SMALLHOLDER IRRIGATION

ECONOMIC CONSIDERATIONS TO THE DESIGN OF SOCIO-TECHNICAL SYSTEMS

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U N I V E R S I T Y O F R E A D I N G

DEPARTMENT OF AGRICULTURAL ECONOMICS AND MANAGEMENT

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This dissertation is dedicated to one of the least advantaged smallholders of all : the "paysan" of Haiti.

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FOREWORD

Literature on irrigation is over-abundant. To keep up with abstracts on literature on irrigation may even be no easy task. Why then the "felt need" to contribute some more?

The reasons are mainly twofold:

Firstly because in all this abundance, information about the intended beneficiaries of irrigation and their interrelationships with irrigation systems is rare. Exceptions are some location specific studies which by nature are subject to 'limitations of the special case'.[1)]

Secondly, because it is my feeling that the speech of Mc Namara in Nairobi in 1973, which is often regarded as a turning point which brought about increased attention to the rural poor in the Third World, has left irrigation planning largely untouched. In this respect, it has been pointedly suggested that "irrigation experts would prefer to continue their merry way'.[2)]

Both considerations have seduced me to engage in this exploratory and conceptual study of a broad subject inspite of limitations of time and inspite of well intended warnings as to the possible pitfalls in doing so.

My thanks are due to Dr.D.S. Thornton, my tutor, whose longstanding concern in "people and irrigation" have spured my own interest and to Dr.H. Walker whose enthusiasm in the subject added much to the same.

Last not least thanks are due to my wife Monika who did the drawings and the typing and whose excellent job may not be able to hide the german tilt of my english.

I am solely responsible for the paper.

Reading/England, 30.8.1983

Walter Huppert

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1) CHAMBERS (1977)

2) AYRES (1983) p. 109

1. INTRODUCTION

Information concerning the worldwide or country-wide importance of irrigation usually focuses on its distribution in terms of area irrigated. Detailed and recent data are available in this respect[1]. In contrast however, data on people involved in irrigated agriculture are not easily accessible and cross-country-comparisons are sparse.

Likewise, books and treatises continue to be published that cover general aspects of irrigation but hardly refer to its intended users. And large capital investments are undertaken in irrigation, without taking the viewpoint of the officially stated "beneficiaries" into account.[2]

This is why the basic question to which this dissertation is trying to explore some answers in economic and socio-economic terms, is the question CARRUTHERS and CLARK ask in a self-critical way when admitting the neglect of farmers in own writings about irrigation:

'Could there lie behind this admission, which on reflection reveals a widespread attitude, a partial explanation for poor performance of plans ?'[3]

Such a question appears to be important since the performance of irrigation __is__ poor in many contexts, while its importance is growing at the same time.

With reference to Africa e.g. the "Berg-Report" of the World Bank[4] notes that in spite of considerable investment in irrigation development in the 1970's, total cultivated areas hardly increased in a number of countries due to the need to abandon or rehabilitate parts of the developed area[5]. In India. of 30 million hectares of potential surface-irrigation area only about 1/3 is effectively irrigated[6] and FAO has estimated that roughly one-half of the world's

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1) e.g. IBRD World-Development Report 1981/82; FAO Prod.Yearbook 1977
2) compare references quoted in para 3.2.5.1
3) CARRUTHERS and CLARK (1981) p. 209
4) WORLD BANK (1981) p. 76
5) ibid.
6) SECKLER (1981) p.5

irrigated land is subject to serious declines in productivity resulting from salinization[1]. In all of those cases the problems are predominantly due to human factors in irrigation.
Such considerations point to the socio-technical nature of irrigation schemes and to the need to take the interactions between people and technology in irrigation increasingly into account if improvements are intended.
And the need for such improvements is evident even if only on very pragmatic grounds: funds are already committed to bring approx. 2.5 million hectares of newly irrigated land into production each year till 1985, a figure which is likely to rise thereafter [2].

Attention in this dissertation therefore is focused on the socio-technical nature of irrigation schemes in low income countries (LIC's), problems involved in planning-approaches that neglect this nature - refered to as "conventional" irrigation - and on some explicitely exploratory considerations related to orientations of potential improvements.

The dissertation is based in three premises:

1) that irrigation development cannot be successful unless people involved in it are willing to cooperate
2) that people involved in irrigation are rational decision-makers, and that the decisions they make are largely determined by the social structures and reward-systems in which they live.[3]
3) that irrigation schemes in LIC's are intended to help the rural poor[4], even if there may be multiple other goals.

The term "smallholder" throughout this paper is meant to refer to actual or potential water users, whether owner-operators, tenants or owner-tenants, who rely largely on family labour, who occupy a little or least advantaged socio-economic position in their institutional environment and for whom risk-avoidance considerations are predominant in the way described in chapter 4.

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1) BERRY, FORD and HOSIER (1980) p. 3
2) ibid., p. 2
3) BIGGS (1978) p. 257
4) officially stated in most irrigation appraisal reports; assumed by BOTTRALL (1981) with reference to World Bank policies.

2. A SYSTEMS-APPROACH TO SMALLHOLDER IRRIGATION

2.1 General

Irrigation systems comprise people, water distribution networks, vehicles, buildings, roads and numerous other elements that are organized on the basis of intricate and complex interrelationships. This is why it may be difficult in practice to relate particular results of irrigation efforts to a well defined set of inputs, since a number of other factors may have contributed to such outcomes as well.

From this follows that prior to attempts to manipulate such a system in a preconceived manner or to predict its behaviour in given circumstances, it is essential to identify and describe its nature, i.e. to proceed according to a "systems-approach". SPEDDING defines a "system" as

> 'a group of interacting components, operating together for a common purpose, capable of reacting as a whole to external stimuli: it is unaffected directly by its own outputs and has a specified boundary based on the inclusion of all significant feedbacks.'[1]

Systems as defined in this way may comprise various "subsystems" that can be identified seperately and that describe the specific effects of changes in one or a set of components on the output of the system.[2] On the other hand, systems themselves are subsystems in a wider systems-context. An important consideration in systems identification relates to the definition of the system boundary, since deficiencies in boundary definition, i.e. in subsystem-selection from the larger overall system can have "incorrect, undesirable or deleterious results" in dealing with the system[3].

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1) SPEDDING (1979) p. 18
2) ibid. p. 30
3) DE GREENE (1973) p. 26

2.2 Irrigation schemes as socio-technical systems

Irrigation systems are socio-technical systems and are as such distinct through the fact that they comprise a human and a technical subsystem. Moreover, socio-technical systems are open systems, i.e. they are dependant upon the environment and there are continuous interchanges with the environment.
However, as mentioned in the above quoted definition there is supposed to be no significant "feedback", i.e. the system has to remain largely unaffected by its own outputs, if boundary selection has been appropriate.
WALKER illustrates such characteristics of an irrigation system by way of a schematic graph that is depicted in FIG. 2.1 [1] In the interpretation of such an illustration however, it is essential to emphasize dynamics rather than statics, as well as feedback relationships and the complexity of interactions.

