Land Use and Water Resources Research

Land-water linkages in rural watersheds:

Results from the FAO electronic workshop

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Introduction

This article summarises the findings from the electronic workshop *Land and Water Linkages in Rural Watersheds* organised by the FAO Land and Water Development Division during September and October 2000. About 470 people from all over the world subscribed to this electronic forum to address three main questions:

- What are the biophysical impacts of upstream land uses on downstream water resources in rural watersheds[1]?
- How can these impacts be valued in terms of benefits and costs to downstream people?
- Which mechanisms can be identified to share these benefits and costs among upstream and downstream land and water users?

This article draws on interventions, case studies and background documents presented at the workshop.[2] The complete workshop documentation is also available online at

http://www.fao.org/landandwater/watershed

Discussions were grouped into two main categories: the *Landscape Perspective*, or questions regarding biophysical impacts; and the *Lifescape Perspective*, encompassing questions about assessing benefits and costs to upstream and downstream resource users, and mechanisms for benefit-sharing in watershed management.

Landscape perspective – biophysical impacts of land use on water resources

Classification and identification

Classifications of biophysical impacts have tended to reflect the concerns of the more intensively studied areas, which are disproportionately in northern temperate zones, and have much higher average rates of runoff than arid and semi-arid countries. Much less is known about processes that are important in the arid and semi-arid countries, where water stored in soil may be more important than surface water, and erosion and sedimentation rates are naturally much higher.

The most significant impacts of land use are often associated with infrequent and extreme events. For example, the greatest transport of eroded sediment and pollutants will occur during large rainstorms, during extreme storm events such as hurricanes or when heavy rains follow a period of drought. Variability of natural processes, most notably climate variability, is an important parameter affecting land use practices. Land use impacts are compounded by the complexity of hillslope processes and, potentially, by climate change. The knowledge of natural processes relative to the impact of anthropogenic land use change is critical for development of effective and appropriate response strategies.

Given that impacts of land use on water resources are the result of complex interaction between diverse site-specific factors and off-site conditions, standardised types of responses will rarely be adequate. These relationships

[1] During the workshop, the terms “watershed”, “catchment” and “river basin” were used interchangeably, denoting the area which drains into a common point such as a river, lake or aquifer.

[2] FAO 2002. *Land-water linkages in rural watersheds*. Land and Water Bulletin No. 9, Rome.

Zimbabwe: influence of a headwater wetland on downstream river flows

Dambos, a type of seasonal wetland, are common in the headwaters of many major river systems in southern and central Africa. Although largely based on assumptions, dambos have been attributed an important role in the regional hydrological cycle in the form of dry season flows, and their disturbance is perceived to conflict with their function as a source of downstream flow. Results obtained in this study suggest instead that, although they store significant amounts of water during the wet season, its depletion is dominated by evaporation, with only a small portion contributing to stream flow. Also, that they may reduce floods at the start of the wet season but once the soils are saturated, they generate flood runoff. This suggests that shallow rooted crops could be grown in dambos with little impact on dry season flows.

Source: McCartney, Case Study 20

can be better understood through the use of process models, which must be combined with site-specific assessment.

Change in the relative importance of land-water interactions with the size of the watershed: considerations of scale

As a general rule, impacts of land use activities on hydrological and sediment-related processes can only be verified at smaller scales (up to some tens of square kilometres) where they can be distinguished from natural processes and other sources of degradation. This suggests that the use of economic instruments and mechanisms will also be most effective at this scale. Assumptions that relationships observed at smaller scales hold at the largest scales, and that processes observed in one particular region can be applied to another, have often led to inappropriate and ineffective responses.

