HYDROLOGICAL IMPACTS OF FOREST, AGROFORESTRY AND UPLAND CROPPING AS A BASIS FOR REWARDING ENVIRONMENTAL SERVICE PROVIDERS IN INDONESIA

Fahmuddin Agus, Farida and Meine van Noordwijk (Editors)

Proceedings of a workshop in Padang/Singkarak, West Sumatra, Indonesia, 25-28 February 2004

WORLD AGROFORESTRY CENTRE

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Pictures of front cover: Durian- (*Durio zibethinus*) base agroforestry in Maninjau; Singkarak Lake and its special fish ('ikan bilih'); outflowing water from Singkarak Lake to Ombilin River and water wheel as a traditional irrigation system for paddy farming.

Photographs by Meine van Noordwijk

Design/lay out by Dwiati Novita Rini

Executive Summary

Watershed functions and the way they are affected by 'development' are much debated and are nearly everybody's concern…..

When natural forests are logged or cleared by slash-and-burn methods for establishing tree crop plantations or upland food crops…,

when roads are built on forested slopes and induce landslides and rapid pathways for mudstreams to reach the rivers…,

when people start to live in upper watersheds and pollute streams by domestic use, livestock or use of agrochemicals…,

when the demand for water increases because of greater use for lowland irrigation, industry or cities…,

when fast-growing trees that use more water than other vegetation are planted,

when government agencies claim control and impose their solutions on the local community,…

when the floodplains and wetlands that used to provide storage and buffer capacity are drained for 'development'…or

when villages are built in places that are prone to flooding and mudslides…

….the end result is 'problems with watershed functions' that affect all of us one way or another.

but there are many ways in which specific problems can be solved through combinations of forests, agroforestry and upland cropping…..

The standard solution to 'rehabilitation of watersheds' is to plant trees in the hope of re-creating the benign conditions of a natural forest. Natural forests, however, provide livelihood options only at low population densities, so it cannot really solve current pressures on the land in areas with high population densities. Tree planting as such may actually increase the problem (fast-growing trees with high water use will reduce dry-season flows of streams and rivers), while mixed multi-strata systems can protect the soil and maintain water quantity and quality as well as providing livelihood to resource-poor local community.

once we have a common perception (criteria and indicators) of what exactly is the problem to be addressed.

Because there are many potential 'solutions' we need to be clear and specific about what the problem is and whether the selected solutions really address the problems. A list of three criteria for water quantity (Transmit water, Buffer peak flows, Release water gradually), water quality (Reduce sediment loads and other pollutants, Maintain aquatic biodiversity) and integrity of the land surface (Control landslides, Reduce loss of fertile topsoil through erosion), needs to be combined with criteria that relate to biodiversity conservation and to the social and economic welfare of the people living in watershed areas. Once seen against these criteria, many 'solutions' are in fact causing new problems. The different stakeholder may in fact have opposite interests, and a broad process of negotiation is needed to establish integrated natural resource management.

For example the way the GNRHL tries to achieve environmental protection goal may miss opportunities to build on local participations ….

Indonesia's current national program for reforestation and land rehabilitation is aimed at addressing widespread concern over degradation of watersheds, through a program targeted at planting X million trees per year on 500,000 ha of 'critical lands'. Assumptions that are yet to be met for the program's success are:

1. Convergence in stakeholders' perception on underlying knowledge of what the trees can actually provide to the environment and the community
2. Suitability and synergy of the supplied tree seedlings with existing local agro-ecosystems
3. Guarantee for acceptance by the local community and maintenance after planting to ensure tree survival
4. Guarantee for non-disruption of local livelihood because of changes in land use systems
5. Community education since early stage, starting from primary schools, on science based, rather than myths, of the relationship between land uses and the environments as well as socio-economic conditions
6. Institutional strengthening at the local/farmers level

7. Application of participatory approach (as opposed to a 'project' approach) with 'pendampingan' ('facilitation') of NGOs and researchers, including empowerment of local community in accessing and utilizing local land and tree resources.

to support the various ways in which proper land management with trees can provide local as well as national (environmental) benefits,

Indonesia is rich in examples of landscapes where farmers have combined the use of trees for productive purposes with elements of the natural forest that provide environmental services and areas that are used for intensive food crop production. These 'agroforestry mosaic' landscapes can be seen as 'Kebun Lindung' ('protective gardens') that offer great opportunity for combining economic and environment targets. Yet, there are obstacles in the recognition of these systems, as they may not meet the legal definitions of 'forest' or be in conflict with the existing land use regulation system and policies - even though it could pass the test when functional criteria and indicators of forest would be used.

while ensuring that outside stakeholders provide recognition and rewards in ways that are transparent, effective and pro-poor.

New ways to build 'hulu-hilir' (upstream-downstream) relationships that can satisfy everybody's needs, will require ways to share the benefits that lowland community enjoy from the effectively protected water resources, ways to enhance recognition and respect for upstream communities and their ability to monitor and solve problems, and means to reduce rural poverty. A combination of public and private rewards and payments is most likely to be successful in watershed management. Test sites for this new approach include the Singkarak and Sumberjaya (West Lampung District) action research sites of the RUPES (Rewarding the Upland Poor for the Environmental Services They Provide) program.

Our overall message is:

We need to rebuild effective communication between local, scientific and public/policy perceptions and knowledge of the problems that development can cause to 'watershed functions' and try to find solutions that build on local opportunities rather than blue-print standardized solutions.

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Basic relationships between forests and watershed functions

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If forests are converted into other land uses, the soil, vegetation and consequently the cycle of water will be subject to changes. This chapter aims to discuss some of the consequences of the conversion of moist tropical forest to agricultural land, especially the response of water yield and soil loss. Soil conservation strategies will be discussed as well, as this is the main key to restore appropriate land use and an attempt to increase the production of small farmers in rainfed agricultural uplands.

Introduction

With their unique diversity of plant and animal life, tropical forests represent an immense source of food, fibre, timber, medicines and fuel for local farmers, hunters and gatherers and (indirectly) city dwellers elsewhere. Forests are also of concern to the world community as a whole, in the way they constitute a significant element in the global carbon budget and harbour a large share of global biodiversity.