Apart from the above mentioned features, socio-technical systems have a number of other particular characteristics which deserve attention when focussing on irrigation schemes:
Firstly, they are highly complex, i.e. there is a multitude of interrelationships both within the system as with the environment.[2] Secondly and as a result of this, the boundary of such systems has to be seen as dynamic, flexible and permeable. 'An element can be a member of more than one system at a given time and a member of one system at one time and another system at a later time'.[3] And thirdly, socio-technical systems are goal-oriented.[4]

2.3 Systems approaches to irrigation

Cybernetics, a particular systems concept, dating back to the 1940's and widely applied in the study of dynamic properties of organizations[5] takes the goal orientation of socio-technical systems into

1) WALKER (1981) p. 50
2) HILL et. al (1976) as quoted in WALKER (1981) p. 27
3) DE GREENE (1973) p. 4
4) ibid., p. 34
5) DE GREENE (1973) p. 41

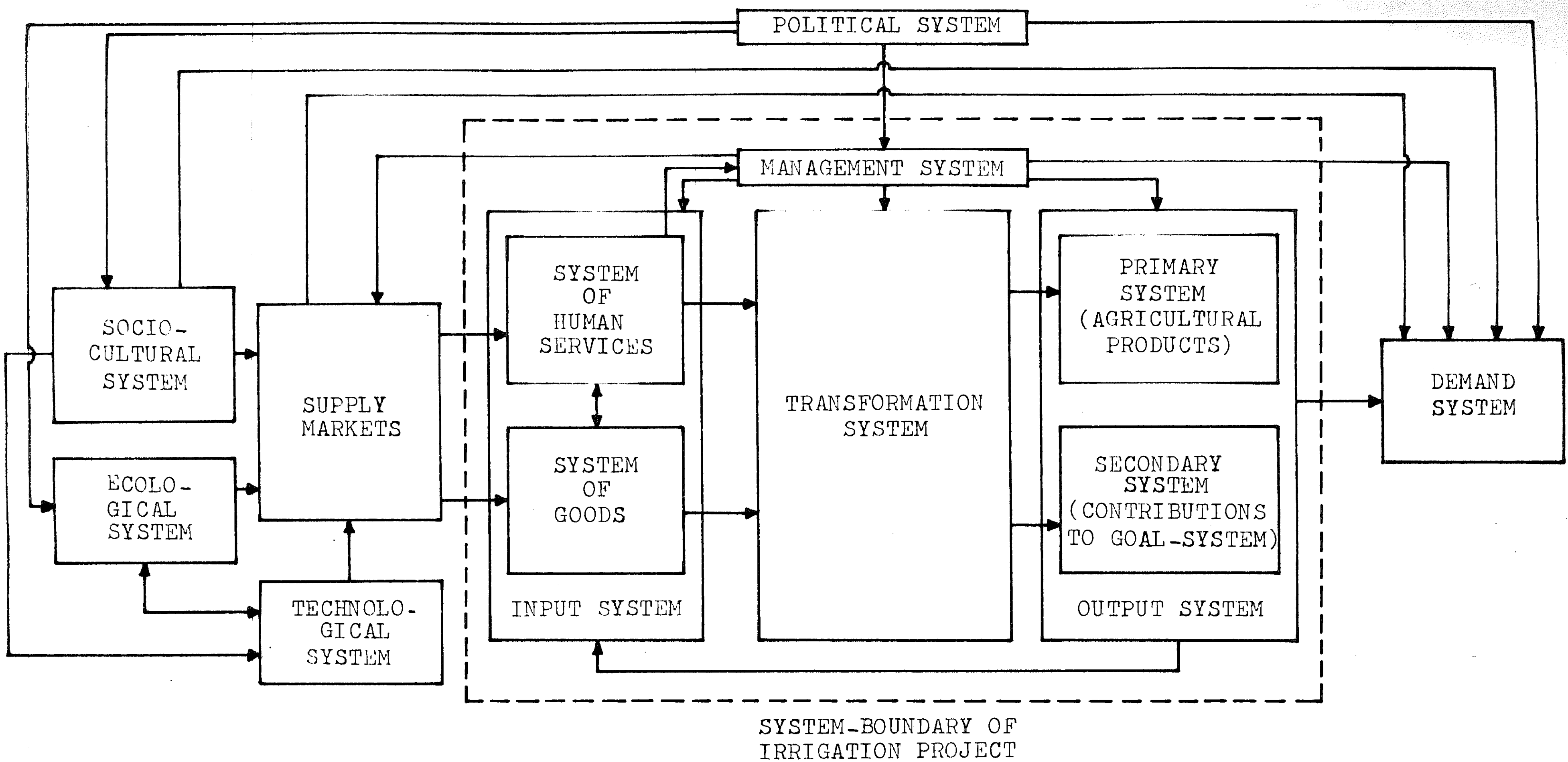

FIG. 2.1 The systems-context of an irrigation-organisation.

source: WALKER (1981) p. 51

account. It attemps to "steer" this inherent goal-orientation of an organization to predetermined ends utilizing information feed back for the ongoing measurement of the performance of a given organizational design. Thus actual performance is continuously compared with preconcieved goal-levels and management control is used for corrective action to reduce the disparity between actual and desired performance [1]. Such concepts focus on the performance of isolated functions similar to assembly-line operations and are hence to a large extend "inward looking", i.e. concentrated on the system and its subsystem, with less emphasis on the nature and relationships of the system as a subsystem in its environment.
Systems approaches of cybernetics are largely applied in engineering and industry.
In contrast to systems approaches of cybernetics, more recent concepts expressively stress the openness of socio-technical systems and hence their interrelationships with the environment.[2] Open systems theory stresses that the understanding of a production system requires consideration of both the technical and social elements. This is because

' there is no simple one-to-one relationship between variations in inputs and outputs, because different combinations of inputs may result, depending on the technological system in similar outputs and different products may result from similar inputs. Further, the technological system, in converting inputs to outputs is a major determinant of the self regulating properties of the system.' [3]

Open systems approaches to organizational design stress, that organizations are constrained by their environment and that they encounter boundary conditions that may change the characteristics of the organization. [4]
In consequence of such considerations, the design of socio technical systems requires the continuous, iterative adjustment between the <u>goals</u> which the system is supposed to pursue, the <u>environment</u> [5]

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1) DE GREENE (1973) p. 42
2) compare DE GREENE (1973); PATZAK (1982)
3) DE GREENE (1973) p. 45
4) ibid., p. 44
5) "environment" is meant here to embrace both the "ecological environment" and the "social environment". In the context of this dissertation, this means in particular that the smallholders and their interests, aspirations and needs have to be perceived as part of the environment and not only in terms of "human production factors" controlled by the irrigation organization.

- as far as it can be influenced - and the design-characteristics that determine the systems performance.
The following chapters are going to explore, to what extend conventional approaches to smallholder irrigation correspond to such requirements of open socio-technical systems and in what respect improvements may be desirable and feasible.

3. PROJECT-GOALS FOR SMALLHOLDER IRRIGATION - A DIAGNOSIS

3.1 General considerations

The evaluation of conventional irrigation planning with respect to its suitability for the smallholder raises the central question as to the goals persued.

After all, irrigation schemes are implemented to achieve certain ends. And their performance is judged on the basis of expected achievements. If however the expected achievements bear no relation to the originally intended ends or "goals"[1] any judgement about the degree of success or failure must be futile.

Moreover, irrigation planning, -implementation and -operation needs to be managed. And 'management <u>is</u> the setting of objectives' (P.DRUCKER). Measures of results are needed if the use of scarce resources is to be justified. And the relative value of any course of action - and hence of any irrigation "plan" - can only be compared to alternative courses of action in the light of preconceived goals.

If it is assumed then that there is interest in seeking ways to improve irrigation in order to help the rural poor[2] then it is essential to ask whether or not objectives set for irrigation planning and -management are such that they can match this expectation. This is why particular attention is given in this chapter to procedures and problems related to goal formulation and operationalization in irrigation schemes and to the compatibility of these goals with the interests of the smallholders[3].

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1) The terms "objectives" and "goals" are used interchangeably here in accordance with common practice in literature although in a strict sense an objective is a goal of lower-rank in the hierarchy of goals, where objectives, contrary to goals, connote a more specific relationship to a particular policy, programme or project (SAGARDOY, 1982, p. 6)

2) BOTTRALL (1981) p. 26 with reference to World Bank.

3) Conditions of the landless labourers in irrigation schemes are an important topic but are only touched marginally in the context of this dissertation.

3.2 Operational goals

Generally, objectives of irrigation are described in terms of goal variables such as "increase in agricultural production", "production of agricultural surplus for local consumption", "creating of employment opportunities", "improving of living standards of farming population" etc..

However, while such statements describe indisputable goals, they are "operationally meaningless" [1] both for the planning and the management of irrigation schemes. With respect to the formulation of operationally viable goals in management BOTTRALL mentions 'the establishment of consistent and clearly defined objectives for project management to pursue' as the foremost in a list of important factors to be considered [2] and GROSS [3] argues that 'the essence of planning is the selection of strategic objectives in the form of specific sequences of action to be taken'.

