WATER, POVERTY AND AGRICULTURE INTERACTIONS IN UPPER CATCHMENTS: KEY CONCEPTS AND ISSUES

(DRAFT)

CONCEPTUAL FRAMEWORK

THEME 2: MULTIPLE USE OF UPPER CATCHMENTS

CGIAR CHALLENGE PROGRAM ON WATER AND FOOD

Water, poverty and agriculture interactions in upper catchments: key concepts and issues

(Draft)

Background

Who needs to read this document?

Theme 2 of the Water and Food Challenge Program focuses on "Multiple use of upper catchments." The background paper (CGIAR, 2002) indicates that four issues will be tackled: 1. Water and poverty in upland watersheds - examining the significance of water to the rural poor in upland catchments, and the opportunities and impacts of water management. 2. Identifying the hydrologic basis for improvement - identifying the general opportunities for increasing the provision of adequate water for the range of potential uses. 3. Enabling change - enhancing the benefits from water and reducing the risk of induced hazards. 4. Knowledge generation - adapting, generalizing, extrapolating and communicating research results from specific sites in selected sub-catchments to broader audiences who will translate it into significant impact on water productivity and poverty alleviation.

Primary clients for a conceptual framework for the theme are research teams working on the Water and Food Challenge Programme. Teams can use this document to develop proposals, to formulate and implement research projects, to monitor and assess results from their research projects, and to synthesise and extrapolate project-specific results to other areas. Benchmark basin teams could also use the framework during priority setting, project integration and impact assessment.

Secondary clients for this work are organizations formulating strategies for research and development for watershed management in developing countries. This includes, among others, the regional and global development banks, agencies of the United Nations, bilateral development agencies and large non-governmental organizations. Activities that are currently underway in this area are the Water and Poverty initiative of the Asian Development Bank and partners, the World Bank Netherlands water fund, and the series of workshops on watershed management being convened by the FAO and others during 2003.

Why should they read this document?

There are several general reasons why researchers and their managers may take the time to read this document:

The first is to alert themselves to the range of issues covered by the theme. This is centered largely on an unusual and occasionally difficult confluence of social and biophysical sciences.

The second is to increase awareness of the depth of existing literature, both published and grey, which describes insights acquired from prior investment of many millions of dollars.

A third is to position their own research within the broader effort represented by the Challenge Program, and so facilitate linkage between individual projects.

This conceptual framework should also provide a basis for easy addition of subsequent synthesis reports and reviews on specialist topics, which will be commissioned later.

1 Water and poverty in Upper Catchments

Key questions

Key questions that this theme and the projects within it should address relating to poverty and water include:

- What is the nature of poverty in upper catchments? Where are the poor located and which is their relationship with environmental degradation?
- To what extent will poverty in upper catchments be alleviated through investments in technologies, institutional change, and social learning?
- Under what circumstances is poverty driving environmental degradation? What technological and institutional options can reverse such processes?
- Given the social, cultural and economic constraints and opportunities of inhabitants of upper catchments, and in order to address problems at a regional or basin scale, which are the most convenient land and water management practices and technologies to be promoted and implemented?
- To what extend will multiple scales of analysis and intervention be required to remove poverty traps in upper catchments?

It goes without saying that poverty alleviation measures for upper catchments must be prefaced on a thorough understanding of the nature of poverty in those areas. Livelihood portfolios of households in the upper catchments are diverse, based on agriculture; use of forest products; varied income-generating non-farm activities; wage labour; and, remittances from family members and in many cases also maintenance, restoration and improvement of environmental and ecosystems good and services. The identification and measurement in upper catchments of the relative influence on poverty of the diversity of economic activities, cultural features, political processes and ecosystems goods and services is an urgent need. Strategic research focused on the most influencing processes and drivers at their right timing and location could lessen the effort in time and resources to reduce poverty and its underlying causes.

1.1 Poverty and investment in water management in upper catchments

Many technologies and practices such as pumps, tanks, or water harvesting structures exist that have the potential to dramatically improve water quality and availability and thus alleviate poverty. While in some cases the technologies are not appropriate given the economic, cultural and ecological conditions, in other cases financial or other constraints prevent adoption. We generally think of poverty as a consequence of lack of water, however where poverty constrains the ability to adopt these improved water management technologies, poverty can be a cause of water shortages as well (Grey and Sadoff, 2003). In such cases, the relationship between poverty and water is an example of the vicious circles of low production and under-investment that economists call “poverty traps” (Chambers and Conway, 1992). Poverty traps can occur at different scales, from household to nation. In some cases, it may be possible to break out of a poverty trap through a single intervention at the scale where poverty traps are observed, for example through an infusion of human or financial capital. In many cases, however poverty traps are linked across scales. For example, low productivity observed at the farm level may be related to under-investment in infrastructure at the community or regional level (Grey and Sadoff, 2003, Campbell et al., 2002). For example, new technology on farm may not improve welfare unless new roads are built to take surplus to market. Pressure by farmers for road construction can emerge as a result of perceived marketing opportunities, however the effectiveness of the pressure will also depend on the efficiency and effectiveness of collective action institutions at the community level. Collective action is the result of individual decisions to participate or not, which depend on their expected benefits, and opportunity costs of time and resources required for participation. In these cases, selecting the combinations or sequences of interventions, based on an assessment of the costs and benefits of a range of alternatives at different scales, and understanding how they are likely to relate to each other.

Lack of knowledge of the resource base and its appropriate management can also undermines technological investments or triggers deterioration of water resources. Investment in biophysical studies to quantify and estimate the feasibility of technological interventions will help in understand better hydrological processes and recommend potential changes to infringe on them.

Economic and environmental impact assessment of proposed changes to land and water practices should suggest the path for development interventions. Quantification of environmental services and externalities potentially captured by local poor inhabitants are also needed.

1.2 Poverty and land management in upper catchments

Water quality and availability may also be affected indirectly by how other resources such as cropland, pastures or forests are managed and used. The uncertainties on the relationships between land use and water availability have to be stated. Otherwise, effects of patterns of land use on hydrological processes and their differential effects will continue being a quest. Upper catchments are complex in topography, soils, microclimate and mainly, in land management activities. The interaction land use – water quality and quantity is very controversial. The use of agronomic practices (contour farming, strip cropping and reclamation, tillage, mulching, cover crops among other) or practices at the cropping system (rotations, grassland and fire management, use of scrubs and trees) or the use of technical methods (irrigation and drainage, terraces, etc) in combination with climate and soil patterns have a kaleidoscope of effects in local and regional water regimes. How different land and water management practices at local level affects the water basin regime is then a research need.

When large-scale factors such as climate climatic variability, which includes past, present and future condition are incorporated into the study, it is required an analysis that spans on time and space, forcing a wider participation of the international community and from institutions that cover that range of issues. To overcome complexity, the use of high-end technology and recent advances in the area of data management, hydrological models and simulation techniques becomes essential. The distances between information management, knowledge generation and practical implementation of land/water management need to be shortened.

