



Strategies for Sustainable Management of Freshwater Resources

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ABSTRACT

Water resources, being the most widespread substance to be found in the environment, occupy a special place among other natural resources. The demand for fresh water resources is accelerating, and competition for fresh water is increasingly of concern to planners and policy makers. Today, the issue of freshwater resources is an increasing problem. In many areas of the world people do not have access to clean and sufficient drinking water. The perspectives of sustainable use of freshwater are of great importance from an environmental point of view. This paper aims to give an insight into key issues connected with sustainable use and management of freshwater resources. It outlines the framework within which environmental issues, such as forests and floods, affect availability of freshwater across the regions of the globe. The paper also presents key strategic interventions required for the purpose of ensuring sustainable use and management of freshwater resources at macro and micro levels. Secondary data have been used and nature of analysis is descriptive. The paper concludes that addressing water problems requires an inter-sectoral approach that recognizes the interlinkages (for example, between land and water, agriculture and water, technology and water, health and water) that affect water management.

Keywords: Freshwater resources; sustainable use; management; cloud; post-2015 development agenda

1. INTRODUCTION

One of the central challenges facing many governments, communities and companies is how to bring sustainability to the management of freshwater resources in order to meet the needs of a growing global population while sustaining flows to the 'ecological infrastructure' that often supplies that water (UNEP, 2007). Water resources occupy a special place among other natural resources. Water is a fundamental element in sustainable development. Better access to safe drinking water, adequate sanitation and increased water for food production and industry contribute to: health, Livelihood and broader economic

development outcomes.

Fresh water resources are also essential for the environment services provided by wetlands and other aquatic ecosystems. Water resources occupy a special place among other natural resources. Fresh water is a renewable resource, yet the world's supply of groundwater is steadily decreasing, with depletion occurring most prominently in Asia and North America. Today, the issue of freshwater resources is an increasing problem. In many areas of the world people do not have access to clean and sufficient drinking water. This not only causes many diseases among the population but it is

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also-in certain regions of the world-one of the major risk factors in maintaining peace. Thus, the perspectives of sustainable use of freshwater are of great importance from an environmental point of view. On the one hand, the sustainable use of freshwater resources often has an international dimension, since the use of such resources may concern several nations. On the other hand, in a human rights law perspective, the aspect of internal access to freshwater (including domestic consumption) also has a significant importance. Finally, it must be pointed out that the use of freshwater resources can have a great impact on future generations, and therefore also influences the "principles of sustainable development". The impacts of climate change on freshwater systems and their management are mainly due to the observed and projected increases in temperature, sea level and precipitation variability (Kundzewicz et al., 2007). In addition to environmental and economic considerations, there are social issues connected with freshwater resource management. Water is a fundamental social, environmental and economic resource. As a global company, one knows that access to sufficient sources of water, including fresh water and water of lower quality, is essential for the communities. As users of this critical natural resource, we must manage it responsibly. This includes improving our water-use efficiency and continuing our focus on managing water-related social and environmental impacts (Chevron Corporation, 2015).

This paper aims to give an insight into key issues connected with sustainable use and management of freshwater resources. It outlines the framework within which environmental issues, such as forests and floods, affect availability of freshwater across the regions of the globe. The paper also presents key strategic interventions required for the purpose of ensuring sustainable use and management of freshwater resources at macro

and micro levels. Secondary data have been used and nature of analysis is descriptive.

2. AVAILABILITY OF FRESHWATER RESOURCES ON THE EARTH

Water is the most widespread substance to be found in the natural environment. Water exists in three states: liquid, solid, and invisible vapour. It forms the oceans, seas, lakes, rivers and the underground waters found in the top layers of the Earth's crust and soil cover. In a solid state, it exists as ice and snow cover in polar and alpine regions. A certain amount of water is contained in the air as water vapour, water droplets and ice crystals, as well as in the biosphere. Huge amounts of water are bound up in the composition of the different minerals of the Earth's crust and core.

