues.
3. "An irrigation project is classed as productive and sanctioned against loan funds when it has been shown to the satisfaction of the Secretary of State that it is likely to fulfil the condition of productive public works, that is to yield a net revenue 10 years after completion sufficient to cover interest charges on the sum-at-charge at that date. By 'sum-at-charge' is meant the total direct and indirect capital cost plus the excess, if any, of interest charges to date over net revenue". (Quoted in Research Programmes Committee, Planning Commission, India (20).

Criticisms have been levelled, particularly since Independence, at the details used in the measurement of both capital and revenue in calculating the productivity criterion. But it is particularly the one-sidedness of the calculation, being only concerned with the benefits accruing to the Government in its investment programme, that has caused dissatisfaction.[1] The possible secondary and tertiary effects of dam-and-irrigation development have also attracted attention. The calculation of social costs and benefits and their comparison have been urged as a more suitable alternative, following in general the suggestions of the 'Green Book'.[2] While this method of measurement has rightly broadened the basis of judgment it has also introduced many complications: a detailed knowledge of existing production must be obtained before net value added can be calculated, as for instance was done in great detail for the Hirakud Project;[3] difficult decisions have to be made about the likely movement of prices of products and inputs during the life of a project and about the rate at which the full potential of the irrigation water will be realised (which is likely to be longer where the farmers are free to use their own discretion, as in India, than when a new and appropriate crop pattern is prescribed and supervised as in Sudan); difficult decisions have to be made about the discounting procedures which must be used to compare project alternatives if the costs and incomes are spread differently in time;[4] the opportunity cost of the capital to be employed has to be estimated, and the secondary and tertiary effects - which depend not only on the size of the primary incomes but also on how these will be used as between consumption and saving - these also have to be judged. The uncertainties arising from all these considerations make the task of comparing projects a formidable one. Benefit/cost ratios by themselves, moreover, give little assistance in judging how total net return might be increased by adjusting emphasis between projects.

While accumulated surpluses to investment in Indian irrigation appear to have exceeded arrears of interest on unprofitable schemes in pre-Independence years, there seems to have been a relaxation of standards since Independence, if returns on capital be taken as the sole criterion. In particular, those low-return projects which are justified on the grounds that they will correct a tendency to local food shortage may be using resources (including scarce foreign exchange) which could be providing more food in another way - for

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1. Gadgil D.R. (21) p.172
2. Sub Committee on Benefits and Costs. U.S. (22)
3. Sovani N.V. and Rath N. (23) Ch.III-IV.
4. Low rates of time discounting on public projects of regional or national importance are sometimes justified on the grounds that it is as important for the State to plan for production (particularly food) in the next generation as in the present. This argument entails the dangers that relatively short term investments producing re-investable surpluses are neglected and that countries with small resources are stuck with installations outmoded by changes in technology and markets.

instance by investing in other farm inputs elsewhere, by investment in food storage, improved transport etc.. The introduction into the calculation too, of secondary and teriary effects has the doubtful virtue of justifying projects the returns of which are expected in the very distant and uncertain future.[1]

Sudan's practices in assessing capital investment alternatives in major irrigation projects have been less publicised and discussed. Capital budgets were done for the Roseires dam project; subsequently likely returns on capital and benefit/cost ratios have both been calculated in consultants' reports on the associated irrigation projects. Retrospective calculations on Gezira have shown good returns to investment over the years as a whole, and estimates on Khasm-el-Girba and Managil Extension projects suggest that returns on capital at or near the local market rate can be expected as these schemes settle down, in two or three years, to normal operation.[2]

Return to capital is a criterion of little importance in those minor works created, in the main, by surplus farm labour. But it is a crucial measure where equipment must be purchased (often imported) and constructional labour hired. This applies to tube wells and pumpschemes, many of which are in private or corporate ownership. Apart from their modest size, the fact that a smaller initial capital per acre irrigated is required may well be an additional attraction to the private investor (some 60% of calculated watering costs are fixed costs in the large White Nile pumpschemes as compared with 80% in Managil gravity irrigation,[3] and the proportion is doubtless even lower in small schemes). The criterion applied by the private investor is obviously the local alternative return obtainable (unless development subsidies play a substantial part as in India). There is little doubt that in Sudan in the early 1950's on Cotton Schemes on the Blue and White Niles, returns to those owners operating on the ubiquitous 50 : 50 crop sharing basis with well-managed cultivators, achieved capital/output ratios of 1 : 1 and a recovery of their initial investment in a very few years. Good opportunities with private tube wells exist now and are being seized in India by progressive, relatively large Punjabi farmers.

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1. Calculations carried out by the Reserve Bank of India and quoted by K.R. Nair suggest a marked fall in overall capital - product ratio in irrigation investment as between 1949-50 and 1960-61. (24) Table VI.p.161.
2. A number of writers e.g. Wynn R.F. (25) p.111 and Rao V.K.R.V. and Narrain D. (26) p.82, have drawn attention however to the substantial effects on the calculation of returns to capital exerted by the opportunity cost of capital that is assumed. The rates of interest in the international capital market from which loans for much of the capital required will be obtained are themselves substantially lower than internal rates. It is suspected that, on occasion, the existence of these lower interest rates so influences judgment as to result in greater investment than may be justified taking other considerations into account, and in the diversion of choice away from projects which might better develop the country's all-important entrepreneurial and managerial talent, which mostly resides in the private sector.
3. Wynn R.F. (25) p.114.

ii. Availability of Capital

Even if capital be taken as a major factor limiting the scale of development, the measurement simply of total capital as a criterion is insufficient in the present situation of developing countries.

In the first place these countries are almost always short of foreign exchange. They are also indebted to varying degrees.[1] Increasing investment in irrigation, insofar as there is a tendency to move to more sophisticated methods of control in increasingly difficult and remote sites[2] tends to involve more rather than less foreign exchange both for exotic materials and equipment and for highly qualified engineering personnel. Because of the clear need to reduce this burden to a minimum, there is therefore a premium on the selection of those works in which scarce foreign exchange can be substituted by the internal mobilisation of manpower, perhaps with the use of food aid as a means of payment for such labour. (Such a policy may have rather more relevance to India, where rural labour is seriously under-employed at least at certain seasons, than in Sudan). While the need is realised, this kind of substitution raises its own organisational and economic difficulties, however.

In the second place, internal capital must be assembled. The choice of method of development may itself affect the amount of capital available for re-investment and therefore in the long term, the rate of overall national (and irrigation) development. Investment in areas producing high value, and therefore taxable, crops, or using a system in which the Government automatically shares in the product, will tend to yield the quickest returns which can then be ploughed back.

In the third place, there may be private hoards of capital which, if they are to be utilised, will only be available for certain types of irrigation investment. This consideration may well affect both the balance of emphasis between public and publicly-assisted private development, and influence the form of supplier/user relationship chosen where Governments invest directly. The attractiveness of irrigated commercial agriculture to private capital in Sudan in the pumpschemes and in Maharashtra in sugar production may provide important lessons to take into account in future decisions about the scale (and type) of investment and the conditions under which it can be encouraged.

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1. In the estimated requirements of foreign exchange in the Indian Third Plan, for instance, no less than 500 out of Rs.2,600 Cr. of foreign exchange expenditure were earmarked for servicing and repayment of loans already taken up. (Planning Commission, India (3) p.109.).
2. This is reflected in increased costs particularly arising from the very long lengths of link canals e.g. Roseires Link Canal to Blue Nile East Bank projects 114 miles, Harike Barrage to Rajasthan Project 134 miles.

(b) The Problem of Manpower Productivity

Alongside problems of capital assembly and deployment, both India and Sudan face manpower problems at two levels - untrained rural labour and skilled technical and administrative personnel.

(i) Untrained Rural Labour

In the matter of untrained rural labour the two countries are strongly contrasted. India has a surplus of underemployed and seasonally unemployed rural people for whom it is a major objective of national policy to find employment. The number of these is so large and the difficulties of quick urban expansion so great that it is accepted that this problem, together with the food insufficiency, must be tackled simultaneously in the rural areas. While village industrialisation may be expected to have some effect the bulk of the opportunity lies in intensification of agricultural production. If irrigation allows the growing of more high value crops, insures a high percentage of crop maturity, increases yields of crops and animals, or allows other inputs to be used more effectively, then it can be expected to have a salutary effect on labour productivity. But its potential will vary appreciably from one area to another, and there will be many areas where no irrigation will be possible. Some attention therefore, may have to be given to increasing differential mobility of labour in Indian rural areas, if not from one area to another, then in terms of different rates of emigration to cities. To the extent that families become tied to their homes and landed interests, any policies which reduce the number available to move towards higher cash wages, as do some aspects of recent land reform, will reduce the possibility of this kind of adjustment. The uncertainties inherent in paid agricultural employment in India and the rigidities of the caste and village systems[1] only tend to increase immobility; any changes which result in a weakening of these influences would appear to be working, in the long run, in favour of increasing the productivity of labour.

Sudan, except in the Northern Province, has no problem of rural overcrowding in the same sense that India has. Further development of irrigation will rather be accompanied by the problem of finding settlers and casual labour. Future development must be justified therefore not only by a satisfactory 'added value' in comparison with existing local rainland agriculture (often semi-nomadic in character) but also by an increment over and above the value of the agricultural pursuits any immigrants from elsewhere in Sudan will be called on to give up. The suggestion, moreover, of a high preference for leisure and low elasticity of supply amongst those likely to be available for settlement[2] may add to the difficulties of expansion of the irrigated areas.

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1. Difficulties in assembling labour, in spite of claims of rural unemployment are reported by Raj in respect of construction works on the Bhakra-Nangal project (7) p.78.
2. Sam Ibrahim el Khatim (27).