Nowadays, forests are being cleared in order to expand the area of productive agricultural land. Thus the unique properties of the forest are lost to humankind. Fortunately, in both tropical and temperate countries conservationists and more and more citizens are concerned with the wellbeing of indigenous people and the negative environmental effects of forest destruction. It matters a great deal what conversion method is used to derive agricultural lands from forest. It also matters a lot how agricultural lands are managed - some of the 'forest functions' can be maintained in agricultural landscapes, while others (especially the biodiversity) may significantly loss due to forest conversion.

There are ways in which forest in the humid tropics can be used, with consequences in productivity, biodiversity, and environmental services:

- Maintain the forest with little or no disturbance by man, for protection purposes,
- Sustained management of the forest for continuous production of wood and other commodities and services such as soil and water conservation, wildlife and recreation,
- Clear forest areas for temporary food crops and planting of commercial tree crops, but allow for a regrowth of forest species in an 'agroforest' context
- Clear forest and use the land for permanent farming and grazing, plantation forestry or agroforestry.

Figure 1: Forest with epiphytes that only thrive in moist air. (*Source: Hamilton and Bruijnzeel, 2000*)l

The consequences for water yield and soil loss of these options can be understood from the basic hydrology of forest areas. This overview relies heavily on a recent review by Bruijnzeel (2004), the interpretation, however, is that of the authors.

The hydrological cycle of humid tropical forests

This section explains how the interaction between forest vegetation, soils and atmosphere persists. This interaction process between various factors in an ecosystem is called the hydrological cycle and based on this we can gain insight in what will happen if a forest is converted to another type of land use.

The hydrological cycle contains several factors, which influence the cycle of water through a system. These factors are:

- Precipitation (rainfall)
- Interception by tree canopies, other vegetation or surface litter
- Throughfall and stemflow reaching the soil

- Infiltration or overland flow
- Evapotranspiration (evaporation and transpiration)

Precipitation

Rain is the main precipitation input to forests in the humid tropics. A small part reaches the forest floor directly as 'throughfall' without touching the canopy.

Interception

Of the rain that strikes the vegetation a substantial portion is intercepted by the canopy and evaporates back into the atmosphere during and immediately after the storm.

Stemflow and throughfall

The remainder of the rain reaches the forest floor as crown drip and via branches and trunks as stemflow after the respective storage capacity of the canopy and the trunks has been filled. The sum of direct throughfall, crown drip and stemflow is commonly called net precipitation.

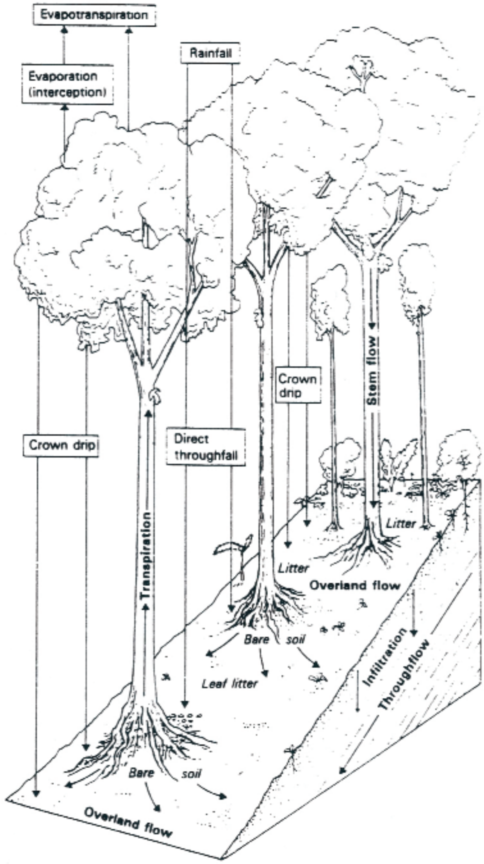

Figure 2: Hydrological cycle for a forested ecosystem. (*Source: Critchley and Bruijnzeel, 1994*)

The rainfall arriving at the soil surface encounters a filter that determines the path to reach the stream channel. The water in various pathways may leach amounts of nutrients from the rhizosphere system.

Evapotranspiration

Water evaporates from the soil surface and returns to the atmosphere. Soil moisture content and water table depth play an important role in the amount of evaporation. Also water is returned to the atmosphere by transpiration via plant leaves. This process is dependent on climatic, soil properties and physiological characteristics of the vegetation. The evaporation from the soil and the transpiration losses via vegetation are often difficult to measure separately and therefore are combined in the term 'evapotranspiration' which is usually calculated by empirical formulas in combination with measurements as air temperature, relative humidity, daylight hours, sunshine hours and wind velocity.

Forest can influence the evapotranspiration by their effect on wind turbulence, high humidity in the forest, interception of rain water and their root-system. In general forests return more water to the atmosphere than do other vegetation types or bare soil due to the great transpiration and evaporation of intercepted water.

What is the influence of a forest on infiltration and soil moisture content?

In general the infiltration rate in forests is higher than on other land, because of the many biopores in the soil caused by the activity of soil fauna, roots and high organic matter content. Leaf litter protects the soil against clogging. As a consequence forests soils have high storage capacities.

Wet or dry sponges

The complexity of forest soils, roots and litter has often been described as a sponge soaking up water during rainy events and releasing it gradually during dry periods. If a sponge is wet, however, it cannot take up further water and this is what may happen during heavy rainfall or consecutive days of moderate rainfall. The rate at which water can leave the sponge is an interesting subject of discussion. Although forest soils generally have higher infiltration and storage capacities than soils with less organic matter, most of this water is consumed again by the forest rather than used to sustain streamflow.

What is the influence of a forest on run off and streamflow?

If rainfall intensities below the forest exceed the infiltration capacity of the soil, the unabsorbed excess runs off as "Hortonian" or "infiltration excess" overland flow. The remainder infiltrates into the soil and, depending on vertical and lateral hydraulic conductivities, local soil moisture and slope steepness, may take one of several routes to the main stream channel. Forests have good storage and infiltration capacities of the soil and therefore overland flow hardly occurs. If it occurs, it is restricted to very small areas where soil is disturbed due to, for example, burning. Due to the high amounts of pores in the soil a substantial part of the water flows off as quick subsurface flow which can give storm flow in a river.