To assess the total water storage on the Earth reliably is a complicated problem because water is so very dynamic. It is in permanent motion, constantly changing from liquid to solid or gaseous phase, and back again. It is usual to estimate the quantity of water found in the so-called hydrosphere. This is all the free water existing in liquid, solid or gaseous state in the atmosphere, on the Earth's surface and in the crust down to a depth of 2000 metres. Current estimates are that the Earth's hydrosphere contains a huge amount of water-about 1386 million cubic kilometres. However, 97.5% of this amount is saline waters and only 2.5% is fresh water. The greater portion of this fresh water (68.7%) is in the form of ice and permanent snow cover in the Antarctic, the Arctic, and in the mountainous regions. Next, 29.9% exists as fresh groundwater. Only 0.26% of the total amount of fresh waters on the Earth is concentrated in lakes, reservoirs and river systems where they are most easily accessible for our economic needs and absolutely vital for water ecosystems (Shiklomanov, 1998).

Further, glaciers and ice caps cover about 10% of the world's landmass. These are concentrated in Greenland and Antarctica and contain 70% of the world's freshwater. Unfortunately, most of these resources are located far from human habitation and are not readily accessible for human use. According to the

United States Geological Survey (USGS), 96% of the world's frozen freshwater is at the South and North Poles, with the remaining 4% spread over 550,000 km of glaciers and mountainous icecaps measuring about 180,000 km (UNEP, 2008).



Figure 1 Global Hydrological Cycle (Merriam-webster Online, 2010)

These are the values for natural, static, water storage in the hydrosphere. It is the amount of water contained simultaneously, on average, over a long period of time-in water bodies, aquifers, and the atmosphere. For shorter time intervals such as a single year, a couple of seasons, or a few months, the volume of water stored in the hydrosphere will vary as water exchanges take place between the oceans, land and the atmosphere. This exchange is usually called the turnover of water on the Earth, or the global hydrological cycle. This is shown in Fig. 1 which shows continuous circulation of water in its different states (liquid, solid and gaseous) between the oceans, the atmosphere and the Earth's surface.

3. KEY ISSUES IN FRESHWATER RESOURCES

Dependable freshwater supplies and the ability to cope with the extremes of too little or too much water are requisites for sustainable human development. Warnings of freshwater scarcity issued at the end of the twentieth century (Falkenmark, 1989; Kundzewicz, 1997; Vorosmarty et al., 2000) are proving to be accurate, to the point that lack of water now threatens food security, livelihoods and human health (IFPRI, 2001; UN, 1992). Worldwide, freshwater:

- Supports about 40% of all food-crop production via irrigation.

- Supports 12% of all fish consumed by humans.
- Generates 20% of all electric power.

In addition to the direct impact of water scarcity, impaired quality of water reduces its usability (Johnson et al., 2001). More than 3 billion people worldwide do not have access to clean water, and the problem is particularly acute in developing countries, where 90 percent of wastewater is discharged into streams without treatment (Johnson et al., 2001). Of the more than 3 million deaths that are attributed to polluted water and poor sanitation annually, more than 2 million are children in developing countries (Van Damme, 2001). Furthermore, extensive loss of life and economic productivity result each year from rain-induced landslides, floods and torrents in developed and developing countries alike. Water and its management are therefore strategically important to economies and the well-being of people, and water management has become one of the major challenges of this century. Conflicts over water use will arise as water becomes increasingly scarce, making action on many fronts imperative.

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The loss of forest cover and conversion to

other land uses can adversely affect freshwater supplies and compound human disasters resulting from hydro meteorological extremes. Watershed conditions can be improved and overall water resource management facilitated if forests are managed with hydrological objectives in mind. For the purpose of resolving water issues, forests can provide tangible economic and environmental benefits. A watershed framework helps identify these benefits in both upstream and downstream areas.

Forests are found where there are large quantities of water, normally where precipitation is abundant or in riparian areas where soil moisture is high. Perception of the influence of forests on water led to the establishment of the national forest system in the United States, as forest cover was considered necessary to sustain river flow (Lee, 1980). Most forests were subsequently found to use great amounts of water, contrary to early thinking.