(ii) Skilled technical and administrative personnel

The supply of technical and administrative personnel depends upon the numbers with a sufficiently high level of general education and with specialist training and experience. These are absolutely short in Sudan; there the dearth of agriculturally qualified technicians, field organisers and advisers threatens to be the major weakness in recently irrigated areas, which the engineers have been so quick to design and execute and which have completely inexperienced settlers. Moreover, the prospective rate of further development exceeds the rate at which suitably trained personnel are likely to come forward in the next few years. In India, while much thought has gone into the administrative and technical aspects of the Community Development System which has formed so important a part of recent national policy, the quality of the personnel is frequently criticised. The crucial Village Level Worker, required in theory at the rate of one per ten villages, is in fact required at far greater densities and at a much higher level of education and maturity; recent concentration of the activities of this cadre on agricultural production rather than on all aspects of village development only partially solves the problem. At the Tehsil and District levels the need is for people with higher training. At the same time the country has a surplus of highly educated personnel trained in the Arts. Here the success of agricultural intensification seems to depend at least in part upon training by specialist courses those basically educated people who are interested in working in rural areas.

The shortage, in both countries, of skilled technical and administrative personnel makes this a highly important criterion against which to compare alternative plans for development.

(3) Criteria in Project Modification

Attention in Section (2) was concentrated on choosing new projects. In future, planners are likely to turn increasingly to the intensification of areas where irrigation facilities already exist,

(i) to reduce wastage of water (through seepage or evaporation)
(ii) to increase the irrigation water available for more intensive cropping, and
(iii) for reclamation.

(i) The simplest type of decision within this category appears to be whether or not to line existing canals. This is an important question in those areas of India where soils are porous. Here the cost of lining has only to be set against the value of the increased water available, though costs will vary according to the availability of suitable materials (on which intensive research and development are being done) and the ease of execution. But lining may also be part of a more elaborate policy of groundwater control.

(ii) The degree of intensification of watering that is economically justified both in terms of the intensity of irrigation (i.e. raising the acreage

watered in relation to the C.C.A.) and in terms of more intensive application on any one acre, depends primarily on existing canal capacity and the degree to which it is already utilised in any one season and through the year as a whole. Recent decisions have been made to intensify the Gezira Scheme in Sudan using water soon to be available from the new Roseires dam within the existing canal system. Hitherto the Gezira Main area was cropped in a uniform rotation only at 44% intensity; by introducing more winter cropping (particularly wheat) and intensifying water use (on groundnuts) in the Kharif, cropping intensity will be raised to 75%. A dead season (April-June) has been preserved as a disease prevention measure and the temptation to crop the fallows preceding the two cotton breaks in the rotation has been resisted. Studies are being made of the economics of a degree of further intensification (not necessarily uniformly over the scheme) which would require enlargement of some canals.

Intensification of watering in India could result in one or more of three advantages; increasing the intensity of cropping,[1] reducing the risks inherent in most of the Indian systems in which the farmer has no control over the date of application and no certainty about when the water will arrive; lengthening the cropping season.

Such improvements might be achieved by increasing the control of stream flows or (more likely) by the development of supplementary supplies from tube wells. The economic criteria to be applied in these choices have been lucidly described by Van der Tak and Schmedtje[2] but problems of procedure in planning these changes remain and have so far been given insufficient systematic thought.

The first of these is the breakdown of the planning problem. In areas served by large networks, three levels of decision may be required at Scheme, Block[3] and Chak level. The water allocation problem may be conceived as the optimisation of distribution in these three steps. In modifying an existing layout, decisions at Scheme level will include the total amount of change economically and socially justified and the distribution of this change in the form of modified water regimes as between parts of the irrigated area. At Block level a further refinement of distribution would be planned, when possible including supplementary water sources, and taking into account the detailed potentialities of markets, population changes etc. facing the farmers. At Chak level, and linked with Community Development, the detailed

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1. The low intensities for instance of the Bhakra-Nangal system have already been referred to and even lower intensities are reported in some areas, such as the Sarda Canal in United Provinces (N.C.A.E.R.(28) p.88). In the Rajasthan project now being started, however, intensity in perennial areas is planned at 78% (33% Kharif and 45% Rabi).
2. Van der Tak H.G. and Schmedtje J.K. (29) Ch.III.
3. A Block consists of some 1-200 villages each with perhaps 700 acres of land; a Chak is that area watered from one canal outlet, say 1000-1500 acres.

distribution problems between farmers and between land of different locational, topographical and soil qualities, would be solved. Some inefficiencies in water application arising from uncertainties, uneven human abilities, technological changes etc. would undoubtedly result or eventually emerge and careful thought would be required on the degree of flexibility to be retained at each level to allow for these.

The same devolution might well be considered in large Sudanese schemes such as Gezira, so as to take advantage of local differences in output potential arising from market locations as well as climatic and soil differences. Heterogeneity of terrain and the characteristics of local markets have tended to be less important in the past when the economic dominance of cotton was unquestioned, but they will almost certainly be more important in future.

A second problem facing the planners of modifications is the establishment of principles on which changes are to be made. The decision on the method by which irrigation water should be allocated is at least partly political. In areas where demand for water substantially exceeds supply and no ways of reducing demand can be devised, some principle of equitability is inevitable. This is by no means a clearcut matter however; wide variation between chaks or districts may be justified according to the local circumstances. In general, the more severe the problem of survival in thickly populated areas, the more justifiable would be a distortion of water distribution from that pattern which is economically optimal. But there is a danger that the comparative advantages provided by certain environments and by a measure of specialisation may be lost. It might be expected that the security associated with personal or local self-sufficiency could be dispensed with as technical knowledge, levels of yields, and marketing organisation lead to a more commercial approach to farm production.

The third problem concerns the integration of irrigation water with other agricultural inputs in the general desire for agricultural development. This problem is already being imaginatively tackled in India by the I.A.D.P.[1] which has, because of its less than universal spread, an experimental element in it at this stage. Similar action within Sudan is so far limited[2] though plans for the development of extension and the training of field men and farmers are in hand. The taking up of further selected areas for intensive application of technical expertise, credit, organisational innovation etc. might well be an effective step at this stage in Sudan development.

(iii) Reclamation, a problem which does not occur in Sudan,[3] involves the

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1. Min. of Food and Agriculture, India (9) p.32.
2. The Sudan Gezira Board has had notable success in its Village Farm Experiment in stimulating highly successful intensive agriculture.
3. The very limited areas of saline land now abandoned around Khartoum could have been avoided given adequate soil survey. The attractiveness of their location near a growing market may make them worth reclamation in the future.

total rehabilitation of land that has ceased to repay human effort. Its productivity has been reduced through water-logging or salinity or a combination of both.

So far, in the foregoing discussion irrigation water has been treated entirely as a consumable resource and the economic attitude implied has been one of optimising output per unit of water consumed. This approach is suitable for Sudan, where the control of water application is very nearly complete[1] and subject only to the unpredictability of rains, and where impervious clays simplify decisions about the frequency and quality of water applications. But it is too simple an approach for much of Northwest India.

Past policy in India has been, as already stated, to distribute seasonal and variable water as widely as possible, assuming that where easily available, groundwater will be utilised by the farmer as a supplement. There have been two results:

(1) There has occurred a steady rise of the water table, starting earliest in the areas earliest irrigated. This rise has now spread so far that areas where, at the turn of the century, the water table was 70 feet below the surface, now suffer from water-logging and from surface flooding in the rainy season. In the absence of satisfactory surface drains this flooding may persist, after a heavy monsoon, for most of the growing season.

(2) There has been increasing salinity in the surface layers of soils hitherto non-saline even though the irrigation water itself has low mineral content. This process is the result of inadequate irrigation, the leaching movement of water down through the profile being less than the movement upwards during the dry period. This has,over time,resulted in the accumulation of salts in the crucial surface layers. Salinity tends to develop before waterlogging - it is already becoming a problem in the newly irrigated areas of Hissar for instance where concentration of 0·6% are already being recorded[2]- but continues in conjunction with it.

These two scourges can only be removed by a completely new approach to water control, the characteristics of which are (1) a controlled water table (2) a greatly increased downflow of water through the soil profile (3) surface drainage adequate to deal with stormwater. While certain plants (of little economic value) may be grown to take up soil salts, and some crop plants (notably rice and lucerne) thrive in soils with relative high pH and have

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1. Exceptions occur in the flush irrigation areas of Tokar and Gash deltas already described and areas of flood irrigation, sometimes rising to 100,000 feddans, along the Main Nile.
2. 0·2% is regarded as the upper tolerable limit.

heavy irrigation requirements, land improvement through cropping is only an assistant to the more fundamental engineering task of water control and soil amelioration. This can only be achieved by a balanced process which involves a combination of the recirculation of groundwater through the profile, the application of increased gravity-fed supplies, and the removal of saline water either into river channels or into salt lakes for evaporation. Large scale reclamation is now under way in West Pakistan and results are encouraging.[1] Steps so far taken in India are less comprehensive, but the problem is a complex one. Not only is the process itself complicated; also soil types, and the courses of water carriers and railway embankments built up over a long period of time, form an intricate pattern which defy the application of simple solutions. The approach in West Pakistan has been the sectionalising of the abandoned areas and an integrated plan in each section to restore healthily productive conditions. A similar approach, though modified to suit local conditions will almost certainly be required in Northwest India.

As will be developed further below, the necessity for much closer control of soil water balance, which emerges from this discussion, poses problems of many kinds. Economic choices - how much water to apply and where, etc. remain, but these become implicated in broader economic issues of a long-term nature, and also in organisational problems. Other questions too - such as response of plants to different size, number and timing of water applications, the degree of freedom of choice that can be allowed private entrepreneurs, and so on, take on increased significance.