Because of the great infiltration capacity of the forest soil, the accessibility to the groundwater system is relatively high with a result that a lot of water is stored in the groundwater reservoir and released again gradually as base flow in rivers. Because of high evapotranspiration capacity in general, forests have a lower total stream discharge in relation to other forms of land-use.

Cloud forests

Cloud belts on tropical mountains, where amounts of water reaching the soil surface, are strongly influenced by the presence of trees. In these so-called 'cloud forests', 'elfin forests' or 'mossy forests' a significant portion of the incoming precipitation is stripped by the vegetation from low clouds and fog, blown through the forest canopy.

Cloud forests are usually short-statured, twisted, epiphyte-laden, dense canopied forests of hard-leafed species. They are usually found in a relatively narrow altitude range, but their actual position varies widely from tropics to temperate zones. Cloud forests have developed as low as 500 m above sea level on small islands in humid equatorial locations such as Fiji, but also in semi-arid small islands in oceans at the leeward side of the mountain, in contradiction to humid climates where the most developed dwarf-forests with epiphytes and lichens usually are situated at the windward side of the mountain. More often they are found in large mountain ranges between 2000 and 3500 m such as the Andes. From the movement of saturated air masses these trees, with their epiphytes, lichens and mosses, are able to condense the

Figure 3: Cloud forest. (*Source: Hamilton and Bruijnzeel, 2000*)

cloud or fog which then drips or runs to the ground and is added to the water budget of the area. Contributions by such fog stripping may reach several hundreds of mm yr^{-1} and even embodies the only input of moisture during an otherwise dry season.

> In the coastal ranges of the arid Pacific areas of Chile, Bolivia and Peru, a persistent fog, the *camanchaca* strikes the uplands between 500 and 1000 m. Artificial nets and screens are erected and trees are planted in order to capture water for potable domestic use.
>
> In the uplands of West-Java, Indonesia, at heights from 800 m and more, tea plantations have been established where in the past the hills where covered with cloud forests. Tea plantations generate a good ground cover but the capacity to capture fog is generally lost.

Another important characteristic of cloud forests is their extremely low water use, which is probably related to their often limited height. The net result is that in combination with the extra water supplied by the fog, it is not unusual for streamflow totals from such areas to be higher than measured amounts of incoming ordinary rainfall. Therefore, catchment headwater areas covered with these forests should be protected if a steady supply of water to the adjacent lowlands is to be guaranteed. In their natural state, because of their unusual environment, these cloud forests structure and species have a great importance for biodiversity. Unfortunately, in many tropical montane areas they are rapidly disappearing. The replacement of trees by any other short crops brings the contribution of water by 'cloud stripping' to an end and may result in a diminished stream flow.

Water yield and soil loss measurements for 'small' and 'large' catchments

Usually during hydrological investigations, the hydrological in- and outputs of an area are measured in a catchment. This can be a catchment of a huge river basin or only a small drainage basin of several hectares.

To study the hydrological response of an area to land conversion, a small catchment is preferred by researchers because when land conversion takes places, this is usually uniformly be done over the area such that the effects of land use changes on hydrological processes could easily be detected. In the large catchment, land use changes take place on only small parts of the total area. In addition, in a large catchment the land use is more spatially varied and this will complicate the hydrological processes. Therefore, the measurements from small catchments may not simply be extrapolated to a larger area.

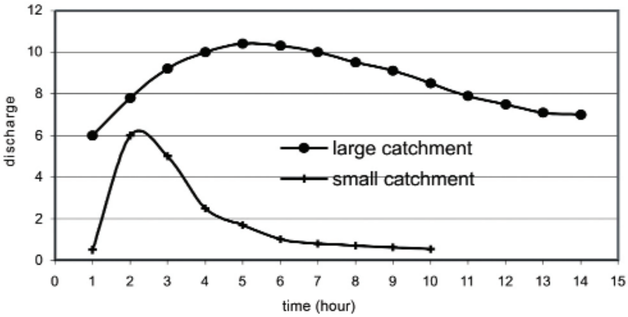

Figure 4: Differences in discharge from small and large catchments.

Small catchment	**Large catchment**
Uniform rainfall	Pluriform rainfall in time and space
Uniform land use	Pluriform land use
Uniform geology	Pluriform geology

It has been demonstrated that contrasts in catchment response between drainage basins within a small area are primarily the result of catchment characteristics (geology, topography, soil, vegetation characteristics) rather than meteorological inputs. In large catchment areas, there is also a large variation in time and space of the meteorological input (rain, sunshine, wind). Therefore, the discharge of a larger-scale catchment area after rainfall differs from that from a small-scale drainage basin.

In small catchments there is less spatial variation in soil type, drainage situation and vegetation type, but small catchments in headwater areas may be leaky and part of the flow may go unrecorded as deep leakage through rock fissures and fault zones or through the valley fill, thereby producing an underestimate of the hydrologic nutrient losses or misestimates in the factors of the hydrological cycle.

It is also possible to measure water yield and soil losses in very small areas, for example in plots of only a few square meters. Because this area is so small, the influences of groundwater flow can be neglected and also surface properties of the area cannot be compared straightforwardly with larger areas. In a large catchment area almost all watershed functions are available to compute a water balance of the area.

What is a water balance?

The water balance of an area can be made to compute the various in- and outputs of an area. The main input to an area is precipitation. The outputs are: evaporation from the soil, transpiration via trees, stream flow and groundwater flow:

$$P = E_i + E_s + T + Q_s + Q_g + S$$

Where

P = precipitation,

E_s, E_i = evaporation from the soil and water intercepted by canopy surfaces,

T = transpiration by plants,

Q_s, Q_g = stream flow and groundwater flow,

ΔS = change in soil moisture storage.