In many upper catchments, the poor can be found working on the steep slopes with thin soils that are most likely to generate externalities. Given their inherent low productivity, costly investments in soil and water management may not be warranted on the basis of agricultural productivity alone. Some evidence suggests that technologies that are less labour intensive or that give high economic returns in early years are more likely to be adopted, even if their conservation benefits are lower. Evidence suggests that the poor depend proportionately more than the non-poor on common lands such as forests or pastures or interstitial areas like borders or buffer zones (Cavendish, 2002; Campbell et al., 2002; need refs from non-drylands). . Therefore, changes in how these resources are managed—e.g. closing forests, limiting grazing—will have a proportionately larger impact on the poor (Kerr, 2002).

Poverty is also related to the strength of and basis for property rights to resources. The poor often don't own land or other resources, and without security of tenure they have little incentive to invest in it. Some gain temporary access via renting, while others have negotiated or even simply tolerated use. To the extent that these uses are informal and based on claims outside of the formal legal system, they may be harder to defend against external pressure. It may also be more difficult to make a case for compensation for loss of rights that were never formally recognized.

1.3 Poverty and governance in upper watersheds

Natural resource systems managed by multiple users for multiple functions will inevitably entail trade-offs. This will often lead to conflicts among stakeholders. Facilitated negotiation and conflict management among interested parties will often be needed to resolve conflicts and allow equitable resource use practices to emerge. How decisions are made and who participates in the process clearly has implications for the equity of outcomes. Often rights to resources confer rights to participation in decisions about how those resources are managed. In spite of the dependence on common resources, the poor are often presumed to not participate in collective decision making, either because they are excluded deliberately or because they choose not to participate due to lack of time or confidence. It is also the case that the poor mostly do not have access to appropriate information to decide, and without it, participation and decision-making is not the same. As mentioned earlier, social, cultural exclusion, information gaps, and voicelessness are often important components of poverty. Incorporating the poor is not easy; differences in wealth and power among stakeholders are hard to manage yet cannot be ignored in collaborative decision making processes (Edmunds and Wollenberg, 2001)

This is not to say that the poor are entirely passive or powerless. For example, the poor might have an easier time participating at some scales than others. In some cases, the poor may be able to participate and defend their rights in local fora where personal ties and obligations strengthen the basis for their claims. In other cases, rigid local power structures may squeeze the poor out, whereas collective action at the regional or national scale may offer more space for achieving their goals, especially when supported by external organizations. At all scales, where the poor and those marginalized are adversely affected by decisions, they often have ways of expressing their discontent, for example via non-compliance, sabotage, or even violence (Ravnborg and Ashby, 1996 on burning of barriers, Tomich et al on fires in Indonesia, Kerr on livestock in India).

The preconditions for successful catchment management have received some attention from researchers, who have drawn on the significant body of experience that has come from attempts at integrated catchment management, common property resource management and devolution of control for natural resource management (Gibbs, 1986; Hinchcliffe et al., 1999; Lovell et al., 2002; Ravnborg and Ashby, 1996; Rhoades, 1998). Watershed management is increasingly being seen as a participatory process of social learning where stakeholders inside and outside the watershed interact within and across scales, and build up knowledge about both the human and the biophysical resources (Mandondo et al., in prep). On the basis of this shared knowledge, stakeholders negotiate priorities, take decisions and evaluate outcomes. Incorporating the poor into the learning process is essential. For widespread impact the importance of forging links, from the outset of projects, between community-based and national programs has also been stressed (Lovell et al., 2002).

2 Processes and interactions in upper watersheds

Key questions

Key questions that this theme and the projects within it include:

- What are the factors determining the degree of sensitivity and resilience? How can significant slow variables be identified? How sensitive and resilient are upper catchments to changes in slow variables (e.g. climate change)?
- What scales should be included to define significant factors and potential interventions?
- To what extent do mismatches between organisational/administrative units and biophysical units impact on the success of collective action or social learning in landscape mosaics of upper catchments?
- How effective are different types of filters in landscape mosaics in upper catchments?
- To what extent can actions by downstream users influence the behavior of upstream users? To what extent does this influence poverty and environmental outcomes?
- How will knowledge generated by research contribute to processes of social learning, governance and policy?[1]

[1] Meine van Noordwijk's work on process and categorical models

This section describes three types of features defined by watershed-based research: physical and socio-economic processes, institutions that aim to control the processes and the scale at which these operate.

2.1 Physical and socio economic processes: What people do to sustain livelihoods in Upper Catchments

There are concrete activities carried out by farmers and the upper watershed population in general that affects biophysical processes in general and water resources specifically. Such activities have a spatial and temporal contexts that go from the plot passing by the farm, local village, micro basin or basin to a regional context and from day to month, years or decades, to century contexts. Their effects can either be beneficial or detrimental at local or downstream locations. Activities such as:

- farming in sloping hills without conservation measures increases erosional processes and sedimentation;
- extensive grazing accelerates soil compaction and subsequent runoff;
- deforestation changes base flow regimes and influences canopy interception, which facilitates the flux of water in an uncontrollable fashion.

On the contrary,

- moisture conservation is obtained by the use of vegetative contour barriers or by the use of planted windbreaks;
- intensive livestock management with the introduction of legumes and fodder crops can reduce the pressure on soils and erosion;
- agro forestry and silvicultural systems increases CO_2 capture, moisture retention in cloud forest areas and soil protection increasing infiltration and soil water retention (Reijntjes, C et al. 1992).

Use of technology can also have good and bad consequences:

- Irrigation systems in mountain areas facilitates the production of high cash crops such as vegetables and fruits but also are potentially dangerous to produce landslides if drainage systems lack proper design.
- Small ponds or dams to store water for livestock and domestic purposes improves water availability where rainfall is scarce or where extension of planting season is wanted. Water harvesting in this and other many systems are of great benefit though involve many risks and require considerable labour to construct and maintain the structures (Reijntjes, C et al. 1992).

Where, how and in which magnitude to implement water and land management changes will always depend on local biophysical conditions as in social organizations that clearly identify that investments in labour, capital and land will have an impact locally and downstream (Reijntjes, C et al. 1992). Appendix 1 presents a preliminary inventory of technological options for water management improvement considering its sources, access, storage, purification and use in irrigation/crop production. There has not been a helpful global initiative "which address in a field context the necessary technological response integrated with policy and management" (HELP, 2001, p.12). Recent water initiatives emerged due to the feeling that the application of hydrological science and the implementation of technologies for its use have been blocked by what is called the "Paradigm Lock". The understanding of hydrological process obtained by scientist is isolated by lack of proven utility while water policy and management are by-products of disaggregated institutions maintaining the current practices as the accepted ones (Ibid, p12).

The problem is not with technology itself but with the strategies used in its implementation. In different issues technology has contributed to watershed management from systematic regional planning to household's water supply and sanitation. The experience of the UNDP/World Bank's Water and Sanitation program is an example of this. "In its early years, the Program focused on the development of low-cost technology, especially hand pumps and latrines. It learned the hard way that "..rules which favour highly centralized decision-making about service allocations and the level and intensity of local demands have not produced either efficient or sustainable services"" [UNDP/World Bank, 1996, p. 8 cited by Winpenny, 1997].

On the basis of nutritional productivity analysis, Renault and Wallender (2000) demonstrate that a significant part of the additional water resource to produce food for the next century population can be generated by changes in food habits; especially by reducing red meat consumption.

