15. Watersheds and Rural Development Planning

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Summary

We have attempted to show how the drainage basin concept is often a valid and useful integrating unit for understanding the structure and function of social and natural systems, and that man-environment activities causing environmental impacts can also be organized within this framework.

The impact of man's interaction with the environment can change both biophysical and social systems spatially distributed throughout the drainage basin, in different ways and at different times. Consideration of past changes can help to predict the adaptability and resilience of natural and social systems to planned future changes.

For many kinds of regional rural development planning activities in developing countries, the drainage basin is the most appropriate spatial unit for planning. When used properly, the integration of patterns and processes of natural and social systems can be achieved more easily, without neglecting or glossing over major aspects of either system.

Introduction

Many, if not most, rural development planning and implementation activities should consider the use of the watershed or drainage basin as a suitable development planning unit. At the very least, the myriad aspects of natural and social processes which are linked in this hydrologic/topographic unit must be recognized, and incorporated into plans and programmes. The purpose of this paper is to present support for this thesis.

Rural Development Planning

In general, the objectives of rural development planning are to identify a range of existing or potential activities, especially resource uses and to promote those which will improve the welfare of the rural population within the guidelines or policies established by national development objectives and priorities. Simultaneously, such planning should minimize conflict, social disruption, unsustainable use of natural resources, inequitable distribution of benefits and costs, and adverse environmental impacts.

In rural areas in particular, such plans and programmes must have the support or acquiescence of persons and groups outside of the planning area, who have greater numbers, greater wealth, and more power. This will not materialize if the offsite products of activities (externalities) are harms rather than benefits (e.g., decreased low flows, water quality impairment). The majority of rural planning undertakings today are in the upland areas. The most numerous and important offsite *physical* products from planned changes in rural activities in the uplands, are delivered via gravity or via a part of the hydrologic cycle to areas of the lower basin, thus making the watershed an important candidate for a basic planning unit. This is, of course, not true if the product is air pollution from some new industrial use in the area, though even here, in topographically constrained areas, the watershed and the airshed may coincide. It is not necessarily true in the case of the offsite benefits of an aesthetic landscape, though a watershed in a 'high state of conservation' is usually also a landscape of high aesthetic appeal. Similarly so[illegible] other benefits or costs delivered offsite from the area under planning scrutiny (e.g., loss of species, out-migration of people, etc.) are not related to watershed units, but nonetheless these externalities are not necessarily mishandled by using a watershed for planning and programme implementation.

Some rural development needs, for example improved education and public health services, are not related to watersheds, and if these are the most pressing needs, then the hydrologic unit may be irrelevant. However, where the land/water/climate/people interaction is a major focus for development (i.e., land and water use) this interaction is most strongly expressed in a watershed. Moreover, water seems increasingly to be the key physical resource limiting or triggering economic development in rural areas. The success or failure of a plan can lie in choosing a boundary which is relevant to the principal planning issues, covers sufficient natural and social linkages to

