Journal of Natural Sciences Research
ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online)
Vol.6, No.15, 2016

Review Paper on Roles of Forests in Hydrological and Carbon Sequestration

Belay Beyene[1] Belachew Beyene[2]* Abayneh Unasho (Ass. Prof)[3*] Habtamu Derbe[4]*
1. Dilla university Natural and computational science
2. Jimma University, College of Agriculture and Veterinary Medicine
3.1Dilla university Natural and computational science
4. Jimma University, College of Agriculture and Veterinary Medicine

Abstract:
The sustainable use of the biodiversity is very important for every life. Forests play a significant role in the global carbon cycle. The relationship among the forest rainfall and water yield, carbon sequestration and other watershed ecosystem services intensifies worldwide. Clearing of the forest decreases the evaporation and increases the stream and vice versa. To reduce the carbon emission the sustainable uses of the biodiversity is the crucial issue today. The governmental policy and the international convention like Kyoto protocol agreement implementation are very important to reduce the emission by minimizing deforestation and enhancing vegetation plantation.

Keywords: carbon sequestration, forest, water, stream flow

1. Introduction

Tropical forests have been disappearing over the years as a consequence of unsustainable natural resource exploitation, imposing a threat against biodiversity conservation, clean drinking water supplies and climate stability (Benavides *and* Veenstra, 2005). The recurrence of extreme weather events, climate change and the need for adaptation strategies are focusing international attention on water, water-related ecosystems and watersheds *(*Zingari and Achouri, 2007). The availability and quality of water in many regions of the world are more and more threatened by misuse and pollution and it is increasingly recognized that both are strongly influenced by forests. Moreover, climate change is altering forest's role in regulating water flows (FAO, 2003).

Deforestation, which annually averaged 14.6 million hectares (ha) worldwide between 1990 and 2000, will continue given that humans assign a higher value to wood products and agriculture than to ecosystem services provided by the forest, such as watershed protection, wildlife conservation and carbon sequestration (Sweeney *et al.,* 2004). There is now widespread acceptance among professional foresters, governmental agencies and environmental groups that the ecological, social and economic functions of the world's forests are under stress. Deforestation, forest degradation and climate-related impacts on forest ecosystems are combining to contribute to extraordinary species losses, with significant implications for ecosystem services (Levin *et al.,* 2008).

Forests play a significant role in the global carbon cycle. Biomass and soil store approximately three times the amount of carbon that is currently found in the atmosphere and the annual exchange of carbon between the atmosphere and natural forests is 10 times more than the annual global carbon emissions from humans burning fossil fuels. Despite natural forests storing such significant amounts of carbon, there has been scant consideration given by policymakers to the role of forests in addressing the climate change problem. At the 2007 United Nations Climate Change Conference in Bali (UNFCCC CoP 13), however, the international community recognized the need to reduce emissions from deforestation and forest degradation (REDD) as a vital component of a comprehensive solution to the climate change problem (Mackey *et al.,* 2008). However, as we shall see in forthcoming sections, some researchers (e.g**.** Jackson *et al.(*2005) and Farley *et al.(*2005) warn that carbon sequestration strategies which emphasize tree plantations without considering their full environmental consequences can have negative side effects such as reduction in water yield.

Forest hydrology research conducted during the 1980s and 1990s suggests a rather different picture regarding some of the traditionally perceived hydrometreological roles of forests. Although the important role of upstream forest cover in ensuring the delivery of high quality water has been confirmed, earlier generalizations about the benefits of upstream forest cover on downstream annual and seasonal flows were generally fallacious and misleading. Studies have shown instead that, especially in arid or semi-arid ecosystems, forests are not the best land cover to increase downstream water yield (Calder *et al.,* 2007).

Despite significant advances in scientific understanding of forest and water interactions, the role of forests in relation to the sustainable management of water resources remains a contentious issue (Achouri 2002; Andreassian, 2004; Calder *et al.,* 2007 and Bruijnzeel, 2004). The debate on water and forests remained for a long time confined to a romantic and historical argument. The only way out of this dead end was through watershed experiments. To these end, paired-watershed experiments came into being (Andreassian, 2004). Using this approach, two watersheds that are similar in size, initial land use or land cover, and other attributes are selected for study. Both are monitored, and while one is left as a "control," the other is "treated" (subjected to manipulations such as forest cutting, road building, fires and so on). The measured changes in the stream flow and water quality between the two watersheds quantify the effects of forest treatment and growth. Paired watershed studies, plot-scale studies and hydrologic modeling are important elements of forest hydrology (NAS, 2008).

As the demand for clean water, carbon sequestration and other watershed ecosystem services intensifies worldwide, it has become increasingly important to understand the role of vegetation cover in regulating the hydrologic cycles (Changqing-Zuo *et al.*, 2008). Moreover, carbon sequestration programs, including afforestation and reforestation, are gaining attention globally. However, converting grasslands or shrub lands to plantations will likely affect many other ecosystem processes, including water yield from rivers and streams. Some researchers(such as Farley *et al.(*2005) and Jackson *et al.(* 2005)) say the environmental 'co-effects' of carbon sequestration programs have received much less attention than the carbon sequestration potential. A reduction in stream flow can be expected with afforestation of grasslands and shrub lands, which will have ecological and socioeconomic consequences. In many regions, reduced runoff will cause or intensify water shortages, a tradeoff that should be explicitly recognized before land conversion. For instance, the planting of eucalypts has met particularly vigorous opposition in the popular environmental literature, mainly because they are claimed to be voracious consumers of water (Bruijnzeel, 2004).

Overall, the relationship among forests, rainfall and water yield has long been controversial. With the intention of bringing more balance and clarity to such debate, this paper reviews various scientific evidence pertaining to the influence exert by the presence or absence of a good forest cover on rainfall, water yield as well as on water quality. This review paper can also give an explanation for the tradeoffs and benefits of carbon sequestration, identifying potential problems and management needs for a sustainable sequestration policy.

2. Forests and water yield

2.1 Conventional vis-à-vis scientific views of forest-water yield connections

According to the "sponge theory", which came under criticism as early as 1920, forest areas absorb a large amount of water during wet periods or snow melt and slowly release water into streams and rivers during dry periods when water is most needed (Achouri, 2002). In the conventional wisdom, a common notion about the hydrological role of forests is that the complex of forest soil, roots and litter acts as a 'sponge' soaking up water during rainy periods and releasing it evenly during dry periods. Upon clearing, the 'sponge effect' is lost through the rapid oxidation of soil organic matter, compaction by machinery or grazing, etc, with diminished water yield as a result (Bruijnzeel, 2004). Hence, proponents of the conventional view argued that with forest destruction, springs dry up or become seasonal or i.e. that deforestation reduces the quantity of running water (Andreassian, 2004 and Bruijnzeel, 2004). Accordingly, the past policy-making was often based on the assumption that the more trees, the more water (Calder *et al.,* 2007). Current forest hydrology research challenges this assumption. The more 'scientific' view of forest functioning, which is of course based on water shade experiments, considers that 'roots may be more appropriately labeled a pump rather than a sponge' and that 'roots certainly do not release water in the dry season but rather remove it from the soil in order that the trees may transpire and grow'(Bruijnzeel, 2004). The forest-water yield connections, which are inferred from various waters hade experiments, are outlined below.

2.2 Forest-water yield connections overview

The total amount of water flowing from a watershed, through surface and subsurface flow, is known as water yield (Pike, 2003). Water yield is altered through changes in transpiration, interception and evaporation all of which tend to increase when grasslands or shrub lands are replaced with trees (Farley *et al.,* 2005). The vast majority of the world's catchment experiments indicate decreased runoff (stream flow) from areas under forests as compared with areas under shorter crops. These studies indicate that in wet conditions interception losses will be higher from forests than shorter crops. In dry (drought) conditions the studies show that transpiration from forests is likely to be greater because of the generally increased rooting depth of trees as compared with shorter crops and their consequent greater access to soil water. Hence, contrary to the widely accepted folklore, runoff (stream flow) will be decreased from forested areas as compared with those under shorter vegetation (Calder, 2002 and Calder, 2000). On average, according to Farley *et.,(*2005), trees are able to use approximately 15% more precipitation than grasses or shrubs.