Different processes take place at different speeds; some processes may be studied over short time frames while others may have to be studied over decades. 'Slow variables' present particular challenges. These variables affect the dynamics of more rapid processes and when they reach thresholds or trigger breakpoints they may cause sudden and surprising shifts in systems, which have negative impacts on livelihoods (Gunderson and Holling, 2002). Accumulations of toxic chemicals in soils, water and organisms, gradual erosion of soil fertility and depletion of ground water are all slow variables that may need to be tracked in studies of complex resource systems. Caution has to be exercised to ensure that adaptive learning frameworks do not exclude consideration of slower variables. Methods are being developed that combine local with scientific knowledge. Their purpose is to capture the richness of local empirical knowledge with the consistency of generalized scientific knowledge.

Upstream-downstream interactions

Since "upper" catchments are defined relative to other parts of the catchment, any framework for analyzing upper catchments must situate them within the broader catchment environment. Hydrology effectively links people in different parts of the watershed through features which are important to livelihoods of all, including water supply, sediment loading, water quality or flood control. A problem occurs if water use upstream penalises downstream users through the reduction in water quantity or quality. The impacts of the actions of upstream land users on downstream water supplies constitute a classic and widely documented class of externalities, though the links may show numerous complexities. Such interactions can occur at any scale. At local scale, the introduction of Eucalyptus trees to semi-arid catchments in Africa threatens local contributions to stream flow; at catchment scale, the excessive use of agrochemicals for market vegetable production may threaten the quality of water to downstream users; or at national scale, the construction of dams on the Euphrates river in Turkey diverts water which might otherwise be used by neighbouring Syria downstream.

While the hydrological linkages are often known but difficult to quantify, many of the socio-economic processes are more difficult to define, let alone quantify. If the effects of externalities are big enough, downstream residents may take action to try to reduce, mitigate or, in the case of positive externalities, increase them. For example, downstream residents can make investments upstream that affect the way land and water are used. Alternatively they can pressure government to change land or water use regulations, or to invest in water management infrastructure upstream. However, what happens if the effects are non-obvious, or suspected?

The actions on the part of downstream residents can alleviate, aggravate or entrench poverty—specific outcomes will depend on the type of actions, on the nature of the institutions that link upstream and downstream residents, and on the specific characteristics of the upper catchment. In all cases, equitable solutions are obstructed by a general lack of definition and quantification. Figure 1 and 2 presents conceptual models of upstream-downstream interactions in watersheds.

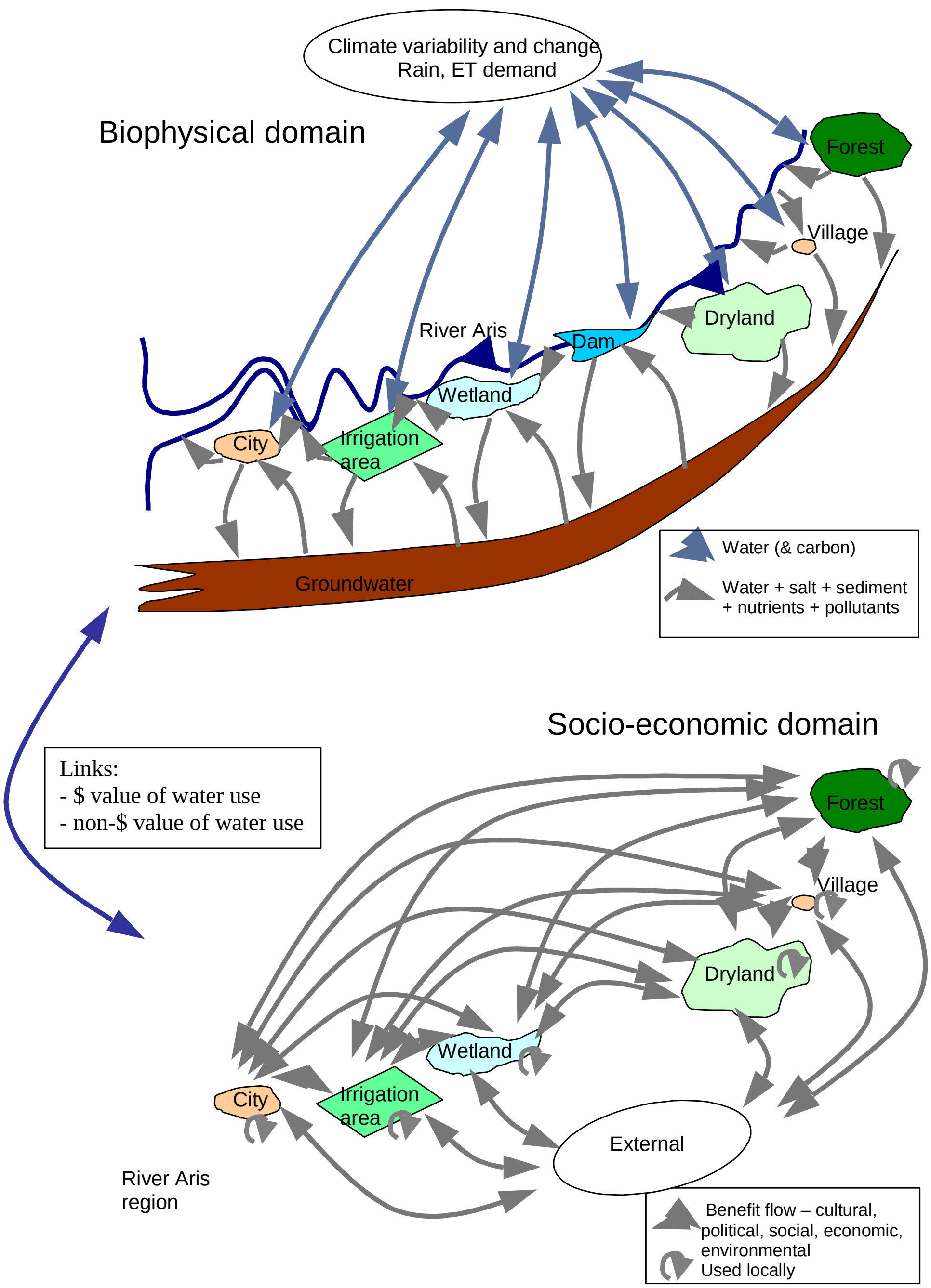

Figure 1 Conceptual model of upstream - downstream interactions (Kirkby, 2003 perosnal communication).

Loosely following Molden et al, (2001), the watershed is divided into 3 hydronomic zones (Figure 2): uplands, midlands and lowlands. Within each zone, the interaction of technologies (including water storage), water, other assets[2], and institutions determines the livelihood options pursued by individuals and households. The outcomes of these livelihood options determine welfare.

