Land - Water Linkages and Socioeconomic Challenges with Special Reference to Coastal Zones

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INTRODUCTION

Man depends on access to water in the landscape for several parallel functions. These include human and community health and well-being; biomass production; other forms of socioeconomic production; the maintenance of habitats for ecological protection; and the transport of soluble and solid materials such as nutrients, pollutants and sediments. The water passing through a landscape is influenced by human activities in that landscape, and may therefore present problems which must be anticipated and met by mitigating measures.

The single most important parameter for determining impacts may be the ranges of variability of rainfall, runoff and water flows, particularly in arid areas. This is because many hydrological impacts are dominated by extreme though infrequent events. Transport of sediment and other pollutants disproportionately occur during these events because they are linked to increases in water volume and velocity. Given their high variability, average yearly rates are irrelevant for predicting actual rates of sedimentation. Climate change is also an important consideration, as it may increase the frequency of extreme events including local droughts, intense rainfall with increased soil erosion and runoff, flooding, sea level rise and coastal inundation. In the identification of hydrological impacts, another important distinction is between hill-slope elements and the hydrographic networks that drain hill-slope flows. Hill-slope processes play a more important role in smaller watersheds, and where structural management changes, such as dams, have altered their temporal scale. Because of their more diversified topography, they also interact with rainfall in more complex ways.

Water may sustain land use but may also be a constraint on land use and socio-economic and biomass production. At the same time, land use influences water characteristics by its partitioning of incoming rainfall between the vertical return flow to the atmosphere as evaporation and evapotranspiration, and the horizontal flow to aquifers and rivers (here classified as **"blue water"**). The various functions listed above, related to human activities, also affect both physical and chemical characteristics of water, as shown in Table 1.

Table 1 Effects of human action on physical and chemical water flow determinants

Activity sector	Altered physical flow determinants				Input of chemicals		
	relief	plant cover	soil	drainage density	air	land	water
urbanization	*	*	*	*		*	*
industry	*				*	*	*
agriculture	*	*	*	*		*	*
forest management		*				*	
Tourism	*	*	*				

For his use of natural resources, man must manipulate the landscape that contains them. Natural laws operating in that landscape produce side effects, often designated as "environmental impacts". For instance, changes in land use alter the two "joints", or boundaries in the soil profile that determine the partitioning of incoming water. The first of these boundaries, at the soil surface, serves as a division between flood flows and infiltration. The other, in the root zone, is a partition between the "green water" accessible in the root zone, later to be used in plant production, and the surplus water that flows on to recharge aquifers or other water bodies.

Man's Influence on the Water Cycle

The effects of human activities are propagated throughout the water cycle, from atmosphere to land, to groundwater and rivers, to lakes and coastal waters. Basically, man practices three types of disturbing activities. These relate to:

- waste handling, which results in sending pollutants to the atmosphere;
- manipulation of land and water systems to meet the needs of biomass dependence;
- manipulation of land and water systems to satisfy water dependence needs.

The influence of these interventions cascades through the water cycle, producing secondary effects on terrestrial, aquatic and marine ecosystems, and thus on the sustainability of the environment and of natural resources development and management. However, the resulting problem profiles are quite different in different hydroclimatic regions, both in the occurrence and the weight, or severity, of the problems generated (Table 2).

Table 2 Sustainability problems in different hydroclimates

Region	waste-related		biomass-related			water-dependence-related			rapid pop. growth
	human	indust.	agric.	fuel-wood	forest.	Water over use	water under use	energy supply	
temp.		*				o		*	
dry trop.	*	o	*	*		o	o	*	*
humid trop.	*	*	*	*					*

Degree of problem severity: '*' indicates higher, 'o' indicates lower.

Problems of water over-use and under-use can occur simultaneously, for example in different parts of the water cycle, e.g. "green" and "blue" waters.

Land Water Linkages

To preclude unexpected problems through land-water linkages, there must be an integrated approach to land use and water. The integrity of the water cycle makes the river basin, or catchment the appropriate spatial unit for such integration, as decisions on upstream land use also effectively equate to decisions on downstream water resources, reflecting upstream-downstream interdependencies.