Tree canopies reduce groundwater and stream flow, through interception of precipitation and evaporation and transpiration from the foliage (Calder *et al.,* 2007). Forests also influence how water is routed and stored in a watershed. Water that reaches the ground's surface will either infiltrate the soil or move over its surface. Infiltration is the rate at which water enters the soil matrix. Most forest soils readily absorb water and as a result, surface runoff (overland flow) rarely occurs outside of stream channels in forested areas (Pike, *2003* and Scherer and Pike, 2003).

2.3 Changes in Forest Cover and Water Yield/Stream Flow

Trees are pumps, using their deep rooting systems access large amounts of groundwater. Replacing trees with less 'thirsty' plants such as grasses and annual crops allows groundwater reserves to recover as long as soil degradation is kept moderate (Ziemer, 1986 and Anonymous, 2008). Hence, forest harvesting increases the amount of water available for stream flow as forest water consumption is generally higher than that of other vegetation types (Pike, *2003*; Scherer and Pike, 2003; FAO, 2003 and Andreassian, 2004). Forest harvesting also reduces evapotranspiration/interception losses through "eliminating transpiration and evaporation from the elevated canopy". This leads to increased water available for stream flow (Pike, *2003* and Scherer and Pike, 2003).

Because evapotranspiration can account for 40-60% of the annual water loss from forested catchments, vegetation is an important regulator of stream flow. Removal of forest vegetation decreases evapotranspiration and increases stream flow roughly in proportion to the catchment area cleared (Webster *et al.,* 1992; FAO, 2003 and Bruijnzeel, 2004). More than 100 watershed experiments around the world have shown that forest removal increases stream flow, which varies in magnitude with climate and forest type (FAO, 2003 and Nik, *1988).*

Because evapotranspiration can account for 40-60% of the annual water loss from forested catchments, vegetation is an important regulator of stream flow. Removal of forest vegetation decreases evapotranspiration and increases stream flow roughly in proportion to the catchment area cleared (Webster *et al.,* 1992; FAO, 2003 and Bruijnzeel, 2004). More than 100 watershed experiments around the world have shown that forest removal increases stream flow, which varies in magnitude with climate and forest type (FAO, 2003 and Nik, *1988).*

The magnitude of increases in stream flows depend on how much of the watershed area is clear cut. More than 25% of a watershed's forest cover needs to be removed (i.e., clear cut) before changes in stream flows will be observed (assuming that the entire watershed was originally forested) (Scherer and Pike, 2003). Similarly, Andreassian (2004) asserts effects start to become detectable when 25% of the watershed is treated. The longevity of annual water yield increases is highly dependent on the rate of vegetation recovery because vegetation recovery directly influences evapotranspiration rates. The greatest increase in stream flow occurs during the first growing season after the clear cut (Muth, 2008). A majority of studies indicate that water yields will return to pretreatment levels approximately 10 to >30 years after harvesting (Scherer and Pike, 2003; Bruijnzeel, 2004 and Webster *et al., 1992).* The following figure illustrates ground cover vs. water yield: lows

will be observed (assuming that the entire watershed was originally forested) (Scherer and Pike, 2003). Similarly, Andreassian (2004) asserts effects start to become detectable when 25% of the watershed is treated. The longevity of annual water yield increases is highly dependent on the rate of vegetation recovery because vegetation recovery directly influences evapotranspiration rates. The greatest increase in stream flow occurs during the first growing season after the clear cut (Muth, 2008). A majority of studies indicate that water yields will return to pretreatment levels approximately 10 to >30 years after harvesting (Scherer and Pike, 2003; Bruijnzeel, 2004 and Webster *et al., 1992).* The following figure illustrates ground cover vs. water yield:

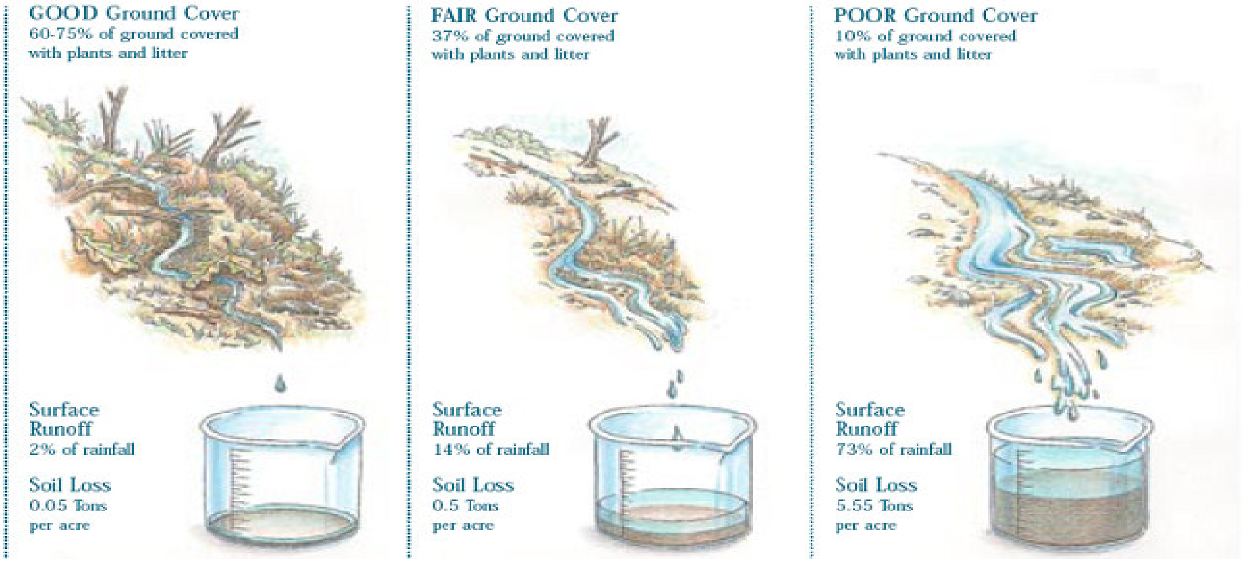


Figure-1: Experimental results of the effect of ground cover on runoff /stream flow (Sedell *et al.,* 2000).

Stream flow responses to forest harvesting also depend on the precipitation in a given year. An area with high mean annual precipitation will tend to show a larger increase in water yield than an area with low mean annual precipitation. Increases in water yield are unlikely to occur as a result of forest harvesting in areas with precipitation <400 mm/y, and the potential for increases is only marginal in areas with precipitation between 400 and 500 mm/y. Increases in water yield become difficult to detect in larger basins due to variations in groundwater storage and release, tributary contributions, and differing patterns of precipitation across a basin (Scherer and Pike, 2003). In dry land areas, attempts to increase water yield by treating vegetation have been unsuccessful because soil water recharge is quickly lost to invading pioneer vegetation (Ziemer, 1986).

Afforestation of grasslands and shrub lands will typically result in a loss of one-third to three-quarters of stream flow on average. Stream flow reductions are attained very rapidly after afforestation, with losses of more than 10% of stream-flow occurring in the first 2–3 years after tree establishment for most catchments. Stream flow response to afforestation can be expected to be very rapid (within 5 years of planting), maximum runoff reductions can be expected between 15 and 20 years after planting, and runoff reductions will likely be larger and more sustained when grasslands are afforested than when shrub lands are(Farley *et al.,* 2005).

Based on synthesis of more than 600 observations and climate modeling, Jackson *et al. (*2005) documented substantial losses in stream flow, and increased soil salinization and acidification with afforestation. Plantations decreased stream flow by 227 millimeters per year globally (52%), with 13% of streams drying completely for at least 1 year. Regional modeling of U.S. plantation scenarios suggests that climate feedbacks are unlikely to offset such water losses and could exacerbate them. Plantations can help control groundwater recharge and upwelling but reduce stream flow. In addition to influencing water budgets, plantations require additional base cations and other nutrients to balance the stoichiometry of their extra biomass. In consequence, trade-offs of sequestration with water yield and soil fertility, including nutrient depletion are likely (Jackson *et al.,* 2005). Hence, carbon sequestration strategies which underscore tree plantations need to consider their full environmental consequences.

Man-made forests generally reduce the amount of water available downstream, especially when fast-growing evergreen tree species with high moisture requirements in the dry season are planted. There is little evidence that reforestation schemes actually achieve their aim, namely to restore the watershed functions attributed to natural forest cover. It is important for policy makers to understand which vegetation changes will affect the quantity, quality and regularity of river flow and to be aware of the possible consequences in terms of changes in flooding, erosion and landslide hazards (Anonymous, 2008).