4. FORESTS, ATMOSPHERIC WATER AND WATER YIELD

The relationship among forests, atmospheric moisture and water yield has long been controversial. The natural coincidence of forest cover and higher precipitation is at least partly responsible for the popular notion that forests increase or attract rain, which leads to the assumption that their removal would significantly diminish precipitation. Globally, this is not the case; the removal of all forest cover would only reduce global precipitation by 1% to 2% at most (Lee, 1980). Deforestation has little effect on regional precipitation, although exceptions could occur in basins where rainfall largely depends on internally driven circulation patterns, such as the Amazon basin (Calder, 1999a). Even then, it has been estimated that complete deforestation and replacement with non-forest vegetation would reduce basin

rainfall by less than 20% (Brooks et al., 1997). Most importantly, however, there are circumstances, in which forests intercept fog or low clouds (cloud forests), adding moisture to the site that would otherwise remain in the atmosphere. The relationship between forests and the yield of freshwater differs between cloud forest and non-cloud forest conditions.

4.1 Cloud forests and freshwater yield

Cloud forests occur along coastal areas in temperate climates and also in tropical montane regions where fog or low cloud conditions are common. The following are examples of freshwater augmentation by cloud forests:

- Coastal forests in the fog belt of western Oregon, the United States, augment water yield (Harr, 1982; Ingwersen, 1985). The removal of conifer forests from the municipal watershed of Portland, Oregon, reduced summer stream flow.

- Water augmentation by tropical montane cloud forests varies with altitude, location and season (Bruijnzeel and Proctor, 1993). The ratio of horizontal precipitation to annual rainfall was shown to vary between 4 and 85 percent, with higher values corresponding to dry seasons, while average horizontal precipitation varied between 0.2 and 4 mm per day. Annual stream flow from tropical montane cloud forest for a given rainfall was higher than from other tropical forests. The stream flow response to conversion of tropical montane cloud forest to other land uses has not been widely documented, although research is under way in Central America (Calder, 1999b; Kaimowitz, 2000).

4.2 Non-cloud forests and freshwater yield

Outside fog or tropical montane cloud forest regions, forests generally consume large quantities of water. More than 100 watershed

experiments around the world have shown that forest removal influences stream flow, which varies in magnitude with climate and forest type and diminishes as forests regenerate (Bari et al., 1996; Bosch and Hewlett, 1982; Lesch and Scott, 1997; Verry et al., 2000; Whitehead and Robinson, 1993). When other land uses replace forests, flow increases are sustained. With few exceptions, results show the following:

- Removal of forest cover increases annual water yield by 60 to 650 mm. The size of the increase is generally proportional to the amount of biomass removed and is greater in wetter areas. Little effect has been reported in dry land areas where annual precipitation is less than 400 mm.

- Flow during dry seasons generally increases after forests are thinned or removed.

- Forests with high interception rates (e.g., conifers) or high transpiration rates (e.g., eucalypts) yield less water than those with lower interception and transpiration rates. Water yield would therefore be expected to increase when conifer forests are replaced by broadleaf forests and to decrease when broadleaf forests, shrubs or grasses are replaced by conifers (see Box opposite).

5. FORESTS, FLOODS AND DEBRIS FLOWS

Forests produce low levels of storm flow and greater soil stability than any other vegetation type because of their high infiltration rates, protective ground cover, high consumption of soil water, and high tensile strength of roots. These attributes are particularly beneficial in mountainous terrain that is subject to torrential rainfall. Forest removal and road construction are problematic in such areas because they increase the frequency and magnitude of landslides and debris flows (Sidle, 2000). However, there is a limit to the protection that

forest cover provides, as was found in Taiwan Province of China (Lu et al., 2001). As the amount of rainfall becomes extreme, the extent to which forests can help to prevent landslides, debris flows and flooding diminishes.

A frequently asked question is the extent to which forest cover affects flooding. In northern Minnesota, the United States, rainfall-generated peak flows up to the 25 to 30 year recurrence interval (RI) increased when 70% of the forest cover on a small watershed was clear-cut (Lu, 1994; Verry, 2000). Larger floods were not affected by forest cover removal. This supports the claim that changes in forest cover have little effect on large floods in major streams.