Conventionally, there is a dichotomy between land use and water resources. This is apparent even in UNCED Agenda 21, where land use and freshwater chapters show little appreciation of water related phenomena as determinants of land use, or of land use practices as determining water pathways, water flow and water quality.

Past Attempts at Land Characterization

In the past, national institutions and also the various FAO Services that dealt with individual aspects of natural resources and their use, tended to go their own way, both conceptually and in the execution of field programmes.

Soil specialists gave much weight to soil profile characterization and classification, and their mapping work centered on these classification units. This occurred even though the landscape-ecological context and the concept of land units were obvious and easy guides in the delineation of soil units, associations and complexes. There were instances in the early FAO field programmes where soil mapping specialists who wanted to use geomorphological criteria as a framework for mapping legends were actually dissuaded from doing so by their superiors.

Hydrologists had methodologies of their own, concentrating on the lateral dynamics of water resources, and rarely using landscape units as unifying criteria. Irrigation and drainage specialists tended to identify spatial units on the basis of rigid grid observations on meso-topography and soil-water properties. Civil engineers engaged in road building and other construction work had their own sampling techniques at fixed distances, disregarding any information from other disciplines that might be available.

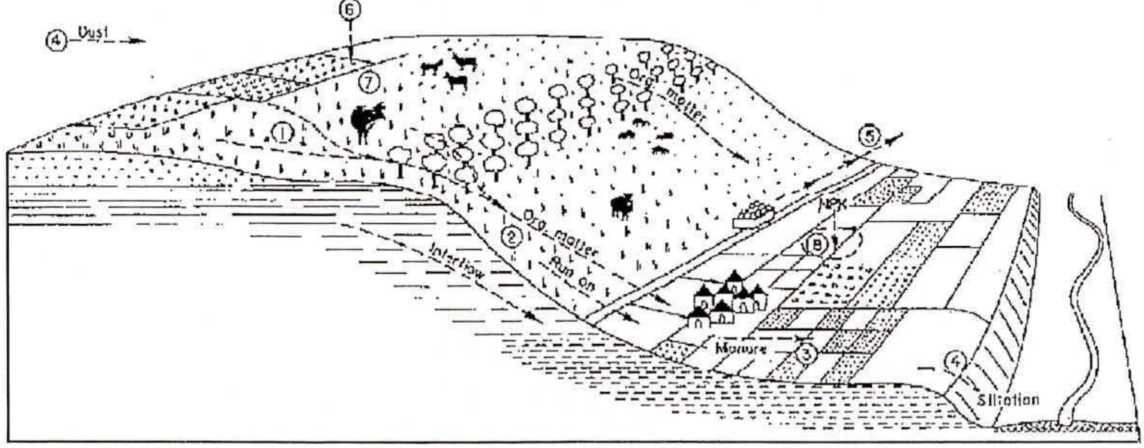

Fig. 1 Landscape-related nutrient dynamics in mixed farming systems

1 Local nutrient mining	3 Local nutrient enrichment	5 Anthropic nutrient export	7 Possible nutrient fatigue
2 Nutrient harvesting	4 Natural nutrient import	6 Anthropic nutrient import	8 Integrated nutrient husbandry

Soil fertility and fertilizer promotion specialists tended to forego soil classification criteria and soil mapping units as starting points, preferring random or grid experimental and demonstration plots (one of the reasons being that soil classification criteria centered on the subsurface layer rather than the topsoil).

Vegetation and forestry specialists, too, paid scant attention to land units, and the same held true for specialists on agro-climatic conditions - even though the latter should include near-surface and soil climatic aspects. Such mono-disciplinary activities often resulted in a tangle of boundaries of land management units when maps of field information on the various natural resources were combined. As a consequence, land use planning and its execution had no clear-cut natural terrain units as a starting point.

It should be mentioned that physical geographers have been trying all along to advocate a landscape and catchment area approach. This resulted in the "catena" concept of Milne, the "land system" approach of Australia, the "geo-pedo-morpho-hydrological" and "landscape ecological" concepts of Troll, Tricart and others (see Vink, 1986). These concepts were, however, not easily adopted by civil and hydraulic engineers, soil scientists, agronomists and foresters respectively, because of different educational backgrounds, professional experience, and location in different, sometimes competing, institutions and ministries.