2.4 Caution: Sustainability of increases in water yield via forest removal

As both natural and human established forests use more water than most replacement land cover (including agriculture and forage), there is no question that forest removal (even partial) increases downstream water yields. Consequently, removal of heavy water demanding forest cover has sometimes been suggested, especially in semi-arid areas, as a means of preventing or mitigating drought. However, such a policy should be weighed against the consequent loss of the many other services and goods that forests supply, including erosion control, improved water quality, carbon fixation, recreation and aesthetic appeal, timber, fuel wood, other forest products and biodiversity (Calder *et al.,* 2007; Ziemer, 1986; NAS, 2008; Nik, *1988* and Muth, 2008). Besides**,** the increases in water yield are generally not sustained over the long-term, and any increases in water yield are most likely to occur during high precipitation events and not likely to occur during drier times when water demand is high (NAS, 2008).

Although it has clearly been shown that vegetation treatments can increase water yield on plots and small experimental watersheds, there is less assurance that such yields can be observed at downstream points of use. First, transmission losses through untreated portions of the routing system may decrease the added water. Second, if the treated area is a small proportion of the watershed area above the point of use, the increased flow may not be detectable even if transmission loss is negligible (Ziemer, 1986 and Sedell *et al.,* 2000). Given that the observed response of water yield to forest harvesting is highly variable and complex, it is difficult to create general quantifiable “rules-of-thumb” or guidelines regarding how harvesting method, location, and rate of harvest will affect water yield (Pike, 2003 and Scherer and Pike, 2003). Moreover, deforestation typically leads to a decline in stream flow when the removal of trees, and the use of land that follows this, reduces infiltration more than it affects transpiration. In other words, it is the combined effect of changes in infiltration plus vegetation water use that determines the outcome for stream flows (Anonymous, 2008).

2.5 Cloud forests and water yield

As stated earlier in this section, forests are "consumers" of water and hence forest harvesting generally increases the amount of water available for stream flow**.** The few exceptions are cloud *forests* where cloud-water deposition may exceed interception losses (Calder, 2002 and Calder, 2000). There is a growing body of evidence that cloud forest clearance for pasture or annual cropping may lead to decreased flows in the dry season**.** Evapotranspiration in cloud forests is known to be low. Hence, reforestation of degraded grass or crop land with such forests may result in enhanced low flows. Contributions by intercepted cloud water to the water budget of montane cloud forests may attain substantial values during rainless periods (Bruijnzeel, 2004).

3. Forests and Precipitation

Precipitation is water from the atmosphere that is deposited in various forms (snow, hail, and rain) depending on temperature (Pike, 2003). In the conventional wisdom, Andreassian (2004) argues**,** the role of trees is rather simple: "*the trees may be considered as intermediaries between the clouds and the earth; they command from far away the wandering waters of the atmosphere to approach and pour into the earth to feed the springs, make the streams flow."* It was argued that the destruction of forests had a strong negative impact on rainfall (Andreassian, 2004 and Bruijnzeel, 2004). Conversely, Pereira (1989) cited in Calder (2000) states in relation to forests and rainfall:

The worldwide evidence that high hills and mountains usually have more rainfall and more natural forests than do the adjacent lowlands has, historically led to confusion of cause and effect. Although the physical explanations have been known for more than 50 years, the idea that forests cause or attract rainfall has persisted. The legend was created more than a century ago by foresters in depence of their trees… The legend was written into the textbooks and became an article of faith for early generations of foresters.

Similarly, Lee (1980) cited in FAO (2003) contends, forests are found where there are large quantities of water, normally where precipitation is abundant or in riparian areas where soil moisture is high. 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 percent at most. Studies suggest that 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. Even then, it has been estimated that complete deforestation and replacement with non-forest vegetation would reduce basin rainfall by less than 20 percent (FAO, 2003).

Any observations of enhanced rainfall in forested areas were attributed either to orographic effects (forests being found in uplands where chances of cloud formation were simply greater because of atmospheric cooling of rising air) or to differences in rain gauge exposure to wind and rain (sheltered in forest clearings versus exposed in cleared terrain)(Bruijnzeel, 2004).

Hence, the idea that forests importantly affect precipitation is rejected by most meteorologists, except where fog drip and rime occur frequently. Fog drip is water from the atmosphere (fog) that is collected /deposited on vegetation surfaces and subsequently falls to the ground once vegetation storage capacities are exceeded. Rime is the formation of ice on vegetation surfaces through the process of water droplets freezing onto cold surfaces (Pike, 2003).

The overwhelming hydrological evidence supports that forests are not generators of rainfall. Yet this "myth", like many others in forest hydrology may contain a small amount of truth that prevents it from being totally rejected. There is some evidence for land-use controls on precipitation but often the magnitude of these effects are considerably less than is commonly imagined. There is some evidence that, on a continental scale, forests may form part of a hydrological feedback loop with evaporation contributing to further rainfall. Thus, though the effects of forests on rainfall are likely to be relatively small they cannot be totally dismissed from a water resources perspective (Calder, 2000).

There is evidence that large-scale (> 1,000 – 10,000 km2) removal or addition of old-growth forest in humid parts of the world affects rainfall during the transition between rainy and dry season. Effects on annual rainfall are modest (5-10%) but do manifest themselves mostly during this critical time of year (Anonymous, 2008). Similarly, studies revealed reduced cloud formation over the deforested parts of Costa Rica during the dry season. An interesting recent finding which may offer a potential alternative explanation for reduced cloud formation above deforested areas is that biogenic aerosols (particles that are produced by the disintegration and dispersion of plant and animal material from a variety of surfaces into the atmosphere) produced by large areas of forest appear to play an important role as cloud condensation nuclei (that act as the initial sites for condensation of water vapor into cloud droplets or cloud ice particles) during convection. However, not all types of large-scale rain forest conversion to agricultural cropping would seem to have such a negative climatic impact (Bruijnzeel, 2004).

3.1 Cloud forests and precipitation

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. Cloud forests occur along coastal areas in temperate climates and also in tropical montane regions where fog or low cloud conditions are common. Forests intercept atmospheric moisture, which condenses on and drips from foliage, adding moisture to the soil. Rainfall is not increased, but forests add moisture that low-growing vegetation would not (FAO, 2003). Thus**,** there are specific locations, such as coastal and montane fog or cloud belts, where the presence of tall vegetation may increase the amount of water reaching the forest floor as canopy drip. This is affected via the process of fog or cloud interception, i.e. the capturing of atmospheric moisture by the canopy of these 'cloud forests' where subjected to more or less persistent wind-driven fog or clouds. Contributions by cloud water interception generally lie within the range of 5–20% of ordinary rainfall at wet tropical locations but can be much higher (>1000mm per year) at certain particularly exposed locations although it is not always certain to what extent such high values include wind-driven rain (Bruijnzeel, 2004).

4. Forests and flood mitigation

Due to their high infiltration capacity, forests reduce runoff rates and therefore minimize, to some extent, floods (Achouri 2002 and Calder, 2000). Certain types of plantation forests may also serve to increase infiltration rates through providing preferential flow pathways down both live and dead root channels (Calder, 2000). Porous soils of the forest floor readily allow water to infiltrate, increasing groundwater recharge and reducing the potential for flash floods (Ervin *et al., 2008).*

Forests produce low levels of runoff and greater soil stability than any other vegetation type because of their 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 is problematic in such areas because they increase the frequency and magnitude of landslides and debris flows (FAO, 2003). Hence, it is well known that partial or complete removal of tree cover may accelerate water discharge and increase flood risk during the rainy season (Calder *et al.,* 2007 and Andreassian, 2004). However, for the largest, most damaging flood events there is little scientific evidence to support anecdotal reports of deforestation as being the cause (Calder, 2000).

For instance, disastrous floods in Bangladesh and northern India are almost always associated with "deforestation of the Himalayas"; similarly in Europe floods are often attributed by the media to "deforestation in the Alps". However, hydrological studies carried out in many parts of the world do not support this view (Calder, 2000). Hence, strong scientific evidence refutes the myth that deforestation in the Himalayas causes big floods in the lowlands; the large-scale floods result rather from a combination of simultaneous discharge peaks of the large rivers, high runoff from hills adjacent to the floodplains, heavy rainfall, high groundwater tables and spring tides, lateral river embankments and the disappearance of storage areas (Calder *et al.,* 2007).