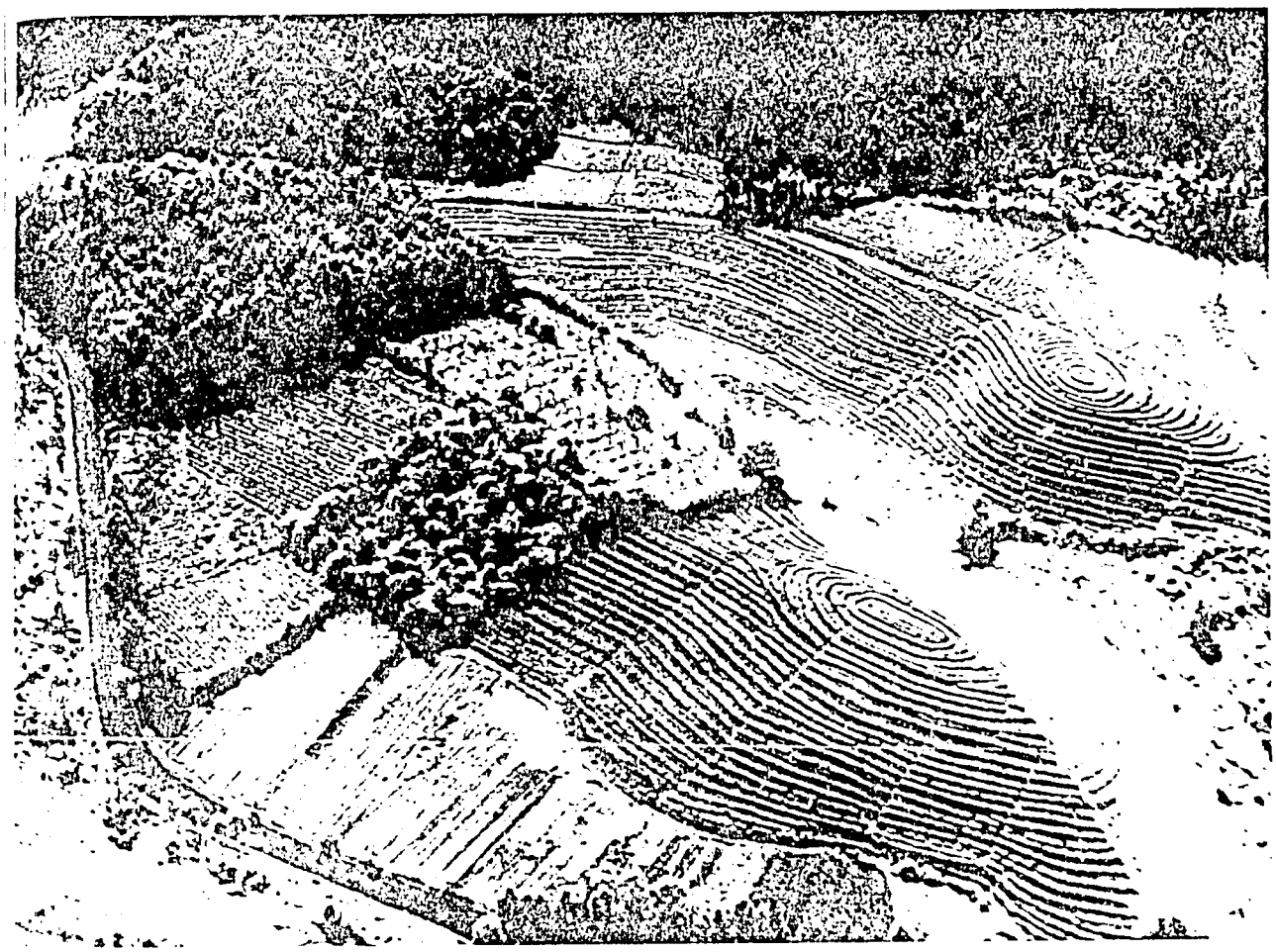

Fig. 15.1. Land-use patterns are determined by both biophysical factors and socio-economic aspects—an interaction between natural and social systems.

operate as a functional unit, and allows effective plan implementation. Some criteria and constraints indicating the appropriateness of a watershed or drainage basin as the planning unit are presented in the Appendix to this paper. Thus the watershed unit not only integrates natural systems, but also many social processes and patterns as well, and is therefore worthy of serious consideration in rural development (Fig. 15.1).

The Watershed as an Integrator of Ecosystem Patterns and Processes

The non-living environment is characterized by variations in climate and features such as soil types in a catena, lithological types in a geologic sequence, or geomorphological forms from deltaic alluvium at the river mouth to rugged outcrops on the ridges. The drainage basin is most successful in organizing these variations because they tend to follow an elevation gradient from basin ridgeline to the river and down the river to its lowest point. Similarly, climatic variation within the basin is also related to elevation. Plants and animals will occupy the various habitats afforded by these variations in soil, geomorphology, and climate. Aquatic ecosystems will vary along the main stream and tributaries, from estuarine to mountain stream ecosystems.

Ecosystem processes describe exchange of materials and flows of energy through each of the structural elements of the ecosystem and provide compelling reasons for using the drainage basin as an integrating planning unit.