Extreme hydrological events are the result of natural processes of erosion and sediment motion interacting with human systems (Davies, 1997). Where land scarcity concentrates people and their dwellings in hazardous areas, disasters will occur whether uplands are fully forested or not. This is the situation in Taiwan Province of China, with a population density approaching 600 inhabitants per square kilometer. People living on steep slopes, in the mouths of small drainage basins and in floodplains are bound to be vulnerable. A coordinated watershed management program among government agencies has been suggested in order to address this threat for both upstream and downstream communities (Lu et al., 2001).

Hazardous areas must be identified, and policies and institutions established to provide incentives for people to avoid them. Terrain analysis based on Geographic Information Systems (GIS) offers the means to mark hazardous terrain in mountainous watersheds (Gupta and Joshi, 1990; Sidle, 2000), and methods to delineate floodplains and define zones according to the type and degree of risk are well known (Bedient and Huber, 1988). An example of an incentive to change people's behaviour is the Federal Flood Insurance

Program in the United States, under which insurance rates in areas adjacent to rivers are linked to the degree of hazard.

6. FORESTS AND SEDIMENTATION

Because watersheds with healthy forests export the lowest levels of sediment of any cover type (Brooks et al., 1997), it is not surprising that forests are often looked to as a means of reducing levels of downstream sediment in water supply reservoirs. Reforestation has been recommended in order to reverse a threefold increase in sedimentation in the Alhajuela Reservoir in Panama following the clearing of 18.2% of the watershed (Larson and Albertin, 1984). Few such studies exist, and some people, therefore, suggest that the benefits from forest cover in reservoir protection have been over-estimated (Kaimowitz, 2000). Reasons for such scepticism include:

- Inadequate monitoring, and therefore limited empirical evidence linking forest changes to reservoir sedimentation levels.
- The fact that forest cover changes have occurred over such small areas of watersheds that little effect has been observed.
- The distance between upstream watershed projects and downstream reservoirs, which masks the effects.
- The recognition that other factors, such as non-forest land use, can increase stream flow peaks and affect sedimentation.

Downstream sediment delivery is affected both by changes in stream flow discharge from upland watersheds and by alterations in riparian areas along stream banks (Rosgen, 1994; Tabacchi et al., 2000). Sediment levels of rivers are determined by both sediment availability and stream flow discharge. The most effective discharge for transporting sediment over time is that associated with the bank-full stage (when the river channel is full

but not overflowing), usually corresponding approximately to the average annual peak flow. When land use increases the size of these flows, the stream channel becomes unstable and sediment levels increase, regardless of whether erosion rates have been reduced. Healthy riparian forests can also reduce sediment levels by filtering out soil erosion inputs to channels and by maintaining stable stream banks. Degradation of both upland and riparian forests can therefore combine to increase sediment delivery to reservoirs.

7. FORESTS AND WATER QUALITY

Water pollution impairs water use by downstream users and seriously affects human health. The exceptionally high quality of water discharged from forested watersheds is the main reason that protected forests are preferred for municipal watersheds. Forests efficiently cycle nutrients and chemicals and decrease the sediment exported, thus reducing pollutants such as phosphorus and some heavy metals. The lower rate of rainfall runoff also reduces the load of all nutrients and pollutants entering water bodies.

In many developing countries, the food and resource needs of the rural poor, coupled with land scarcity and institutional limitations, constrain efforts to protect forested watersheds for municipal water supplies. However, the problems of polluted drinking-water and associated diseases significantly jeopardize the welfare of rural populations and urban communities alike. Water storage and transport facilities are sorely needed in many areas, along with improved sanitation and water treatment. Well-managed forested catchments above reservoirs can result in minimal requirements for water treatment. (Echavarría and Lochman, 1999).