Impacts of forest cover removal are evident only at the micro level (100 to1000 Ha) and in association with short duration and low-intensity rainfall events (which are usually the most frequent). As rainfall duration or intensity increases, or as distance of the rainfall area from the watershed increases, the influence of tree cover on flow regulation decreases (Calder *et al.,* 2007 and Bruijnzeel, 2004). Similarly, Achouri (2002) and FAO (2003) contend, as the amount of rainfall becomes extreme, the extent to which forests can help to prevent landslides, debris flows and flooding diminishes.

5. Forests and water quality

The provision of clean water is arguably the most visible and essential ecosystem service that forests supply (Krezek *et al.,* 2008, Calder *et al.,* 2007 and Sedell *et al.,* 2000). Research shows that the quality of water in undisturbed forests and grasslands is usually good. In managed ecosystems, water quality depends on the particular land-use practices being implemented. Some land-use practices can protect or restore water quality, but others may degrade or pose risks to clean water (Sedell *et al.,* 2000). Forest-management decisions can potentially affect water quality by altering temperature and nutrient regimes, and by putting sediments and nutrients into aquatic ecosystems (Scherer and Pike, 2003).

A forested corridor along streams, rivers and lakes helps to prevent water pollution. Forests protect water quality by stabilizing banks, shading the water, taking up nutrients and filtering pollutants. The extensive network of tree roots holds the soils of the bank in place, reducing erosion and keeping the stream banks and shoreline stable. The shade helps reduce water temperatures and maintain high oxygen levels that benefit many kinds of aquatic wildlife. 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. Many nutrients, sediment, and pollutants contained in storm runoff are filtered out before they reach the water and are held in humus layer on the forest floor. The nutrients are used for tree growth while pollutants are broken down into harmless compounds (Ervin *et al.,* 2008; Calder *et al.,* 2007 and FAO, 2003). Well-managed forested catchments can result in minimal requirements for water treatment (FAO, 2003).

Forests are also the preferred land use for water supply catchments because of their perceived "sterile" qualities associated with an absence of livestock and an absence of human activities. The generally reduced fertilizer and pesticide applications to managed forests and forest plantations compared with agricultural lands has been regarded as a benefit with regard to water quality (Calder, 2000 and Calder *et al.,* 2007)

5.1 Forests and sediment yield

Forests make excellent watersheds chiefly because their soils usually have a high infiltration capacity. Therefore, rainstorms or melting snow in forests produce relatively little surface runoff with the associated problems of erosion (detachment and movement of soil) and sedimentation (the deposition of soil). Generally, the water flowing through streams in stable forests has very low turbidity (Muth, 2008).

Healthy riparian forests can also reduce sediment levels by filtering out soil erosion inputs and by maintaining stable stream banks. Degradation of both upland and riparian forests can therefore combine to increase sediment delivery to reservoirs (FAO, 2003). The sediment can affect storage capacity of reservoirs, water quality, irrigation systems and hydroelectric dams (Achouri, 2002). Sediment can also have a high nutrient, metal or pesticide content, which can contribute to the enrichment and contamination of downstream waters, particularly reservoirs and lakes where the sediment may remain for a considerable period of time. High turbidity levels due to inputs of fine sediments such as clay, silt and fine sand can have an adverse impact on the aquatic flora and fauna. Light penetration is reduced, affecting overall productivity, fish feeding and migration. Suspended sediment can also affect fish respiration. Large inputs of coarse sediment can have a serious impact, leading to the destabilization of stream beds and channels, the shallowing of watercourses, blockage of pipelines and water intakes to treatment works, and a long-term reduction in reservoir storage capacity (Forestry commission, 2003). Well managed forested watersheds play an important role in reducing sediment and in discharging high quality of water and consequently in reducing the costs related to water treatment at downstreams (Achouri, 2002).

Forest cover provides the most effective barrier to splash-induced soil erosion, largely because of the contribution of the lower canopy leaves and the ground litter in reducing the force of splashing. Forest removal and replacement with other land use systems leads in most cases to higher and accelerated erosion. Erosion is generally associated with a higher sediment concentration in runoff and with siltation of water courses. The surface cover, debris and tree roots trap sediments and stop their down slope movement. Moreover, deep tree roots stabilize slopes and help prevent shallow landslides. Planting forest on erosion-prone soils and runoff pathways can reduce and intercept sediment (Calder *et al.,* 2007 and Bruijnzeel, 2004).

Soil erosion after forest conversion to annual cropping without proper soil conservation measures typically increases hill slope soil erosion by 10-20 times due to direct exposure of the soil to rainfall, gradual decreases in soil organic matter content and associated deterioration of soil infiltration capacity and aggregate stability. Stream sedimentation after forest conversion to cropping typically increases by a factor of 2-10. Planting trees or restoring natural vegetation on eroding land usually fixes surface erosion and stream sedimentation within a decade primarily through the establishment of a permanent litter layer and enhanced infiltration, unless deep natural land sliding is the chief source of the stream sediment (Anonymous, 2008).

Soil organic matter, particularly the litter layer, is an important regulator of erodability in forest soils. Accumulated litter protects soil from the erosive energy of raindrops, promotes soil particle aggregation and accelerates rain water percolation. Disturbances that remove the litter layer or compact forest soils promote overland flow and erosion of mineral soil (sediment) into stream channels. Sediment yields decrease as vegetation regrows (Webster *et al.,* 1992).

The effects of catchment deforestation on erosion, and the benefits gained by afforesting degraded and eroded catchments will be very dependent on the situation and the management methods employed. In situations of high natural sediment yield as a result of steep terrain, high rainfall rates and geological factors, little, if any influence will be exerted by man. Also, in situations where overland flow is negligible as in drier land, little advantage will be gained from afforestation. On the other hand, in more intermediate conditions of relatively low natural rates of erosion and under more stable geological conditions, man-induced effects may be considerable. In these situations catchment degradation may well be hastened by deforestation so that, conversely, there may be opportunities for reversing degradation by well-managed afforestation programs. The choice of tree species will also be important in any program designed to reduce erosion and catchment degradation. The use of large leaved tree species (which generate large drop sizes) in erosion control programmes would be ill advised, especially if there is any possibility of understorey removal taking place (Calder, 2002).

5.2 Role of forests in maintaining stream biochemistry and pollutant mitigation

In addition to sediment, various types of pollution can impair water quality. Potential pollutants include excessive concentrations of organic matter (leading to water eutrophication) and agricultural or industrial chemicals. Forest is certainly an appropriate ground cover for drinking water–supply watersheds, because forestry activities (with the exception of intensively managed plantations) generally use no fertilizers or pesticides and avoid pollution from domestic sewage or industrial processes. In addition, non-point source pollution (i.e. pollution from many diffuse sources) from domestic, industrial and agricultural use can be greatly reduced or even eliminated by maintaining adequate riparian forest buffer zones along watercourses (Calder *et al.,* 2007).

Not only do forest buffers prevent nonpoint source pollutants from entering small streams, they also enhance the in-stream processing of pollutants, thereby reducing their impact on downstream rivers and estuaries

(Sweeney *et al.,* 2004). Forest vegetation regulates nutrient inputs to streams by two primary mechanisms: through uptake of nutrients from soil solution and storage in biomass, and by decreasing water movement through soils. Following disturbance, vegetative nutrient uptake is reduced and soil conditions accelerate mineralization of organic matter. As vegetation becomes re-established and nutrients begin to accumulate in biomass, nutrient concentrations in soil solution and stream water decrease (Webster *et al.,* 1992). A study by Williams et al. (1997) cited in Biggs *et al.* (2008) revealed an increased fluxes of total dissolved nitrogen (TDN), total dissolved phosphorus (TDP) and small increases in fluxes of Cl after 80% of the watershed was slashed and burned.

Deforestation can be accompanied by a significant increase in river chemical pollution (Benavides and Veenstra, 2005). Deforestation causes changes in stream biogeochemistry that can be either transient or chronic depending on the rate of clearing, the final extent of deforestation and the subsequent land use. Rapid clearing and burning of forest vegetation produces a pulse of cations and nutrients in soil pore waters and in stream waters. These pulses may persist for several years. After clearing, more permanent changes in vegetation and land use can also cause chronic changes in the concentrations of nutrients in receiving streams, including increased nitrogen and/or phosphorus concentrations. The changes in the nutrient and light regime can lead to changes in algal production, dissolved oxygen, and ecosystem productivity. Further changes in land use including cattle establishment, agricultural intensification, fertilizer use, and urbanization also impact nutrient concentrations and biogeochemical functioning in streams (Biggs *et al.,* 2008).