Watersheds have an accumulated potential energy contributed by past geological processes—uplifted mountains having higher potential energy than the alluvial plains. The soil, vegetation, and animal life have stores of organic (chemical) energy contributed by past inputs of solar energy. Thus soil erosion should be seen not just as the loss of a physical or nutrient medium, but also as the loss of accumulated organic energy.

To these stores of energy are added current inputs of solar energy via the sun, rain, wind, and other climatic factors. These inputs are spatially

distributed over the watershed, with the upland areas typically receiving greater inputs of energy than lowland areas. Some of the energy input is lost directly from the basin through reradiation, another portion is lost as waste heat as it passes through various life processes, and a small proportion is assimilated into living things and redistributed through the basin by gravity, water transport, or by humans. The transformation of potential energy into kinetic energy permits man to generate hydroelectricity energy, irrigate fields, grind flour, float goods to market, and to disperse pollutants; it also causes destruction from floods, erosion and deposition.

Similarly, inorganic materials are either brought into the basin by precipitation or made available from geologic stores and are redistributed throughout the basin by gravity, wind, water, and biological processes. Organic matter, chemical compounds (harmful or beneficial), soil, minerals, animal life, and vegetation are transported through the basin by the kinetic energy transformations mainly wrought by gravity and aided by water.

It is contended that water is the most important material flowing through the basin, and the movement of materials downhill by gravity is one of the most important ecosystem processes which can be influenced by human actions. The component processes of the hydrologic cycle are best managed in a watershed context.

The drainage basin is also important for several other ecological processes in physical planning. The location and extent of floodplains can be identified from the landscape and vegetation, and should be mapped to avoid, if possible, the widespread loss of life and property damage from encroachment of human activities into areas which are regularly flooded. In topographically constrained valleys, airshed behaviour and assimilative capacity may be predicted.

The ecological processes of aquatic organisms including fish are spatially distributed along the river; spawning, nurture, feeding, reproduction, and migration. All have water quality and quantity requirements which are affected by developments 'upstream'.

Social System Patterns and Processes

In many developing countries, there are occupational, social, or ethnic differences between highlanders and lowlanders, hill tribes and valley tribes, upstream residents and downstream residents which reflect the spatial characteristics of drainage basins. An integrative classification was first suggested by Patrick Geddes in the late 19th Century; an idealised pattern he called the 'valley section'. His student, Lewis Mumford (1934) describes the schematic valley section as follows:

> "Toward the mountain top, where on the steeper slopes the rocks perhaps crop out,—the quarry and the mine ... . In the forest that stretches from the crown of the mountain seaward the hunter stalks his game ... . Further down the valley, where the little mountain torrents and brooks gather together in a stream ... is the realm of the primitive woodman: the wood chopper, the forester, the millwright, the carpenter ... . Below the primitive woodman lies the province of the herdsman and the peasant. Goatherd, shepherd cowherd occupy the upland pastures or broad grass lands of the plain-plateaus ... . Below the more barren pastures, the peasant takes permanent possession of the land and cultivates it. He expands into the heavier river bottom soil as his command over tools and domesticated animals grows, or as the struggle for existence becomes more keen ... . Finally, at the oceanside plying in and out behind the barrier beaches and salt marshes, lives the fisherman."

Although the correlation between occupations and ecological habitats is not always followed in drainage basins, the valley section concept is often valid in developing countries, since the resources available permit a limited range of occupations in predominantly subsistence economies.

In industrialized economies, where exogenous inputs of energy and materials, and other location factors predominate, the correlation between landscape opportunities and occupation may not apply. On the other hand, where land-use patterns have been stable for many centuries, land capability has been learned by trial and error. Accordingly, the existing spatial distribution of occupations may be correlated with current land capability.

Environmental opportunities for certain occupations can lead to spatial specialization in the production of material goods needed by communities. These production imbalances are redressed by trade; the upland herdsmen trade woollen goods for fish from the coastal fishermen, the cultivator trades agricultural produce for wood products, and so on. Thus trade linkages drawn together at market places can be profoundly influenced by the resources spatially distributed throughout the drainage basin. The raw materials also require energy to be transformed into manufactured goods. Although much of the energy input in developing countries is from intensive human activity, the waterwheel, small

grinding mills, and firewood are energy inputs drawn from environmental opportunities in the drainage basin.