These statements point to two important implications related to the identification of "operational" goals:

a) that for operational relevance, goals need be 'consistent and clearly defined' [4]

b) that there are different levels of goals and hence that a hierarchy of goals exists, where the achievement of one goal presupposes the achievement of others.
   For illustrative purposes only, an exemple of such a hierarchy is given in FIG. 3.1.

Consequently, it appears essential that planners of irrigation schemes observe the following requirements:

A) - specify clearly defined and quantifyable goals

B) - check for consistency between such goals

C) - identify hierarchies of goals which indicate practible sequences of achievement.

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1) SAGARDOY (1982) p. 6
2) BOTTRAL (1981) p. 63
3) GROSS quoted in DE GREENE (1973) p. 175
4) 'consistency requiring that there should be no conflicts between objectives'.

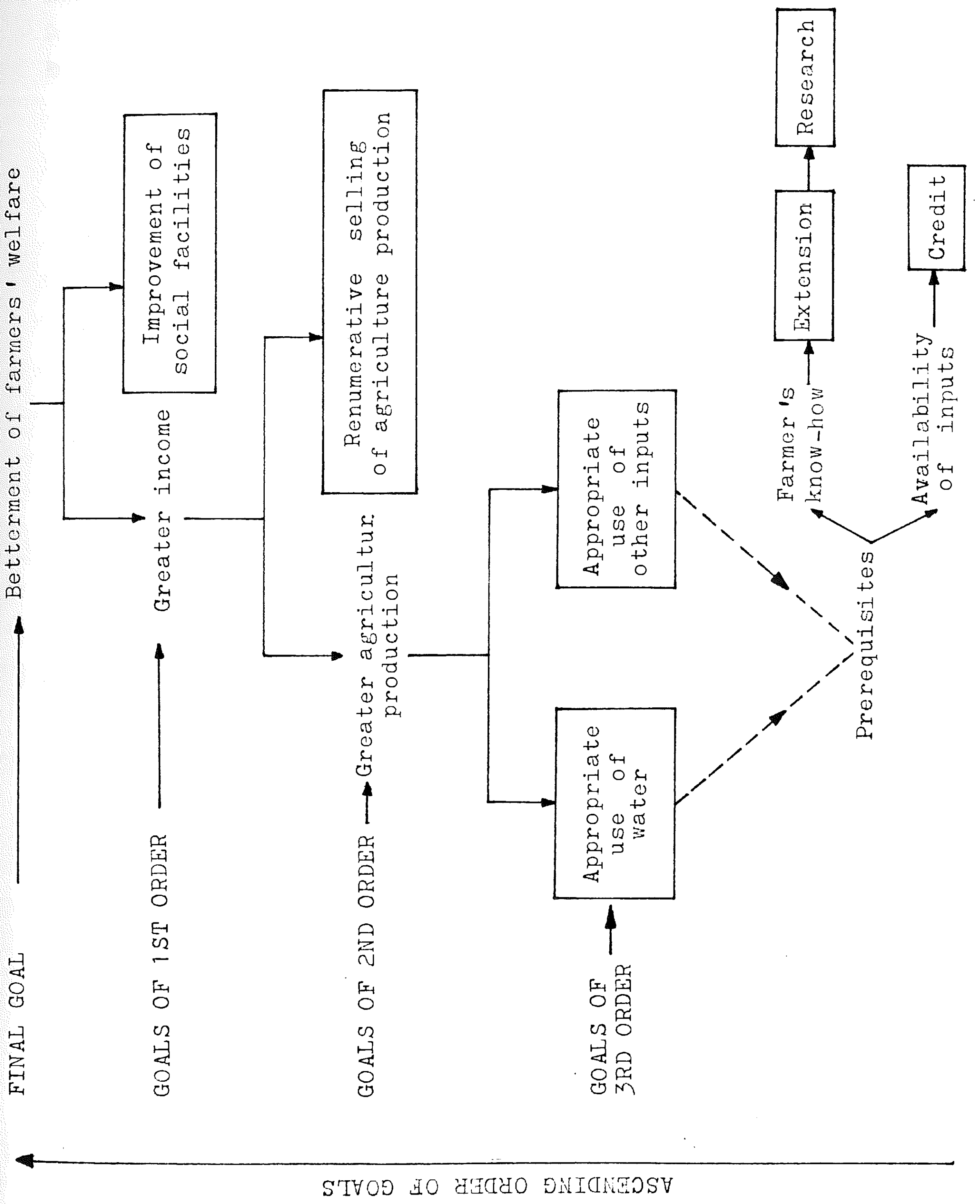

FIG. 3.1 Illustrative example of a hierarchy of goals in irrigation.
Source: SAGARDOY (1982)

Attemps to identify well defined and quantifiable sets of goals which are generally applicable to irrigation schemes have been numerous and are partially reviewed by WALKER [1].
Different sets of goals as proposed by THORNTON [2], CHAMBERS [3], and BOTTRALL [4] are listed in TAB. 3.1 .

If one generalizes these criteria by regarding "environmental stability" as contributing to the higher level goal of "intergenerational equity" and if one integrates economical and technical efficiency considerations under a common efficiency heading, it appears, that the important generally applied categories of goals may be summarized by the terms productivity (P), efficiency (E) and equity (EQ).

Referring back to the above mentioned requirements necessary to be fulfilled in order to render such objectives operational, the following sections attempt to explore the viability of productivity-, efficiency- and equity-goals with respect to these requirements and in the light of their suitability for smallholder oriented irrigation planning.

3.2.1 Productivity

The importance of irrigation is seen and has been seen primarily in its potentional contribution to the solution of impending food problems faced by the countries which refer to its use.
New developments in irrigation technology plus complementary advances in plant breeding, crop protection and agronomy "packages" have increased the potential productivity and profitability of irrigation agriculture. This increased productivity may come from higher yields, multiple cropping, often two or even three crops a year, and reduced risk of crop failure[5].
The predominance of productivity criteria hence seems to be an "inbuilt" characteristic of irrigated agriculture. No wonder then

1) WALKER (1981) pp. 86 - 94
2) THORNTON (1975) p. 185 - 187 summarized by WALKER (1981) p. 91
3) CHAMBERS (1976) as quoted in WALKER (1981) p. 88
4) BOTTRALL (1981) p. 43
5) CARRUTHERS (1982); as to the risk reduction of irrigation compare chapters 4 and 5

CHAMBERS (1975)		THORNTON (1975)		BOTTRALL (1981)	
1. 'Productivity: e.g. productivity of water'	P	1. 'Economic criteria: e.g. social/private cost-benefit terms.'	E	1. 'Productivity (especially of water) - This is a function not only of the quantity of water delivered but also of the timeliness and reliability of deliveries.'	P
2. 'Equity: e.g. equitable distribution of water to cultivators.'	EQ	2. 'Productivity criteria: especially productivity of water'	P	2. 'Equity (especially of water distribution)'	EQ
3. 'Convenience: e.g. convenience of cultivators with respect to "predictability of water-delivery" (including reliability and certainty) and "appropriateness of water delivery (including quantity delivered, place of delivery, timeliness and controllability)'	E	3. 'Water utilization efficiency e.g. in terms of the water finally absorbed by plants as a percentage of water diverted from the original source.'	E	3. 'Environmental stability'	EQ
4. 'Stability: capacity of longterm sustained operation without environmental depletion'	EQ	4. 'Efficiency of water administration: e.g. efficiency of the personnel involved, effectiveness of two-way communication within the organisation and across the gap between the public body and the farmers, adequacy of technical knowledge at relevant levels, strength of morale and attitudes.'	E	4. 'Cost'	E
5. 'Cost-effectiveness: concerns the relationship between benefits in the form of objectives achieved, and costs in terms of finance and other scarce organisational resources used.'	E			5. 'Cost-recovery'	E
				Generalizing abbreviations (see text): P = productivity; E = efficiency; EQ = equity	

TAB. 3.1 Goals of irrigation projects.
Source: WALKER (1981)

that agronomists and technicians tend to focus with fascination on figures of yield per hectare achieved as the prime indicator of success or failure of an irrigation scheme. The production targets they have in mind and which they often enter as yield expectations into the farm model budgets of project appraisals are orientated at productivity indices of other countries or of research stations where the irrigation technology "package" has achieved the results they have in mind (FIG. 3.2):

> 'Clearly, irrigation <u>is</u> capable of higher yields. In Asia, water control and other inputs on working farms result in rice yields up to five times higher than those in unirrigated areas. Scientifically managed irrigation does even better. On research farms, yields with irrigation can be as much as four times higher than yield of irrigated working farms'[1]

Since productivity increases indeed may be caused by technological advance - interpreted then as a shift to a new production function - the fulfilment or non-fulfilment of production targets thus tends to be taken as an indicator of the degree of "development" achieved.