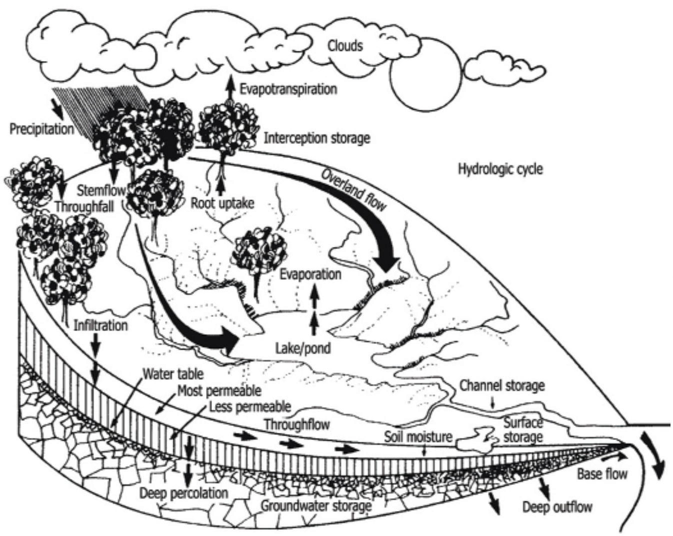

Figure 5: A catchment with its various hydrological inputs and outputs. (*Source: Messerli and Ives, 1997*)

In short we can state that a forest has its own specific hydrological cycle, controlled by the **interaction between** forest **vegetation**, **soil**, **landscape**, **climate**, and **so forth**. If this interaction is disturbed, various factors of the hydrological cycle (evapotranspiration, interception, throughfall, infiltration) will change which leads to another response to rainfall.

What are the impacts of deforestation?

In general, there are three intensity levels of disturbance of a forest that can be distinguished:

- Low: small scale and short-lived events of forest clearing
- Intermediate: selective logging, forest fire, shifting cultivation -- with a chance of recovery of forest vegetation
- High: forest clearing, conversion to pasture, monocultures of tree crops, timber plantations or permanent annual cropping -- with very little chance of recovery of forest vegetation.

Figure 6. Slash-and-burn clearing can be the start of a 'temporary' disturbance of the hydrological cycle and it can also be the start of irreversible conversion. (*Source: Dephutbun, 2000*)

Logging operations of any type cause disturbance to the soil and the vegetation. Yet, the way logging is performed can make a lot of difference. Use of heavy machinery that compacts the soil, pulling logs into streams and rivers for easy transport and careless felling can cause disproportionate levels of damage to watershed functions. As lowlands already are converted in agricultural lands, loggers turn their attention to steeper terrain and uplands. Where heavy machinery is used to cut and transport the timber, up to 30 % of the soil surface may be laid bare in the forms of roads and tracks. Especially on wet clayey soils the porosity and infiltration capacity are seriously reduced after the use of wheeled machinery.

Hydrological effects of forest conversion

As a result of deforestation the response of the land to rainfall will change depending on the type of deforestation, a region's climate, geological setting, as well as the rainfall during and after the conversion.

The key to the hydrological behavior of a forest is the presence of the canopy and the forest floor, with its leaf litter and concentrated roots. The canopy (through its interception of rainfall and its evaporation loss via transpiration) together with the litter on the ground (through its effects on infiltration) is crucial in the hydrological cycle of the forest. One of the most important factors which will change when deforestation including disturbance of the soil takes place, is a diminished capability of the soil to absorb water; in other words: ***the infiltration capacity of the soil reduces***.

In general after conversion of tropical forest into agricultural land the infiltration capacity of the soil and the water uptake by trees diminish due to the following reasons:

- ***Exposure of bare soil to intensive rainfall***

  If protecting canopy and leaf litter layer is removed, the soil is exposed to the erosive power of rain. Part of the soil pores are sealed and thus give an increase to runoff and erosion. Due to erosion, the fertile and permeable topsoil is removed or compacted, thereby lowering further the infiltration capacity.

- ***Transpiration decrease***

  Conversion of forest land into agricultural lands reduces transpiration because crops do not have a full leaf canopy throughout the year and the leaf area of field crops is much lower compared to that of forest. Agricultural crops tend to have shallower root systems than trees and as a consequence only use soil water in the upper part of the soil. This reduced transpiration means a higher total annual flow to the river.

- ***Compaction of topsoil***

  If tropical forest is converted into man-made areas, like agricultural lands and/or inhabited areas there will be a strong increase in the amount of impervious surfaces like roads, yards and roofs, which will give an extra impact on the amount of surface runoff and consequently will reduce infiltration.

- ***Gradual disappearance of soil faunal activity***

  Most soil fauna (indirectly) depends on the continued inputs of organic material in the form of leaf, fruit or wood litter. Conversion of forest tends to reduce litterfall which also reduces food supplies for the soil fauna. Furthermore the use of fertilizers and pesticides diminishes the soil faunal activity and thus lowering the rate of soil manipulation and natural tillage.

Figure 7. Water logging and surface runoff due to decreased soil infiltration capacity. (*Source: van Dijk, 2002*)

Erosivity of rainfall in the tropics

In the humid tropics rainfall usually is intense, with a large amount of water received over a short period. Due to these rainfall characteristics in the humid tropics, the raindrops usually have a high kinetic energy and thus have a quite high erosive power.

Response of total streamflow: greater water yields

One of the results of changing land use to agriculture is an increase of annual stream flow out of the area. This is a simple consequence of the water balance: if evaporation of intercepted water and transpiration by vegetation are reduced, more water will leave the area as stream flow once the storage capacity of the soil is saturated. The overall catchment water yield increases significantly under rainfed agricultural use (typically by 150-450 mm yr^{-1}, depending on rainfall) compared to undisturbed natural forest. The greater 'water yield' may, however, come in the form of 'peak flows' rather than as 'base flow' thus potentially increase the frequency and intensity of floods if the down stream area is flood prone.

Response of total streamflow: less buffered flows

After logging, the forest still keeps a percentage of the ground cover, protecting the soil against erosion. After clearing of the forest floor, however, the protecting layer of leaf litter, branches and trunks are removed, remaining the soil bare. No longer are there trees to intercept rainfall and evaporate it directly back into the atmosphere. Due to high precipitation intensities in the humid tropics the soil pore is clogged and infiltration capacity is diminished dramatically. This will result in a more pronounced catchment response to rainfall and the increase in storm runoff during the rainy season. This increase may become so large as to seriously impair the recharging of the soil and groundwater reserves which normally feed springs and maintain base flow.