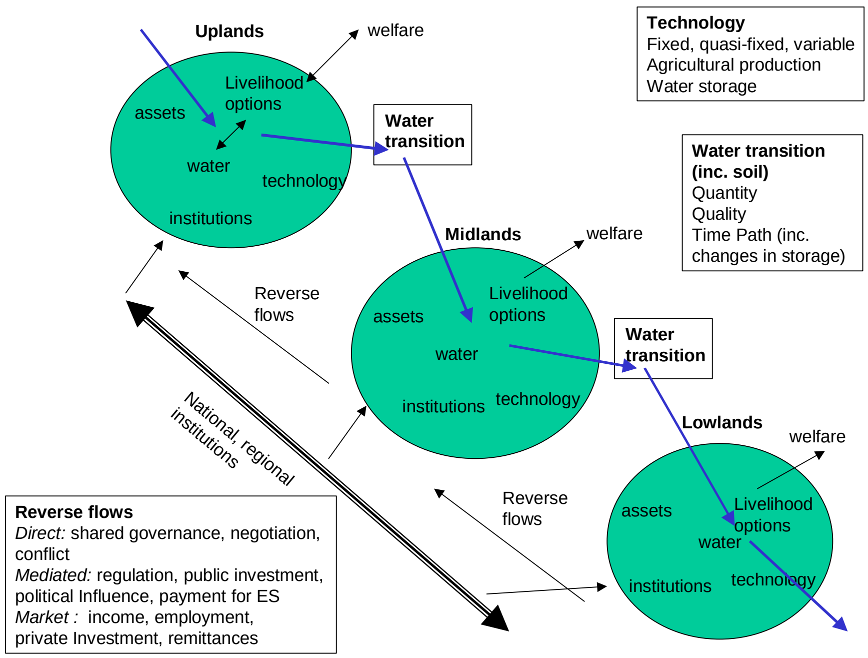

Figure 2 Conceptual model of upstream-downstream interactions in watersheds

The way that water is managed—with water management defined as the deliberate manipulation of quantity, quality and timing of water through use of technology—by individuals and groups for consumption and production in a given zone affects welfare directly in that zone. It can also influence livelihood options in lower zones indirectly through its effect on water transitions. **Water transitions** are changes in the quantity, quality or timing of water flows between hydronomic zones. They depend on water use and the biophysical characteristics of the catchments, as well as on technology and management practices. A similar concept to that of hydronomic zones but concerned mainly with biophysical processes is called Hydrological Response Units (HRU). These are areas having representative properties of the landscape "that includes precipitation, evaporation, infiltration and runoff at the land surface (e.g., soil, land use, slope, administrative areas, or some combination of these with drainage boundaries)"(Maidment, 2002). This way of partitioning the landscape is a basic step in data integration and for developing manual and computerised models for simulating hydrological processes

Water transitions and their impacts may be counterbalanced by actions taken by downstream users to influence upstream users, related to power or economic differentials. These can take a variety of forms. Direct actions can range from cooperation and negotiation among upstream and downstream stakeholders, to conflict and use of force. Some actions may be indirect, mediated by the government, as in the case of regulations or public investments in water infrastructure. Downstream users can also influence upstream users via product, capital or labour markets. The way in which people act and organise themselves to operate on specific resources bring us to the concept of Institutions discussed in more detailed in the following paragraphs.

---

[2] Natural, social, human, physical and financial capitals or assets

Institutions

"Institutions can be defined as the sets of working rules that are used to determine who is eligible to make decisions in some arena, what actions are allowed or constrained, what aggregation rules will be used, what procedures must be followed, what information must or must not be provided, and what payoffs will be assigned to individuals dependent on their actions" (Ostrom, 1986). Boundaries are central to natural resource management since they specify the area over which jurisdictions apply as well as the roles that particular actors are assigned (Lovell et al., 2002). Specifying areas over which jurisdictions apply is, nevertheless, easier said than done, not least because administrative boundaries, infrastructure links, ethnic groups, user groups, community limits and informal networks seldom correspond with biophysical boundaries. To complicate matters further, natural resource management usually involves the integrated management of a multitude of common property, open-access and privately owned resources such as croplands, pastures, forests and water. Each resource has an associated complex of often-conflicting interests held by 'stakeholders' both inside and outside the particular resource boundary.

The choice of organisational scale for integrated research and management can conceptually be made from a continuum of options ranging from national and regional to local levels. Small units mitigate the transaction costs of organising for collective action and are generally associated with mutuality of interest and greater social cohesion arising from easy day-to-day contact. However, the small unit approach can result in a multiplicity of fragmented jurisdictions that lack coordination when it comes to tackling bigger problems of both a local and trans-local nature. These bigger problems that cannot be tackled in isolation at localised scales are better addressed by bigger, unitary jurisdictions, but such jurisdictions are often directed from a remote centre out of touch with local priorities and aspirations.

Rules or relationships tend to be specific to one scale. Resource management practices identified at one scale of investigation will often be location-specific and often time-specific. The dynamics associated with single scales of investigation, and the additional feedbacks and interactions that develop increasing scale, pose serious challenges for natural resource research.

A special problem in upper landscapes concerns the intricacy of landscape mosaics. Seldom, even in very small study areas are we dealing with single function landscapes. Van Noordwijk et al. (2001) use the terms 'lateral flows' and 'filters' to provide a theoretical basis for understanding scale relationships in mosaics of forest and agricultural land. Scale relationships depend on lateral flows of entities such as organisms, fire, smoke, water, sediment, nutrients, people, money and ideas. Filters are anything that can intercept a lateral flow; examples are shelterbelts or legal boundaries. Filter elements can be easily overlooked as they typically occupy a small fraction of the total area. However, they can have a large impact per unit area occupied. They can thus be regarded as 'keystone' elements of a landscape and should be the focus of research if we want to understand how the landscape functions as a whole. Conserving or establishing filters to intervene in lateral flows may provide attractive options to mitigate the impacts of local decisions, compared with elimination of the 'root cause'.

Instruments that facilitate interaction between people

Instruments:

Instruments are based on stable methodologies, which are known to work. The Global Water Partnership forum provides descriptions of regulatory, economic, social and institutional instruments which can deployed in a program of improved water management (GWP, 2003a and GWP, 2003b)

Management Instruments Offered by the IHE Toolbox (GWP, 2003)	
Water resources assessment	Understanding resources and needs based on best available physical and socio-economic data.
Plans for Integrated Water Resource Management	A flexible and dynamic approach to establishing priorities and actions for management
Demand and supply management	Increasing the emphasis on demand management to use water more efficiently
Social change instruments	Influencing attitudes in individuals and institutions to encourage a water oriented civil society
Conflict resolution	Procedures for consensus building and conflict management
Regulatory instruments	Allocation and setting of water use limits through direct regulation, economic or market regulation, self-regulation and social regulation.
Economic instruments	Where and how to use values, prices, taxes and subsidies for efficient and equitable water use.
Information management and exchange	Developing the knowledge bases for better water management

Environmental services

This section will be expanded by T. Dalton contribution to the Conceptual Framework.

How scale affects processes and interactions

We normally think of scale as a characteristic that delimits processes within distinct space and time dimensions. Concepts are associated with particular scales, e.g. catchment hydrology, annual forecast, community-based collective action, household livelihoods, or national markets. While many processes are indeed scale dependent (Sposito, 1998), it is important to remember that it is the observer who defines the scale of observation, analysis and intervention. Processes tend not to stop conveniently at the limits of study, but merge into neighbouring scales, introducing uncertainty as they go. Van Noordwijk et al. (2001) describe the concept of a scale 'hierarchy'– how processes at different levels relate to each other.

All natural resource management systems have multiple scales of interaction and response; interventions at global, national and household scales invariably have impacts at other scales (Lovell et al., 2002; Sayer and Campbell, 2004). A key feature of integrated research is its attempt to reconcile these spatial and temporal scale issues but some of the most contentious contemporary issues confronting natural resource managers relate to scale, nowhere more so than in the case of catchment management. Solutions to resource management problems at one scale may or may not solve problems at the next scale, and may actually cause problems 'downstream'.