8. RIPARIAN FORESTS

Forest buffers and agro forestry systems along water bodies further improve water quality. Riparian forests and vegetated areas should not be heavily used for grazing and farming. Also, they help to stabilize stream banks, reduce wastewater and chemical discharge into water bodies from upland areas and maintain cooler water temperatures, thus improving dissolved oxygen levels in water (Brooks et al., 1997). The water quality can be enhanced for human consumption, leading to better health and productivity and greater diversity of aquatic ecosystems, including mangrove forests. As a result, healthy riparian forests increase fish production. Riparian systems are heavily utilized because of their proximity to water and their high productivity for grazing and farming, and it is therefore unrealistic to protect them from all uses. With proper management, however, riparian forests and agro forestry systems along water bodies can mitigate the effects of nutrient, chemical and human waste discharge. At the same time, these systems can provide wood, forage and other products for the rural poor.

9. WATERSHEDS: RECOGNIZING “UPSTREAM-DOWNSTREAM LINKAGES”

9.1 Scale and cumulative effects

Freshwater benefits to downstream areas naturally accompany sound management of upland and riparian forests, but management can also be directed to specific freshwater objectives. In either case, benefits may be masked by spatial aspects, for example the location and diffuse nature of land-use practices and their effects; the scale of activities in proportion to watershed size; and the time needed for benefits to be realized. Changes on the land can have incremental

effects that may not be individually apparent but can be considerable over the whole watershed and over time. This complexity has clouded the view of decision-makers in many parts of the world and weakened their commitment to watershed management. However, these cumulative effects must be recognized in environmental and economic assessments.

Cumulative effects of land use on downstream water flow, sediment loads and pollutants can best be observed on islands, over a few kilometers rather than hundreds. For example, deforestation and cropping practices on islands in the Caribbean and the Pacific have been linked to the degradation of estuaries, coral reefs and their dependent fisheries. In eastern Jamaica, the replacement of forests with upland coffee farming has increased soil erosion and the export of chemicals, which have contributed to the degradation of coral reefs. Such linkages are clear in river basins, but in larger systems the impact may take decades or longer to become evident, and may be masked by other land-use practices. Midwestern states in the United States are focusing on restoring riparian forests and wetlands and improving agricultural land use to reduce total maximum daily loads to the Mississippi River, in accordance with federal legislation calling on all states to improve impaired bodies of water. Urban and peri-urban forest and tree programs are being developed and promoted to address poverty and food insecurity as well as to support protection and sustainable use of land resources.

9.2 Economic considerations

Forest management and other watershed improvements to protect and manage freshwater require economic justification. A watershed perspective provides clarity in determining the economic value of forests for these purposes.

There is economic importance of the water-related ecosystem services provided by forests (Johnson et al., 2001). However, no comprehensive economic analyses that consider the full range of these benefits have so far been made, because of a number of difficulties. These include inadequate monitoring and evaluation of watershed services from forestry projects; difficulties in placing an accurate value on many services, particularly those that are not traded in the marketplace; and water subsidies. In many parts of the world, water is heavily subsidized and often considered a free good. Its scarcity is now causing people to determine the value of freshwater more realistically. In contrast, the economic benefits of well-managed or protected forests have not been fully considered in terms of avoided losses from: soil erosion, debris flows, sedimentation and floods, etc.

Improved watershed economics may, thus, be forthcoming as a result of water scarcity. What some are calling a new global water economy is emerging, in which freshwater is viewed more as an economic commodity than as a publicly managed resource (Anderson, 2002).

The new water economy faces hurdles in developing countries, where water has often been treated as a free good because of longstanding practices and religious beliefs (Rosegrant and Cline, 2002). More efficient water allocation and innovative pricing policies can provide incentives to support forest management for water supply purposes. Policies that continue to treat water as a free good or that heavily subsidizes it will continue to promote waste in developing and developed countries alike.