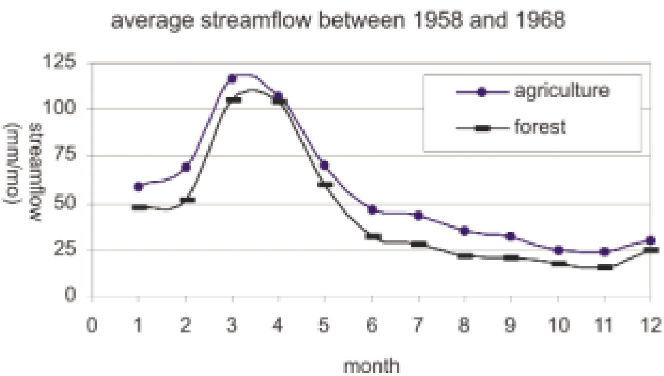

Figure 8. Changes in seasonal distribution of stream flow following changes in land use, in the Mbeya area (Tanzania), where montane forest was replaced by subsistence agriculture; in this case stream flows increased during the dry periods as well as in the peak of the rainy season. (*Source: Critchley and Bruijnzeel, 1996*)

In undisturbed tropical forest, infiltration excess-overland flow makes up less than 1 % of the incoming rainfall but on agricultural fields with no or less conservation practices this may increase to about 30 %. The portion of precipitation that contributes to infiltration excess-overland flow directly runs off to the nearest channel, instead of infiltrating the soil and subsequently recharging the groundwater supply.

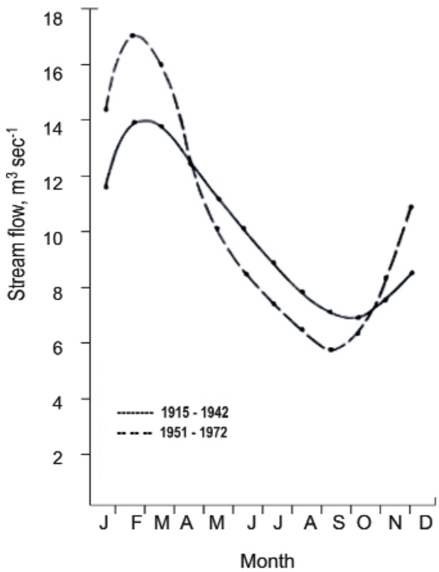

Figure 9. Change in seasonal distribution of streamflow out of the Konto-river basin, Indonesia. In the second period a significant conversion of forest to agricultural land took place. (*Source: Brujinzeel, 1990*)

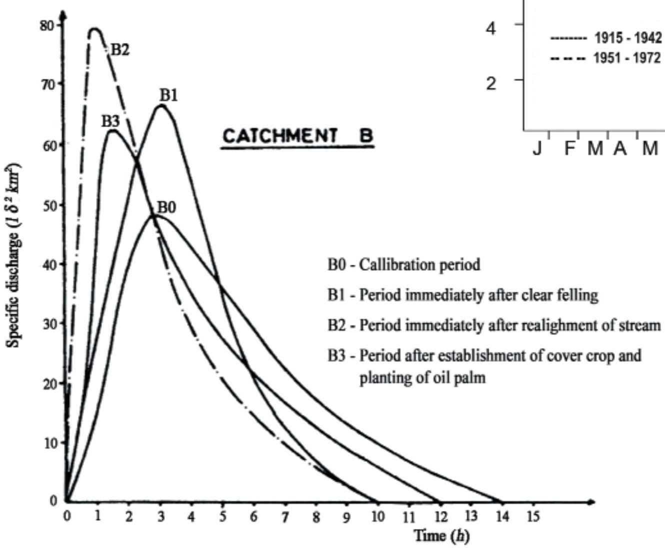

Figure 10. Stream discharge after B1: clear felling, B2: realignment of stream B3: re-establishment of cover crop and planting of oil palm (*Source: Brujinzeel, 1988*).

What is the response of deforestation to dry season flow?

Under undisturbed forest, generally the dry season flow or base flow is maintained. This flow is generated in the rainy season when enough water is able to infiltrate via the highly permeable soil of the forest and infiltrated to deeper soil layers, which drain the area. As a result of disturbance of the forest floor, less water is capable to infiltrate. The remainder is running off over the surface directly during and after a rainfall event.

Decreasing infiltration capacity forces the water to run off overland if the infiltration capacity of the soil is exceeded by the precipitation intensity. This will lead to a direct contribution of runoff water to the storm flow stream instead of a contribution to the deeper soil water.

Under disturbed circumstances of the forest floor or when forest is converted into agricultural land, a larger portion of the incoming rainwater will run off quickly after and during the rainfall event. Less water is left to replenish deeper water bearing layers and so less water is left to maintain a continuous flow during dry seasons.

This could be explained by the fact that agricultural crops almost always use less water than the original forest. For example, total stream flow from forest that has been converted to rubber or cocoa plantation will be permanently about 300-400 mm yr^{-1} higher than when the area is covered by natural forest. After a few years of conversion to plantation the increase of water yield becomes less pronounced as a result of uptake of water by the growing vegetation and the recovery of undergrowth.

Effects on soil loss

Erosion is the process by which soil and rock particles are loosened and broken down and carried or washed away by runoff water or by raindrops (splash erosion). Undisturbed natural forest usually has the lowest surface erosion rates of any form of land use in the humid tropics. The leaf litter, undergrowth and highly permeable topsoil help to keep surface runoff low, and thus erosion to a minimum.

The main factors which control erosion are:

- relief: the steeper and the longer the slope, the higher the velocity of runoff water and thus the more the soil suffers from erosion and the easier is the sediment transported downslope.
- rainfall: high amount and high intensity of rainfall stimulate a higher erosion rate
- soil: soils are usually shallow on steep slopes and in converted forest sites. The shallow soils are more susceptible to erosion.
- plant and soil cover: the cover of the floor will be reduced after conversion.
- management: management systems such as strip cropping, terracing etc. can reduce runoff and erosion.

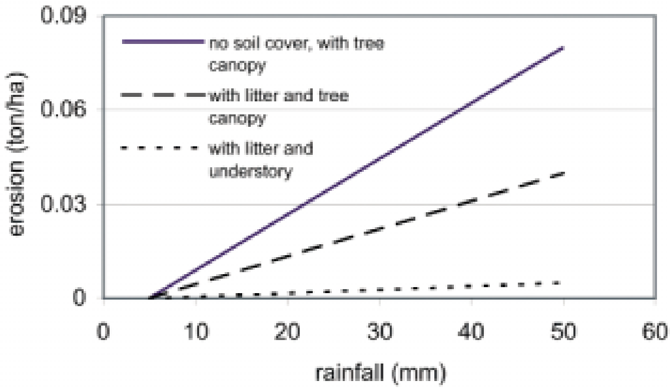

Figure 11. Surface erosion in a young forest plantation as a function of soil surface conditions. (*Source: Critchley and Bruijnzeel, 1996*)

What kind of erosion can be distinguished?