4. Criteria for combining irrigation with other uses for water

In the three foregoing sections which have so far dealt with considerations which must influence the scale of development of irrigation, the alternative and competing uses for water have been ignored. Neither Sudan nor India are in a position to treat irrigation development in isolation.

Two sorts of complication must be considered here. First, because the control of a river can produce a number of different benefits at various places in its course and, indeed, because control at one point may well have important effects on the river's behaviour lower down, it is becoming increasingly evident that river basins must be treated as a whole. In order, too, to preserve the system in healthy condition for as long as possible it is often necessary to associate other conservation measures. Thus it is becoming common, at any rate in India, for river development to be considered on a river-basin basis and including, in one comprehensive plan, measures of erosion control (including afforestation), diversion for irrigation, hydro-electric power generation, protection of river beds and banks, control of floods in the lower reaches, and the protection and promotion of navigation and fisheries.

The second complication is the increasing importance of H.E.P. as a contributor to the power requirements of developing countries.

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1. White House - Dept. of Interior Panel (30) p.316.

(i) Comprehensive river control

As in the foregoing section 3, the problem in arriving at optimal solutions here lies not only in the highly complex estimates of costs and returns (which are particularly difficult because large-scale measures with long-term and indirect effects are concerned), but also in the devising of an administrative structure for tackling them effectively. This is further complicated where the control of a river basin involves the interest of more than one State or more than one country.

This last difficulty has deeply influenced the recent history of both countries. In Sudan the arrangements that have finally been achieved in Nile Waters Agreements have profoundly affected Sudanese development; the 1960 Agreement between Pakistan and India whereby the waters of the Punjab rivers were divided between the two countries has directly determined the form and cost of the water utilisation of the Sutlej, Bias and Ravi rivers in India, and their diversion into the Bhakra-Nangal and Rajasthan Canal projects.

Within India too, inter-state co-operation has been necessary as for instance, in the distribution of costs and benefits of irrigation and H.E.P. as between Rajasthan and Mahdya Pradesh of the Chambal Project. It has often been difficult to make smooth the operations of those responsible for development and their relations with the State administrations concerned.

That this importance of co-ordination is well understood is illustrated by the Report of the Krishna-Godavari Commission.[1] Occupying one sixth of India's land surface and more than a quarter of the culturable area, the Krishna-Godavari Basin is located in no less than five States. Of the total 141 million acres the Commission calculated that 7·7 are irrigated, 1·9 million acres from wells, 2·5 from tanks and 3·3 from canals. Since 1951 the States have acted independently in their development plans against a dearth of hydrological and other information for the Basin as a whole, and with little or no attention to the needs of neighbouring States nor to the effects of plans on one another. The Commission also drew attention to the variations between the States in their irrigation legislation, and in the variable thoroughness with which plans for water conservation, land levelling etc. were being made. They also pointed to the multiplicity of Departments concerned with irrigation in any one State and the lack of contact between States and with the independent Dandakaranya Development Authority operating in part of the Basin. Water rates were found to vary within the Basin and appeared not to be related to any general standard. In addition to a long list of recommendations designed to ensure integrated use of the Basin's waters, the Commission recommended the setting up of an Interstate River Board to co-ordinate State Plans.

Sudan's river development problem is almost entirely concerned with one river system over which, since 1959, it has had substantially increased

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1. Krishna - Godavari Commission (31).

rights. While the Government has always been alive to the 'wholeness' of the Nile waters, the mood of the last few years has been affected by the apparent abundance of water; planning of new development has gone ahead without much discussion of optimising water use over the whole. It is now being realised however that the 18·5 million cubic metres awarded as Sudan's share of the 1959 Nile Waters Agreement will be taken up when the second stage of the new Roseires Dam and the associated areas of some 6 million irrigated acres are developed (probably during the 1970's). As a result, new thinking is now going on which has the two objectives (a) to reduce wastage by evaporation of potential irrigation water[1] and (b) to consider in much more detail the future deployment of the water available.[2]

The White Nile, the flow of which is steady throughout the year, loses a very large proportion of its water by evaporation in the Sudd of Southern Sudan. The idea of canalising and controlling the river through this area, which was explored in detail in 1953,[3] therefore takes on a new significance; not only would this result in the reduction of flooding and the opportunity to cultivate large areas of reclaimed land in the Sudd region; the Jonglei project, together with the draining of other marshes further downstream would add perhaps up to 20 milliard cubic metres to the water budget of Sudan.

But the scope for irrigation is particularly in the lands bordering the Blue Nile. The flow of the two Niles (and the Atbara) must therefore continue to be regarded as a whole, the delivery of agreed supplies to Egypt and home consumption being measured against the total flow of all three rivers.

The building of the Roseires Dam and other subsequent works will of course have widespread direct and indirect effects all over the Nile Basin, not least in the Northern Province where the Main Nile regime will be modified, with consequent effects on the economics both of pump irrigation and of improving water supplies to those areas at present irrigated by flood. Any comprehensive study of the way to optimise the use of Nile waters must include such related effects.

(ii) Hydro Electric Power

The exploitation of cheap power sources is as important for economic development as the expansion of agricultural production. H.E.P. has the advantage over power generated from coal, gas and oil that as a source it is more or less inexhaustible. In most situations it is also cheapest, particularly if solid fuels have to be imported. On the other hand it must be produced at those points which gravity dictates and transmission quickly adds to

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1. Yahia A/Magid Ahmed (32) p.325
2. The problem here is of course a dynamic one; the optimal plan will be that which fits best the build-up of capital and work force necessary for its ultimate completion.
3. Jonglei Investigation Report (33).

the capital required (particularly in the form of scarce foreign exchange), and therefore the unit cost of supply. Once available however, it can be deployed for a variety of uses including fertiliser manufacture, water pumping for irrigation and domestic supplies, rural electrification for industries and home use, as well as for urban uses.

While H.E.P. production is complementary to river control and irrigation, that pattern of flow through the natural river channel and diversionary channels which is most valuable for irrigation is seldom that most productive of H.E.P. The planning problem at any one dam site therefore becomes one of reconciling competing H.E.P. and irrigation demands (bearing in mind other considerations treated in Section 4 (i) above), while investment policy in irrigation development as a whole, including dam building, is influenced by the ability of H.E.P. to compete with other sources of electric power. Moreover, the situation is almost certain to be dynamic, particularly on the H.E.P. side. In India, the utilisation of power is increasing rapidly, particularly in some of the more backward states. H.E.P. production in India is approximately doubling every five years. This high rate of growth and the obvious uncertainties about future demand make it extremely difficult to resolve the conflict of interests between H.E.P. and irrigation.[1]

Both Sudan's and India's rivers are very seasonal in their flow.[2] Both irrigation and H.E.P. consumers prefer steady supplies. The preference for perennial irrigation and firm power create further problems of choice. These difficulties are illustrated in Sudan in the choices to be made in the case of the new Roseires Dam.[3] Here power will be taken from spills from the dam, and irrigation water partly by canal from the Dam reservoir, and partly downstream from the Dam. Irrigation water drawn from the reservoir reduces the amount available for spill through the H.E.P. turbines; and the timing of its use affects the head available for power generation; water used for irrigation downstream, though it will have already contributed to power supply at Roseires, has its own optimal seasonal pattern. The seasonal flow of the Blue Nile is such that the ability to produce firm power will be strictly limited, the peak for a short period at the end of the flood in October being very marked. The result for Sudan's power policy will therefore be that considerable investment in supplementary thermal plants will be required for supplies in some seasons of the year as the national demand for firm power rises. In order, also, to make use of the H.E.P., a 400 mile transmission line capable of carrying peak loads will be required from Roseires to the main consuming area round Khartoum.

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1. For instance, the rapid rise in demand for Hirakud H.E.P. has resulted in some of the flood control policy of the project being abandoned.
2. The chief exception, the White Nile, has no satisfactory damming sites in Sudan.
3. Wynn R.F. (25) p.117.

India's problem in utilising Bhakra-Nangal power is similar in many ways, though increased by the difficulties of integrating the policies of the individual States. H.E.P. is cheap at the point of production compared with other forms of power. Though the capital cost is estimated[1] at Rs.1,000 per K.W. of installed capacity compared with Rs.4-5000 per Kilowatt for deisel plant and an intermediate value for coal, running costs are very low, giving a total cost per unit produced only 8 - 10% of the cost of power produced from oil or coal. On the other hand, the location of H.E.P. generating points is remote from main consuming centres and transmission lines add heavy additional costs.

Moreover the seasonality of river low results in a firm supply far below peak supply capacity. This is particularly characteristic of the Bhakra-Nangal system. Besides distributing irrigation water over a wide area it was planned in 1953 that generating sets (partly on the Nangal off-take canal and partly in the Bhakra dam) would be installed as required over a long period. A Nitrogen fertiliser-heavy water plant was then constructed near the Bhakra Dam which required large quantities of steady power. The effect of this was to reduce and render much more variable both seasonally and year-to-year the electricity supply to the Punjab-Rajasthan-Delhi grid. The demands for power also affected water releases to the extent that it became impossible to satisfy planned irrigation requirements and necessitated supplementary irrigation supplies from sources other than the Sutlej River.

B. THE GOVERNMENT'S FUNCTIONS IN IRRIGATION DEVELOPMENT

Enough has been said about the importance and complexity of irrigation to make it obvious that Government must necessarily take a major interest in its development. Of the functions that it is appropriate for the Government to perform some will be unquestioned but others will be more debatable. It is not intended to dwell long on the first group which includes

(i) to investigate land and water resource potential with surveys and to make known the findings,
(ii) to investigate techniques of water control, works condtruction, plant water requirements, etc.,
(iii) insofar as much development may be government-directed, to investigate demand for products,
(iv) to educate all concerned in irrigation methods, land and water conservation, etc.,
(v) to plan overall development of land and water so as to optimise use, and avoid wastage and dereliction.