However, there are a number of problems related to such a productivity focused approach:

1) Under conditions where land and food - and foreign exchange - are scarce but where there is abundance of labour supply and capital, attention will be focused on increases in yields. In such circumstances the project will be prefered, that promises the greatest increase in 'productivity of land'[2]. The criterion "net productivity of land" is derived by deducting costs of inputs purchased outside of the project from the gross product in cereal equivalent (CE) [3]:

$$\text{net productivity of irrigated land } (^{CE}/ha) = \frac{\text{net productive output}}{\text{area of irrigated land}}$$

However, if there is greater scarcity in other factors of production, e.g. in capital for investment or in foreign exchange, "productivity of capital" or "productivity of foreign exchange" would have to be the relevant criteria. And since water is becoming increasingly scarce in many countries, "producti-

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1) BERRY, FORD, HOSIER (1980)
2) BERGMANN (1973) p. 70
3) CE is a unit that allows all agricultural products to be reduced to a common denominator (cereals) and may be replaced by constant reference prices (BERGMANN, 1973, p. 70).

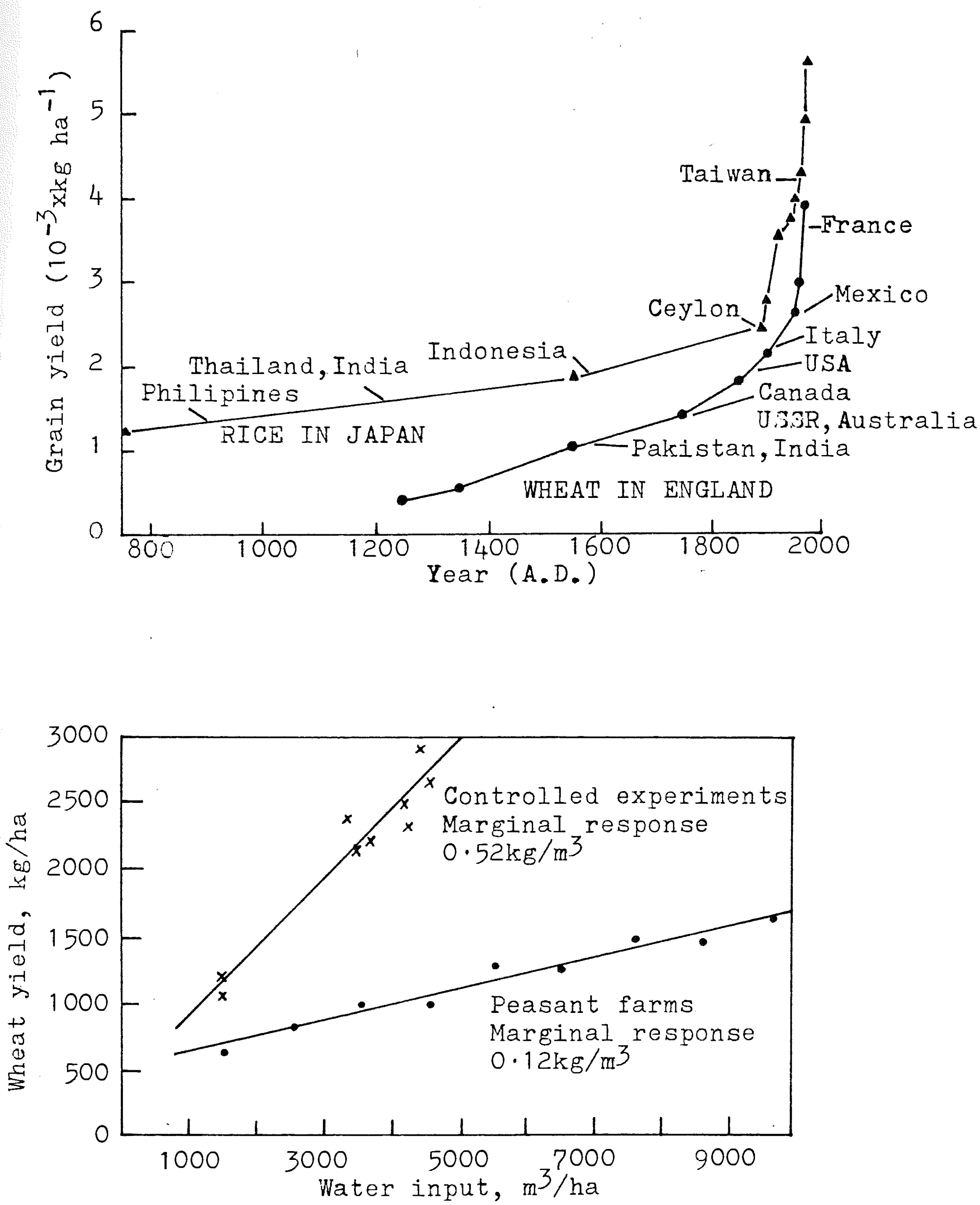

FIG. 3.2 - Differences between technical possibilities and actual performances in irrigation as demonstrated by inter-country-comparisons (above) and research-station/ on-farm comparisons (below).

Source : CARRUTHERS and CLARK (1981) p. 50

vity of water" will have to attract more attention. This, however, is often connected with additional problems: a water source may fluctuate throughout the seasons or the years and thus land and water may alternatively become the most scarce resource. Moreover, within the project, water distribution may vary such, that in the head reaches of canals were water is often overabundant, land productivity and in the lower reaches where water is frequently scarce, water productivity would be the appropriate criterion respectively.
This means, that productivity criteria look at irrigation from a very limited standpoint and may have value as operational project goals only in extreme economic situations [1].

2) A productivity criterion that is expressed as a single factor productivity term, in fact is a "total" or "over all productivity"-index, as the output measured is not merely a function of one factor, e.g. land, but of other factors as well, e.g. water, fertilizer, skilled and unskilled labour, management etc. and of the technological conditions of production.
This problem of input aggregation results in the fact that changes in the single factor productivity term may in fact indicate changes induced by other excluded factors[2].

Focussing on productivity of land and yield/ha e.g., makes it impossible to single out factors that actually have caused increases or have inhibited such increases in production. Cross country comparisons or reference to research station data as indictators of the degree of project success or failure are hence a priori of little operational meaning.[3]

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1) BERGMANN (1973) p. 71
2) RUSTEMEYER (1964)
3) It needs to be mentioned that theoretically "corresponding single-factor net productivity" values (RUSTERMEYER 1964) can be worked out. This can be achieved by first deriving net productivity values (deducting the production equivalent of non-farm inputs and services from the output values) and then by "clearing" step by step the output of contributions made by all factors other than the single factor expressed in the productivity term. With respect to irrigation planning the procedure as such may be helpful in some cases of "with" and "without"-comparisons related to a certain factor, however is difficult to apply and its operational meaning given the mentioned input aggregation - problems is questioned by UPTON (1979).

3.) Even if figures of yield per ha are implicitely understood to be total-factor productivity indices, they can only be interpretated as an indicator of a shift to a new production function, under two preconditions[1]:

a) If the marginal rate of factor substitution remains constant. If this condition is not fulfilled, then changes in productivity merely indicate changes in factor combinations.

b) There must be conditions of constant returns to scale, otherwise increases or decreases in productivity may result from increasing or decreasing returns to scale. Overall productivity terms may hence indicate a combination of technological advance and scale effects, where seperation is very difficult.