The conceptual framework helps us to think about water management at different scales. For example, one option for managing water within a zone is to manage demand via technologies and local institutions for water allocation. Another is to influence the supply of water via inter-zone transfers. Assessing the potential efficiency and equity impacts of such transfers requires looking at their implications for local welfare as well as their impact on water transitions.

The study of water and its interaction with other biophysical and social processes/components at different scales is more complex than it looks. Figure 3 illustrates an example in Honduras of the different linkages that exists when analysing water resources and their relationships with other parts of the system.

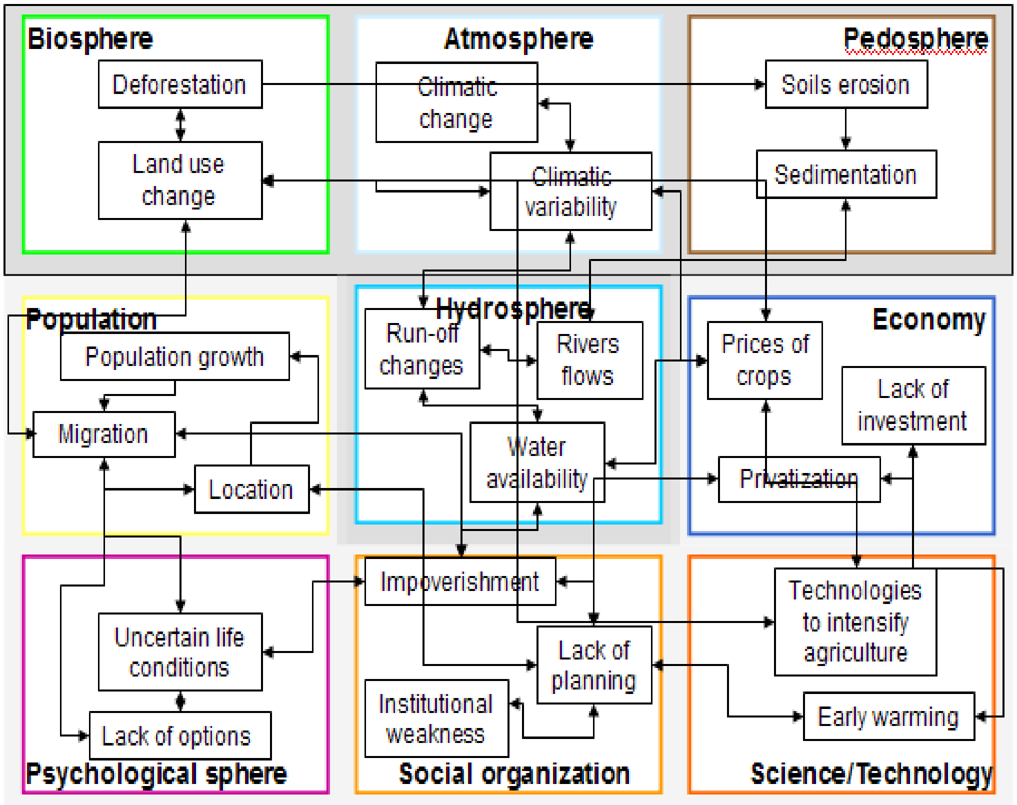

Figure 3. Social and biophysical components/processes related to water issues (From Winograd, 2002)

2.2 A conceptual model of water, poverty, and agriculture: Using water to address poverty through agriculture in upper watersheds[3]

The CP is about water for food and agriculture. In this section, we present a framework that focuses specifically on how households allocate water across multiple activities in agriculture. The dominant model of agricultural intensification focuses on land use intensity. Water availability and quality may constrain land use and returns to technology. Where water is the prime limitation, development cannot proceed without it.

Households are assumed to allocate water according to its productivity in both productive and reproductive uses. It is important to consider reproductive or consumptive uses since meeting this requirement is critical for poverty alleviation, affecting health and, therefore, productivity in other activities such as agriculture. Small increases beyond the basic minimum requirements can have very large welfare impacts (case study evidence from Water Aid, South Africa, Kenya). In addition to total quantity of water, households also consider water quality, distance to water source and timing of availability. Certain activities can only be done with high quality water, and others require stability of supply for some all or of the year. The impacts may be felt at different scales. For example, a household producing vegetables for home consumption may be more careful about the quality of irrigation water than a household producing for market.

In addition to considering water as an input, the framework also looks at what impact different activities have on water transitions, that is, on how they affect the quality, quantity or timing of water available for other activities. Comparing the payoffs and tradeoffs associated with different water uses can lead to a more integrated view of rural water supplies, bridging the traditional gap between water for domestic use (potable systems) and water for agriculture (irrigation systems). In reality, there is potential for domestic water to be produced by irrigation schemes and/or water for small-scale agriculture water as a bi-product of domestic water schemes, water harvesting or rainwater catchment. In such cases, productive uses could help to generate finance for domestic water supply.

Integrating land uses within catchments

Table 1 presents the results of a first analysis of different uses of water for domestic and agricultural uses. Activities are listed according to quantity thresholds. We would expect households faced with very limited water supplies to meet minimum needs for higher ranked activities before allocating any water to lower ranked activities.[4] [5]

On the basis of the table, we can rank different uses in terms of contribution of different aspects of water to poverty alleviation, for example:

Quantity thresholds: domestic > home garden + animals > small scale horticulture > cereals > extensive grazing

---

[3] Some of these ideas were generated in the course of conversations between Brent Swallow, Bill Thorpe of ILRI, and Ruth Meinzen-Dick in early 2003.

[4] In economics terminology, we hypothesize that the marginal value of water declines with water quantity; that the marginal value of water for human survival is extremely high at levels before 10 litres per person per day, but declines rapidly after 20 litres per person per day; that the marginal value of water in home garden production (esp. in drylands) also starts high, but declines fairly rapidly, and that the marginal value of water in commercial horticulture starts somewhat lower, but is relatively constant across units of water. The marginal value of water in timber production is low for low units, but perhaps constant across all units of water. The marginal value of water functions also depend on quality; low quality will shift the domestic water value function downwards the most and the timber water value function the least.

[5] One of the key issues we have not yet addressed is the cost of water of different quality, temporal availability, and spatial availability.

Benefits of quality: domestic > home garden + horticulture > livestock > cereals & fruit > timber tree production

Benefits of temporal continuity: domestic > home garden + intensive livestock + irrigated cereals and fish > commercial horticulture + rainfed cereals > perennials and timber trees

Benefits of temporal certainty: domestic+ fish> home garden+intensive livestock>irrigated and rainfed cereals+commercial horticulture+ perennials>timber trees

Impacts of water transitions: home and garden uses are generally low while the others depend on the site.