In areas of rugged topography, the least energy demanding routes for trade and social linkages will be chosen. In those countries where most travel is by foot or pack animals, the trade routes are generally through a low pass in the dividing range and along the floor of the river valley. Where navigation is possible barges or rafts are used along the river, as this is the least energy demanding route. In some countries the topography or other factors have led to trade routes along the ridge lines and villages are found on the ridges rather than on the valley floor. A ridge top location may provide greater security, protection from disease-carrying insects, or a more tolerable climate. Whether the routes are along ridges or valley floors, most developing countries, (where road networks are still sparse), will display a pattern of trade linkages and social interaction related to topographic features of the drainage basin.

Another social process having spatial aspects related to basins has to do with conflict. It has been expressed in 'valley against valley' usually due to isolation effects and sometimes intermarriage within clans. In some societies there is a sense of identity with a drainage basin, fostered by a vague mistrust of inhabitants over the ridge line. A second and almost reverse pattern has developed elsewhere in which the mountain folk and the flatlanders within a basin, have a conflict relationship. Even in developed societies today a certain polarization of interest and values between upstream and downstream inhabitants is very real. Squabbles over water rights of 'upstreamers' versus 'downstreamers' are not uncommon. If planning in a drainage basin is undertaken, then the upstream/downstream social conflict must be recognized as a potential impediment. Upstream residents often perceive of themselves as bearing the brunt of the costs to the benefit of the downstream people. Where this is indeed the case, some system of trade-offs or compensation should be considered. Using a drainage basin does internalize these elements.

Only a partial list of social interactions has been considered here; others may be more important in different traditional societies. Planners should be aware of the spatial dimensions of social processes, since an apparently beneficial change such as a new road through the drainage basin can completely disrupt traditional social exchanges and threaten the existing social structure.

Environmental Hazards

One can often mistakenly attribute all environmental problems to man's interference with the environment, yet certain natural environmental processes can be hazardous to social activities and be largely outside man's influence or control.

On steep slopes in the upper part of the drainage basin, the principal environmental hazards relating to land and water are avalanches, rockslides, mudflows, landslides and other kinds of slope instability. Elsewhere, areas prone to floods, stream bank erosion and sediment deposition, and to geological movements such as earthquakes, may exist. Other hazards such as lightning, blizzards or drought are related to climatic factors distributed through the basin. Fire hazard is related to vegetative, climatic, and topographic factors.

One of the planning functions should be to map these hazards so that human use of life-threatening hazardous areas is avoided, and structural or other modifications can be made for less serious hazards. Several development proposals can exacerbate the environmental hazards; large dams can increase earthquake hazard, roads can increase landslide hazard, and conifer plantations can increase fire hazard. Most environmental hazards and their effects are best identified, displayed and mitigated by planning based on the hydrologic unit.

Environmental Impacts

Man-initiated environmental impacts are often best accounted for in a watershed context, because many of the processes through which they emerge are expressed through gravity and hydrology. For example, consider the construction of a reservoir primarily designed to provide hydropower, flood control and/or irrigation. Good engineering design usually ensures that the project meets these somewhat incompatible primary objectives. Initially the new reservoir also provides secondary beneficial effects through the development of a new reservoir fishery or water-based tourism. However, the construction of a barrier across the river may prevent migratory fish from proceeding upstream to spawn, thus causing a detrimental impact on downstream populations of that species. Downstream water temperatures may also be altered, further affecting the below-dam fishery. Tertiary impacts include the fact that upstream communities now have new sources of livelihood whereas downstream fishing communities may have had their source of livelihood

Fig. 15.2. Watershed land-use in the Philippines is affecting the water quality and storage capacity of this reservoir; and in turn the existence of the reservoir has affected the kind and intensity of spontaneous land use. In many cases land-use adjustments based on planning and some control or inducement are called for.

reduced. These changes could set in motion another round of impacts: the downstream community could abandon their fishing village and move to the cities in search of work, the upstream communities could abandon their traditional shifting agriculture to become reservoir fishermen or tourist guides—each shift having environmental impacts (Fig. 15.2).