Erosion in disturbed forests can occur in different types:

- surface (sheet) erosion, also known as inter-rill erosion.
- rill erosion, where little streams start to form on the surface
- gully erosion, where new streams are deeply incised in the landscape
- stream erosion
- landslides and mass movements of soil, due to interruption of subsurface flow pathways by roads and / or loss of tree root 'anchoring' of the soil

Surface erosion can be a severe problem in steep agricultural lands, such as in West Java, where soils are degraded and soil particles have a low stability. Stream erosion will occur if runoff rainwater is already came together in a small stream and if flow velocity and thereby erosive energy is high enough to take up soil particles with the flow.

High stream flows may cause gully erosion usually as a consequence of improper discharging of runoff from roads, trails and settlements. Water streaming down with a high velocity has, depending on the type of soil, enough energy to take up soil particles and this kind of erosion can attribute to increased gully erosion.

Mass wasting (landslides) can occur in forested areas under conditions of steep topography, tectonic activity (earthquakes) and intense rainfall.

Figure 12. Heavy erosion on a poorly drained road. (*Source: Critchley and Bruijnzeel, 1994*)

Mass wasting and landslides: natural or man-induced process?

Factors controlling mass wasting under natural forest cover are:

- steep slopes
- unstable nature of rocks and unconsolidated soils
- depth and degree of weathering
- high seismicity
- oversteeping of slopes cause by undercutting of rivers
- (over) saturation of soil

In forested areas a distinction can be made between deep-seated and shallow (< 3m) landslides. The deep ones seems not to be influenced by the presence or absence of a well-developed root system, but are more controlled by geologic factors. Shallow landslides are controlled by disturbances of the soil. If the protective root-system in the topsoil, which stabilizes the soil on steep hill sides, is disturbed, landslides occur frequently. Under natural conditions, disturbance of a part of the forest floor can take place by tree fall, fire or heavily flooding.

Non-natural disturbances of a forest soil are removal of the forest for production purposes, cultivation and grazing or construction of roads, canals and housing areas. Irrigation canals in upland areas are frequently associated with slope failures due to the removal of the toe of the slope and the saturation of the weathering layer by seepage and overflow.

What are the on- and off-site effects of erosion?

Erosion not only affects the location where soil loss takes place (on-site) but also downstream (off-site). The on-site effects of erosion include:

- decrease of soil fertility as a result of soil loss
- decline of physical soil properties, due to loss of organic matter
- decrease of infiltration capacity
- reduction of agricultural lands productivity

Figure 13. Sediment-laden river, resulting from adverse land use in Sapi-watershed, Central Java, Indonesia. (*Source: Critchley and Bruijnzeel, 1994*)

Table 1. Surface erosion in tropical forest and tree crop systems (Mg ha^{-1} yr^{-1})

Land use	**Erosion**		
	Min	**median**	**Max**
Natural forest	0.03	0.3	6.2
Shifting cultivation, fallow period	0.05	0.2	7.4
Plantations	0.02	0.6	6.2
Multi-stored tree gardens	0.01	0.1	0.2
Tree crops with cover crop/mulch	0.10	0.8	5.6
Shifting cultivation, cropping	0.40	2.8	70.0
Agricultural intercropping in young forest plantation	0.60	5.2	17.4
Tree crops, clean weeded	1.20	48.0	183.0
Forest plantation, litter removed or burned	5.90	53.0	105.0

Source: Bruijnzeel (1988b)

The downstream, off-site, effects of erosion include:

- lower quality and use value of river water
- sedimentation in the reservoirs and channels

- damaging watercourses, land and properties
- change of the hydrological regime of rivers

Is soil erosion measured upstream the same as the sediment loads measured downstream?

Individual sediment particles undergo a period of transport, deposition and remobilization by water as they travel downstream. The residence time of sediment in various storage locations varies widely depending on the type of deposition site. There can be a great time lag in soil erosion and sediment yield measured off-site. The time lag increases with catchment area because of the increase storage opportunities, decrease gradients and wider range of depositional sites in larger catchments. The ratio between sediment measured at the exit of the catchment and sediment generated on-site is called 'sediment delivery ratio' and it represents the fraction of on-site generated sediment that is stored somewhere in the catchment.

Between different scales of measurements of soil loss (individual terrace units vs. total catchments) there can be a significant difference in the average amount of transported sediment. This is caused by the fact that within an area there will be always some places in which sediment can be deposited. This process of deposition and storage of sediment has a widely spatial and temporal range. Therefore sediment generated upstream does not have to be equal the amount of sediment yield measured downstream.

Land use effects on soil nutrients

Soil formation in the humid tropics is relatively fast due to high temperature, high rate of organic matter production and high rainfall. Tropical forests can produce a huge amount of biomass, even when their soils are very low in fertility. Forests have a relatively 'closed' nutrient cycle: the plant nutrients entering the forest system are being cycled continuously between the canopy and the soil. When a forest system is disturbed, the nutrient cycle is interrupted, leaving the soil with a deficiency of nutrients. Upon tropical forest clearing, nutrients are lost from the ecosystem in various ways, depending on geological and climatic factors:

- Harvesting of stems: the amount of nutrients incorporated in the stem and bark of trees varies for calcium and phosphorous between 10 and

75%, potassium between 20 and 80 % and magnesium 20-65% of the amount available in above and below ground biomass. This amount of nutrient is transported out of the system when the wood is transported.

- Slashing and burning: nitrogen and carbon go up in smoke. Between 25 and 80 % of all calcium, potassium and phosphorous present in slash may be lost, depending on the intensity of fire.
- Nutrients carried away in eroded sediment.
- Nutrient loss through increased leaching and drainage of the soil.

After conversion to agriculture a new nutrient balance will be established. Plantations present the opportunity to establish a system which, with careful management, can provide an accepted alternative to the nutrient cycle of a forest.