Table 1 Measurability of land use impacts by basin size

Impact Type	*Basin size [km²]* 0.1	1	10	10^2	10^3	10^4	10^5
Average flow	x	x	x	x	–	–	–
Peak flow	x	x	x	x	–	–	–
Base flow	x	x	x	x	–	–	–
Groundwater recharge	x	x	x	x	–	–	–
Sediment load	x	x	x	x	–	–	–
Nutrients	x	x	x	x	x	–	–
Organic matter	x	x	x	x	–	–	–
Pathogens	x	x	x	–	–	–	–
Salinity	x	x	x	x	x	x	x
Pesticides	x	x	x	x	x	x	x
Heavy metals	x	x	x	x	x	x	x
Thermal regime	x	x	–	–	–	–	–

x = Measurable impact; – = No measurable impact

Source: *Kiersch, Discussion Paper 1*

Impacts of land use on reservoir sedimentation: a case study from Morocco

In the preparation phase for a large-scale watershed management project in Morocco, hydrologists were requested to assess the possible impact of the project for reducing sedimentation of reservoirs. Sedimentation is a critical problem for Morocco's large dams, as they are the main source of water for the country's large irrigation systems and cities. In 1994, 8% of their total capacity had already been lost. The watershed areas range from 1 000 to 50 000 km², with a variation in sediment yield between 300 and 3 000 t/km²/yr, depending on the geology of the watershed.

It was expected that hydrologists could quantify the extent to which proposed land conservation practices would reduce sedimentation of reservoirs, and that these impacts could then be valued and accounted for in the overall financial analysis of the project. It became clear to the hydrologists, however, that the impact on sedimentation of reservoirs would be negligible, regardless of the extent of land included in the programme. The main reasons for this are:

- The land that could benefit economically from erosion control measures represents only a small percentage of the total area of each watershed and could therefore contribute only marginally to the reduction of sedimentation.

- Using the participatory approach, efforts concentrate on the improvement and reduction of erosion of farmer's land, whereas the badlands, which are the areas contributing the most to sedimentation, would not be treated by the project, as they were not of interest for farmers in the uplands. The high rate of natural erosion compared to human-induced erosion was regarded as a serious constraint.

- The alarming rate at which dams are filling implies the need for an action that can have immediate effects. Any significant action in upland areas would only be expected to show benefit after several decades due to the size of the watersheds. This was not an option that could be considered by the Water Resources Department, which then had to find other remediation actions.

- The extremely high variability of the erosion and sediment transport processes made any assessment of the average yearly rate irrelevant: most of the erosion and sediment transport occur on the occasion of extreme events, (such as storms which lead to landslides) on which soil and water conservation actions would show little impact.

In conclusion, it was not possible for the hydrologists to significantly quantify the impact of watershed management activities on sedimentation in reservoirs. Different results might apply to other areas, with smaller watersheds and different geological conditions, but in this specific case, each of the reasons given above was sufficient to discard any clear linkage between land management and water resources.

Source: Faurès, Intervention 4

Certain impacts of land use on water quality, such as salinity, have an impact at larger scales as well. At the largest scales, impacts are difficult or impossible to verify because of a long time lag between cause and effect, and many overlapping factors. This makes it more difficult to arrive at agreements between users about rights and responsibilities. Such agreements are needed to implement mechanisms for sharing costs and benefits in large river-basins.

In sum, impacts and responses to them need to be considered at the appropriate scale – efforts to change land use practices and to implement mechanisms for sharing of benefits and costs will be most successful in response to measurable problems in small basins. At larger scales, long-term monitoring is needed because of the long time lag between cause and effect. Mechanisms of sharing costs and benefits at these scales will most likely deal with water quality concerns.

Adequacy of existing knowledge and understanding

Knowledge about land–water interaction is often used to make generalisations that are not always appropriate. Site-specific information is often inadequate to determine which management actions will be most effective, which makes stakeholder negotiations difficult. Community involvement is needed to identify and agree on causes of and responsibilities for land use changes, and to clarify uncertainty for stakeholders. There is a need to build greater capacity for site-specific research, including participatory approaches, and long-term hydrological monitoring and forecasting systems to arrive at a better understanding of large scale and cumulative effects.

Variability, uncertainty and myths about land-water linkages

In the absence of complete information, overgeneralisations or myths about links between land use activities and hydrological processes have emerged, such as ‘deforestation causes flooding’ regardless of basin size, or ‘deforestation causes erosion’, even where natural erosion rates are high. These generalisations, which cannot be verified, and in some cases have been disproved scientifically, are still frequently used as justifications for policy and programmes.