One of the practical reluctances in accepting a landscape-ecological approach consisted of the fact that geomorphologists among themselves were often in disagreement on a unified approach; they developed a number of very fancy schemes on geomorphodynamics but not one single classification scheme on landforms that could be easily understood and used by non-specialists on the subject.

Land and Water in a Holistic Sense

With the advance of aerial photography, satellite remote sensing and Geographic Information Systems as tools, the advantages of a holistic approach to land characterization and land management have become obvious. Time has come for international organizations such as FAO, as well as national institutions, to start cooperating more effectively, on the basis of unifying concepts. The Agro-Ecological Zoning system of FAO has achieved a degree of integration at scales between continental (1:5 million) and about 1:50000 (district or province-level), but hydrological and vegetational aspects have not yet been harnessed in the system.

The degree of holism hinges on the definition of "Land". I advance the following one (Sombroek, Brinkman and Gommes, 1993), now being incorporated in the draft texts for an Intergovernmental Framework Convention for Control of Desertification and Drought ("desertification" understood to be "land degradation in dry-land areas"):

"Land is a delineable portion of the earth's terrestrial surface, encompassing all attributes of the biosphere immediately above or below this surface, including those of the near-surface climate, the soil and terrain forms, the surface hydrology (including shallow lakes, rivers, marshes and swamps), the near-surface sedimentary layers and associated groundwater and geohydrological reserve, the plant and animal populations, the human settlement pattern and the physical results of past and present human activity (terracing, water storage or drainage structures, roads, etc.)."

In this holistic approach, a unit of land has both a vertical aspect - from atmospheric climate down to groundwater resources, and a horizontal aspect - an identifiable repetitive sequence of soil, terrain, hydrological and vegetation or land use elements ("landscape", "land unit" or "terroir" units). Mineral resources and deeper geohydrological resources (confined aquifers) would, however, be excluded from land attributes.

One should therefore integrate all compartments vertically; from groundwater-related qualities, through qualities of soil profile, soil surface, slope position and vegetative cover, to overhead climatic qualities. The qualities of the vegetative cover came to the fore at the recent involvement in agro-ecological and socio-economic zoning of Amazon countries.

One should also integrate all aspects horizontally at the landscape level. This is the land unit approach of physical geographers, which takes into account the typical, micro-geographically repetitive elements of terrain, top or plateau, scarp or upper slope, main slope, lower slope or springline, bottomland or flood plain; with their mutual influence whether natural or under current land use. This influence can be in the sense of internal hydrology (for instance, rainfall moving into the soil of the plateaux and surfacing at the springline, including the lateral movement of chemical substances such as salts and silica), or the surface transport of soil material through erosion from upper slopes and accumulating in the bottomland or flood plain. Either of these processes can be detrimental or positive at the receiving end, depending on the rate of transport and the prevailing climatic conditions. The lateral influence also relates to chemical soil fertility. Nutrients may be transformed down-slope by natural processes, or from outlying land to arable fields near homesteads in traditional farming systems.

It is true that the water component of the above holistic definition of "land" has some special attributes: bulkiness, mobility, transience or evasiveness and, at the same, time is site-specific in its management. Most of the water attributes can be harnessed in a land-centred GIS system. In practice, however, one may want to continue to use "water" and "land" as of equal weight (as in the AGL Division of FAO); then the "land" definition should be less holistic and be restricted to soil and topographic features (land *sensu strictu*; ss)

A key unifying element of land characterization is the landscape unit. Only in rare cases, when the topography is homogeneous over large distances - the Great Plains of the USA or Russia; the Cerrado lands around Brasilia - may one disregard the landscape or land unit concept. In most actual field situations, the land facet analysis of a land unit is of paramount importance for sustainability assessments.