There are financial mechanisms that can enhance the restoration, maintenance and improvement of water-related services from forested watersheds (Johnson et al., 2001). In most cases, the methodology to perform the

needed financial and economic analysis exists. Upstream and downstream data, sometimes sorely lacking, are transformed into benefits and costs that can be contrasted under 'with' and 'without' conditions (Gregersen et al., 1987). This approach has been used to assess watershed projects in Morocco and China, encompassing, but not limited to, changes in forest cover and management (Brooks et al., 1982; Duan et al., 2001). In both cases, watershed improvements, including forests and agro forestry, were found to be economically viable (with economic rates of return of 10% to 16%) when production and water resource benefits were combined.

Hydrological computer models can be used to examine human-induced effects on watersheds. Changes in water yield, flooding and sediment transport, for example, can be simulated and related to specific sites where economic benefits and costs are of interest. The cumulative effects of agricultural development, the loss of riparian forests in floodplains and wetland drainage were simulated for a watershed of the Minnesota River basin in the United States, using the Hydrocomp Simulation Program-Fortran (HSPF) model (Miller, 1999). These land-use changes increased annual stream flow and peak flow discharges, which can be related to "lost storage" in the basin. The downstream damage associated with a major recent flood could have been significantly reduced by restoring sufficient areas of riparian forest cover, floodplains and wetlands in the basin. Farmers could justifiably be compensated for such land conversion on the basis of reduced economic losses from future flooding. Such innovative approaches need to be expanded and considered for tropical watersheds and developing countries, with emphasis on developing computer simulation models (Hey, 2001).

9.3 Institutional and policy considerations

Better management of forests and water resources to improve human welfare requires more than just technical knowledge. While technical information provides a foundation for assessing upstream-downstream linkages and carrying out economic analyses, transforming such information into management practices requires the effective participation of stakeholders in order to develop a consensus and provide incentives for implementation (Eckman et al., 2000). A policy environment must be created that supports, rather than hinders, the integration of land and water management. Since watershed and political boundaries rarely coincide, the coordination of land and water management depends on organizations to resolve transboundary issues and water-use disputes. In the United States during the 1990s the absence of effective watershed- or basin-level organizations led to the formation of more than 1500 watershed districts to deal with upstream-downstream issues (Lant, 1999). Nile-basin countries established a partnership of nine riparian countries to resolve transboundary issues and to move towards more sustainable development (Baecher et al., 2000). The inequities of water distribution in this region are amplified because more than 80 percent of the flow to the lower Nile, on which the Sudan and Egypt depend, originates in mountainous Ethiopia. Without cooperation and coordination, disputes over water use and development could clearly arise.

10. SUGGESTED STRATEGIES FOR SUSTAINABLE USE AND MANAGEMENT OF FRESHWATER RESOURCES

The scarcity of freshwater is a global problem calling for more effective and efficient water management, from local watersheds to major

river basins. Forests in mountains prevent landslides. Effective strategies on “sustainable use of freshwater resources” can help to focus global attention on issues and solutions and on the need for a comprehensive approach to cope with scarcity, on the one hand, and excess, on the other. Forests can have an important role in supplying freshwater, but their management must complement water management. Technology exists for the most part, but implementation requires policies and institutions to promote inter-sectoral dialogue and cooperation. The followings are some potential ways in which the management of forests and water can be mutually supportive.

First, mountainous forested watersheds require special attention as the highest freshwater-yielding areas in the world, but also as the source areas for landslides, torrents and floods. People inhabiting the headwater regions and those living in the downstream lowlands depend on freshwater from the uplands, and also feel the effects of hydro-meteorological extremes. Actions to prevent or mitigate disasters in mountainous terrain should include:

- Maintenance of healthy forest cover on mountainous watersheds that are subject to torrential rainfall.
- Development of programs that combine forest protection with zoning, floodplain management and engineering structures to protect people from landslides, debris flows and floods.

Second, forests can be managed to enhance freshwater supplies, but as a component of comprehensive and multifaceted water management programs. The economic value of water and its source areas must be recognized. By reducing water subsidies and treating water as a commodity rather than a free good, economic incentives can support better management in the following ways:

- The water yield of municipal watersheds in

non-cloud forest conditions can be augmented when tree species with low consumptive use replace those with high consumptive use or when forest stands are periodically thinned and harvested.