Such myths may selectively single out particular causes from multiple ones in order to support institutional and political agendas, and may be a convenient basis for advice because their assumptions are unverifiable. This leads to misguided policies and remedial approaches, and often results in poor and minority populations in upland areas being made scapegoats, despite their relatively minor contributions to the problem.

General statements about land–water interactions need to be questioned continuously to determine whether they represent the best available information and whose interests they support in decision-making processes. Due to the complexity of landscape processes and the long time lag between cause and effect, uncertainty is inherent in any scientific findings and assumptions about land-water interactions. This uncertainty needs to be made explicit to avoid the emergence of new myths.

Zimbabwe: The causes of sedimentation

An experience from south-eastern Zimbabwe was described regarding the myth that “poor agricultural practices in the headwaters are leading to increased siltation in reservoirs”. The large sugar estates of the lowlands are major agribusiness users of water in Zimbabwe, and rely on an extensive series of mid-catchment storage dams that all face problems of sedimentation. Often, the increased sediment is blamed on poor local farming practices, including deforestation and overgrazing by the ‘indigenous’, ‘subsistence’ farmers of land in the headwaters.

Following the devastating drought of the early 1990s, some of the sugar estates started outreach programmes to work with the farmers in the headwaters to ‘improve’ their land management. By the late 1990s, those involved in the outreach programme were reporting positive results: the suspended solids entering their dams were decreasing dramatically. Yet, to an outside observer it seemed highly unlikely that changes in how the headwaters were managed could have been responsible for these dramatic falls in sediment load. The outreach programme was tiny, and the catchment area large. Research also revealed a 10-year cyclical pattern of above and below ‘average’ rainfall, possibly related to the El Niño Southern Oscillation (ENSO). The 1980s, which were capped by a drought, had been the driest on record.

The combination of research and local farmers’ perspectives allows development of an alternative narrative to that of the sugar cane farmers. This suggests that during the long dry years, water levels drop, shrubs and grass die, and livestock (before dying) exacerbates the situation by eating everything available, turning the area into a desert. During this period, sediment levels generally increase and the erosive force of rainfall is large, as soils are not protected by vegetation. In particular, large storm events at the end of the dry period can move huge quantities of ‘stored’ soil. However, once a wetter period is entered, browse and crop cover quickly returns, aided by low livestock numbers, and erosion more or less ceases – until the next dry cycle.

Just as the account of sugar cane farmers, the above is a narrative rather than a scientifically proven account. Proof, in this case, would require monitoring sediment loads and other key parameters for a full 20-year cycle. However, it corresponds with what is known of erosion from other arid and semi-arid regions. Photographs of the study site in the 1990s show a bare expanse of red earth, in no way comparable to the lush ‘humid’ vegetation seen since 1994. Sediment measured leaving a small headwater catchment, where there had been no outreach programme and where subsistence agriculture was being practised, never exceeded 5 t/ha – far below the 70-100 t/ha reported from many plot-based experiments.

Source: Moriarty, Intervention 26

Assessment of land-water interactions

Tools and methods of assessment range from particular methods applied to the understanding of individual processes, to more integrated and participatory approaches. Since land–water interactions are very dependent efforts, site-specific process models should be developed that allow local conditions to be considered in the design of interventions. Project budgets and timelines should allow for stakeholder participation in research and in monitoring. Though slow and expensive to initiate, participatory approaches increase the potential for research to have impacts on policy. Other advantages include simplicity, cost-effectiveness and local relevance, that may outweigh potential bias and lack of precision, and which can be calibrated through comparisons of results with researchers.

Indicators need to be scientifically validated, of relevance to the affected community, as well as practical and

Hydrological impacts of forests – common perception and reality

While there is a consensus that watershed management interventions should be based on sound science, considerable controversy about the direction and magnitude of the land use impacts on water resources prevails, especially with regard to the role of forests. One background paper examined different popular 'myths' relating to forestry.

Forests increase rainfall?
The overwhelming hydrological evidence supports the notion that forests are not generators of rainfall. Although the effects of forests on rainfall are likely to be relatively small, they cannot be totally dismissed from a water resources perspective. Further research is required to determine the magnitude of the effect, particularly at the regional scale.