The various attributes of units of land can be translated into land qualities (Table 3), as a starting point for multidisciplinary land evaluation and subsequent land use planning. Implementation of the latter should take into account the current land use practices and patterns and the overall socioeconomic conditions, as separate layers in a GIS system, and should employ land use negotiation methods to become acceptable to all stakeholders (Röling, 1994).

For the purpose of our discussions on concepts, frameworks, and strategies in a holistic approach, one may usefully make distinctions among local, i.e. village-level landscapes; sub-catchment areas; whole river basin, major lake or coastal catchments within a climatic zone; and international river basins that traverse different climatic zones and major geological structures.

Table 3 Land qualities (amplified from Sombroek, 1994)

A. ATMOSPHERIC QUALITIES

- Atmospheric moisture supply: rainfall, evaporation, dew formation.
- Atmospheric energy for photosynthesis: temperature, day-length, sunshine conditions.
- Atmospheric conditions for crop ripening, harvesting and land preparation: dry-spell occurrence.
- Liability to atmospheric calamities: hazard of tornadoes, hailstorms, etc.

B. LAND COVER QUALITIES

- Value of the standing vegetation as "crop" (e.g. timber).
- Value of the standing vegetation as germ plasm (biodiversity value).
- Value of the standing vegetation as protection against soil degradation.
- Value of the standing vegetation as protection for crops and cattle against adverse atmospheric influences.
- Hindrance of vegetation at introduction of crops and pastures: the land "development" costs.

C. LAND SURFACE QUALITIES

- Surface receptivity as seedbed: the tilth condition.
- Surface treadibility: the bearing capacity for cattle, machinery, etc.
- Surface limitations for the use of implements (stoniness, stickiness, etc.): the arability.
- Spatial regularity of soil and terrain pattern: the degree of freedom at determining the size and shape of fields with a capacity for uniform management.
- Surface liability to deformation: the occurrence or hazard of wind and water erosion.
- Accessibility of the land: the degree of remoteness from means of transport.
- Surface water storage capacity of the terrain: the presence or potential of local "waterholes", on-farm reservoirs, bunds, fish ponds, etc.
- Surface propensity to yield runoff water (for local water harvesting or downstream water supply).
- Accumulation position of the land: degree of fertility renewal and/or crop damaging by overflow or overblow.

D. SOIL PROFILE QUALITIES

- Physical soil fertility: the net moisture storage capacity in the rootable zone.
- Physical soil toxicity: the presence or hazard of waterlogging in the rootable zone (i.e. the absence of oxygen or the excess of CO_2).
- Chemical soil fertility: the availability of plant nutrients.
- Chemical soil toxicity: salinity or salinization hazard; excess of exchangeable aluminium.
- Biological soil fertility: the N-fixation capacity of the soil biomass; the microbial capacity for the transformation of fresh soil organic matter into readily available plant nutrients.
- Biological soil toxicity: the presence or hazard of soil-borne pests and diseases.

E. SUBSTRATUM QUALITIES

- Groundwater level and quality in relation to (irrigated) land use.
- Substratum potential for water storage (local use) and conductance (downstream use).
- Presence of unconfined freshwater aquifers.
- Substratum (and soil profile) suitability for foundation works (buildings, roads, canals, etc.).
- Substratum (and soil profile) as source of construction materials.

Local village-level landscapes

(i) Scope of intervention: physical improvement of land, water and plant nutrient conservation and management on a village scale, with full participation of the local community ("gestion de terroir").
(ii) Scales of inventory and evaluation: 1:5,000 to 1:10,000
(iii) Transverse links between land attributes and land use pattern
(iv) Mainly transverse drainage influences
(v) Prime building block of soil-and-terrain units in the SOTER approach

Sub-catchment areas

(i) Scope of intervention: district-level multipurpose land use planning for (re)settlement schemes
(ii) Scales of inventory and evaluation: 1:50 000 to 1:100 000
(iii) Links between land attributes and between land use patterns mainly transverse
(iv) Dendritic drainage influences
(v) Several soil-and-terrain units, often with the same land facets or components but in different percentages

Coastal zone series of catchments (within same ecological zone)