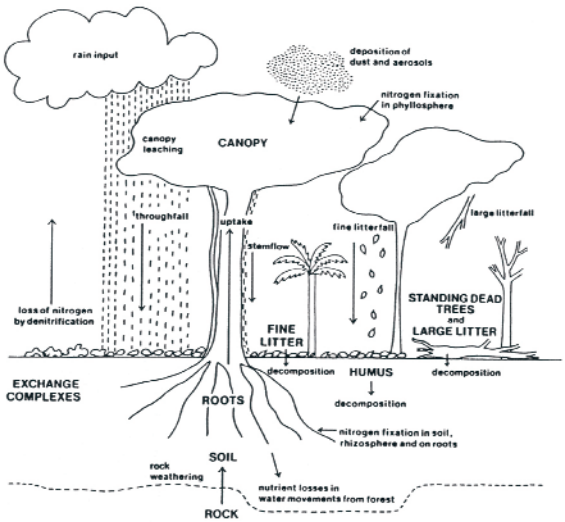

Figure 14: Nutrient cycle in a moist tropical forest. (*Source: van Dijk, 2002*)

The loss of nutrients from a soil can only be compensated by inputs from precipitation (rain and dry deposition), weathering and fertilizing. The loss of nutrients by forest clearing is very hard to equilibrate by a new supply of nutrients through precipitation or rock weathering because of the relatively slow process of rock weathering and the relatively little amounts of nutrient input by precipitation. Therefore, nutrients balances during forest clearing are disturbed when too much biomass is removed or when too little time is given to the land for natural re-growth of the vegetation.

Conclusions

Forests exhibit the most ideal land use in terms of its functions in regulating hydrological processes and in protecting the soil. Deforestation causes the decrease in soil infiltration capacity, with as a consequence of increase runoff and accelerated soil erosion, and more extreme discharge characteristics. The amount of water streaming out of the area increases whereas the difference of water yield between the dry and wet seasons also increases.

Generally, deforestation decreases evaporation (especially from the intercepted rainfall on plant canopy) and transpiration due to lower leaf area and shallower root system of the successive vegetation. Infiltration decreases following deforestation due to combined effects of soil compaction, exposure of soil surface to rain drops and removal of tree litter that otherwise protect the soil surface. These lead to increased runoff and soil loss and subsequently lower productivity of the land. The downstream area could be affected because of the higher wet season flow and lower quality of stream water due to sediment load following deforestation.

What safeguards are needed during forest clearing, and in the development of alternative land use systems, to minimize damage to the environment?

- Well developed ground cover
- Well developed canopy
- Proper lay-out of road system
- No use of heavy machinery
- Maintaining riparian buffer zones
- Selective logging (not too much removal of biomass)

If a piece of land is deforested with care, in other words, if the soil properties are maintained and the infiltration capacity of the soil stays at the same level, then base flow will increase (due to lower evapotranspiration of crops compared to forest).

Forests represent important values over and beyond their hydrological functions. Damage to watershed functions can, however, be avoided by more careful conversion practices and by securing protective land use practices that re-create the essential 'forest functions' in an agriculturally used landscape.

Role of agroforestry in maintenance of hydrological functions in water catchment areas

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After a century of attention for 'watershed management, there is still a remarkable lack of clear criteria and indicators of the hydrological functions that society expects to be met from water catchment areas. The lack of realistic expectations leads to large public investments in 'reforestation' that are unlikely to achieve value for the money spent. Hydrological functions of watersheds, given the rainfall that the area receives, include the capacity to 1. Transmit water, 2. Buffer peak rain events, 3. Release water gradually, 4. Maintain water quality and 5. Reduce mass wasting (such as landslides).

The relation between full ('forest') and partial ('agroforestry') tree cover and hydrological functions in this sense involves changes at different time scales, and tradeoffs between total water yield and the degree of buffering of peak river flows relative to peak rainfall events. The role of land use can be analyzed in terms of changes in evapotranspiration linked to the presence of trees, infiltration linked to conditions of the soil and the rate of drainage linked to the drain network in the landscape. Models that link the dynamics of macropores in the soil and the space-time characteristics of rainfall to the dynamics of river flow can fairly well reproduce the time series of data from intensively studied (sub)catchments. We may thus have some confidence in their use for extrapolation to future land use change scenarios. A major lesson from the intensive studies is that forms of farmer-managed agroforestry can maintain the hydrological functions that society expects from 'protection forest' ('hutan

lindung'), while providing income for rural population densities in the range 50 - 100 persons km^{-2}. These 'kebun lindung' forms of land use lack recognition, so far, and conflicts over access to and stewardship of state forest lands remain a major obstacle. If the multi-stakeholder negotiation of the use and management of upper watersheds could become more based on functional criteria and transparent indicators, these 'kebun lindung' forms of land use could reduce the perception of an unavoidable environment - development conflict.

Introduction

The concept of watershed management to secure a steady supply of water of good quality is probably as old as irrigation agriculture. Yet, there is still a remarkable lack of clear criteria and indicators that represent realistic expectations based on well-established cause-effect relationships and the multiple interests of stakeholders involved. Watershed management is, in the public debate, often directly linked to the degree of 'forest cover' with the assumption that 'reforestation' can, in essence, undo the negative impacts of deforestation. There is still considerable confusion over and lack of reference to empirical data sets on the question whether river flow at an annual basis and specifically in the dry season will increase or decrease after forest conversion or reforestation.

The term 'sustainable management' has become a cliché that does not recognize the need for farmers to keep adjusting their enterprise to the changing opportunities in markets and does not provide a method to monitor progress and success in achieving the environmental objectives. Realities of rural population densities and their livelihood needs and expectations are often left out of discussions on desirable land cover forms, contributing to large discrepancies between the colours on the planners' land use maps and the situation on the ground.

In this contribution we propose a set of criteria and indicators for the hydrological functions of catchment areas that can be used to evaluate options for sustainable management of such area, and focus on the potential of agroforestry to reconcile productive land use with the protection of these hydrological functions.