Forests increase runoff?
Catchment experiments generally indicate reduced runoff from forested areas compared with areas under shorter vegetation. Exceptions to this finding are cloud forests, where cloud-water deposition may exceed interception losses, and very old forests.

Forests regulate flows – increase dry season flows?
Forestation will not necessarily increase dry season flows. Competing processes may result in either increased or reduced dry season flows. Effects on dry season flows are likely to be very site-specific. The complexity of the competing processes affecting dry season flows indicates that detailed, site-specific models will be required to predict impacts.

Forests reduce erosion?
Competing processes might result in either increased or reduced erosion from disturbed forests and forest plantations. Forest cover as such does not guarantee low rates of erosion: the forest quality, e.g.existence of surface litter, is an equally — if not more — important factor.

Forests reduce floods?
For the largest, most damaging flood events, there is little scientific evidence to support anecdotal reports of deforestation as being the cause. Whereas on a micro-scale (small watershed) the effects of human interventions such as forest cutting can be directly documented in terms of higher discharge peaks or higher sediment load, on a large-scale natural processes are dominant, and the impacts of human activities are neither detectable nor measurable. Field studies generally indicate that often it is the management activities associated with forestry — cultivation, drainage, road construction, soil compaction during logging — that are more likely to influence flood response, rather than the presence or absence of the forests themselves.

Source: Calder, Background Paper 1

Myths about land–water linkages: the case of the Ganges-Bramaputhra

An example of media headlines for this region states that: "the severe floods in Eastern India and Bangladesh are not the result of a natural disaster, but of a ruthless exploitation of wood which has been practised over centuries in the forests of the Himalayas". Headlines such as these are based on assumptions that the forest cover in the Himalaya is rapidly decreasing, which only holds true for certain areas, e.g. the Western Himalayas of Pakistan. Also, that there is a direct link between forest removal in the Himalayas and flooding in the lowlands of the Ganga and Brahmaputra river systems, and that the mountain people with their forest management practices are responsible for the inundations in the plains — a highly sensitive statement.

The newspaper statement reflects the still widespread wrong assumption that land–water linkages observed in a small and medium sized watershed can be extrapolated to large watersheds. In many studies, it can be documented that in small watersheds the human impact on land–water influences is dominant. In medium sized watersheds it is already difficult to distinguish between man-made and natural impacts on the land–water linkages. In large watersheds, natural factors (e.g. heavy rainfall events and deep landslides) are clearly the dominant links between land and water.

There is, of course, a significant contribution of 'base flow' from the highland catchments of the Brahmaputra and the Ganga to the floods, but this input is just one element of many others and is not a flood-triggering one. The natural rates of weathering and erosion in this tectonically active steep land zone are high, and sediment transport is a dominant process, irrespective of vegetation cover. Inappropriate land use practices may still have disastrous consequences within a highland watershed, but conservation practices should not be undertaken with the expectation that they will prevent floods in the lowlands.

Source: Hofer, Intervention 4

inexpensive to measure. Potential indicators mentioned during workshop discussions are: eroded soils and sediment contamination of streams, altered stream flows and soil export, bacterial contamination, demographics and land use, and community perceptions, memories and experience. It will be easier to find agreement among stakeholders on narrower, more technical indicators. However, conflicts among different interest groups may be inherent in deciding which impacts matter and in selecting appropriate indicators for them. Such conflicts should be anticipated in the assessment process.

By definition, a watershed approach implies addressing complex issues in large areas over long periods of time. This is difficult to achieve in a narrow technical framework and with budget limitations. Since financial and technical means are usually limited, however, uncertainty and the need for value judgements become inherent in decision-making. These need to be made transparent to stakeholders.