(i) Scope of intervention: integrated coastal zone management (upland forestation and agricultural land use; irrigation and drainage of the plains; protection of marshes and swamps; fisheries and aquaculture; coastal defence works; water supply to towns; harbour development; tourism)
(ii) Scale of inventory and evaluation: ± 1:250,000
(iii) Links between land use pattern and freshwater - brackish water - mainly longitudinal seawater conditions
(iv) Parallel drainage and two-way flooding pattern
(v) Limited number of soil-and-terrain units, but clearly distinguished in composition

River basin catchment areas (*mainly within same ecological zone)*

(i) Scope of intervention: catchment-level assessment of water resources and their potential use, especially downstream (conservation or reforestation projects in upstream parts, irrigation and drainage projects in lower parts; some fishery development); identification and protection of high biodiversity values; national parks and indigenous delineation of reserves
(ii) Scale of inventory and evaluation: 1: 100,000 to 1: 250,000
(iii) Links between land and water attributes and land use patterns are mainly longitudinal
(iv) Converging drainage and river flow pattern
(v) Many soil-and-terrain units, only partly with the same land facets in different percentages

Major lake catchment areas (within same ecological zone)

(i) Scope of intervention: as under river basin areas, but with special attention to influence of midstream water use on the sustainability of fishery in the lake; aquifer management; polluting influences, including salinization
(ii) Scale of inventory and evaluation: 1: 500,000 to 1: 1,000,000
(iii) Patterns of land attributes and land use in circular bands around the lake
(iv) Centripetal drainage and flooding pattern
(v) Many soil-and-terrain units, often without any land facet links

International river basins (traversing several distinct ecological and geological zones)

(i) Scope of intervention: modelling of the conservation and development of upstream water resources for downstream water use, taking into account existing international agreements on water apportioning
(ii) Scale of inventory and evaluation: 1: 1,000 000 to 1: 5,000,000
(iii) Very complicated links between land and water attributes and land use patterns; GIS subsystems required
(iv) Mainly longitudinal river discharge elements, including interruption structures (dams; major diversions)
(v) A multitude of very diverse soil-and-terrain units; appropriate SOTER "shell" approach, with climatic and geohydrologic conditions as essential relational data bases

LAND USE CHANGE AND ITS IMPACT ON WATER RESOURCES OF KERALA STATE

Deforestation - Land use changes:

Conversion of watershed area has altered the hydrological regime while enhancing the silt movement – lowering water yield in the catchment affecting the groundwater recharge. Large-scale deforestation in the Western Ghats and introduction of plantation crops in highlands replacing the natural vegetation reduced the storage capacity of soil and resulted in surface soil erosion in watersheds and sedimentation in rivers. This has affected summer flow in rivers and some perennial rivers and rivulets have became seasonal in the last few decades due to large scale land cover changes.

Sand Quarrying and River Bank Agriculture

Sand quarrying in rivers and watersheds are killing the rivers. Such activities lead to bank erosion, lowering of water table and create several environmental problems. Ground water level in some of the watersheds has gone down by nearly one meter in the last two decades. Agricultural practices in the riverbanks (and also inside the dry riverbeds) during non-rainy months also add to bank erosion and sedimentation in rivers.

Degradation of Water Resources

All 44 rivers in Kerala are highly polluted due to inflow of untreated domestic, industrial wastes and agriculture runoff. Most of the industries are near the thickly populated riversides, often near cities and towns. There is no efficient water treatment system in industries and city municipalities. Pollution level in some of the sites is far above permissible limits.

Land Reclamation and Construction:

Sand filling of ponds, farmlands, wetlands and other water bodies affects natural water flow and groundwater recharge. Construction of new roads and buildings has blocked many canals, which were important for navigation and freshwater. Vast areas of wetlands and paddy fields have been converted into settlement and industrial areas in the recent times.