Beyond this point the functions of Government in India and Sudan, as already illustrated, have tended to diverge.

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1 Raj K.N. (7) p.117.

Government in India, in pursuing the objective of fostering the welfare of as many people as possible, has in the past tended to treat water as a utility to be used as the farmer wished and was able. Such a policy naturally entails certain risks - that there will be a slowness to make full use of the water, that it may not be combined with other resources in the best possible way, that in the long term serious damage may be done to the soil if water is used unwisely. All these three difficulties have arisen in recent years in India (though the third is not the fault of the farmers in this case).

Solution of these difficulties implies further Government action in three main directions

(1) education to achieve better standards of husbandry
(2) modification of incentives so as to encourage better resource use
(3) greater regulation and control of water resources to ensure optimal deployment.

All these needs are realised and steps are being taken but it may be that further effort can most effectively be made in these three directions.

General education, together with the more specialised development of Extension within the Community Development programme are the means employed to advance in the first direction.

Modification of incentives implies not only the making effective of agrarian reforms already enacted, which were designed at least in part to make land and capital more readily available to those wishing to use them productively. It also implies appropriate influencing of the prices of inputs (particularly water and fertilisers) and of products.

The third direction of advance implies more intervention by Government in the control of the many sources of water which are brought together in any one area. This may entail the rather strict licensing of water suppliers, close dovetailing of private and public supplies, careful supervision of water use, and the imposition of broad cropping controls to ensure long-run soil fertility and water balance.

The achievement of progress in these three directions will depend on effective organisation. The need to think about this, probably at three levels, has already been referred to. At least in those regions where irrigation introduces major changes into the nature of agriculture (as distinct from those where it provides a minor supplement to rainfall), its provision and use raise problems which can really best be solved by organising economic and social institutions in relation to it. Indeed, newly settled areas which enjoy the benefit of centralised comprehensive water control, start with many initial advantages over those areas where water is added to an existing economic and social pattern.

There is obviously no simple solution to the organisational problem in India's case. She already has a galaxy of organisations concerned with rural development. There is first the District Administration of each State, divided into Sub-divisions, Tehsils (or Teluks) of 2-600 villages each, revenue circles and villages. Among the functions of the Administration are included administration of land and other policies, relief of distress and promotion of popular welfare. Second, there is the newer Community Development framework, organised at District, Block and Village level in which agricultural development is now a primary objective. Third, there are formal groups such as co-operatives and informal groups such as those related to caste and family.

Conditions obviously vary widely between States not least because population density varies, from 10-15/sq.mile on the West Pakistan border to 1000-1500/sq.mile in the deltas of East and Southeast India. The integration, with the existing structure, of institutions which satisfactorily control water and at the same time inspire its optimal application, will not only be a major task, therefore, but one likely to be resolved differently in different places.

Hitherto major irrigation development has been planned and executed primarily by the Ministry of Irrigation while minor irrigation, to the extent that its development has been influenced by Government, has been organised within the District Administration and Community Development Systems. Moreover, the link between irrigation and agricultural development has in the past been tenuous. The recent closer association of agriculture and irrigation at the Centre under one Minister and the co-ordinating arrangements now being made in a number of State Administrations[1] are steps in what must surely become closer association down through the whole Administration to the village farm level.

In Sudan Government policy has been, on the one hand, control and encouragement of private enterprise in riverain situations and, on the other, large-scale uniformity of production and social development in areas irrigated by gravity. The first has resulted in a wide variety of commercial forms and the beginning of substantial private capital investment, particularly by merchants, in agriculture. The second has been successful in the past particularly in the physical environment and market conditions which have applied, and has provided a satisfactory way of beginning the process of turning semi-nomads into settled cultivators.

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1. In Punjab, for instance, there is now a State Government sub-committee bringing together officers from Agriculture and Irrigation to study the water supplies and production pattern of the State as a whole, the objectives being (1) to consider ways of improving overall distribution, particularly by increasing water intensity with tube-wells and supplies from the new Pong Dam and (2) to encourage better local organisation of watering. This has followed the setting up (in 1960) of a Minor Irrigation Board to co-ordinate irrigation and agricultural activity.

Nevertheless there are signs that widespread changes may come about in the not-too-distant future. In the pumpschemes the problems largely centre on the relationship between pumpowner and cultivator and the method and level of payment for water by the cultivator. In the areas of flush irrigation the main difficulty is to find an effective substitute for long-staple cotton when cotton prices are tending to fall but when the aspirations of the local people and administrative costs are tending to rise. Drastic changes in the way these irrigation supplies are utilised may have to be made.

In the major areas of gravity irrigation a number of considerations indicate that radical rethinking may be necessary. First there have been few signs of improving yields in cash crops, food crops and livestock over the years. This is particularly noticeable in the case of cotton in spite of increasing expenditure, particularly on cultural operations, fertilisers, new seed varieties and disease control measures, and in spite of the large possibilities suggested by research findings; this suggests that either education is deficient or that there is a lack of incentive, on the part of the cultivator, to improve. Second, there appears to have grown up a conflict of viewpoint as between Government and farmers, which suggests that the present system needs reconsideration in some fundamental way. Third, in the very large Gezira Scheme it is becoming increasingly difficult within the present framework to take central decisions which are certain to result in optimal use pf resources; this arises because diversity of opportunity in marketing, the importance of local physical differences and the unevenness in the working and managerial ability of the cultivators are all increasing. Fourth, as already observed, there are already anomalies in the organisation of both the Gezira Scheme and Khasm-el-Girba in the crucial matter of payment for water.

Current discussion therefore, tends to centre on ways of providing increased incentives to the tenant farmers, possibly by revising the present methods of paying for water and other services, and modifying other aspects of their terms of tenure.

Meanwhile however, the important advantages of a centralised organisation for development such as the Sudan Gezira Board, which controls the bulk of the present gravity fed area, must be stressed. It has achieved notable success in raising the standard of living and has, over the years, provided a substantial contribution to the National Economy.[1] The main advantage which the Board organisation has provided, which is plain when comparing Gezira experience with other development in Sudan, resides in the high degree of local co-ordination of operations it has been possible to achieve in all aspects of the production and marketing of cotton. The esprit de corps built up among its staff is closely related to the degree of efficiency achieved and has been an important factor in its success. There appear to be strong arguments for setting up parallel organisations elsewhere in

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1. This averaged 12% of total Government revenue during the five years ending 1962-3. Shaw D.J. (34) p.203.

Sudan and outside, though the problems of adapting to technological and social changes at the same time as providing some security in the cultivators' livelihood need to be solved, appropriate modifications being built into the framework chosen.

We may therefore, conclude that conditions in Sudan and India are at present such that their directions of advance seem to be in some respects convergent. In Sudan, the interests of both Government and cultivators seem to be in finding ways of introducing effective incentives to individual effort and management. In India, while increasing incentives to increased production are equally important, there is also a pressing need to improve the conservation and use of the water resource and to co-ordinate agricultural and irrigation programmes more effectively.

C. SUPPLIER-USER RELATIONS

An outstanding difference between Sudan and India lies in the prevalence of a sharing relationship in both public and private schemes in Sudan as contrasted with the payment of water charges in cash in India.

(1) Crop sharing system

Crop sharing implies sharing of the risks and uncertainties of the business of irrigated agriculture, that is, the sharing between parties of the entrepreneurial function. Where entrepreneurship is in fact divided this system of dividing the rewards is a logical one.[1] Moreover, the system has distinct advantages where a large-scale investor, particularly the Government is co-operating with farmers new to settled agriculture and unfamiliar techniques. This is especially true in the case of centrally processed and marketed cash crops such as cotton; for instance:-

(i) in communities where cultivators' cash reserves are always small,[2] the collection of charges for services provided - irrigation water, ploughing, advice etc. - is easier by deduction of part of the proceeds of sales than in the form of cash.

(ii) advances can easily be made to the cultivator for his seasonal cash outgoings and easily deducted from his share, thus reducing the curse of local money-lending

(iii) risks and uncertainties and resulting income fluctuations can be shared; this is an important advantage where the production of a single crop subject to wide fluctuations in yields and prices (or a group of products all fluctuating together) is the purpose of the enterprise and

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1. Examples of quite complex sharing arrangements in use at the beginning of the Century are quoted by Shaw.(35) p.178.
2. As difficulties in the collection of water rates in some years in the Northern Province have illustrated.

(iv) where the Government is one of the parties, tax collection can be associated directly and simply with other charges in the Government's share.

In the Sudanese Government schemes since the 1920's and latterly in the private pumpschemes, the system has worked fairly well until recently, and it is common in Sudan for thinking to be cast in this product-sharing form. But the system can be criticised on a number of counts:-

(i) payment for use of resources on the basis of income received rather than on the basis of cost is illogical unless entrepreneurship over the whole enterprise is being shared, and is liable to confuse all parties in their decision-making. With the exception of the private pumpschemes of the Northern Province it has always been characteristic of Sudanese irrigation schemes that crop-sharing does not apply to the cultivators' food and fodder crops, which are allowed for subsistence purposes, free of water charge. In the early stages of a scheme for settlement and development, this arrangement works well and indeed, may be a necessary inducement to cultivators to accept a radical change in their way of living.The transition to commercial conditions in Sudan is tending to render the system inappropriate in some, if not all, schemes, however. First, diversification of cash cropping is being introduced (e.g. castor in Gash, wheat and groundnuts in Gezira) and marketing control through a central organisation is less easy.[1] Second, the growth of a market in the country for food grains and vegetables (and even locally, for fodder) reduces the justification for providing subsistence crops as insurance; it is now debatable whether, in view of the availability of rainland dura (sorghum), land and water should be devoted to this exhaustive crop in the irrigated areas.[2] Where all land and water can be diverted to the production of crops and livestock products for sale and where cultivators have some freedom of choice in deploying their labour and management, a crop sharing system focussed on one crop obviously has become an anachronism.