These considerations reveal, that the approach to express objectives of irrigation schemes in terms of quantified productivity increases faces a number of problems, which are particularly relevant if one focuses on the smallholder.
E.g. if production is increased due to higher water use at large farms that work on a higher production function (HYV's), at the expense of water use for traditional varieties at small farms, then productivity criteria will indicate improvements where the conditions for the smallholder may actually have deteriorated.[2]
The same may be the case, if structural changes are at the origin of overall productivity increases. Such situations may arise if the productivity index is based on the aggregation of different production processes with different productivity levels, e.g. large mechanized farms and smallholder farms in the same project.
The "structure effect" then indicates changes in the aggregate productivity level which are not due to changes in productivity levels of the different production processes but only due to structural changes between these processes[3].
With reference to an irrigation scheme, this may mean e.g., that changes in the relation of large farms to small farms caused by the scheme may give rise to productivity changes without related changes

1) RUSTEMEYER (1964)
2) see FIG. 3.7 and compare para 4.3.3
3) RUSTEMEYER (1964) p. 49

in input-output relationships of small or of large farms as such.

Productivity criteria hence need to be handled with care if improvements in living conditions for the smallholder are to be of any concern. The foregoing discussion indicates that preoccupation with productivity figures may actually contribute to the neglect of vital interests of smaller users in the context of irrigation development.

3.2.2 Efficiency

Since the optimum use of available resources is in fact the essence of an "appropriate technology", efficiency criteria as put forward in TAB. 3.1 seem indeed to be appropriate goals in the context of smallholder irrigation.

"Technical efficiency" indicates the ratio of the amount of a given resource actually used in the production process as compared to the total amount supplied. If e.g. water is a scarce resource, which is increasingly the case in most environments where irrigation is practiced, then the aim to achieve high efficiency of water use seems to be an adequate project goal. This is why increasing importance is attached to "water utilization efficiency", which BOS and NUGTEREN, with respect to the overall project define as 'the ratio between the quantity of water placed in the root zone (rain deficit) and the total quantity supplied to the irrigated area.' [1)]

Whatever the scarce resources for which efficiency criteria are to be applied - CHAMBERS and MORIS e.g. urge to include administrative capacity and negotiating capacity at a national level[2)] - an important distinction has to be made between technical and economic efficiency.

'In the use of resources, economic efficiency requires that any given output is produced at minimum cost, which means both that waste and

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1) Depending on the various subsequent stages in the water distribution process from head intake to farm and finally to plant-root zone, BOS and NUGTEREN distinguish further between distribution efficiency, farm efficiency, water-conveyance efficiency, farm ditch efficiency and field application efficiency. BOS and NUGTEREN (1974) p. 11.

2) CHAMBERS and MORIS (1973)

technological inefficiency are avoided and that appropriate input prices are used to find the cost-minimizing production process'[1] UPTON[2] illustrates the differences and trade-offs between economic and technical efficiency for factor product and factor-factor relationships: In both FIG.3.3 and FIG.3.4 the points "B" indicate technically inefficient points of operation, lying below the production function or above the isoquant-curve respectively while operation at points "C" which lie on these curves is said to be technically efficient. However, only points "A", where operation takes place in a technically efficient way and at the same time at a profit maximizing level (for variable output) or at a least cost level (for a given level of output) can be regarded as economically efficient.

This then explains a seeming paradox to which CARRUTHERS refers and which lies at the very heart of much of the inappropriate planning with respect to irrigation:

' Rainfed farming is a high risk, low productivity system of agriculture and irrigation is a low risk, high productivity system. The paradox is that in practice rainfed farming is often economically efficient whereas irrigation farming can be economically disapointing. It is a puzzle as to how it is that a system of agriculture which can produce 5 to 6 tons of paddy hectare is inefficient compared to a system under which it would be difficult to exceed the 2-3 tons per hectare average.
The answer to this paradox lies in the financial and human resource scarcity. A very heavy investment is required to produce irrigation facilities, skilled management and further financial resources are needed to operate them effectively and higher levels of input services and farmer accomplishment are also demanded.
There is often a wide gulf between maximum yield and optimum yield, that is between technical and economic efficiency for which we have to plan '.[3]

In order to avoid that objectives of technical efficiency are persued instead of economic efficiency, project planners would have to adjust their systems design to the environment and the prevailing resource scarcities. This however, is rarely the case, since planners mostly display "inward looking" perspectives adopted from engineering and tend to neglect interrelationships between the irrigation system and its environment and thus do not adjust systems- designs to most efficient resource use in the way

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1) BAXTER and REES (1982) p. 144
2) UPTON (1973) pp. 192, 193
3) CARRUTHERS (1982) p. 6; however with respect to "low risk" assumptions attributed to irrigation compare chapter 4.

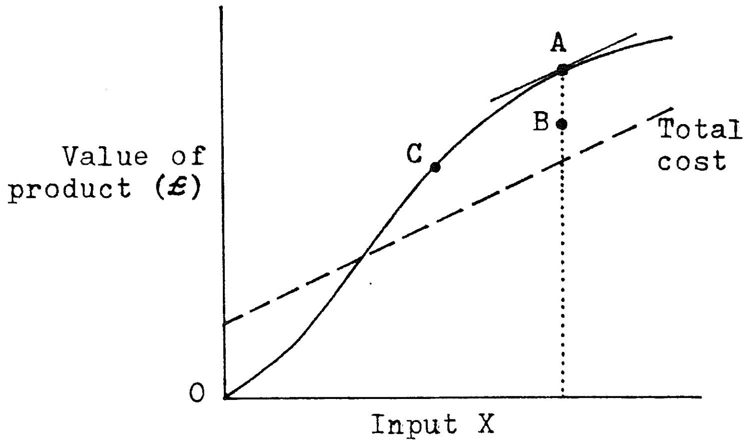

FIG. 3.3 - <u>Efficiency in factor-product relationships</u>

Operation at A : economically efficient
Operation at B : technically inefficient
Operation at C : economically inefficient

Source : UPTON (1973)

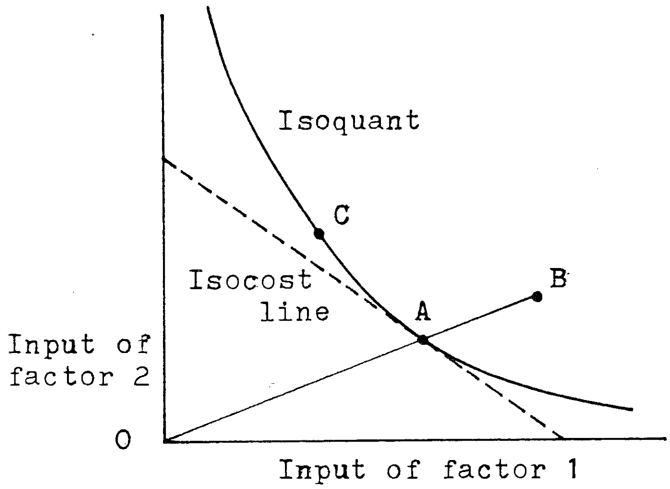

FIG. 3.4 - <u>Efficiency in factor-factor relationships</u>

Operation at A : economically efficient
Operation at B : technically inefficient
Operation at C : economically inefficient

Source : UPTON (1973)

mentioned above. CARRUTHERS observes that

' economists appraise irrigation projects using shadow prices but design engineers choose least-cost-solutions using market prices '. [1]
' Since shadow prices represent the "true" value of resources and since engineers do not use shadow-prices and related techniques, then economists in appraising engineering designs are likely to be applying their techniques too late. In other words, the appraisal will often be made of socially inappropriate designs '. [2]

This means e.g. that if in the case of a particular irrigation peoject, the domestic currency is over-valued and unskilled labour is priced according to minimum wage legislation while its opportunity cost is close to zero, then 'engineering design which uses market prices will be too capital- and foreign exchange intensive and employment levels will be suboptimal. '[3]

Thus, in summary, it may be said, that efficiency goals as indicated in TAB. 3.1 , if interpreted in terms of ecomomic efficiency can indeed be regarded as appropriate objectives for smallholder irrigation schemes in LIC's where scarcity of various resources may be notorious.
However, in practice the problems arise, that technical efficiency is often pursued instead of economic efficiency and/or that economic efficiency goals are aimed for in the context of project designs that are not geared to such ends.