Land-use intensification around the reservoir can cause soil erosion thus increasing sedimentation which in turn reduces the life of the reservoir, its fishery potential, and the life of the hydroelectric turbine blades. The retention of sediment in the reservoir decreases sediment supply to downstream areas, which, in turn, could reduce nutrient replenishment of alluvial soils, and initiate coastal erosion. Alteration of freshwater nutrient flows and sedimentation can adversely affect mangrove forests (a major cause of mangrove destruction worldwide), and thereby reduce fish and shellfish production as well as the other services and wood and wildlife products of these important forests.

The tie between welfare of the coastal mangroves and the storage of water (and changes in sediment) has not often been recognized in planning which has been based on political or other boundaries.

Land-use intensification of downstream areas due to the availability of increased irrigation can cause waterlogging, salinization of soils, and saline-, pesticide-, or nutrient-rich runoff into drainage waters, which in turn impact on fisheries, mangroves and other downstream uses of water.

These and other environmental impacts all reverberate through the natural and social systems. Similarly many other kinds of development proposals can be shown to distribute beneficial and detrimental environmental impacts throughout the drainage basin, and over varying time periods. The point is that these chains of consequences are often made most apparent when environmental assessments are based on drainage basins.

It is obvious that environmental impacts also operate as feedback loops, changing both ecosystems and social systems. The floodplain, once a scene of frequent inundation, devastation of property, and loss of life, could become safer to

inhabit. The estuarine ecosystem and the below-dam fishery could become less productive. The upstream shifting cultivation system could change over time into a settled community around the reservoir dependent on fishing and tourism for cash income, and on settled cultivation around the reservoir margins for food. This might well relieve some shifting cultivation pressure on the upland forest. For the downstream community who progressively lose the fish resource, the social changes may be measured as reduced socio-economic status or forced migration. Some of the lowland cultivators who initially benefit from the project may also be forced to migrate as the irrigated areas become waterlogged and salinized. The urban dwellers who benefit from the expanded electricity supply and the new tourist facilities, may find changes initiated by the increased rural-urban migration and reduced output of electricity, as the reservoir becomes silted up.

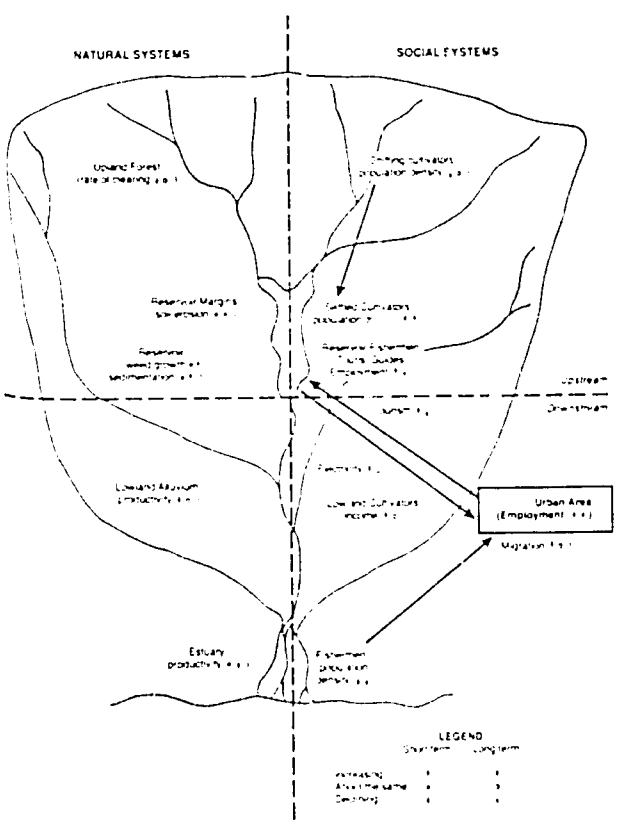

Fig. 15.3. Some indicators of the short- and long-term adjustments that might occur in a typical drainage basin.