5.3 Stream temperature regulation

Headwater streams draining forested areas are typically heavily shaded. Removing overhanging vegetation increases isolation, resulting in increased average stream temperatures (Webster *et al., 1992* and Moore *et al.,* 2005). Forest harvesting, particularly removal of riparian vegetation, may result in stream heating or other changes in water temperature that could have deleterious effects on aquatic organisms. Riparian buffers can help minimize these changes.

Reductions in solar radiation under forest cover range from more than 90 percent with dense canopies to less than 75 percent in open stands (Moore *et al.,* 2005).

6. Roles of forests in carbon sequestration

Forests play a significant role in the global carbon cycle, absorbing approximately one third of recent anthropogenic emissions of carbon dioxide (CO2) to the atmosphere. Forests capture carbon (C) from the atmosphere through photosynthesis, converting that photosynthate to forest biomass, and emitting C back into the atmosphere during plant respiration and decomposition. Thus, controlling land use change practices involving forests might prevent to some degree the increase in atmospheric greenhouse gases i.e. forest management activities might effectively reduce the rate of CO2 accumulation in the atmosphere (Percy *et al.,* 2003 and Mackey *et al.,* 2008). Forests, therefore, must be part of a comprehensive response to the climate change problem (Mackey *et al.,* 2008). The following figure illustrates processes through which trees and soils can gain and lose carbon:

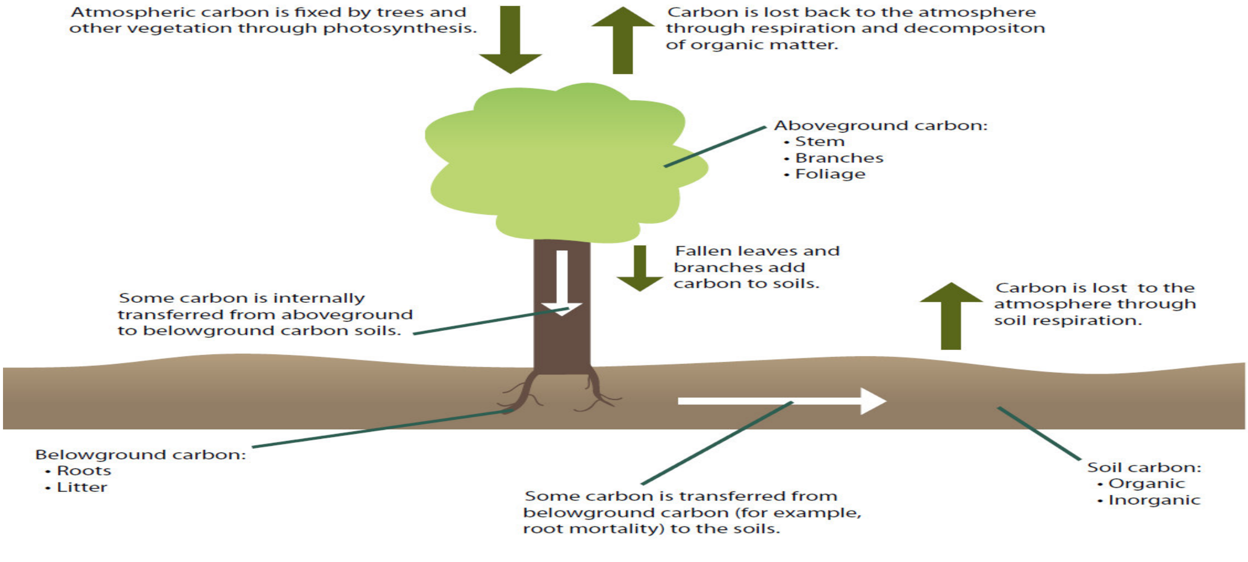


Figure 1 Processes through which trees and soils can gain and lose carbon (Schahczenski and Hill, 2009).

Globally, the exchanges of C between forests and the atmosphere are influenced by human-caused and natural disturbances. Deforestation (primarily in the tropics) has been a source of carbon emitted to the atmosphere contributing about one fifth of the annual anthropogenic emissions (Percy *et al.,* 2003). The loss of natural forests around the world contributes more to global emissions each year than does the transport sector. In fact, estimates suggest that the relative contribution of greenhouse gas emissions from deforestation (the conversion of forest land to non-forest land) and forest degradation (the decrease of carbon stocks per unit area not resulting from the reduction or disappearance of forest cover) range between 10–25% of global emissions (Fry*, 2008).*

Tropical deforestation released ~1.5 billion metric tons of carbon (GtC) to the atmosphere annually throughout the 1990s, accounting for almost 20% of anthropogenic greenhouse gas emissions. Without implementation of effective policies and measures to slow deforestation, clearing of tropical forests will likely release an additional 87 to 130 GtC by 2100, corresponding to the carbon release of more than a decade of global fossil fuel combustion at current rates. Drought-induced tree mortality, logging and fire may double these emissions and loss of carbon uptake (i.e., sink capacity) as forest area decreases may further amplify atmospheric CO2 levels (Gullison *et al., 2007).*

The Intergovernmental Panel on Climate Change (IPCC) estimates that at least one-third of the world's remaining forests may be adversely affected by changing climate, especially in the boreal zone where the warming will be greatest. The Hadley Centre for Climate Change at the UK Meteorological Office has predicted that, by 2050, forests globally will become a significant net source of CO_2 emissions. This will lead to even greater emissions of carbon dioxide, contributing to a climate change cycle already well-underway (WWF, 2002).

Moreover, climate change might also adversely impact tropical forests by reducing precipitation and evapotranspiration, making them drier, more susceptible to fires, and more prone to replacement by shrub lands, grasslands, or savanna ecosystems, which store much less carbon (Gullison *et al.,* 2007). Similarly, Percy *et al.(*2003) contends, changes that make the climate more arid are reducing growth, or rendering land unsuitable for forests in some regions of the globe. Severity and extent of moisture stress will increase as climate change continues. Recent evidence suggests that increased atmospheric CO_2 concentrations may make trees more susceptible to defoliating insects. These indirect effects of changing climate will reduce productivity, and consequently C sequestration (Percy *et al.,* 2003).

Recognition of the gravity of deforestation and forest degradation problems has led to significant and sustained attention on the part of intergovernmental institutions, public-private partnerships and private market-based efforts to reverse such trends (Levin *et al.,* 2008). Aggressive action to reduce (and ultimately halt) emissions from deforestation and forest degradation (REDD) must be part of any serious policy to address the climate crisis, while at the same time respecting other forest values. Without REDD, keeping global average surface temperature increase below 2°C will likely be impossible. Exceeding 2°C of warming creates a much larger risk of triggering critical climate tipping points leading to large-scale species extinctions, catastrophic reductions in water supply, or increasingly rapid disintegration of ice sheets with resulting devastating increases in sea level (WWF, 2009).

Forest carbon sequestration (sinks) is (are) characterized as an increase in carbon stocks on the land base through such activities as afforestation, reforestation, agroforestry and forest restoration (WWF, 2002). The proposals on reducing emissions from deforestation and degradation in developing countries (REDD) being discussed under the UN Framework Convention on Climate Change (UNFCCC) would have significant implications for biodiversity conservation and associated livelihoods. In the following section- the general of principle of REDD and its potential the climate dilemma are briefly described.

7. REDD+ as a policy instrument to combat climate change

Reducing greenhouse gas emissions from deforestation and forest degradation (REDD) is likely to be central to a post-Kyoto climate change mitigation agreement. In the last decade, climate change mitigation has received much international recognition, most notably with the implementation of the Kyoto Protocol under the United Nations Framework Convention on Climate Change (UNFCCC). Deforestation, occurring primarily in tropical forests, is a prevalent and, until recently, overlooked source of greenhouse gas (GHG) emissions, accounting for up to one-third of global emissions(Oestreicher *et al.,* 2009).