(ii) It may be argued that crop-sharing depresses the cultivator's incentive to improve, the benefits of any improvements he makes, having to be shared with those providing the water and land. (It may of course be equally argued that those other parties also have to share with the cultivator the results of any additional investment they may make.) This weakness will be intensified where land is tenanted by the cultivator and where tenancy is insecure. In Sudan the majority of cultivators are tenants enjoying annual tenancies. In the cotton schemes they are liable to lose their holdings if their performance on their cotton hawashas is poor (though in practice evictions have been rather infrequent). It is noticeable that the tenant has improved little over the years, still requires supervision,

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1. Smuggling of cotton from the Gash delta to Ethiopia weakens control of even the cotton crop in that Scheme.
2. The case for retaining it, as a complement to wheat, has been made by Simpson (36) p.11.

and, on occasion, punitive treatment in the growing of his cotton; and to the limited extent that he has stepped up investment in his agricultural interests, he has tended to concentrate on the crops other than cotton, the proceeds of which are entirely his own. He has often done this against what seems to be his own best interest; an increase in even a share of the cotton crop would often be more rewarding than the results of similar efforts elsewhere.

(iii) Where a crop-sharing system persists internal versatility within the irrigated area is made more difficult. The crop-sharing system, particularly if applied to only part of the total production tends to cloud the judgment of both the suppliers and the users of water (to the extent that they have autonomy of choice) about how best to modify investment in and combine irrigation and other inputs. The pattern of production over two million acres of Gezira-Managil is geared to only two rotations. Given more local freedom of choice, the productivity of the Scheme might be much enhanced by local diversity of production, though this would admittedly entail major modifications in the administrative structure of the Scheme, in tenancy arrangements, etc..

As already remarked there is considerable dissatisfaction with the present crop-sharing arrangements on all sides in Sudan. In the larger established cotton-growing areas this has taken the form of pressure from organised tenants' interests to achieve more favourable terms by modifications within the present framework. In the newly settled Khasm-el-Girba difficulties have been encountered with the anomalous system whereby, of the three compulsory crops of the tenancies on Government land, cotton is being treated as a shared crop, wheat is liable to water rate and groundnuts incur no charge.[1] In the Northern Province field studies indicate widespread dissatisfaction with private pump-schemes where crop-sharing is practised (the practice itself among other things, coming in for criticism), and show preference among cultivators for the nine Government Schemes where water charges are levied.[2]

(2) Charges for Water

If it is agreed, at least in the long run, that water charges are preferable to crop shares as a method of recoupment, two questions remain: "what form should these take?" and "at what level should they be set?"

(i) The form of the water charge

The supplier of water, whether private or public, incurs two expenses: the initial investment and operating expenses. By comparison with many other types of productive investment, the initial investment in irrigation is high relative to operating expenses. There appear to be at least three good reasons for treating these two charges separately during both the planning

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1. Thornton D.S. and Wynn R.F. (37) p.10.
2. Thornton D.S. (38) p.105.

and operational stages of the scheme: first, the cost of providing the facility for irrigation should be distinguished from the extent to which it is used, second, the costs of operation may vary with time, depending on changing wage rates, salary scales, etc. while the initial investment cost, once incurred, is fixed, and third, where the land-owner and the user of water on that land may be two different parties, charges for the two items fall on different people. A distinction therefore, seems logical between (a) a charge related to the fixed investment and (b) a water rate related to the operating costs, the former no doubt being reflected, where appropriate, in land rent adjustment to tenants enjoying the new facility.

It might be further argued that a distinction should be made between the 'fixed costs' of the regular operation of an irrigation system and the variable costs entailed if water is actually taken, and advocated that a water cess should be regularly levied from potential users in respect of the former and a variable water rate should be charged in respect of the latter. Insofar as there is the need in all irrigation systems to encourage use of water where it is economically beneficial but to discourage waste, a combination of this kind seems desirable. On the other hand, where irrigators are thoroughly at home with the service provided and the usefulness of irrigation water is universally acknowledged there may be little point in the distinction.

Once decisions have been taken on these broad issues the actual form of the water rate - whether on a volumetric basis, whether charged on a single-crop rate or whether applied on a rotational block, will depend on practical considerations. These considerations include the ability of cultivators to apply water meticulously and the cost of metering it, and the amount of control over cropping that the water authority wishes to have. Unsophisticated cultivators appear to suffer from two weaknesses - they tend to rely for too long on rain if the decision of when to water is left to them, and they tend, rather naturally, to over-water if the allocation is left to them. As cultivators' understanding increases, it might be expected that the most economical basis for water rate fixing will tend to shift towards the more precise types, and the forms where the cultivator has greater freedom of choice.

(ii) The level of the water charge

The level of the total water charge will depend in part on the purposes being pursued in irrigation policy. But it seems true that "the achievement of an economically optimal distribution of water among various users is one such purpose which appears to be sacrificed too readily, or unwittingly, to others e.g. taxation or subsidisation of an agrarian economy by means of water charges." 1

In calculating the level of charge two bench-marks are commonly considered: the cost of providing the water, and the value of the net benefits derived by the users. There are those who argue that, while it is necessary to take potential net benefits into account when choosing an

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1. Wynn R.F. (39) p.2.

irrigation scheme, after its introduction the recoupment of cost is the important thing; that these costs should be reflected in the size of the total water charge however this is composed; and that taxation should be treated separately in relation to users' incomes. Otherwise, water will not be used to the best advantage in those locations and on those crops which most repay watering.[1] On the other hand there are those who advocate charges related to additional net benefits, conceived as the difference between revenue-minus-costs after irrigation and revenue-minus-costs before irrigation.[2] Here the argument appears to be that, although there may be difficulties in the calculation (it is seldom possible to attribute gains to increments in one input only, there is the question of indirect and secondary benefits etc.) yet nevertheless there is a surplus similar to the Recardian economic rent on land which can be skimmed off by the supplier of the water.

A suitable solution which retains the incentive element in the water charge yet mops up surplus might be:-

(1) A water rate related to the operating cost, together with
(2) An irrigation tax representing the annual cost of the investment together with a betterment levy (preferably also as an annual rate) which partly or wholly removes gains in land value.

The first would be charged to the user, the second to the landowner. The water rate would vary with the season if stored water provided the supply at some seasons, and in the larger schemes both water rate and irrigation tax might vary with distance from the water source. The degree of detailed variation possible would depend on practical administrative considerations.

Two other different arguments are often put forward. One is that water rates in a predominantly subsistence economy should be related to the farmer's capacity to pay. Another related contention is that small farmers should pay less per unit for their water than large farmers. Assuming however, that the ultimate purpose is to progress towards a state of "informed autonomy" where the water-users can be expected to make a collection of choices which in sum result in optimum water utilisation, any fundamental deviation from the principles stated above would seem to be unreasonable. It would be preferable to treat welfare considerations separately, using such devices as cheap food distribution, tax exemption etc. as long as these are necessary to support the poorest in the community.

In the case of India, two complications must be borne in mind. These are, first, the unreliability of water supplies in many Indian irrigated areas, and second, the need to maintain the water table at its most economic level for the community as a whole and to avoid dereliction from water logging and salinisation. In these circumstances, it would be difficult to avoid introducing some

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1. Clark cites the economically wasteful use of water to irrigated rice in the Murrumbidgee Basin in Australia. (40) p.26.
2. N.C.A.E.R. (28) p.71.

principle of equitability, ensuring as far as possible the survival of crops planted, and at the same time, difficult to do without some 'outline control' of the pattern of cropping to ensure a general pattern of water use which is consistent with a stable water table and the maintenance of soil condition.

In Sudan the introduction of water charges in place of crop-sharing would, especially where cotton is the chief crop, cause greater instability in cultivators' income. This instability might be a very real reason to the farmer for giving up cotton-growing in some areas where the relative advantage of cotton over other crops is already narrow when the cost of water is taken into account. It would here be necessary to consider what price stabilisation measures could be economically introduced. If cotton growing remained a condition of occupying a tenancy some form of incentive income based on performance might be more appropriate than a revenue entirely variable with price. This also would imply an arrangement to achieve some measure of year-to-year stabilisation.

D. THE ACHIEVEMENT OF PLANNED TARGETS

Finally, and underlying the problems of plan formulation and organisational design discussed in the foregoing sections, there lies the problem of assessing what rate of change the rural people are capable of undertaking. Ultimately development depends on what the affected people themselves like and dislike and, to a limited extent, what they can be persuaded to accept as being in their best interests. The necessity of finding effective incentives to optimise water uses and the slowness to utilise irrigation when this is a matter of free choice have both been referred to earlier. Too often, development targets are set in a form and on a scale which reflect the attitudes of mind of those educated in Western culture; as a result the very radical nature of many of the changes proposed is insufficiently recognised.

The provision of irrigation waters to a rainland farmer entails a complete revolution of his way of life.[1] If the water is sufficient only to increase the food supply for a growing population, irrigation implies not only a change in food crops grown but a major change in the length of the growing season and pattern of work. It also implies new relationships with authorities both in water regulation and collection of dues. The disincentives to work may be substantial particularly if there is a fall

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1. This is almost equally true where the source of irrigation water is changed, as in the replacement of Northern Province sagia by diesel pump or where canal irrigation is introduced as a supplement to wells, as in Northwest India.

in the marginal productivity of labour.[1] Where levels of aspiration are so low as to imply that even the standards of nutrition prescribed by Western

1. Ester Boserup makes this suggestion with reference to Indian Farm Management Survey data (41) p.40. Calculation of the marginal productivity of labour from existing data is extremely difficult however. Calculations based on the data for the Research Programme Committee's comparative studies on irrigated and unirrigated farm samples in five widely scattered districts (20) suggest that family labour income (gross output less all other inputs) was greater on irrigated farms in all samples with one exception and that the ratio between gross output and imputed total labour cost was also greater, with the same exception. It is noticeable that in the exceptional case (Damodar I) cropping in the irrigated and unirrigated areas was almost identical being nearly all subsistence crops. Moreover, holdings were smallest in this district.