3.2.3 Equity

' In the allocation of resources, economic efficiency requires that it must not be possible to change the existing resource-allocation in such a way that someone is made better off and no one worse off, since, if this is possible, the existing resource allocation must involve a welfare waste '. [4]

With such a criteria of allocative efficiency[5] and the related equity-problems one enters a realm of consideration which has tradi-

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1) CARRUTHERS (1976) p. 2
2) CARRUTHERS (1978) p. 48
3) ibid. p. 48
4) BAXTER and REES (1982) p. 144
5) known as PARETO-criterion. Other criteria have been put forward but are not further discussed in this context e.g.: HICKS- CALDER-, SCITOVSKY- and LITTLE- criterion.

tionally tended to be avoided by techniciens - not only by irrigation planners. Such normative concepts which had to be based largely on ethical and political value-judgements were looked upon as being outside of their field of competence. Preoccupied with growth and hence productivity- and efficiency-concepts, they expected eventual "trickle-down-effects" or government-programmes to take care of subsequent redistribution issues, if needed.

However, the general trend from "growth" to "growth-with-equity" concepts in development thinking in the 1970's changed that focus. Moreover, the experiences of the "Green Revolution" had not been overly encouraging: despite world-wide boosts in food-grain-production with the help of irrigation it became obvious that benefits tended to accrue to larger farmers and that pre-existing inequalities had often been accentuated. One started to realize that it was no longer acceptable to ignore second-order-consequences of irrigation development such as increasing land concentration and structural unemployment observed in the aftermath of project-implementations.

However, inspite of increasing awareness of the problem of inequality, one remains uncomfortably conscious that the issues involved are complex and embrace economic, social, political, spatial and intergenerational aspects at once.

Attemps to translate such calls for more equity into the practice of irrigation planning have so far essentially been threefold:

i) Through the instrument of the social cost-benefit analysis which aims to achieve income redistributions through differential cost benefit weightings

ii) Through equity-considerations in water allocation

iii) Through emphasis on long-term resource-stability and hence on intertemporal equity.

Social cost benefit analysis tries to take distributive consequences of projects into account by weighing costs and benefits accruing to different income groups and occurring at different points in time on the basis of estimations of the different value of additions to income at different income levels and time periods. This may be an appropriate approach to equity considerations on a national-, intra-regional or even inter-generational level through its effect on preferential project selection with respect to such con-

siderations. However, once a project has been selected, these differential weightings expressed in money-terms do not represent clearly defined and quantifyable objectives that ensure the prevalence of equity goals during project operation and are hence most often neglected. Thus, the preoccupation with shadow prices and net social benefit determinations leads to the neglect of more important issues[1], e.g. improved knowledge about the constraint situation of the different income-groups involved or institutional issues which are at the root of the inequality problem.
BROMLEY argues that current benefit-cost procedures are insufficient in both scope and content to assess properly the mutual importance of planning- and socio economic considerations. For example social cost-benefit analysis per se is unlikely to highlight the social inefficiency of an irrigation network design which has been perceived such that all the large farmers will become top-enders, while the poor smallholders will be located at canal-tail-ends. 'What will appear as a "good" project in our conventional view may indeed be a serious failure'.[2]

Outside of the context of cost-benefit analysis the consideration of equity goals as indicated in TAB. 3.1 has been restricted mainly to two aspects:

a) Equity of water allocation
b) Long-term environmental stability which can be seen as an aspect of intertemporal equity.

Although important and often unduly neglected, further considerations of environmental stability goals go beyond the scope of this dissertation and are therefore not further considered.
With respect to present time equity-issues in discussions of irrigation management, it is usually assumed that assuring a more equitable water delivery would contribute to redistributions of income. With rare exeptions water distribution in irrigation schemes throughout the world is considered to be "equitable", if the water allocation to each farmer is in proportion to the size of his holding.[3]

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1) BOTTRALL (1981) p. 26
2) BROMLEY (1982) p. 68
3) compare BOTTRALL (1981) p. 27 and MALHOTRA (1982) p. 38

Two aspects of an "inequitable" water-delivery are distinguished:

- selective or preferential allocation of water by those managing the distribution
- differing water allocation between heads and tails of canal systems brought about as the result of second-order- or "externality-effects" of the activities of the people involved in the water distribution process.

Important as issues of equitable water allocation might be, the question arises, whether such a narrow interpretation of the equity objective can seriously be expected to contribute to prevent problems of inequality as they have come about in many irrigation schemes in the course of the Green Revolution.
Equitable water allocation will not help the smallholder if his equitable share of water is supplied so untimely and unpredictably that he cannot take the risk to purchase costly inputs "just in case".[1)]
Equitable water receipts will not be sufficient for him if he lacks the bargaining power to ensure his access to essential extension services, inputs and credit. And any question of water allocation will be irrelevant to him if he is evicted as a tenant, because irrigated agriculture is hoped to be so profitable that the landowner takes over the land himself.

'It is the social situation of the small cultivator vis-à-vis the purveyors of his inputs, coupled with the economic fragility of his enterprise due to his penurious supply of land, that turns the excellent agronomic potential of the new technology into a indifferent bargain. Continued use of a hardy low-cost technology for his food supplies usually offers him a safer option in the real world, which he knows all too well.'[2)]

On the other hand also and in contrast to such circumstances, equitable water allocation[3)] may make little sense in irrigation-situations where the land tenure status of irrigators is secure and where water is supplied reliably and sufficiently according to varying crop water requirements and on a basis of benefit water pricing.

Such considerations indicate, that equity objectives as applied in conventional irrigation appear to be insufficient to ensure income distributional effects in irrigation schemes.

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1) compare discussion in para 4.3.4
2) PEARSE (1980)
3) if strictly understood in term of allocation proportional to land area

Moreover it follows from the above discussion that it makes little sense to operationalize equity objectives without a close systems adaptation of such goals to environment and design characteristics.

3.2.4 Multiple objectives

With reference to the set of objectives for irrigation which BOTTRALL has proposed (see TAB. 3.1), the same author adds: 'other criteria might well have been added - notably employment generation - ... depending on the objectives and priorities of the country concerned.'[1] This points to the fact, that irrigation schemes, like other socio technical systems are oriented toward the achievement of multiple goals.

Such a set of multiple objectives in principle does not prevent all of these objectives to be rendered operational, that is to induce a hierarchy of sub-objectives and hence particular courses of action in planning and management, provided, as outlined in para 3.2, that the objectives are consistent among each other, i.e. that they do not con flict. If they conflict, operationalization can be assured by one of three procedures described by CARRUTHERS and CLARK[2]:

a) the contributions of different projects or project-alternatives with respect to the various objectives can be listed in tabular form of a socalled "decision-matrix" which demonstrates to decision-makers the consequences of specific choices. (An illustrative example-layout of such a matrix as presented by the same authors is shown in TAB. 3.2).

b) the contribution to one objective is given priority and the other objectives are satisfied at fixed minimum levels of performance. E.g. 'a maximum economic rate of return might be sought, subject to a specified level of income redistribution to a defined low-income category of farmers or landless labourers in the project area.'[3]

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1) BOTTRALL (1981) p. 43
2) CARRUTHERS and CLARK (1981) pp. 210-213
3) ibid., p. 211

Project alternatives	Criteria: Economic internal rate of return	Financial internal rate of return: To farmers	Financial internal rate of return: To government	Jobs created/ $ 1000 investment	Propotion of project income to poorest 20% of population %	Location in priority development area (Yes or No)
1	*	*	*	*	*	*
2	*	*	*	*	*	*
3	*	*	*	*	*	*
4	*	*	*	*	*	*
.	.	.	.	.	.	.
.	.	.	.	.	.	.
.	.	.	.	.	.	.
n	*	*	*	*	*	*

TAB. 3.2 - Illustrative example of an economic decision matrix for irrigation projects.