- In cloud-forest conditions, mature and old-growth forests should be protected and managed to sustain stream flow during dry periods.

- Riparian forests should be managed to improve water quality, which can, in turn, enhance the productive capacity of aquatic ecosystems and improve the health and welfare of local human populations. In addition, full use should be made of agro forestry buffer systems that can achieve these goals and also provide food, fodder and wood products.

- Agro forestry systems need to be developed for upland watersheds in order to capture the hydrological benefits of forests, while enhancing food and natural resource production for the rural poor.

Third, the potential exists to mitigate the economic damage caused by floods and sediment delivery through forest management in uplands, riparian areas and floodplains. Although the largest and most damaging floods in major rivers are not affected by the extent of forest cover, moderate and localized floods can increase when forests are removed. Forest degradation brings with it many undesirable effects on water flow and quality. Healthy upland and riparian forests can maintain low levels of sediment delivery to rivers, lakes and reservoirs.

Fourth, a watershed perspective should be incorporated into the planning and management of forests, water, and urban and agricultural land use. This perspective is needed at the local level as well as the highest government levels in order to promote sustainable solutions.

Fifth, incentives and the means to achieve freshwater objectives must be provided

through forest and other land-use management policies and institutions, from the local watershed level to the river basin level. Inter-sectoral dialogue and cooperation are necessary to achieve management objectives and to resolve inequities in terms of who pays for and who benefits from changes in upstream and downstream resource use. Expanded economic analysis is needed to understand these inequities better and to resolve them. The emerging water economy will facilitate the justification of land-use changes to enhance water supplies. Consideration should be given to compensating inhabitants who improve forests and other land uses that reduce downstream losses. The policy environment and institutional support may be enhanced through:

- Improved understanding of the processes and required approaches for upstream-downstream management systems in the context of better water resource management and sustainable development.
- Expanded educational and training programmes that are directed to local watershed inhabitants up to the highest-level policy-makers.
- Better understanding and reconciliation of the role of forests in freshwater management, with emphasis on demonstration and extension programmes aimed at local users of land and water.
- Expanded monitoring and evaluation of projects, as well as improved research on tropical forested watersheds in developing countries, given that many of the questions asked in the 1970s and 1980s about the hydrological role of tropical forests are still largely unanswered, or at least not well documented.

Socio-economic aspects as well as technical components need to be stressed so that the resulting information can provide the foundation for developing new technology and

policies to enhance people's welfare through improved forest and freshwater management. Water has always been a public good but certain uses should not be free.

11. CONCLUSIONS

Depletion of fresh water resources in quantity and quality has profound social, economic and ecological effects. Water is a particularly vital resource. Without water, ecosystems are destroyed, economic activities halt and people die. Freshwater shortages are expected to continue into the future (U.S. Government Accountability Office, 2014).

Addressing water problems requires an inter-sectoral approach that recognizes the interlinkages (for example, between land and water, agriculture and water, technology and water, health and water) that affect water management. Also, there is need for initiatives aimed at accessing fresh or usable water from sources such as stormwater, recycled water and seawater. No single mechanism or approach will be enough (McCaffrey and Weber 2005). Policy packages using a mutually reinforcing mix of institutional and policy reform, and legal, economic and management instruments will be needed. One of the goals of the international water policy and strategy should be "to identify and promote the tools that will address the critical water issues facing humanity". Further, the policy makers and national governments must have the will to deal with "long-term environmental problems". Against this backdrop, there is an emerging consensus on the need for a dedicated water goal in the Post-2015 Development Agenda, one which includes explicit recognition of the importance of good wastewater management and its contribution to protecting water quality. This is accompanied by the realization that the focus on drinking-water and sanitation without due

attention being paid to wastewater may have exacerbated some of the water quality problems seen globally. To sum up, it is hard to be a freshwater scientist today and not wish that society was better managing its freshwater resources (Strayer, 2015). At the same time, the analysis needs to be conducted on water quality, as a consequence of water resources development and use (pollution), and its further influences on the freshwater resources (Babel and Wahid, 2008).

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