	% cultivated	Gross Output Rs/acre total area	Family Labour Income Rs	Labour Input Rs/acre		Ratio of G/O to Total Labour
				Family	Hired	
Irrigated Sample						
Gang (Rajasthan)	92	166	35·1	17·6	17·6	4·59
Sarda (Uttar Pradesh)	80	252	130·2	35·4	17·3	4·78
Tribeni (Bihar)	94	732	456·4	9·4	54·9	11·4
Damodar*I (West Bengal)	99	312	16·0	46·6	66·6	2·76
Damodar II (West Bengal)	99	276	35·0	38·1	49·7	3·14
Cauvery-Mettur (Madras)	95	328	31·3	21·0	57·2	4·20
Unirrigated Sample						
Gang (Rajasthan)	58	57	20·3	11·0	3·1	4·05
Sarda (Uttar Pradesh)	67	230	123·1	41·2	14·3	4·15
Tribeni (Bihar)	98	268	76·1	14·1	34·9	5·47
Damodar (W.Bengal)	92	203	16·6	35·5	35·6	2·86
Cauvery-Mettur (Madras)	65	81	-13·2	26·1	20·7	1·73

* I irrigation introduced 1933
II irrigation introduced 1955

dieticians represent luxury[1], the mental and physical effort required by the change to irrigated agriculture may be beyond the ability of many of the present adult generation.

If the intention is that the water available should be at least partly used for cash-crop production the attractiveness of goods which can only be obtained for cash must already exist in the rural population to induce an increase in total output or to induce substitution of food crops by higher value cash crops.

Rural societies may be expected to show a variety of stages in the subsistence-commercial transition at any one time. In Sudan, the bulk of the irrigated areas are still in the stage of combining one cash crop with an assured food and fodder supply, and development plans for new areas include a staple food crop. In the Northern Province in some of the densely populated pumpschemes near the Khartoum market, cultivators are beginning to sacrifice the assurance of their food supply for high-earning cash crops.[2]

In India many new irrigation schemes are planned on the basis that a proportion of the area will be devoted to cash crops. For instance in the Rajasthan Project the following cropping is foreseen:-[3]

Non-perennial Stage				Perennial Stage			
Kharif		Rabi		Kharif		Rabi	
Cotton	10	Oilseed	10	Cotton	10	Oilseed	7
Rice	5	Wheat and		Sugar & gardens	1	Wheat	20
Fodder	5	Mixed rabi	10	Foodgrains	19	Fodder	3
Other kharif	20			Fodder	3	Other rabi crops	15
	40%		20%		33%		45%

There is marked evidence, moreover, that at least in the rather more advanced Punjab, supply response to cash crop market prices is positive.[4]

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1. Kusum Nair quotes cases where nutrition standards are so low that one meal a day is normal and yet where ambition is to farm very little more than is farmed at present (42) p.31.
2. For instance in Gendettu Government Scheme it is increasingly common to find fasulia (tick beans) and citrus fruit replacing grain crops. The expectation of financial support from emigré relatives may be an important factor ensuring survival in some cases, however.
3. Rajasthan Canal Board. Private Communication July 1965.
4. Raj Krishna showed short-term supply responses for cotton to be 0·6 - 0·7 and long-term responses to be as high as 1·6 (as compared with lower responses for food crops and a negative response for jowar)(43) p.477

Yet even where sensitivity to commercial stimuli is well developed, the preference for leisure (or the desire to preserve traditional social behaviour) may be such as to cause farmers to fall far below the personal performance planned for them. Sudan's irrigated areas provide a good example. In the long-established parts of the Gezira Scheme, the time devoted to work by the tenants and their wives has fallen to very low levels. One estimate[1] put the percentage of tenants' time spent on agricultural work as low as seven; it has become customary for the appearance of wives in the field to be regarded as bad for personal prestige. Attempts in planning future development to design holding sizes suitable for self-contained farm families ignore the high preference for leisure (and the willingness to spend a high proportion of a moderate income on hired labour) among the Northern Sudanese farmers.

Undoubtedly levels of aspiration will rise as consumer goods become increasingly desired and 'standard'. It does not necessarily follow however that all farmers and their sons will be prepared to step up their efforts (in labour and capital inputs) to achieve higher levels of consumption if returns to increased units of input tend to fall or remain uncertain.

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1. Unpublished data of Ministry of Agriculture inquiry on Costs of Production in Gezira Scheme.

III. RESEARCH OPPORTUNITIES

The purpose of this brief section is to draw attention to three particular areas of research amongst a wide variety of possibilities in which economists can make valuable contributions. Economists have, in general, a synthesising role in both positive and normative studies, bringing together materials from engineering and the natural and social sciences, as well as considerations in the field of politics and administration, and using them in a framework of economic thinking. All of the following themes for research have this character.

1. Investigation and planning of agricultural production against a background of fertility maintenance and soil-water stability.
2. Study of social and administrative patterns in the light of declared objectives, giving particular attention to the dynamic elements of social development.
3. Study, at the river-basin and national levels, of the integration of various productive activities using water supplies.

Theme 1

So far, the planning and practice of water utilisation in irrigated areas have been rather crude, far cruder in fact than those of the engineering of installations for water control. The watering regimes prescribed have been suitable for semi-skilled users and have reflected our incomplete knowledge of the water requirements of crop plants. Moreover, in areas of porous soils, insufficient thought has been given to the long-term effects of different regimes of irrigation. The scarcity of water resources and suitable land, together with the increasing demand for the products and services which can be derived, make it increasingly urgent to improve utilisation. The combination of water with other resources is the crucial task of the economic planner and he is most useful in investigating the characteristics of present patterns and planning changes where desirable and feasible in the light of knowledge and experience already to hand.

What is required however is seldom just that which can be yielded by a simple static, single-year programming exercise. The degree of sophistication in the economist's approach must often be adequate to provide solutions to

(a) optimal courses of action in the face of variable product prices (bearing in mind that the variations in the national or world market price of a prominent cash crop may, through their effects on local incomes, affect demand for, and therefore prices of, other products consumed locally);

(b) optimal choices in the fall of a water supply subject to year-to-year fluctuations which are predictable only within wide limits;

(c) optimal long-term production policies which take into account long-term effects on soil fertility and depth of sub-soil water - this

fascinating problem introduces very complex economic questions, particularly when, as is often the case, more than one source of water and different modes of making it available are involved.

The effectiveness of the economist's contribution is partially dependent on the state of knowledge on the consumptive use of crop plants and their water requirements under different environmental conditions and, on a wide range of other technical research. Indeed, the range of material is potentially so wide that the technical researcher can legitimately expect guidance from the economist as to the experimental programme and designs most likely to provide useful data. For instance, if, in respect of a particular irrigation scheme, the economist can indicate that the opportunity cost of units of irrigation water differs from place to place and from time to time between seasons, the natural scientist can focus his search for ways of economising in the most costly units of water, whether by modifying watering regimes, sowing dates, fertiliser applications, plant varieties etc.[1] Similarly, in relation to the project engineers, the economist has the responsibility of suggesting ways in which the project design and development programme might be modified so as to achieve preferred material and social objectives.

It is particularly in the examination of complex production problems and the formulating of practical plans, and in suggesting further research and investigation programmes, that mixed scientific teams or Working Parties have their value.[2] This value is enhanced moreover if periodic reviews can be made using new research data.

The economist has one further role in this work - it is to form an accurate appraisal of the material and social objectives of those concerned in the development project so as to ensure that the appreciations and plans have relevance to what they wish to do and are capable of doing. For this he employs material assembled under Theme 2.

Theme 2.

A truly useful study of social and administrative patterns requires the development of socio-economic surveys in two main ways:-

(a) the devising of effective techniques for judging more accurately how the human and social characteristics of rural communities are changing (in respect of both the aptitudes and attitudes of individuals)

(b) to place greater emphasis on the economics of alternative organisational structures.

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1. The simple objective of yield maximisation regardless of market requirements and local costs is far too naive, as most commercial producers recognise.
2. Two notable examples are the Panel of the White House and U.S.Department of Interior on Waterlogging and Salinity in West Pakistan (30) and the Sudan Ministry of Agriculture's Working Party on Production Planning in the Gezira (44).

Under the first heading at least two approaches may be fruitful. On the one hand, historical examination may provide indications of those institutional changes to which people have responded in the past; from such study might be formed an estimate of the incentive contained in particular agrarian reforms such as increase in security of tenure, sub-division of holdings, etc., or in measures to modify prices, by guaranteeing minimum levels, reducing year-to-year and seasonal variations, and so on.

On the other hand, the adoption of techniques of the social psychologist may discover the less transitory values which colour the attitudes and responses of rural people in development areas. The more standard type of socio-economic survey, which seeks to assess basic measurements such as the general level and variations in standards of living among cultivators, and to describe the characteristics of social structure, is essential in the first instance and increases in value when repetition is sufficient to indicate rates of change. But the planner ideally requires some indications of the effects which introduced changes may have. Changes of mind tend to take place rapidly within societies suddenly pitch-forked from a static to a developing condition such as frequently occurs upon the introduction of irrigation. The reactions to further changes of the family heads themselves are not always predictable and the attitudes of the younger generation may be even less so. While the perfecting of such techniques and their innocuous application in the field are by no means easy, even tentative results might prevent the worst errors which arise when administrators, in the absence of evidence, have to assume that the psychological characteristics of the people involved will remain indefinitely the same over time or will be similar as between existing and new areas of development.