At the United Nations Framework Convention on Climate Change (UNFCCC) Conference of Parties (COP)'s thirteenth session in Bali, parties adopted a decision on reducing emissions from deforestation in developing countries (REDD) (Fry, 2008 and Miles and Kapos, 2008). The basic idea behind Reducing Emissions from Deforestation and Degradation (REDD) is simple: developing countries that are willing and able to reduce emissions from deforestation should be financially compensated for doing so in the post-2012 period (Parker *et al.,* 2008 and Campbell *et al.,* 2008). Previous approaches to curb global deforestation have so far been unsuccessful, however, and REDD provides a new framework to allow deforesting countries to break this historic trend**.** REDD is primarily about emissions reductions. It is based on persuasion that comprehensive approach to mitigate climate change should include: *"Policy approaches and positive incentives on issues* *relating to reducing emissions from deforestation and forest degradation in developing countries".* REDD could simultaneously address climate change and rural poverty, while conserving biodiversity and sustaining vital ecosystem services (Parker *et al.,* 2008). While international attention is now focused on REDD in developing countries, the laws of nature that account for the global carbon cycle operate irrespective of political boundaries. Therefore, a unit of carbon emitted due to deforestation and forest degradation in Australia, the United States, Canada or Russia has exactly the same impact on atmospheric greenhouse gas levels as a unit of carbon emitted from deforestation and degradation of forests in Indonesia, Papua New Guinea, the Congo Basin or Brazil. From a scientific perspective, solving the climate change problem requires, among others things, that REDD be accounted for in all forest biomes, irrespective of the host nation's economic status (Miles and Kapos, 2008).

Providing economic incentives for the maintenance of forest cover can help tropical countries avoid these negative impacts and meet development goals. Industrialized and developing countries urgently need to support the RED policy process and develop effective and equitable compensation schemes to help tropical countries protect their forests, reducing the risk of dangerous climate change (Gullison *et al.,* 2007)

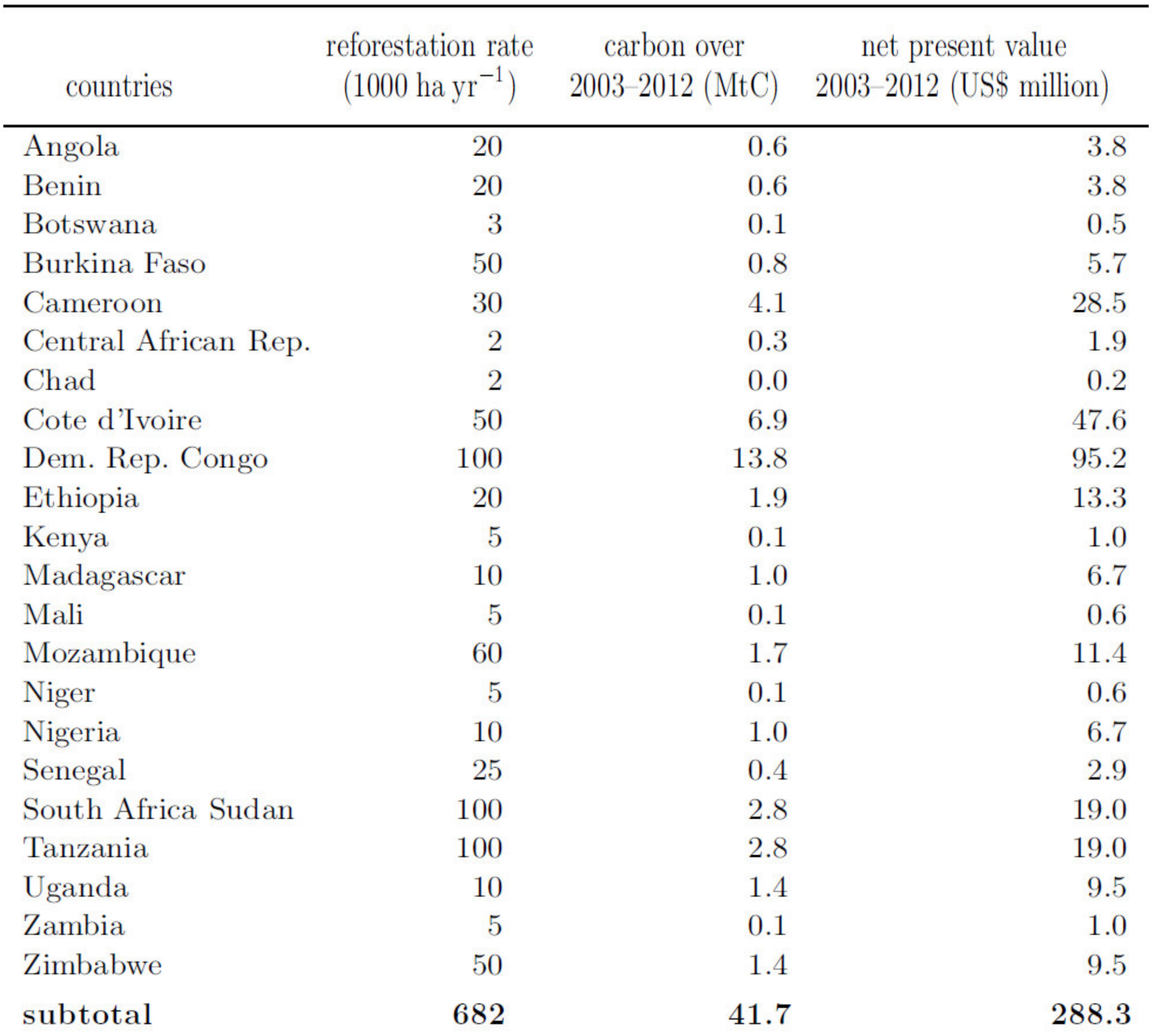
The significance of REDD for mitigating climate change problem can be appreciated when we consider that about 35 percent of greenhouse gases stored in the atmosphere is due to past deforestation, and about 18 per cent of annual global emissions is the result of continuing deforestation. Furthermore, even when forest is not cleared to make way for other land uses, there are significant and continuing emissions of carbon dioxide from commercial logging and other land-use activities that reduce the stock of carbon stored in the ecosystem (Mackey *et al.,* 2008). Emissions reductions from reduced deforestation may be among the least-expensive mitigation options available. Reducing deforestation not only avoids the release of the carbon stored in the conserved forests, but by reducing atmospheric carbon, it also helps to reduce the impacts of climate change on remaining forests. Beyond protecting the climate, reducing tropical deforestation has the potential to eliminate many negative impacts that may compromise the ability of tropical countries to develop sustainably, including loss of biodiversity, degraded human health from biomass burning pollution, and the unintentional loss of productive forests (Gullison *et al.,* 2007).

Policy innovations that emerge under REDD must be assessed by whether, and how, they will simultaneously address the dual problems of global forest loss and degradation especially as related to equity and co-benefits, such as impacts on inter-generational distribution, biodiversity, economic development, local and indigenous communities, and forest governance and global greenhouse gas emissions reductions (Levin *et al.,* 2008).

Many environmentalists have welcomed REDD initiative because it may direct substantial new resources to reduce emissions from deforestation and forest degradation. However, there some controversy over how REDD should be funded. Some of the national parties to the UNFCCC wish to see the issue tackled through a traditional grant funding mechanism. Others, led by the Coalition of Rainforest Nations, seek an eventual market-based mechanism, on the basis that carbon is one of the more easily marketable ecosystem services. This may generate more funds over a longer time scale. A trading mechanism would allow developing countries to sell carbon credits on the basis of successful reductions in emissions from deforestation and forest degradation**.** Such mechanism would generate significant funding to reduce deforestation rates in developing countries. One estimate, based on a relatively low carbon price of U.S. $10 per ton and an estimate of individual countries' ability to slow deforestation, suggests a potential market of U.S. $1.2 billion a year; a more recent estimate suggests that U.S. $10 billion may be a realistic figure. These are large sums in comparison with current investment in forest protection. For example, World Bank funding directed to forest biodiversity conservation and related activities in 2002 totaled U.S. $257 million (Miles and Kapos, 2008).

Hence, if REDD credits were traded on international carbon markets, even moderate decreases in deforestation rates could generate billions of dollars annually for tropical forest conservation. In addition to climate mitigation, REDD funds could help achieve substantial co-benefits for biodiversity conservation and human development (Ebeling and Yasue, 2008). The following tables illustrate Potential carbon mitigation and income in African countries from changes in use and management of forest lands.