The Lifescape Perspective – valuing land-water interactions and implementing upstream-downstream cooperation

Valuation of land use impacts on downstream water resources

Impacts of land use practices can be distinguished in impacts on use values and non-use values. Use values can be further distinguished into consumptive — for example, irrigation

Community-based water quality monitoring: from data collection to sustainable management of water resources

In the community of Lantapan, Mindanao, the Philippines, researchers worked side by side with non-governmental and governmental workers over a five-year period to develop science-based indicators of water quality that proved relevant for developing environmental policy. Citizen monitors collect data on suspended sediment, stream discharge and flow variability, and coliform concentration in water, among other indicators. Elementary school students of Lantapan are being taught which of the rivers of their municipality are clean and which are polluted. Beyond awareness of the environmental problems, these school students and their teachers have begun restoration activities including tree plantings on riverbanks to prevent soil erosion and sedimentation. The participatory monitoring system has influenced resources management policies: the local government has incorporated community-based water testing and some of the research findings and recommendations into their Natural Resource Management Plan.

Source: Deutsch *et al*., Background Paper 3

and domestic use — and non-consumptive values, for example, transportation. Water bodies and riparian areas may also have significant non-use values, for example, as reservoirs of biodiversity. It is equally important to consider the distribution of costs and benefits between upstream and downstream users, as well as within communities. The analysis of affected values is an important basis for selecting the most appropriate benefit-sharing mechanism. The results of valuation should be communicated to stakeholders and used to identify existing land use incentives. Since complete information will rarely be obtainable, it is important to clarify limitations to the valuation, which factors have been included, and the degree of uncertainty.

Uncertainty regarding links between upstream land use activities and impacts on downstream resource users also creates uncertainty regarding economic values. However, even partial values may be sufficient to justify investments in watershed protection. When differences with and without a project do not show significant benefits within the time frame of the analysis, less tangible and less certain costs and benefits can be considered. The decision to implement a benefit-sharing mechanism will then be based primarily on consideration of societal benefits or equity concerns, in addition to the immediate monetary benefits.

Benefit-sharing mechanisms for linking upstream and downstream users

Benefit-sharing mechanisms include a broad range of approaches, ranging from regulatory and market instruments, education and awareness building activities, to development of new institutional arrangements and participatory approaches. These mechanisms are not mutually exclusive. Rather, they seem to work best when different instruments are used in combination and applied simultaneously at different scales.

In the process of scaling up resource management from site level to watershed level, it is important to ensure that all stakeholder groups of people are represented in watershed associations that transcend individual villages and in negotiations over large-scale problems. Appropriate mechanisms need to take into account the distribution of benefits and costs within the communities themselves, both upstream and downstream, and incentives of different stakeholders, based on economic valuation and existing property rights. Security of tenure is an important factor in the adoption of watershed management practices. However, establishment or recognition of property rights should not overlook customary tenure arrangements that may otherwise be put at a disadvantage in formal land titling programmes.

Stakeholder cooperation is more likely if benefits are demonstrable, the distribution of benefits as well as costs is considered fair and acceptable, and agreements are enforceable. It may also be motivated by the threat of regulation.

Successful initiatives have evolved over time, from management of a water body to management of its whole catchment, or from the narrow and *ad hoc* to broad inter-sectoral initiatives, often with the assistance of NGOs. At the largest scales, given the difficulties of linking cause and effect, river basin negotiations tend to emphasise water allocation issues and provide a basis for sharing benefits and reducing costs through more general economic cooperation.

Implementation of mechanisms and instruments may be constrained by conflicts between the objectives of sustaining livelihoods and natural resources, and between different stakeholder groups. Other constraints maybe posed by equity considerations and the acceptability of the instruments' distribution function. For example, transfer payments for watershed protection may not be seen as fair as they may violate the "polluter pays" principle and create perverse incentives. Such payments, when these are necessary and appropriate, may be complemented by taxes on pollutants. On the other hand, such payments may be equitable considering the income situation of the rural poor in marginal upper watershed areas. Lack of property rights and capacity for collective action may constrain the adoption of management practices if expected benefits are long-term. Finally, if significantly affected stakeholders are excluded from the process, they may have an incentive to sabotage any initiatives taken.

One should be realistic as to what participatory approaches can achieve in terms of priority concerns: for example, small-scale erosion control measures typically implemented through such approaches may not have a big impact on downstream sedimentation when structural measures are needed to prevent landslides or streambank erosion.

For benefit-sharing arrangements to be successful, stakeholders must have at least a common understanding and agreement about the nature of expected impacts, the approximate magnitude of costs and benefits, and also about areas of uncertainty. This is best achieved at smaller scales, where anthropogenic impacts can be verified and distinguished from natural processes. At such scales, people will be more likely to be willing to make the commitments necessary for resolving interest conflicts and reaching agreements.