By the same token we may expect highly useful results to flow from similar investigations made at a suitable interval <u>after</u> radical changes have been introduced because, obviously, the type of change and the manner in which it is effected will have a marked influence on the states of mind of the people involved.

Under heading (b), the economist has a role to play which overlaps that of the business administrator. Both must be interested, for instance, in how much to spend in any one development area on educating the cultivators, how to devise a practicable system of water charges which produces the desired effects in the distribution and efficiency of water use, whether subgrouping of cultivators for certain production or marketing functions is likely to increase their satisfaction, and so on. A difficulty of investigating existing practices, which is shared by historical inquiries of the kind mentioned above, is that clear cause-effect relationships can seldom be established with certainty even if the researcher is fortunate enough to be able to investigate alternative institutions operating in fairly similar environments. Comparisons may be unduly influenced by, say, the personalities of individuals involved, or unknown social factors. Nevertheless indications of the comparative merits of alternatives may have some value. Provided they are done carefully, experiments

may be incorporated in planned development.[1] (Alternatively, of course, increased freedom may be given, in some cases, to private enterprise - as for instance in the relaxation of controls on holding size and cropping pattern - so as to allow the market to determine certain organisational characteristics which would otherwise be decided arbitrarily).

Theme 3

This is a field of research activity which has characteristics similar to those described in the preceding themes. The main difference is the large-scale level at which investigations must proceed. It is clearly necessary to study the economics of alternative patterns of water utilisation in river basins as a whole and, equally important, to find the optimal sequence of development, bearing in mind the importance of time (and uncertainties linked with time) in any dynamic enterprise.

At this level conclusions must necessarily be more generalised - the difficulties of placing values on such benefits as protection against soil erosion, on power supplies ten years ahead, etc. make this inevitable. The need for outline plans and policies within which to develop local projects in detail is nevertheless vital.

A variety of tools are available for use in this work.[2] Nevertheless the complexity of some of the choices involved is such that methodological innovation may well prove necessary, perhaps particularly in devising new and acceptable ways of establishing the values of benefits and costs which have hitherto not been quantified.

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1. A good example of an experiment in the effectiveness of extension is that carried out by Michigan State University (46).
2. See particularly Maass et al. (45)

APPENDIX 1 MISCELLANEOUS COMPARATIVE DATA

Population	Sudan	India
Total Population (Millions)	10·25 (1955/6)[1]	439 (1961)[2]
Area (Million sq.miles)	0·97	1·22
Population density (per sq.mile)	10·6	370
Crude Births/1000	51·7	41·7
Crude Deaths/1000	18·5	22·8
Annual Net Increase %	3·3	1·9
% dwelling in rural areas[3]	92	82
% dwelling in urban areas[3]	8	18
Estimates of Annual Net Increase (%) 1958-1963[4]	2·8	2·3

Irrigation[5]

1. Estimated net area irrigated and cropped in 1961:-
   Sudan 1·84 million acres
   India 56·2 million acres

2. Predominant forms of irrigation (as % of net area irrigated and cropped)
   Sudan - Gravity fed 56%
   Pump-lifted 41%
   India - Gravity fed from canals 41%
   Gravity fed from tanks 19%
   Pump lifted from tube wells 3%
   Pump lifted from other wells 27%

3. Estimated % of usable river flow being utilised in 1965 -
   Sudan[6] - 46%
   India - 36%

Gross Domestic Product[7]

	Sudan	India
Breakdown of G.D.P. 1962		
Agriculture	55	45
Mining	-	1
Transport and Trade	16	16
All other	29	38
Annual rate of growth	1956/61	1953/60
Overall	4·7	3·5
Per head	1·2	1·4
In agriculture	4·2	2·4
National Income 1962 (Millions)	£S394	Rs.154,000
Approx.income per head (£ sterling)	32·6	25·5

Notes:-

1. Population data for Sudan are taken from the First Population Census 1955/56. Final Report 1962 (47).
2. Population data for India are taken from the India Reference Manual 1964 (48).
3. The comparative sub-division between Rural and Urban population can only be approximate due to the use of slightly different definitions.
4. United Nations Statistical Yearbook. 1964. (49)
5. Data for Sudan are assembled from various sources and estimates: data for India are taken from the Third Five Year Plan. Govt. of India Planning Commission, pp.380-382. (3)
6. Taking into account the 18½ Milliard cubic metres allowed Sudan under the present Nile Water Agreement but not taking into account any further supplies likely to be made available by canalisation of the Sudd.
7. Data from United Nations Statistical Yearbook 1964. (49).

APPENDIX 2

NOTES ON MULTI-PURPOSE SCHEMES OF MORE THAN ONE MILLION ACRES, SUDAN AND NORTHWEST INDIA

1. GEZIRA (Sudan)

Objectives. Irrigation and settlement with H.E.P. as a minor afterthought. Begun in 1914; Managil extension begun 1959; power plant 1964.

Units of Construction
(1) Sennar Dam on Blue Nile
(2) Gezira Main area
(3) Managil Extension
(4) Sennar Power unit.

Irrigation C.C.A. 1·7 m.feddans. Intensity 44% (Gezira), 66% Managil; Gezira intensity now being raised with supplementary water (see below)

H.E.P. Two units (15 MW), firm power in 80% year 6·4 MW.

Cost £S64·3 M.[1] (Irrigation) £S2·8 M.[2] (power)

Control Sennar Dam - Min.of Irrigation. Irrigated area - Sudan Gezira Board.

N.B.1. See SHAW (35) p.203; includes housing, services etc.
2. See Sudan Economic Planning Secretariat, Min.of Finance and Economics (17) p.113.

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2. ROSEIRES (Sudan)

Objectives. Irrigation, settlement and H.E.P. To be linked in operation with Sennar. Begun 1960.

Units of Construction
(1) Roseires Dam First Phase with power units on Blue Nile.
(2) Intensification and extension of pumpschemes and existing gravity-fed areas.
(3) Right Bank link canal and irrigation projects.
(4) Roseires Dam Second Phase with power units.
(5) Left Bank development.

Irrigation 0·3 M.feddans extension of existing areas, 1·1 M feddans on Right Bank[1]; 2·615 M.feddans on Left Bank.Intensities 66-78%

H.E.P. Total installation 7 sets (210 MW). First Phase will provide 24 MW firm power and 1·6 MW increase at Sennar; Second Phase an additional 6 MW.

2. ROSEIRES (Sudan) (Continued)

Cost — Extension £S9·25M [2]
Major R.B. and L.B. developments, including headworks, canalisation, drainage, housing, services etc. estimated at £S216·2M[3]. Processing and agricultural plant an additional £S27·4 M.(i.e. £S70 + £S8·6 per feddan as compared with Managil £S55 per feddan).

Roseires Dam £S23·43M [2]

Control — Roseires Dam - Min. of Irrigation.

N.B. 1. Assumes incorporation of Rahad River flood water
2. See Sudan Economic Planning Secretariat, Min.of Finance and Economics (17) p.85.
3. See Sudan Ministry of Finance and Economics (50) p.36.

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3. BHAKRA - NANGAL (Punjab and Rajasthan)

Objectives — Irrigation[1] and H.E.P. Some automatic flood control and opportunity for riverain reclamation. Begun 1948.

Units of Construction
(1) Bhakra Dam and power units on Sutlej
(2) Nangal Dam, 8 miles downstream
(3) Nangal Hydel Channel (39·6 miles long)
(4) Ganguwal and Kotla power stations on Nangal Channel.
(5) Remodelling of existing Rupar diversion headworks and Sirhind Canal (35% increase in capacity)
(6) Bhakra Main Line and distributaries.
(7) Bist Doab canals
(8) Transmission of electric energy to Delhi.

Ludhiana and Panipat-Hissar.

Irrigation — Total area "included in irrigation boundary" 6·7 M.acres, together with improvements affecting another 3·5 M.acres. C.C.A. with available water 3·6 M.acres in three areas.

(i) South of Rupar, good rainfall, 'restricted perennial' flow (45% intensity 2·25 cusecs water allowance).
(ii) N.and S.of Sutlej River W. of Rupar - perennial replacing former inundation canals.Non-perennial flow (35% intensity 3·75 cusecs water allowance).
(iii) Perennial[2] irrigation in Rohtak, Hissar and Rajasthan (62% intensity 2·75 cusecs water allowance).

Note that year-to-year variation in Sutlej flow is likely to provide an average stored supply of 4·6 M.acre feet, sometimes falling to 2·9 M., as compared with storage of 6·2 M.acre feet, required to meet the specified irrigation requirements of the 1953 plan.[3]

H.E.P.[4] Bhakra Left Bank 5 units, 450 MW., three units being devoted to fertiliser (ammonium sulphate) - heavy water production.

Bhakra Right Bank 5 units, 600 MW
Nangal Channel 6 units, 154 MW
Total firm power quoted at 400 MW or 680 MW at 60% load factor[3]

Cost Irrigation (including remodelling of Sirhind Canal) R108·59 Cr
Total project R 175 Cr.

Control Development-Bhakra Control Board.

N.B. 1. Some areas developed served to settle refugees
2. 'Perennial' means mainly two seasons Kharif - Rabi
3. RAJ K.N. (7) p.59.
4. Based on B.R.Palta (51). These figures compare with total 699 MW. scheduled in first three Five Year Plans (see Planning Commission, India (3) p.417), and 952 MW.reported in Min.of Information and Broadcasting (48) p.251.

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4. CHAMBAL (Rajasthan and Madhya Pradesh)

Objectives Irrigation and H.E.P., the benefits divided equally between the two States. Begun in 1953.