Table-1 Annual carbon mitigation and associated incomes via forest restoration for the years 2003-2012 (Niles *et al.,* 2002)



countries	reforestation rate (1000 ha yr^{-1})	carbon over 2003–2012 (MtC)	net present value 2003–2012 (US$ million)
Angola	20	0.6	3.8
Benin	20	0.6	3.8
Botswana	3	0.1	0.5
Burkina Faso	50	0.8	5.7
Cameroon	30	4.1	28.5
Central African Rep.	2	0.3	1.9
Chad	2	0.0	0.2
Cote d'Ivoire	50	6.9	47.6
Dem. Rep. Congo	100	13.8	95.2
Ethiopia	20	1.9	13.3
Kenya	5	0.1	1.0
Madagascar	10	1.0	6.7
Mali	5	0.1	0.6
Mozambique	60	1.7	11.4
Niger	5	0.1	0.6
Nigeria	10	1.0	6.7
Senegal	25	0.4	2.9
South Africa Sudan	100	2.8	19.0
Tanzania	100	2.8	19.0
Uganda	10	1.4	9.5
Zambia	5	0.1	1.0
Zimbabwe	50	1.4	9.5
subtotal	**682**	**41.7**	**288.3**

Table-2 Annual carbon mitigation and associated incomes via avoided deforestation for the years 2003-2012 (Niles *et al.,* 2002)

countries	annual deforestation (1000 ha yr^{-1})	deforestation halted (1000 ha yr^{-1})	carbon over 2003–2012 (MtC)	net present value 2003–2012 (US$ million)
Angola	237	11.9	4.3	33.0
Benin	60	15.0	4.4	33.2
Botswana	71	7.1	0.5	3.5
Burkina Faso	32	3.2	0.5	4.1
Cameroon	129	12.9	14.0	106.7
Central African Rep.	128	12.8	12.8	97.5
Chad	94	9.4	2.0	15.4
Cote d'Ivoire	31	6.2	5.1	39.0
Dem. Rep. Congo	740	37.0	63.6	485.0
Ethiopia	62	3.1	0.8	6.1
Kenya	3	0.2	0.0	0.2
Madagascar	130	13.0	12.7	97.1
Mali	114	5.7	1.3	9.8
Mozambique	116	5.8	1.7	12.6
Niger	0	0.0	0.0	0.0
Nigeria	121	12.1	3.0	22.6
Senegal	50	10.0	1.6	12.2
South Africa	15	0.8	0.1	0.9
Sudan	353	35.3	11.3	86.1
Tanzania	323	64.6	14.5	110.8
Uganda	59	8.9	4.5	34.4
Zambia	264	26.4	6.2	47.3
Zimbabwe	50	6.0	0.4	2.7
subtotal	**3299**	**312.1**	**167.8**	**1278.5**

Whether a successful REDD policy process can make an important contribution to global efforts to avoid dangerous climate change depends on two issues. First, are the potential carbon savings from slowing tropical deforestation sufficient to contribute substantially to overall emissions reductions? Second, is it likely that tropical forests (and the forest carbon) protected from deforestation will persist over coming decades and centuries in the face of some unavoidable climate change? The available evidence indicates that the answer to both questions is yes, especially in a future with aggressive efforts to limit atmospheric CO2 (Gullison *et al.,* 2007).

One obvious risk associated with REDD is the displacement of pressures, resulting from continuing demand for food, timber and biofuels, to ecosystems perceived to contain low carbon levels. The least-productive forest ecosystems may become the most threatened simply because they are the only remaining accessible source of land and forest products. Other areas experiencing increased pressure could include non-forest ecosystems such as savannas or wetlands and forests in tropical countries not participating in REDD. The demand for timber from temperate and boreal forests may also increase (Miles and Kapos, 2008). Governance may become a formidable challenge for REDD because some countries with the highest REDD potentials score poorly on governance indices (Ebeling and Yasue, 2008).

Much debate about REDD has so far focused on international aspects and rightly so, given the need to negotiate an effective and equitable post-2012 agreement. But whether REDD will ultimately benefit or marginalize forest communities depends on local to national arrangements about the allocation of benefits within countries. While hopes for some are running high about the opportunities that REDD may offer to forest communities, there are also risks that REDD schemes may result in governments, companies, conservation NGOs or speculators carving up forestlands, and pursuing forest protection approaches that marginalize rather than empower forest people (Cotula and Mayers, 2009).

In wrapping up, how successfully a REDD mechanism can contribute to climate change mitigation, conservation and development will strongly depend on accompanying measures and carefully designed incentive structures involving governments, business as well as the conservation and development communities (Ebeling and Yasue, 2008). Before engaging in an international REDD agreement, tropical forest nations will need to evaluate their ability to curb deforestation, pinpoint factors that will guarantee permanence the sustained and effective protection of forest carbon–and develop strategies to circumvent leakage-the displacement of deforestation to relatively unprotected areas (Oestreicher *et al.,* 2009).

Many countries with rainforests appear ill-equipped in practice to ensure that REDD schemes have good prospects of benefiting local people. Tackling some of the powerful players behind deforesting activities, like destructive logging, pressures for infrastructure development and conversion of forests to agribusiness, will require concerted action on an unprecedented scale in many countries (Cotula and Mayers, 2009).

RECOMMENDATION

- Sustainable uses of the resource especial a jungle forest instead of cleared out are an alternate ways of saving and surviving life for next (future) generation otherwise, the nature at threaten.
- Due to it series and crucial importance the government, privet sectors (NGO) and other deli gated bodies and stalk holders should be actively involved in PFMs.
- Strengthening local resource rights, including customary rights. Where local resource rights, including customary rights, are a main resource access mechanism, there is often an urgent need to lift restrictions on commercial use by local people and to address productive land use requirements where these undermine tenure security. Within the context of REDD, forest conservation and restoration may constitute viable economic activities, and at a minimum these forms of productive use should be recognized
- Ensuring carbon rights are effectively established in national regulations. Initial evidence suggests that dangers lurk for local tenure security where carbon rights are separated from land tenure. Rather than allowing unclear situations to be potentially exploited at the expense of local benefit as REDD develops, it is likely to be increasingly important for carbon rights to be defined in national regulations
- Building on practical mechanisms for cross-sectoral engagement. Focusing on issues and forums that ensure forestry protagonists engage with agriculture, infrastructure, trade, employment creation and other sectors is critical – to promote better harmonization of sectoral legislation, increase control of forest resources for local landholders, and address 'circularity' issues where a certain type of land rights is required to acquire forest rights and vice versa
- Developing effective arrangements to channel benefits to the local level. While being alert to the prospects of local elite capture, and the needs for transparency and downward accountability, such arrangements for channeling local benefits are critical. These may include drives for effective decentralization, mechanisms for distributing public revenues, support to community forest enterprises, and partnerships between forest people, government, conservation NGOs and/or the private sector
- Connecting national policy to key international thinking and requirements. National and local policy processes could often benefit from much stronger connection to international developments such as those on the rights of indigenous peoples. Conversely, local priorities need to be better fed into ongoing negotiations for an international agreement on REDD (e.g. what safeguards for local resource rights are vital and what complaint mechanisms are effective)
- REDD simply will not work unless it is locally credible; it will be undermined and overthrown. Effective local institutional capability, and the knowledge and preparedness to put good forestry

into practice, will be essential. For this to be achievable, effective and equitable local property rights are needed. In short, consideration of tenure will need to be the start point not an afterthought.

ACKNOWLEDGMENT

First and foremost, I would like to express deepest appreciation to my advisor Abayneh Unasho (Ass. Prof) for his intellectual and professional guidance and commitment, follow ups and tireless efforts in giving advice throughout the period of this study. Additional I would like to express my sincere gratitude to Belachew Beyene for more information and guide to write the science manuscript and intimate the wave address.

References

Achouri, M.(2002). Forests and Water: Towards Effective Watershed Management. International Expert Meeting on forests and water 20-22 November 2002, Shiga, Japan.