Figure 15.3 illustrates how some indicators of the outcomes of the adjustment process might appear in the short- and long-terms. In reality, additional inputs would become necessary at times to prevent the natural and social systems from continuing in an undesirable direction. Also, in place of this very limited and subjective assessment, one would need to measure a much wider range of natural and social indicators in an extended cost-benefit to provide greater quantification. However, it should be noted that many of the outcomes may be regarded as inter-generational costs on benefits which are outside the economic analysis using normal discount rates.

Planning for these myraid changes can be accommodated by a hydrologic unit because in rural areas social systems are interwoven with ecological systems, and ecological processes are highlighted in watershed planning.

Bibliography

Burgess, L. C. N. (1980) The application of airphoto interpretation to watershed planning and development with special reference to flood susceptibility and frequency determinations, *Ph.D. Thesis*, Cornell University, 2 vols., Ithaca, NY, USA.

Duggan, A. S. (1962) The occurrence of human trypanosomiasis among the Rukuba tribe of Northern Nigeria, *Journal of Tropical Medicine, 65*, pp. 151–163.

Hamilton, L. S. (1981) Water resources development and the emerging concept of environmental protection in the USA *EAPI Working Paper*, East–West Center, Honolulu, Hawaii, USA.

Hays, W. W. (ed.) (1981) Facing geologic and hydrologic hazards: earth science considerations, *US Geological Survey Prof. Paper 1240-B*, US Government Printing Office, Washington DC, U.S.A.

Hufschmidt, M. M. and Hyman, E. L. (eds.) (1982) *Economic Approaches to Natural Resource and Environmental Quality Analysis*, Tycooly International, Dublin, Ireland.

Kunstadter, P., Chapman, F. C. and Sabhasri, S. (eds.) (1978) *Farmers in the Forest*, University Press of Hawaii, Honolulu, Hawaii, USA.

Lotspeich, F. B. (1980) Watersheds as the basic ecosystem: this conceptual framework provides a basis for a natural classification system, *Water Resources Bulletin, 16*(4), pp. 581–586.

Mumford, L. (1934) *Technics and Civilization*, Harcourt, Brace and Co., New York, USA.

Saenger, P., Hegerl, E. S. and Davie, J. D. S. (eds.) (1983) *Report on the Global Status of Mangrove Ecosystems*, IUCN, Commission on Ecology, Gland, Switzerland.

Appendix

Some criteria and constraints indicating the appropriateness of a watershed or drainage basin as the planning unit.

1. Kind of development

Where a key feature of the plan depends on achieving management control over water, such as increasing the amount of water available for use, influencing its timing, or improving its quality, the land/water interaction is best expressed in the hydrologic unit of a drainage basin. Many kinds of agricultural, forestry and some rural industrial and mineral developments are also included

because of their need for water or because the off-site effects are transferred through gravity or hydrology to downstream users of the water resources.

2. Functional unit

Does the drainage basin contain sufficiently strong linkages between economic, social, political, and natural systems to distinguish it from any other areas of equivalent size. Where it is only natural processes which distinguish the drainage basin as a region, other social, economic, or political linkages may take precedence depending on the planning objectives and priorities.

3. Containment

Does the kind of development being planned primarily affect people and resources within the river basin, with relatively little leakage to areas outside the basin? For example, irrigation schemes which require large scale water resource development, integrated flood control, drainage schemes, and new transport networks within the basin, and with relatively little impact external to the basin, are mostly 'contained'.

4. Topographic suitability

Does the topography allow the definition of a drainage basin boundary? Where drainage is internal or radial, the concept of river basin planning may not be topographically applicable. Desert, tundra or plains areas may have no well-defined watershed boundary.

5. Institutional compatibility

Does the political support exist for planning and implementation at the drainage basin level? Where the scale of the planning falls between two powerful extant levels of political administration such as State or local government, they may resent the intrusion of a possible third tier of administration which could usurp their power and reduce their share of the tax base.

6. Social simplicity

Are most economic and social activities generally conducted within a spatially constrained arena? Where subsistence agriculture, cottage or small rural industries, local marketing systems, and non-motorised transport remain the predominant forms of economic and social life, the drainage basin will often be the best unit for rural planning. However, where the society is already developed to such a degree of complexity that the response to topography and natural processes is overridden by global communications, cosmopolitan social groups, and major national transport networks, other units may be more applicable.