Units of Construction (1) Ghandi-Sagar Dam with power units
(2) Rana Pratap Sagar Dam with power units
(3) Kotah Dam with power units
(4) Kotah barrage
all interlinked on the Chambal river to supply
(5) Two main irrigation channels

Irrigation C.C.A. Right Bank 1·2 M.acres
Left Bank 0·2 M.acres

H.E.P. Ghandi Sagar 115 MW[1]
Rana Pratap 129 MW
Kotah Dam 100 MW

Cost Irrigation only Rs.54·85 Cr.[2]

Control Co-ordination of development-Chambal River Board.

N.B. 1. Given in Min.of Information and Broadcasting (48) p.251. The third Five Year Plan gives 92, 128 and 78 MW respectively.
2. Given in Planning Commission India (3) p.413. Total 1958 estimate given in Indian Journal of Power and River Valley Development (52) shows irrigation to be some 75% of total project cost.

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5. RAJASTHAN CANAL (Rajasthan)

Objectives	Irrigation and Settlement. Began 1958
Units of Construction	(1) Harike Barrage on Sutlej River (2) Rajasthan Feeder Canal (lined) (3) Rajasthan Main Canal and distributaries (4) Pong Dam[1] on Beas River together with (5) Beas-Sutlej link with power units utilising 1000 feet fall.
Irrigation	Gross area commanded 5 M.acres. C.C.A. 3·69 acres (2·347 M.acres to be irrigated by gravity, 0·528 M. acres to be irrigated by pumps.)
H.E.P.	Beas Project, producing 240 MW in first stage[2].
Cost	Canals and Harike Barrage R140·26 Cr. Housing, services, extension etc. R149·8 Cr. Share of Pong Dam R43·83 Cr.
Control	Overall control of works and canalisation by Rajasthan Control Board, with 20 year master plan. Colonisation Commissioner in charge of settlement. A high level State Committee to co-ordinate development activity in Rajasthan.

N.B. 1. The Pong Dam and Beas-Sutlej Link Projects together with existing Ravi-Beas link, are designed to increase irrigation supplies and their certainty throughout the Punjab-Rajasthan network, but most benefit will fall to the Rajasthan Project area.

2. See Planning Commission India (3) P.420; quoted at 756 MW. in Min.of Information and Broadcasting (48) p.252.

REFERENCES

(1) Programme Evaluation Organisation, India. "Study of the Problems of Minor Irrigation" P.E.O. Pubn.No.40. 1961.

(2) RAO, V.K.R.V. "Agricultural Development in the Fourth Plan." Govt.of India Planning Commn.1966.

(3) Planning Commission, Govt.of India "Third Five Year Plan". Govt.of India Press, 1961.

(4) Registrar of Co-operatives, Rajasthan. "Co-operation in Rajasthan 1960" State Govt.Press.

(5) Indian Council of Agricultural Research. "Crop Patterns for the Bhakra Canal Area" I.C.A.R.Bull.No.87 1961.

(6) Board of Economic Inquiry, Punjab. "Effects of Bhakra Dam Irrigation on the Economy of the Barani Villages, Hissar Dist.1961-2". Pub.No.102.1964.

(7) RAJ, K.N. "Economic Aspects of the Bhakra Nangal Project" Asia Pub.Co. 1960.

(8) ANSARI, N. "Some Economic Aspects of Irrigation Developments in N.India" Jl.of Agrarian Affairs. Vol.IV.No.1. 1963.

(9) Min. of Food & Agriculture, India. "Intensive Agricultural District Programme Report 1961-63."

(10) PRASHAR C.R.K. and SINGH M. "Soil Moisture Studies and the Effects of varying Levels of Irrigation and Fertilizers on Wheat under Intensive System of Cropping". Indian Jnl.of Agri.Sci.Vol.33 June 1963 No.2 p.91.

(11) TOTHILL J.D. "Agriculture in the Sudan" Oxford U.P.1948.

(12) THORNTON D.S. "The Organisation of Production in the Irrigated Areas of the Sudan". Journal of Agricultural Economics Vol.XVI No.2. Dec.1964.

(13) TEWFIG HASHIM AHMED "The Future of the Gash Delta in Eastern Sudan". Proc.of the Phil.Soc.of Sudan. 13th Annual Conf.1965.

(14) GADGIL D.R. "Pravara Kaskhana Ltd.an Interpretative Account" Sangem Press 1961.

(15) GAITSKELL A. "Gezira; A Story of Development in the Sudan" Faber and Faber 1959.

(16) SULIMAN A.A. & SHAW D.J. "Problems of Income Stabilisation in Developing Countries: A Case Study of the Gezira Scheme".(1966 Forthcoming).

(17) Economic Planning Secretariat,Sudan Min.of Finance & Economics. "The Ten Year Plan of Economic & Social Development 1961/2 - 1970/1" Khartoum Govt.Printing Press 1962.

(18) National Council for Applied Economic Research, India. "A Strategy for the Fourth Plan" Nov.1964. Occasional Paper No.11.

(19) CLARK C.and HASWELL M.R. "The Economics of Subsistence Agriculture". MacMillan 1964.

(20) Research Programmes Committee.Planning Commission India. "Criteria for Appraising the Feasibility of Irrigation Projects" Govt.of India Press 1964.

(21) GADGIL D.R. "Economic Benefits of Irrigation.Report of a Survey of the Direct & Indirect benefits of the Godavari & Pravada Canals".Gokhali Inst.Pub.17. 1948.

(22) Sub-Committee on Benefits and Costs "Proposed Practices for Economic Analysis of River Basin Projects". Report to U.S. Federal Inter-Agency River Basin Committee. 1950.

(23) SOVANI N.V. & RATH N. "Economics of a Multi-purpose River Dam". Gokhali Inst.of Politics & Economics.1960.

(24) NAIR, K.R. "Capital Growth - Indian Agriculture" Ind. Jnl.of Ag.Economics.Vol.XX No.1.Jan.1965.

(25) WYNN R.F. "Water Resource Allocation in the Sudan: an Economic Problem". Proc.of the Philosophical Soc.of the Sudan. 13th Annual Conf.1965.

(26) RAO V.K.R.V. & NARRAIN D. "Foreign Aid and India's Economic Development" Asia Pub.House.1962. p.82.

(27) SAM IBRAHIM EL KHATIM "Casual Labour and its Importance in the Gezira Scheme."Unpub.M.Sc.Thesis. University of Khartoum 1966.

(28) National Council of Applied Economic Research,India. "Criteria for fixation of Water Rates and Selection of Irrigation Projects". Asia Pub.House.1959.

(29) van der TAK H.G. & SCHMEDTJE J.K. "Economic Aspects of Water Utilization in Irrigation Projects".I.B.R.D. and I.D.A.Report EC 132.1965.

(30) Panel of White House & U.S. Dept.of Interior on Water-logging and Salinity in West Pakistan. "Report on Land & Water Development in the Indus Plain". White House.Washn. D.C.1964.

(31) Krishna - Godavari Commission. Report,1962 Govt. of India Press.

(32) YAHYA A/MAGID AHMID "Nile Control for Agricultural Development in the Sudan".Proc.of the Phil. Soc.of Sudan, 13th Annual Conf.1965

(33) Jonglei Investigation Team "The Equatorial Nile Project" Khartoum 1954

(34) SHAW D.J. "Recent Developments in the Gezira Scheme" Land Reform, Land Settlement and Co-operatives No.2.1964.F.A.O.

(35) SHAW D.J. "The Development and Contribution of Irrigated Agriculture in the Sudan". Proc.of the Philosophical Soc.of Sudan 13th Annual Conf.1965.

(36) SIMPSON I.G. "Economic Aspects of Diversification in the Gezira" Proc.of the Phil.Soc. of Sudan 13th Ann.Conf.1965.

(37) THORNTON D.S. & WYNN R.F. "An Economic Assessment of the Khasm-el-Girba Project". Research Paper No.1 Dept.of Rural Economy.University of Khartoum.

(38) THORNTON D.S. "A Comparative Study of Pumpschemes in the Northern Province".Dept.of Rural Economy. University of Khartoum 1965.

(39) WYNN R.F. "A Note on Costing Water Supplies for Irrigation" Journal of Sudan Agricultural Soc.Vol.1.1965.

(40) CLARK C. "The Economics of Irrigation" Indian Journal of Agricultural Economics. Vol. XIX. July 1964.

(41) BOSERUP E. "Economics of Agrarian Change under Population Pressure". George Allen & Unwin Ltd. 1965.

(42) NAIR K. "Blossoms in the Dust" Duckworth 1961.

(43) KRISHNA R. "Farm Supply Response in India-Pakistan: A Case Study of the Punjab Region". Economic Journal Vol. LXXIII. Sept. 1963.

(44) Sudan Ministry of Agriculture Working Party. "Agricultural Development in the Gezira Scheme, Interim Report". (Mimeograph) 1965.

(45) MAASS A. et al. "Design of Water Resource Systems" MacMillan 1962.

(46) NIELSON J.& CROSSWHITE W. The Michigan township extension experiment. Mich. Agr. Exp. Sta. Tech. Bull. 274. Oct. 1959.

(47) Sudan Dept. of Statistics. "First Population Census 1955/6. Final Report" 1962.

(48) Min. of Information & Broadcasting, India. "India A Reference Annual" July 1964.

(49) United Nations "Statistical Year Book" 1964

(50) Min. of Finance & Economics, Sudan. "Memorandum on Utilisation of Water from Roseires Reservoir". Jan. 1966.

(51) PALTA B.R. "Bhakra-Nangal Project nearing Completion" Indian Journal of Power and River Valley Development. March 1962.

(52) Indian Journal of Power and River Valley Development. "The Chambal Project" May and July 1958.

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