Table 1 Comparison of benefits and impacts of alternative water uses in agriculture

Water Use	**Quantity** thresholds	Private benefits of high **quality** water	Social benefits of high **quality** water	Benefits of **temporal continuity**	Benefits of **temporal certainty**	Impacts on **water transitions** (may translate into an externality)
Home	20 l/p/day	Very High	High	Very High	Very High	Low quantity; medium quality within farm
Garden	20-50 l	high	Medium	High	High	Low quantity
Commercial horticulture.	Related to technology	Medium	High	Medium	High	Depends on magnitude, high quality impact through pesticides; maybe high on establishment on riverine areas or hillsides
Intensive livestock	High and lumpy, depends on animal & intensity	Medium-High.	Medium for milk, lower for meat and manure	High	High	Potential farm resources (manure); potential pollution
Rainfed cereals	Depends on crops & water conservation	Low	Low	Medium within season	Medium within season	erosion effects depend on location & mgt, maybe fert or chem. pollution
Irrigated cereals	Depends upon limits of rainfed agr.	Medium low	Medium low	High within season	Medium within season	Erosion low if on flat land; maybe sig. fert or chemical pollution
Perennial cash crops (coffee, tea, bananas, pineapples)	Depends upon limits of rainfed agr.	Medium low	Medium low	Low	Medium	Highly variable depending on phase, crop, mgt,
Timber trees	Some for nursery	Low	Low	Low	Low	Can act as nutrient & pollution sponges, reduce water availability, maybe concern about weediness
Fish	May be added to existing water storage or channel	High	High	High	Very High	Low in production at most viable scales in uplands; maybe high in establishment on wetlands
Important non-agr	Variable	Variable	Variable	Variable	Variable	Variable

3 Increasing the impact of research through extrapolation from well-selected research sites

Key questions

Key questions that this theme should address relating to representativity, extrapolation, and the potential impact of results are:

- How and to what extent do upper catchments of benchmark basins represent other catchments and basins across the tropics?[6]
- What are the conditions for achieving widespread impacts on poverty in upper catchments?
- Which are the generalisable features that can describe and classify a large number of upper catchments.
- What is the most efficient way to transfer research findings from one place to another?
- Which are the means and tools adapted to produce and communicate appropriate information to pertinent users that could be used to perform/assess the impact?

To ensure that results of research can be extrapolated and generalized to the target populations and regions, careful attention must be paid to selecting and characterizing original research sites. These sites, in a sense, define the extrapolation domain of the research results. The topics of extrapolation and generalization were dealt with in section 4 of the background paper, however given the importance of links between site selection/characterization and extrapolation/generalization, we decided to move the topic up front.

Upper watershed can be characterized according to multiple dimensions: biophysical and hydrologic, socio-economic (including poverty and gender), and policy and institutional. The critical analytical task is to identify generalizable principles that allow us to compare and contrast watersheds in meaningful ways.

Within upper catchments, there is generally a large diversity of geographic conditions – slope, aspect, toposequence, water supplies, soils, sensitivity of resources, and linkages to downstream. As a result, even basic biophysical findings may be difficult to generalize and there continue to be controversies about the basic hydrologic relationships in tropical watersheds, e.g. the relationships between land use and hydrology, land use and flood risks, or local water harvesting and downstream flows. (Calder 1999, Kaimowitz 2004, Mugabe et al.,2003, Moriarty and Lovell 1997).

This biophysical diversity is often associated with diversity and geographic clustering of ethnic and language groups. As a result, the livelihood strategies and poverty that are found in upper catchments are marked by a diversity of assets, markets, and livelihood options, all of which make it difficult to extrapolate from one part of a catchment to another, let alone to other catchments.

Poverty has multiple dimensions. Consumption/income poverty is the most common perception, however, vulnerability and voicelessness threaten even households and communities that appear to meet their basic daily needs. Different aspects may predominate in different environments, e.g. voicelessness is a predominant form of poverty in the uplands of SE Asia, while income/consumption poverty is very important in most of Sub-Saharan Africa. Identifying

[6] Link to the Bank-Netherlands Partnership Program (BNPP) project on meso and global analysis of watersheds

and characterizing poverty may require use of locally relevant indicators[7]. Use of specific indicators of water poverty or water security (e.g. ODI), may make the task of the CP much more manageable.

Once defined and measured, we may also want to look at the spatial distribution of poverty within and across catchments. In many regions the poor are relegated to the hillsides (Andes, SE Asia, Central America) while the wealthy occupy the valley bottoms and utilize the wetlands and riverine areas. However, in much of Africa, the poor can often also be found on the lower slopes due to disease and low rainfall.[8] While large numbers of the poor may be concentrated in certain areas, rich and poor may also co-exist in the same regions and communities. This spatial distribution of poverty may relate to its underlying causes. Large spatial concentration of poverty may reflect lack of resources and infrastructure, and large distances from markets, while co-existence of poverty and prosperity in the same areas is likely due to inequities in access to resources or power.

4 Implications for a pro-poor research agenda

The preceding analysis suggests several generic ideas about how research into better management of water can contribute to poverty reduction in upper catchments. The general goal is to enable people collectively to derive greater benefit from water. The more specific goal of this program is to enable people to do this through changes in agriculture which uses the water.

1. Identify the **demands** for investment in water management and other technologies, and the constraints to investment posed by:
    a. Physical obstacles such as excessive cost or high risk of failure. Complex characteristics of resilience, which underwrite sustainability, may not be evident from superficial analysis.
    b. Institutional barriers caused by factors such as conflict, isolation, disorganization, lack of resources, lack of power or distrust.
    c. Lack of appropriate relation-building instruments such as agreements, trusts, laws or markets to support people as they make changes.
2. Identify appropriate **solutions and adapted responses** to alleviate these constraints. A combination of technical and institutional change seems likely. Where current technology is not working, participatory development can help develop more appropriate solutions (Douthwaite, et al. 2002).
3. Promote **instruments** which encourage payoffs to beneficial agricultural land uses in upland areas. An important factor to consider here is the complementarity of strategies and institutions.
4. Modify influence from downstream to upstream users so that more benefits are captured by the poor. This can be done directly by including equity as a criterion in decision making about 'return flows'. It can also be achieved indirectly by strengthening the rights of the poor to land, water and other resources, so that they have a stronger basis for participation in resources use decisions, and for receiving compensation in the case that they bear costs of improved water management at the watershed level.
5. Recognise that while change occurs in situations which are specific to location and time, significant impact is felt only when lessons from one place are used in many others. This

[7] E.g. Helle Ravnborg's empirical work on measurement of poverty with local indicators in central America

[8] Brent Swallow's review of the poverty mapping and poverty analysis literature

process of extrapolation (out-scaling) can be explained and improved by explicit attention to site selection.

6. Recognise also that change which occurs at one level (e.g. community scale) is normally influenced by changes either side of it (e.g. household or national scale). For example national policy can improve the prospects of change at catchment scale; such changes may be hindered through inadequate attention to gender issues which impact at household level.

References

Calder, I.R. 1999. The Blue Revolution, Land Use and Integrated Water Resources Management, Earthscan.

Campbell, B.M., Jeffrey, S., Kozanayi, W., Luckert, M., Mutamba, M. and Zindi, C. 2002. *Household Livelihoods in Semi-arid Regions: Options and Constraints*. Bogor: Center for International Forestry Research. 153 pp.

Cavendish, W. 2002. Quantitative methods for estimating the economic value of resource use to rural households. In: Campbell, B. and Luckert, M. (eds.) Uncovering the hidden harvest: valuation methods for woodland and forest resources, 17-63. 'People and Plants' Conservation Manuals. Earthscan, London.

Cornish, G. and Brabben T. 2001 Field guide on irrigated agriculture for field assistants. FAO-IPTRID.