Land Reclamation

Bacteriological Contamination in Drinking Water Source

Wide spread bacteriological contamination of fecal origin in sources of public drinking water supplies, viz. traditional open dug wells, bore wells and surface sources. This is confirmed by the findings and public concerns expressed during site visits. These concerns for ground and surface water contamination relate to

(i) Close proximity of increasing numbers of leach pit latrines under varying soil conditions, laterite (midland) and sandy soils (coastal area);

(ii) Non point sources of pollution in the catchment area including possible agricultural and surface run off, especially during the rainy season;

(iii) Washing, bathing and other domestic activities around the open dug well sources, especially among the low income communities;

(iv) Inadequate and irregular disinfection of drinking water supplies, including chlorination under KWA schemes;

(v) Inadequate testing and irregular monitoring of drinking water quality.

Water Quality Management

Effective and continuous disinfection of all drinking water supplies so as to maintain minimum residual chlorine of 0.5 mg/l. The experimental results show that the quality of drinking water supplies in the state clearly indicates high level of bacterial contamination. This poses a serious risk to public health. This is confirmed by the high incidence of acute diarrhoeal diseases and other water borne infections among the people especially the poor sections of the community. This brings out the need for a system of continuous disinfection of the water supplies. The traditional wells used as a drinking water sources are reported to be disinfected only

Groundwater Protection

Contamination of Groundwater is more complex than surface water pollution mainly because of difficulty in its timely detection and slow movement. In addition the complex geo-chemical reactions taking place in the subsurface between myriad contaminants and earth materials are not always well-understood. Ideally speaking contamination should be prevented from occurring. After a contaminant or several contaminants are found in groundwater, a decision must be made on whether to rehabilitate the aquifer or find alternative groundwater resources

Responsible Factor	Most Probable Response
Groundwater pollution originating on land surface	
Infiltration ofcontaminated surfacewater	Contamination of stream side aquifer due to pollutedstream
Land disposal of waste	Contamination due to direct disposal of waste
Stock piles (ore) tailings(over burden dumps	Release of mineralized leachate
Disposal ofSewage/Sludge	Release of Biological mineralized leachate
Salt spreading on road	Pollution due to winter time road salting
Animals feed lots	Biological waste
Fertilizer and Pesticides	Run-off resulting from indiscriminate use of such items
Accidental spills	Spill of in-transit chemicals and contamination due tospray water used during such mishap.
Air borne source	Acid/alkali rain particulates as fall out from smoke/ fluedust automobile pollutants
Groundwater pollution originating above the groundwater table	
Septic tanks Cess pools	Biological contamination of groundwater
Surface impoundment	Leachate from lagoons for storage/treatment of sewageindustrial wastewater oil field brines spent acids etc.
Underground storagetanks/pipelines	Corrosion and /or leakage
Artificial Recharge	In case of improper operation the recharge may lead toincreased concentration of nitrates, metals, bacteria,viruses, detergents etc.
Groundwater pollution originating below the groundwater table	
Waste disposal in wet excavations	Contamination through abandoned mines
Agriculture drainage wells	Drainage of agricultural residues from marshes /ponds
Well disposal of waste	Contamination due to direct injection of waste
Secondary recovery ofpetroleum	Migration and ingress of hydrocarbons
Mines	Percolation of mine water
Exploratory wells and testholes	Inter-linking of aquifers leading to dissemination ofpollutants
Abandoned wells	Direct migration of mineralized fluids

Water supply wells	Contamination by surface run-off
Excessive groundwaterdevelopment	Salt

Classification	Transmission	Examples	Preventive strategies
Water-borne (water-borne diseases can also be water washed	Disease is transmitted by ingestion	• Diarrhoeas (e.g. cholera) • Enteric fevers (e.g. typhoid) • Hepatitis A	• Improve quality of drinking water • Prevent casual use of other unimproved sources • Improve sanitation
Water-washed (water scarce)	Transmission is reduced with an increase in water quantity: • Infections of the intestinal tract • Skin or eye infections • Infections caused by lice or mites	Diarrhea (e.g. amoebic dysentery) Trachoma Scabies	Increase water quantity Improve accessibility and reliability of domestic water supply Improve hygiene Improve sanitation
Water-based	The pathogen spends part of its life cycle in an animal which is water-based. The pathogen is transmitted by ingestion or by penetration of the skin.	Guinea worm Schistosomiasis	Decrease need for contact with infected water Control vector host populations Improve quality of the water (for some types) Improve sanitation (for some types)