Source : CARRUTHERS and CLARK (1981) p. 212

This is the approach that lends itself to formalized problem formulation and solution by way of Linear Programming methods, where the priority goal is entered into the objective function and the other goals are expressed by means of resource constraints.

c) all the objectives are entered into the objective function. If target-values for each objective can be defined, then the total deviation from these targets can be minimized, i.e. a best compromise solution can be found.
This is the most complex procedure which may be formalized in a multi-objective-goal programming problem (MOGP).

With reference to the latter method, CARRUTHERS and CLARK judge that it is too sophisticated and hence inappropriate in view of the planning capacity of most irrigation agencies and consider decision-matrix-procedures to lead to better selection decisions especially by non-economists.

However, procedures like those outlined above to render multiple objectives operational reveal several drawbacks if looked upon in the practice of smallholder irrigation planning and management:

1) a set of thus selected objectives may correspond to a "top-down" view of the needs and problems at hand and may hence completely neglect or misinterpret the expectations and "real" objectives of the interest groups involved in the project, especially the farmers.
(see comments in relation to this point in para 3.2.5)
2) such procedures to objective selection neglect the fact that there may be situation-variables of the socio-economic "environment" that cannot be influenced by the project management but which may set limits to goal-achievements: e.g. land tenure systems, local power structures or cultural attitudes may bring about incentive distortions of the farmers and hence achievement levels may be restricted by lack of cooperation.
3) such selection procedures, even if backed by thorough cost benefit analyses, do not take into account organizational requirements to bring about goal-satisfaction, requirements which in reality may be beyond the capacity of existing or future government-, project- or community-organisations.

4) the procedures outlined above do not take into account that objectives are choosen on the basis of information about existing situations and problems. However, given the notorious lack of background-data in many project situations these informations are subject to change in time. Objectives choosen on the basis of information available during identification-phase may be completely obsolete at the time of the appraisal when more data are accessible and goals appropriate at appraisal stage may be partly inadequate by the time of the operation stage of the project.

The consequences of such discrepancies are evident in many irrigation schemes: the objective-formulation of the scheme remains vague, responsabilities are unclear, widely varying courses of planning- and management-actions may be chosen and evaluation is only possible according to differing subjective judgements. This means, that 'adoption by authorities of multiple objectives, with the emphasis upon various goals shifting through time, makes success an extremely elusive concept'.[1)]

However, a further conclusion may be suggested: that it is precisely in such circumstances that the most vulnerable looses most: deficient objective-formulation prevents effective monitoring and evaluation and planning and implementation-procedures as well as management-practices of the irrigation scheme may be easily influenced to the disadvantage of the smallholder by those who are influential enough to pressure for designs of "best fit" to their own interests.

These aspects are of particular relevance if one takes account of the fact that objective-formulation does not only influence management procedures like monitoring and evaluation but design-factors as well, i.e. infrastructural, organizational and operational design-features, which, once selected and applied, are often difficult or even impossible to be changed. The importance of this fact is often overlooked by social scientists who tend to underestimate or to neglect the potential adaptability of such parameters to differential objective criteria. The assumption that 'technology is neu-

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1) CARRUTHERS (1976) para 3

tral in that the significance of its use depends on the purposes and situation of the user[1], although correct in its basic outlook, neglects the fact that design-characteristics are adaptable to environment and to goals.
The negative effects of deficient objective-formulation for the smallholder are thus compunded by their long-term irreversibility.

3.2.5 Stated versus real objectives

3.2.5.1 Farmers objectives

The problem of multiplicity ob objectives, mentioned in para 3.2.4 has yet another dimension. Assessing categories of objectives like those outlined in the foregoing sections, WALKER[2] observes that such sets of criteria may be regarded as formal goal definitions, which are generally applicable to irrigation systems but do not represent systems of real objectives reflecting the expectations and interests of the various groups involved in a scheme. CARRUTHERS and CLARK[3] present the different interest groups as indicated in FIG.3.5 and WALKER[4] specifies the overall set of participants as follows:

- persons directly affected by the project, i.e. farmers and the personnel in the project
- regulating groups (e.g. communal politicians and authorities, foreign experts and local urban competitors for water)
- input suppliers (e.g. domestic and foreign investors, machine suppliers)
- output customers (e.g. local merchants, private households, central marketing organisations)

The fact, that the objective categories discussed in previous para-

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1) PEARSE (1980) p. 7
2) WALKER (1981) p. 92
3) CARRUTHERS and CLARK (1981) p. 202
4) WALKER (1982) p. 2

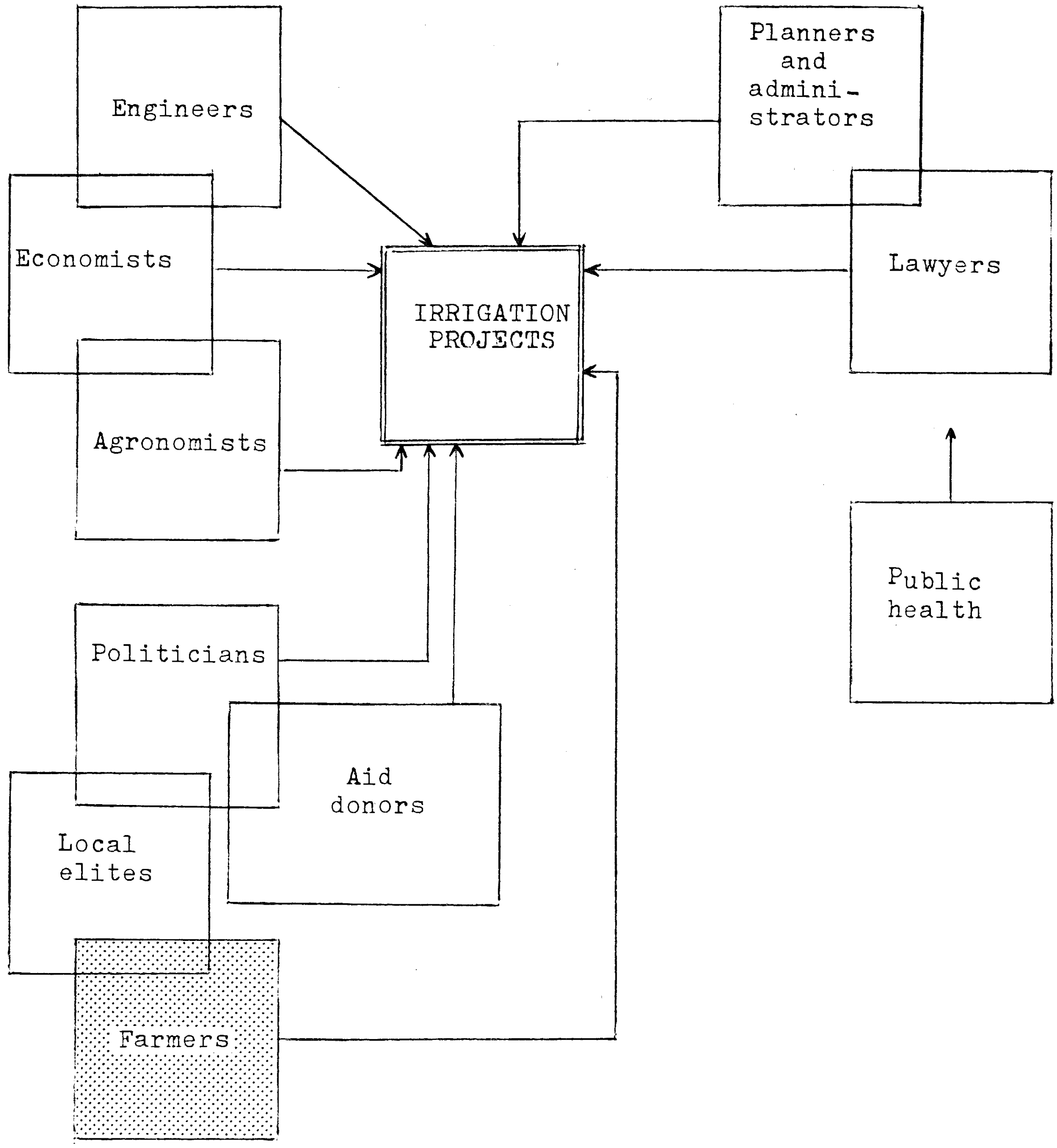

FIG. 3.5 - Interest groups involved in irrigation planning.