CGIAR. 2002. Background papers – Challenge Program on Water and Food. 196 p. URL: http://www.waterforfood.org/

Chambers, R. and Conway, G. R. 1992, Sustainable Rural Livelihoods: Practical Concepts for the 21st Century, Discussion Paper 296, Institute of Development Studies, Falmer, Sussex.

Douthwaite, B. J.D.H. Keatinge and J.R. Park. 2002. Learning selection: A model for planning, implementing and evaluating participatory technology development. Agricultural Systems 72 (2):109-131.

Edmunds, D. and Wollenberg, E. 2001. A strategic approach to multistakeholder negotiations. *Development and Change*, **32**(2): 231-253

Gibbs, C.J.N. 1986. Institutional and organizational concerns in upper watershed management. In *Watershed Resources Management: An Integrated Framework with Studies from Asia and the Pacific*, ed. K.W. Easter, J.A. Dixon and M.M. Hufschmidt. Boulder: Westview Press

Grey, D and Sadoff, C. 2003 Beyond the river: the benefits of cooperation on international rivers. Water Science & Technology Vol 47 No 6 pp 91–96

GWP, 2003a. GWP ToolBox of Integrated Water Resource Management. http://www.gwp.ihe.nl/wwwroot/GwpORG/handler.cfm?event=home.

GWP, 2003b: Framework for Action. URL: http://www.hrwallingford.co.uk/projects/gwp.fau/ffa.html

Gunderson, L. and Holling, C.S. (eds.). 2002. *Panarchy: Understanding Transformations in Human and Natural Systems*. Washington: Island Press.

HELP Hydrology for the Environment, Life and Policy. 2001. The Design and Implementation strategy of The HELP initiative. UNESCO – WMO.

Hinchcliffe, F, Thompson, J., Pretty, J., Guijt, I. and Shah, P. (eds.). 1999. *Fertile Ground: the Impacts of Participatory Watershed Management*. Intermediate Technology Publications.

Kaimowitz, D. 2004. Useful Myths and Intractable Truths: The Politics of the Link Between Forests and Water in Central America. In Bonell, M., Bruijnzeel, L.A. and Kirby, C. (eds), proceedings of an UNESCO – IHP symposium and workshop in Kuala Lumpur August 2000, Cambridge University Press (in press).

Kerr, John. 2002. Watershed Development, Environmental Services, and Poverty Alleviation in India. World Development, Volume 30, Number 8 (August), pp. 1387-1400.

Lee, M.D. and Bastemeijer, T.F. 1991. Drinking Water Source Protection. A review of environmental factors affecting community water supplies Occasional Paper 15 IRC International Water and Sanitation Centre The Hague, The Netherlands.

Lovell, C., Mandondo, A. and Moriarty, P. 2002. The question of scale in integrated natural resource management.' *Conservation Ecology*, **5** (2): 25. [online] URL: http://www.consecol.org/vol5/iss2/art25

Lovell, C.J., Mugabe, F.T. Moriarty, P.B., Hodnett, M.G., Batchelor, C.H. in prep. When is catchment management beneficial? A biophysical case study in a semi-arid crystalline basement area. Institute of Environmental Studies, University of Zimbabwe.

Maidment, D.R. 2002. Arc Hydro – GIS for Water Resources. ESRI. 203 p.

Mandondo, A., Campbell, B., Luckert, M., Nemarundwe, N. and De Jong, W. 2002 Transacting institutional change in contexts of complexity: experiences from Chivi District in Zimbabwe (in preparation)

Molden, D. J., Sakthivadivel, R. and Keller, J. 2001. Hydronomic zones for developing basin water conservation strategies. Colombo, Sri Lanka : International Water Management Institute, 30 p. (Research report ; 56)

Moriarty, P. B., Lovell, C. J., 1997. Ground water resource development in the context of farming systems intensification and changing rainfall regimes: A case study from south-east Zimbabwe. AgREN Network Paper No 81, 15-22, ODI, London.

Mortimore, M. and Tiffen, M. 1994 Population growth and a sustainable environment: the Machakos story. Environment 36: 10-20, 28-32.

Mugabe, FT., Hodnett, M and Senzanje, A 2003 Opportunities for increasing productive water use from dam water: a case study from semi-arid Zimbabwe. Agricultural Water Management 1827 1-15

Ostrom, E. 1986. An Agenda for the Study of Institutions. Public Choice 48: 3-25.

Ravnborg, H. M. and Ashby, J.A. 1996. Organizing for local-level watershed management: lessons from Rio Cabuyal Watershed, Colombia. *AgREN Network Paper 65.* London: ODI

Ravnborg, HM., Ashby, JA., Guerrero, MP., and Rubiano, JE. (1996) Burning in hillsides farming. Experiments with a stakeholder approach for conflict resolution. ILEIA Newsletter, 12(1): 14-15.

Reintjes, C., Haverkort, B. and Waters-Bayer, A., (eds) 1992: Farming for the future: an introduction to low-external-input and sustainable agriculture. Macmillan, London, UK.

Renault, D.; Wallender, W. W. 2000. Nutritional water productivity and diets. Agricultural Water Management 45(3):275-296.

Rhoades, R.E. 1998. Participatory watershed research and management: where the shadow falls. *Gatekeeper Series No. SA81*. London: International Institute for Environment and Development.

Sayer, J. A. and Campbell, B.M. 2003. The Science of sustainable development: local livelihoods and the global environment. Cambridge University Press, Cambridge (in press).

Scoones, I. *et al*. 1996 Hazards and opportunities. Farming livelihoods in dryland Africa: Lessons from Zimbabwe. ZED Books, London.

Tomich, T.P.; Fagi, A.M.; Foresta, H. de; Michon, G.; Mudiyarso, D.; Stolle, F. & Noordwijk, M. van (1998) Indonesia fires: Smoke as a problem, smoke as symptom. Agroforestry Today, January-March 1998: 4-7.

van Noordwijk, M., Tomich, T.P. and Verbist, B. 2001. Negotiation support models for integrated natural resource management in tropical forest margins. *Conservation Ecology*, **5**(2): 21. [online] URL: http://www.consecol.org/vol5/iss2/art21

Winpenny, J. 1997. Water Policy Issues. Department for International Development. Ocassional paper No. 2. 27p.