Andreassian, V. (2004) . Review ,Waters and forests: from historical controversy to scientific debate. *Journal of Hydrology* 291 pp. 1–27

Anonymous(2008). Deforestation & the multiple functions of tropical watersheds. *Special series on tropical forests and water.*© ASB

Benavides, F. *and* Veenstra, J.N. (2005). The impact of tropical deforestation on river chemical pollution. Global nest Journal, Vol. 7, No 2, pp 180-187

Biggs, T.W., Dunne, T., Roberts, D.A. and Matricardi, E. (2008).The rate and extent of deforestation in watersheds of the southwestern amazon basin. *Ecological Applications* 18(1) pp. 31–48

Bruijnzeel, L.A. (2004). Hydrological functions of tropical forests: not seeing the soil for the trees?*Agriculture, Ecosystems and Environment* 104 : 185–228

Calder, I. R. (2002). Forests and Hydrological Services: Reconciling public and science perceptions. *Centre for Land Use and Water Resources Research, University of Newcastle upon Tyne, UK.* Land Use and Water *Resources Research* 2 (2002) 2.1–2.12

Calder, I., Hofer, T., Vermont, S. and Warren, P.(2007). Towards a new understanding of forests and water. An overview of the state of knowledge about forest and water interactions and salient issues in forest and water policy. *Unasylva* 229, Vol. 58

Calder, I.R. (2000). Land Use impacts on Water Resources. Paper to be presented at the FAO electronic workshop on Land-Water Linkages in Rural Watersheds and to be submitted to E-Journal: Land Use and Water Resources Research. Centre for Land Use and Water Resources Research University of Newcastle upon Tyne, UK

Changqing Zuo, S.G., Liu, S., Liu,M., McNulty, S.G. and Vose, J.M.(2008). Watershed Evapotranspiration Increased Due to Changes in Vegetation Composition and Structure Under a Subtropical Climate. *Journal of the American Water Resources Association* (JAWRA) 44(5):1164-1175

Coad, L., Campbell, A., Clark, S., Bolt, K., Roe, D., Miles, L. (2008). *Protecting the future: Carbon, forests, protected areas and local livelihoods*. UNEP World Conservation Monitoring Centre, Cambridge, U.K.

Cotula, L. and Mayers, J. (2009). *Tenure in REDD – Start-point or afterthought?* Natural Resource Issues No. 15. International Institute for Environment and Development. London, UK.

D'Almeida, C., Hurtt,G.C., Marengo, J.A., Dingman, S.L. and Keime, B.D. (2007). Review The effects of deforestation on the hydrological cycle in Amazonia: a review on scale and resolution. *Int. J. Climatol.* 27: 633–647

Ebeling, J. and Yasue, M. (2008). Generating carbon finance through avoided deforestation and its potential to create climatic, conservation and human development benefits. *Phil. Trans. R. Soc. B.* 363: 1917–1924

Ervin, M., Smith, K. L. and Zucker, L.(2008). Managing Streamside Forests for Profit and Clean Water. The Ohio State University

FAO (2003). Sustainable use and management of freshwater resources: the role of forests

Farley, K.A, Jobba, E.G. and Jackson, R.B. (2005). Effects of afforestation on water yield: a global synthesis with implications for policy. *Global Change Biology*.11: 1565–1576

Forestry commission (2003). Forests &water guidelines.Fourth edition. Edinburgh. i–vi + 1–66p

Fry, I. (*2008).* Reducing Emissions from Deforestation and Forest Degradation: Opportunities and Pitfalls in Developing a New Legal Regime. *Reciel 17 (2)*

Gullison, R.E., Frumhoff, P.C., Canadell, J.G., Field, C.B., Nepstad, D.C., Hayhoe, K., Avissar, R., Curran, L.M., Friedlingstein, P., Jones, C.D. and Nobre, C. (2007). Tropical Forests and Climate Policy. *Science* vol 316

Jackson, R.B., Jobba, E.G., Avissar, R., Roy, S.B., Barrett, D.J., Cook, C.W., Farley, K.A., Maitre, D.C., McCarl, B.A. and Murray, B.C. (2005). Trading Water for Carbon with Biological Carbon Sequestration. *Science* vol 310

Krezek, C.C., Buttle, J.M. Beall, F.D., Moore, R.D. Creed, I.F. , Sibley, P.K. Silins, U., Devito, K.J. and

Mendoza, C.A. (*2008).* HydroEcological Land scapes and Pro cesses Pro ject: A National-scale Forest Hydrology Initiative. *Streamline Watershed Management Bulletin Vol. 12/No. 1*

Levin, K., Mcdermott, C. and Cashore, B. (*2008).* The climate regime as global forest governance: can reduced emissions from Deforestation and Forest Degradation (REDD) initiatives pass a 'dual effectiveness' test? *International Forestry Review Vol.10(3)*

Mackey, B.G., Keith, H., Berry, S.L. and David B. Lindenmayer, D.B. (2008). Green Carbon: The role of natural forests in carbon storage. The Fenner School of Environment & Society, The Australian National University

Miles, L. and Kapos, V. (2008). Reducing Greenhouse Gas Emissions from Deforestation and Forest Degradation: Global Land-Use Implications. *Science* 320: 1454

Moore, R. D., Spittlehouse, D. L. and Story, A. (2005). Riparian Microclimate and Stream Temperature Response to Forest Harvesting: A Review. *Journal of the American Water Resources Association* (JAWRA) 41(4):813-834.

Muth, A. (2008). Watershed Management. *Forest Stewardship.* The Pennsylvania State University

NAS (National Academy of Sciences)(2008). Hydrologic Effects of a Changing Forest Landscape. Report in brief

Niles, J.O., Brown, S., Pretty, J., Ball, A.S. and Fay, J. (2002).Potential carbon mitigation and income in developing countries from changes in use and management of agricultural and forest lands. *Phil. Trans. R. Soc. Lond*. A 360, 1621-1639

Nik, A.R.(*1988).* Water yield changes after forest conversion to agricultural landuse in peninsular malaysia. *Journal of Tropical Forest Science* 1(1) : 67- 84.

Oestreicher, J.S., Benessaiah, K., Ruiz-Jaen, M.C., Sloan, S.,Turner, K., Pelletier, J., Guay, B., Clark, K.E., Roche, D.G., Meiners, M. and Potvin, C. (2009). Avoiding deforestation in Panamanian protected areas: An analysis of protection effectiveness and implications for reducing emissions from deforestation and forest degradation. *Global Environmental Change* (19) 279–291

Parker, C., Mitchell, A., Trivedi, M. and Mardas, N. (2008).The Little REDD Book: A guide to governmental and non-governmental proposals for reducing emissions from deforestation and degradation. Global Canopy Foundation

Percy, K.E., Jandl, R., Hall, J.P. and Lavigne, M. (2003). The Role of Forests in Carbon Cycles, Sequestration, and Storage. *Newsletter* No.1

Pike, R.(*2003).* Forest Hydrologic.Cycle Basics. *Streamline Watershed Management Bulletin Vol. 7/No.1*

Schahczenski, J. and Hill, H. (2009). Agriculture, Climate Change and Carbon Sequestration. A Publication of ATTRA—National Sustainable Agriculture Information Service

Scherer, R. and Pike, R. (2003). Effects of forest management activities on streamflow in the Okanagan Basin, British Columbia: Outcomes of a literature review and a workshop. FORREX, Kamloops, B.C. FORREX Series 9.

Sedell, J., Sharpe, M., Apple,D.D., Copenhagen, M. and Furniss, M. (2000). *Water &* the forest service. United states department of agriculture. Forest service washington office. FS-660

Sweeney,B.W.,Bott,T.L., Jackson, J.K.,Kaplan,L.A., Newbold,J.D., and Standley, L.J. (2004). Riparian deforestation, stream narrowing, and loss of stream ecosystem services. Vol. 101 _ no. 39

Webster, J.R., Golladay, S.W., Benfield, E.F., Meyer, J.L., Swank, w.T. and Wallace, j.B. (1992). Catchment Disturbance and Stream Response: An Overview of Stream Research at Coweeta Hydrologic Laboratory. *River Conservation and Management.* © John Wiley & Sons Ltd

WWF *(2002).* Climate change and forest carbon sequestration Position Paper August 2002

WWF (2009). Getting Ready for REDD Toward an Effective and Equitable Policy on International Forest Carbon. Greenprint Issue Brief January 2009

Ziemer, R.R.(1986). Water Yields from Forests: An Agnostic View. Presented at the California Watershed Management Conference, November 18-20, 1986, West Sacramento, California

Zingari, P.C. and Achouri , M. (2007). Five years after Shiga: recent developments in forest and water policy and implementation. Progress since the milestone International Expert Meeting on Forests and Water held in Shiga, Japan in 2002. *Unasylva* Vol. 58