When there are numerous stakeholders, establishment

The role of tenure in the adoption of soil conservation practices: A case from the Philippines

In Southern Mindanao in the Philippines, farmer adoption of soil conservation technologies (Sloping Agricultural Land Technology/SALT) was low, but there was a higher rate of adoption among landowners than tenants. Constraints to the adoption of SALT were that farmers were required to give a significant amount of land to tree crops or hedgerows, which also required an increase in labour. There was a high correlation between security of tenure and SALT uptake. The most innovative farmers, those who readily took to SALT technology tended to be land owners rather than tenants. Even when grants were provided, agroforestry farmers failed to maintain the hedgerows. It is also unlikely that loss in area cultivated will be compensated by higher yields though there may be financial benefit after 3-5 years. Subsidies are therefore needed if this is to be used as a strategy for reversing land degradation.

Source: Hopkins, Intervention 45

Environmental transfer payments in Zamboanga Province, Mindanao, Philippines

In a watershed (area about 900 ha) where upstream farmers had been applying Sloping Agricultural Land Technology (SALT) and other soil and water conservation methods for approximately 8 years, the quality and quantity of fish stocks downstream, which had been nearly depleted, rose significantly. The fishermen observed increased growth of plants in the water and lower siltation levels. A forester from the upstream site brought the farmers' association and the fishermen's association together and they worked out an agreement: in recognition of the beneficial impact of upstream land management regimes which had reduced erosion, fishermen sell their fish to members of the upstream organization at a discount (75-80 percent of market price approximately). This agreement has been in operation since 1997 and the two associations have held quarterly meetings since, always supported by the project staff.

Source: Agostini, Intervention 52

of watershed organisations is an important way to make negotiations manageable and reduce transaction costs, provided that the organisations are representative of all of the relevant interest groups, that they are guided by a transparent and autonomous decision-making process, and are appropriate to the scale of the watershed. Perhaps the most important incentive for stakeholders to participate and invest resources in benefit sharing arrangements is the assurance that they will in fact have access to the benefits, which often take time to materialise.

Because of the site-specific nature of land-water interactions and important differences in the socio-economic context, it is difficult to come up with general guidelines regarding the implementation of benefit-sharing mechanisms in watershed management. Workshop discussions, however, attempted to formulate criteria, or prerequisites, which may contribute to a successful implementation of such mechanisms.

Watershed Protection Fund to preserve drinking water quality in Quito, Ecuador

A case study on the Water and Watershed Protection Fund (FONAG) as a mechanism for the conservation of the nature reserves Cayambe-Coca and Antisana in Ecuador describes a proposed financing mechanism for water and watershed protection activities in the upper watersheds of the city of Quito, Ecuador. Local (e.g. the water supply company) and international sources will be contributing to the fund. The fund will be governed by a board that consists of representatives of the local water and electricity companies, water users, regional and local government, communities and non-governmental organizations. It will finance conservation activities with the aim of ensuring a clean, dependable water supply.

Source: Echavarría, Case study 30

Criteria of success for watershed management resulting from workshop discussions

- There is some common understanding and agreement among stakeholders regarding the impacts of upstream land use on downstream water use, as well as awareness of uncertainty.
- The groups of upstream and downstream stakeholders are generally few and well organised.
- The economic impact of land use on downstream stakeholders can be approximately quantified.
- There is a political commitment to establish upstream-downstream linkages, whether it is through contractual agreements or through policy frameworks, and some underlying technical basis for it.
- There is a strong institutional and legal framework, including land tenure structure, which allows for the implementation of benefit-sharing instruments.
- There should be decision-making autonomy for those who pay and benefit, and a transparent mechanism for deciding how the money is spent.
- Management interventions and also watershed associations should be appropriate to the scale of the river basin.
- Basin treaties should be acceptable to all riparians, for equitable use, protection and management of water resources in basins.
- Information about impacts, and their potential costs and benefits, needs to be communicated using common methods of expression.

Source: Synthesis report