Appendix 1. Preliminary inventory of technological options for water management improvement

Need/ problem	Technological option for water management improvement
Source of water	There are basically three categories of naturally occurring water resources: **groundwater, rainwater and surface water**. **Groundwater** occurs under most of the world's land surface, but there are great variations in the depths at which it is found, its mineral quality, the quantities present and the rates of infiltration (thus yield potential) and the nature of the ground above it (thus accessibility). In hilly areas it emerges from the ground in places as natural springs, otherwise wells have to be constructed and pumps or other lift mechanisms installed. Systems: Sub-Surface Dams, Spring Protection, Hand-Dug Wells, Hand-Drilled Bore wells, Machine-Drilled Bore wells. All these need Pumping which can be manual or powered (electric, petrol) and of suction or force mode (lift) **Rainwater** collection, from roofs or larger catchment areas, can be utilized as a source of drinking water, particularly where there are no other safe water sources available (for example in areas where groundwater is polluted or too deep to economically tap). In extreme situations, small quantities of water can be condensed from the atmosphere (as dew) on screens or similar devices. **Surface** Water, in streams, lakes and ponds is readily available in many populated areas, but it is almost always polluted, often grossly so. It should only be used if there are no other safe sources of water available (Lee and Bastemeijer, 1991).
Access to water	Decisions on the level of service to be provided - how, where and in what quantities water will be delivered to users - are crucial in the planning of any water supply project. System design options are: - **Single Point systems**, which usually consist of dug wells or small-diameter drilled wells from which water is drawn using a hand pump. - **Standpipes: piped distribution systems**, which feed a limited number of public taps, each of which serves all households - and other users - in the vicinity. - **Household Connections**: piped systems, which deliver water to taps in individual household compounds or homes. Piped systems are fed by gravity-flow directly from the source (e.g. a mountain spring) or from an elevated tank into which water is pumped from, for example, a deep bore well. Treatment of the supplies, where necessary, is possible in intermediate storage tanks. Public water points, whether open wells, hand pumps or standpipes, must always be provided with solid, watertight platforms (aprons) from which wastewater is drained away. These can also be supplemented with laundry, bathing and other facilities, including troughs for watering animals and collection systems for watering small vegetable gardens. Piped systems, especially with household connections, provide greater convenience and are thus preferred by people in most communities. Increased convenience always results in increased consumption/usage, which in itself can be expected to have an impact on health status and yield other benefits. Consumption increases of up to 500 percent have been recorded following the introduction of yard taps.

Need/ problem	Technological option for water management improvement
Water storage/distribution	Storage and Distribution Systems **Storage systems** are required in the following situations: - For most standpipe and household connection piped systems and for some systems designed to serve an institution like a school or health post (in some cases storage is not required: for some gravity flow spring catchment systems where water is flowing continuously, and where automatic electric pressure pumps are used to replace storage systems); - In rainwater collection systems, whether for individual households or for communities; - on some single point source systems, usually when a power pump is used to draw water from a deep bore well at set times throughout the day (often corresponding to electricity availability). Storage tanks are usually elevated, and water is drawn from them by gravity. Most commonly, storage tanks and elevation towers are constructed from reinforced concrete or steel. However, lower cost options - such as Ferro cement (thin-walled concrete structures with chicken wire or bamboo reinforcing) and, in some countries like India, medium density polyethylene (MDPE) or other plastic pre-fabricated tanks - are becoming increasingly available. **Distribution systems** should always be designed by experienced professionals or artisans to ensure economy and reliability. **Pipes** come in a variety of materials, appropriate for different uses. - Galvanized iron (GI) pipes are used for high-pressure pipeline stretches and for areas where pipes cannot be buried. GI pipes are much more expensive than most other pipes. - Poly vinyl chloride (PVC) pipes are used for lower water pressures, and must be buried as the material deteriorates with prolonged exposure to sunlight and is easily broken by impact. - High-density polyethylene (HDPE) pipes are often used as an alternative to GI pipes as they can withstand similar pressures and are less expensive. They are often more appropriate than PVC pipes because they come in rolls which are easier to transport and handle than lengths of PVC pipe, and they do not deteriorate in sunlight. - Bamboo trunks formed into pipes are appropriate only in the following specific situation: in a very isolated area with no road access (making other pipes unavailable or prohibitively expensive), with plenty of bamboo, and for use in a low-pressure system (usually gravity spring fed systems). Problems with bamboo include its rapid deterioration unless chemically treated, and difficulties in connecting the bamboo pipes to fittings such as valves. **Standpipes** must be of sturdy design and include an apron and drain for wastewater. As in the case of hand-dug wells and bore wells, care should be taken to ensure that the water is drained completely away, that it reach some ultimate drainage system. In most systems, standard taps are not used as they are easily damaged and tend to be left open, wasting water. "Waste-not" taps are usually employed instead. These taps are of two designs: a spring loaded or a weighted system, which ensures that taps cannot be left on. Standpipe and tap design is ultimately less important than the degree of community management and ownership for the success of the system. There are many cases, for example, where standard taps are used successfully on standpipes, as the system stakeholders are careful to turn them off, and are able and willing to repair them when necessary.

Need/ problem	Technological option for water management improvement
Water Purification	Some methods for this include: **C Chlorination**: while technically very effective, a functional chlorination system is often difficult to implement, especially in rural areas. However, some successes have been achieved with simple pot chlorinators on wells and storage tanks (often using bleaching powder as the source of chlorine). The treatment of water with chlorine can also be effective in institutional settings such as health posts and schools where resources are available and supervision is assured. The use of chlorine tablets to purify small amounts of drinking water in households is not effective as a long-term measure and should only be used in emergencies.
Water Purification **http://www.recycle-water.com/water_recovery.htm**	The proper approach in selecting a system is to review the potential contaminants, decide on the quality of cleaned water required, determine the flow rates needed to meet the application and then select the filtration or chemical processes (more than one) that will provide the quality needed, at the flow rates required and be the most economical from a cost and maintenance standpoint. There are basically three types of water recovery systems on the market today: Mechanical Systems Chemical Systems Combination Systems No one of the water cleaning technologies offers a "silver bullet" for cleaning water. For example, with chemical systems, a floc test can produce a vary clear sample of water, but is the sample usable? In other words, will the residue from the floc used cause problems? Will the effluent being flocked stay consistent? The TDS (Total Dissolved Solids) will almost always be higher after a flocculant is used. What are the economics (cost per gallon) to flocculate? Mechanical Filtration also has limitations. For example, cyclonic separation is very effective, if what is to be removed is a lot heavier than water. But road film, flour, wood fiber, dust, etc., may not be heavy enough. Using a fine filter without pre-filtration will plug (blind) the filter too quickly to be a practical solution by itself.

<table>
<tr><th>Need/ problem</th><th colspan="3">Technological option for water management improvement</th></tr>
<tr><td></td><td>Mechanical: (This term broadly covers)
Cyclonic Separation
Straining
Filters of all types
Membrane Cleaning
Reverse Osmosis
Nano-Filtration
Ultra
Coalescing
Diffused Air Floatation (DAF.)
Weirs
Floatation
Aeration
Carbon Adsorption
Media Absorption or Adsorption</td><td>Chemical: (This term loosely covers)
Flocculation
Acid Cracking
Masking
Oxidation
Separation
De-Ionization (D.I.)
Ozonation</td><td>Combination:
A good, sound, generic "combination system" will typically combine 8 to 10 mechanical filtration methods with 2 or 3 uncomplicated chemical methods. These technologies need to be properly staged in the flow sequence of the system to provide the best resulting water quality while minimizing the maintenance required.</td></tr>
<tr><td>Irrigation/crop production</td><td colspan="3">Irrigated agriculture can be defined as agriculture where the supply of water is increased by artificial means, involving the use of water control technology and including drainage to dispose of excess water. The most spread methods are (Cornish and Brabben, 2001): Watering-can/bucket irrigation, Basin irrigation (flat, raised, ridge bed), Furrow irrigation, Sprinkler irrigation, Micro (drip) irrigation, Sub-surface irrigation.
Crop Production: Increase in the water application efficiency at the field scale, plant breeding, minimizing non-beneficial water use, optimising the gap between actual and maximum yield, improving nutritional water productivity (Renault and Wallender, 2000)</td></tr>
</table>