Source : CARRUTHERS and CLARK (1981) p. 202

graphs are general evaluation-standards but do not express the actual expectations of the different "coalition-partners" in irrigation schemes - and thus correspond only to stated government objectives - results in the fact that goal systems of irrigation projects are basically established without reference to the groups and people involved.[1)]

This means, that the objectives of those who are supposed to be the prime beneficiaries of irrigation schemes and of whose cooperation and participation future project-achievements critically depend, are not taken into consideration.

This neglect of farmers view-points and expectations in the planning of irrigation schemes seems to be notorious. CARRUTHERS and CLARK concede, that the first draft of the graph in FIG. 3.4

'excluded the farmers, although we have been using this diagram, or something like it, for a decade. Why is this? Could there lie in this admission which on refection reveals a widespread attitude, a partial explanation for poor performance of plans?'

BERRY, FORD and HOSIER reviewing irrigation project evaluation procedures, remark:

'In reviewing audiences for existing evaluations, we found considerable emphasis on needs of the donor agency, some attention to host country needs and only slight reference to ways in which user needs might be served...'[2)]

Similarly, GRIFFITH[3)] observes with reference to irrigation in Nigeria:

'So far as I am aware none of the major irrigation projects in the North of Nigeria were even discussed beforehand with the farmers who were to be involved in them...'

And HOBEN evaluating project identification decisions at USAID concludes that 'at no point in the decision making process is the question of what the farmers want and need necessarily given high priority.'[4)]

There can be little doubt about the consequences of approaches, that neglect to take into account the real interests of those groups actually involved in irrigation. CARRUTHERS and CLARK express a

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1) WALKER (1981) p. 92
2) BERRY, FORD, HOSIER (1980) p. 24
3) GRIFFITH (1983) p. 3
4) HOBEN (1980) p. 353

widely shared point of view when they stress that such failures to appreciate the sociopolitical realities of the social environment into which irrigation technology is to be introduced is a sure recipe for problems later.[1] And such problems are abound, especially in countries without long-term irrigation traditions, where irrigation rehabilitation needs are soaring.
ADAMS[2] recently reported that farmers in the Bakalori-Project in Nigeria have responded to the introduction of irrigation in similar ways to those used in times of hazards such as droughts: moving, temporarily at least, out of farming and into other activities.
While it would be simplistic to attribute all the incentive distortions that farmers and especially smallholders face in irrigation schemes to these problems of deficient objective formulation, many authors agree that the role of the farmers should be given a key-place in irrigation planning considerations[3] and in participation with respect to objective formulation.[4] Giving greater weight to farmers interests and decision criteria however does not imply the 'conservation of traditional goal concepts' as WALKER[5] stresses. However it promotes awareness as to the farmers constraint situation which may or may not allow him to take advantage of apparently obvious benefits of irrigation.

3.2.5.2 Objectives in the context of social structures and reward systems

Considering the objectives of regulating groups and project personnel whose activities have a major impact on the small farm subsystem, it is essential, as outlined before, to make clear distinctions between stated and real objectives. In contrast to stated objectives like those listed in TAB. 3.1 real objectives correspond to actual expectations of individuals and groups and hence in-

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1) CARRUTHERS and CLARK (1981) p. 202
2) ADAMS (1983) p. 3
3) JURRIENS and BOS (1980) p. 110
4) MÜLLER (1977) p. 25
5) WALKER (1982) p.3

fluence peoples decision making processes.
The official project goal determining the tasks of a ditch rider may well be an equitable water distribution. If however his personal objective is income-maximization, then it may well depend upon the management of the Operation and Maintenance-Unit that employs him and of the social structure of the farming community he works for, and of the related pay-off or penalty expectations whether preferential water allocation to a larger farmer will be a rational choice for him or not.
This means that real objectives and the related decision making processes have to be seen in a local context of institutions, customs and negotiated relationships[1] and that the decision making environment greatly influences attitudes and preferences of individuals.
BIGGS[2] argues that 'people involved in agricultural and rural technologies are rational decision makers, and that the decisions they make are determined by the social structures and the reward systems in which they live.'
This implies, that project goals even if they have been clearly defined and quantified and if they are consistent are not yet operational in the sense that one can expect them to be translated into sequences of activities and achievements that ultimately lead to goal-satisfaction. What is needed additionally, are reward systems that make it rational for individuals or for groups to pursue such objectives, and hence elimate inconsistencies between stated and real objectives.
BIGGS[3] identifies four social structures which are of particular relevance with respect to decision making processes aimed at promoting technologies to benefit the rural poor: the rural powerstructure, government organisations in low-income-countries, international organizations and institutions in high-income-countries.

BIGGS argues that reward systems in all of those structures are unfavourable to promote technologies that reduce rural poverty or that they are not explicitely geared to do so[4]. HOBEN illustra-

1) BARLETT (1980) p.9
2) BIGGS (1978) p. 257
3) ibid., p. 259-163
4) ibid., p. 263

tes that very point with experiences drawn from the detailed analysis of smallfarmer oriented decision making procedures in the institutional framework of a bilateral donor-agency[1]. He notes that external institutional pressures resulted in the fact that the agency's legislated goal of considering the special needs of small farmers was displaced by objectives of means-provisioning such as obligating funds, having projects, increasing its personnel complement, getting larger appropriations etc.. HOBEN concludes, that 'in the world of development with its many conflicting constituencies, the voice of low-income intended beneficiaries are not clearly heard'.[2]

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1) HOBEN (1980) refering to USAID
2) ibid., p. 351

3.3 Conclusions

Project goals determine the activities that are to be undertaken in the context of an irrigation scheme. It is therefore of prime importance to specify well defined and quantifiable goals in order to make an irrigation project "manageable". This is why the foregoing paragraphs have attempted to analyse the major goals that are conventionally used in irrigation with respect to their suitability to smallholder environments. Chapter 2 and paragraphs 3.1/3.2 have focussed the attention of this diagnosis on two aspects:

1) whether such goals are suitable in the context of open systems planning for irrigation schemes that are perceived as socio-technical systems. This means it is asked whether or not such goals take the environment of irrigation into account, i.e. particularly the interests and expectations of the smallholders.
2) whether the goals that are conventionally used in irrigation can be operationalized, i.e. whether one can expect them to be "translated" into activities that may lead to goal achievement.

The insights emerging from this analysis however have pointed to substantial problems in both respects.

The diagnosis indicates that goals as they are formulated in conventional irrigation planning and -management reflect the "inward looking" tendency of cybernetic systems approaches.[1)] Cybernetic concepts however are basically oriented toward "closed" systems that conceive the environment in input-output-terms only.
They presume a clear delimination between controllable organization and non-controllable environment in contrast to open systems approaches that assume a dynamic boundary region which may not be fully controllable.[2)]
It may be argued that many of the problems in irrigation, particu-

1) see paragraph 2.3
2) compare paragraphs 2.2 and 4.1

larly in the case of government initiated projects in areas were no irrigation tradition existed before are due to the adoption of cybernetic systems concepts adopted from engineering and to the related deficiencies in boundary definition.
In an open systems view of planning, operational goals have to be formulated in the context of an integrated, iterative and dynamic systems adaption between goals, environment and design characteristics. Corresponding to such lines of thought, the next chapter will focus on the environment of irrigation schemes before goal formulation will be reconsidered in connection with design characteristics in chapter 5.