ECONOMICS

In watershed management, the link between `watershed service' and economic activity is a point activity, such as a hydropower generating plant, the link may be straight forward. But where the activity is a dispersed one, requiring household-scale estimation, the nature and quantum of `service' obtained by each household may vary significantly. Agricultural production would actually depend upon water applied to the farm, not water flowing in the stream. And the link between the two hydrological variables is likely to be mediated by technology, capital, location and other variables. Moreover, upstream withdrawal by some households within a village may reduce the streamflow available to households downstreams. All other studies that involve household level impacts also suffer from such simplifications. More attention to the modes of resource use prevailing on the ground and more thinking on the mediating role of technology seems necessary.

Steps in the Economic Analysis Process

Economic appraisals of watershed management components or projects should include at least the following basic steps, once alternatives for achieving an objective have been identified in the planning process. For each alternative identified:

(i) Define and quantify the physical inputs and outputs involved; develop tables that show input and outputs as they occur over time.

(ii) Determine unit values (both actual financial-market prices and economic values) for inputs and output, and develop judgments on likely changes in such values over time, for example, growth in wages or fuel costs

(iii) Compare costs and benefits by calculating relevant measures of project worth and other indices and measures needed to answer relevant questions raised by decision makers; consider the implications of risk and uncertainty, for example, through a sensitivity analysis, which indicates how measures of project worth might change with changes in assumptions concerning input and/or output values.

Developing information on the relationships between input and outputs is one of the major tasks facing the watershed management specialists. Such information, put in a specific project context, provides the basis for estimating and quantifying the inputs and outputs associated with the project being analysed. As such, it is in this first step that the main interaction between economist and technical expert takes place.

Generally, the basic index, i.e. Socio-economic Status Index is estimated as follows:

$$\text{Socioeconomic status Index} = \left[\sum_{1}^{n} \pm (x/y - 1) \right] + C$$

where, x = location and y = total value and c = constant which is calculated as the å y/y after assigning the – or + (by considering the negative or positive impacts upon resources) value to the indication.

In recent years to study the socio-economic impact assessment various methods have been developed. One of the important method suggested by watershed management research group is based on the use of linear programming (LP) techniques to evaluate optimum agricultural land use (at the farm scale) for a range of environments, including the need for machinery and farm labour and the timing of machine operations. This can estimate land use decisions by considering non-significantly different near-optimal solutions and the cost of change; increasing the area of an existing crop will have no penalty, but introducing a new crop would have a start-up penalty.

Table 4 Summary of input variables for land use optimization for socio-economic analysis

	Variables
Crop	Gross margin: yield (primary and secondary), prices, seed rate, fertilizer rates, sprays and costs
	Husbandry operations: list of operations and their feasible timing e.g. plough, cultivate, drill spray, fertilize, harvest, bale
	Timeliness penalties:extra cost or loss of yield of doing operation at other than the optimal timing
	Rotational penalties: reduction in yield from one crop following another, including impossible
Operations	Work rate as a function of size of machinery and amount of e.g. yield or fertilizer or soil type
	Workable hours as a function of soil type, rainfall and time of the year
	Machinery needed (i.e. size, power)
Machinery and labour	Cost; capital, repairs, fuel, resale value
	Replacement interval

The socio-economic approach requires a number of inputs, including crop yield and its variability, and soil workability. A summary of the input variables to the socio-economic analysis also accounts for farm sizes, existing farm systems, and other demographic factors to enable predictions to be made of the likely rate of change of land use, based on the difference in profit between existing and proposed systems. The variability in yield and prices are used to determine a profit risk profile. This method can be used to assess the capacity of different agricultural systems to adapt to climate change and, more importantly, identify which systems will be slow or unable to adapt

SUMMARY

At each level of scaling or geographic aggregation, as outlined above, a multidisciplinary and holistic approach is warranted and feasible. However, the weight between the different disciplines, the approach and the tools to be used are different, as a consequence of the different main purposes of the studies and the interventions envisaged. The smaller the scale, i.e. the larger the area under consideration, the more the longitudinal and water-flow related aspects come to the fore.

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