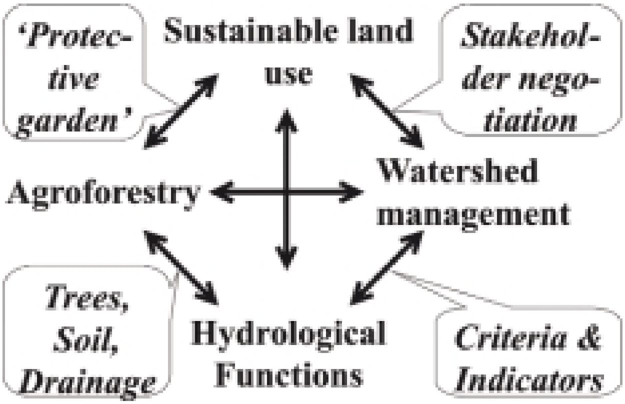

Figure 1. Relationships between sustainable management of water catchment areas, hydrological functions and agroforestry discussed in this contribution.

Development of forest and water concepts in Indonesia

The general public and policy perception of 'watershed protection' specifies a desirable condition ('forest') for the upper watershed and associates any flooding event to a loss of forest cover in the hills and mountains, with tree planting as the knee-jerk rehabilitation measure. An 'ecohydrology' approach involves more than a focus on the degree of forest cover in the upper watersheds, as the quantity, timing and quality of water flows is determined by the land cover and land use in the whole landscape. In Indonesia it seems that the public and policy debate has not progressed much since De Haan (1936) wrote in his 'contemplations on the issue of forest reserves':

> "There has been too much emphasis on the contrast between "**forest**" and "**non-forest**". One often supposed that as long as a certain percentage of an area was reserved as 'protection forest', agriculturalists outside of that area could do as they wished. Nothing is further from the truth. The difference in hydrological behaviour between a montane forest and for example a rubber garden is certainly much smaller than that between this rubber garden and the cropped fields of a smallholder."

Kartasubrata (1981) summarized the development of ideas about forest and water in Indonesia, as they were reflected in debates during the colonial era. As the debate still resonates today, it may be interesting to see the arguments as phrased at that time. The debate heated up with a statement of Heringa (1939) who pleaded for a substantial increase of forest cover on Java, both for the production of timber, resin, turpentine and tannin, as well as for the hydrological significance of forests. On the island of Java with its high volcanoes the rivers have such a strong fall that in the west monsoon the rainwater flows rapidly into the sea in its force transporting much fertile soil and mud from the fields and from the riverbeds to be deposited into the sea. Heringa formulated a theory that stirred up much of the debate, when he said:

> "The forest works as a sponge; it sucks up the water from the soil in the wet season, to release it gradually in the dry monsoon at the time when there is shortage of irrigation water. Decrease of forest cover therefore will bring about decrease of discharge during the East monsoon ('dry season') and cause shortage of the needed irrigation water. Therefore, a balance is needed between forest condition and output of agricultural lands (rice fields). Consequently one has to determine a minimum forest percentage for every catchment area".

Roessel (1939) applauded the idea of extension of industrial forests, however, he criticized the use of hydrological arguments to justify reforestation. He posed the 'infiltration theory' that emphasized that percolation of water through the subsoil produces spring water, not the forests as such. Coster (1938) working at the Forest Research Institute in Bogor provided quantitative data and suggested a synthesis: vegetation determines recharge to the 'sponge', but most water is held in the subsoil, not in the forest as such.

In much of the current debate the more synthetic viewpoints of Coster (1938), with both positive and negative impacts of trees on river flow have not yet been understood, and existing public perceptions and policies are based on Heringa's point of view. The concept that a '***Kebun lindung***' can be as functional in terms of infiltration and hydrological impact as a '***Hutan lindung***' still appears to be novel today, as the dichotomy between forests and all non-forest land use persists in the regulatory frameworks as well as general perceptions. The recent Chambéry Declaration on "Forests & Water" in the context of the International Year of Fresh Water 2003 appears, yet again, to imply that 'non-forests' cannot meet any of the 'forest watershed functions'.

Table 1. Three perspectives on the relationship between forest cover and watershed functions (modified from Kartasubrata, 1981).

Aspect	Forests as sponge theory (Heringa, 1939)	Infiltration theory (Roessel, 1939)	Synthesis and quantification (Coster, 1938)
Dry season river flow	Depends on forest cover	Depends on geological formation	Vegetation determines soil permeability
Required forest area for hydrological functions	A minimum required fraction can be calculated from the area of rice fields to be irrigated with dry season flow	There is no minimum forest cover	Discharge of springs depends on the amount of water that percolates into the soil *minus* the loss of water because of evaporation.
What to do if forest target is not met?	Farm land of farmers and agricultural estates has to be purchased and reforested	Reforestation is only carried out if certain soil types expose susceptibility to erosion, but then after other measures, such as terracing, catching holes and soil cover have proved insufficient	Depends on ***elevation***. Lysimeter measurements indicated that the evaporation of a free soil surface 1200, 900 and 600 mm per year at locations with an elevation of 250, 1500 and 1750 m a.s.l., respectively
Forests or ground cover?	All soil types are equal; afforestation with industrial wood species has the same hydrological effect as natural forest and is (always) better than agricultural estates	An agricultural estate which succeeds to ban superficial run off by terracing etc. or soil cover, is hydrologically more valuable than an industrial timber plantation, where surface run off can still take place, for example, because of steep slopes, poor undergrowth or poor humus formation	Measurements by the Forest Research Institute showed that well maintained tea, coffee, rubber and kina plantations are from a hydrological point of view nearly the same as forests (planted or natural) but superior to agricultural fields. Fires in the grass wilderness in the mountains stimulate water run off and erosion.
Scope of reforestation	All problems with 'watershed functions' can be cured with reforestation	Recovery by reforestation can only be expected in cases where superficial run off and erosion can be controlled with good forests. Forests without undergrowth and without good humus formation are usually not sufficient. A soil cover with grass, dense herbaceous or shrubby vegetation, however, will do.	It is probable that afforestation in low lands may decrease the discharge (including that in the dry season), because of the high evaporation rate from the forest; in the mountains the increased infiltration of abundant rain into the soil more than offsets the increased water use by trees.

As explored by Grove (1995), perceptions on the relationships between deforestation, subsequent changes in rainfall, land degradation and siltation of rivers date back to experiences in the Mediterranean region, with the Greek philosopher Theophrastos as one of the earliest written sources documenting these perceptions. The European colonial expansion into the tropics and particularly their experiences in small islands such as Mauritius strengthened perceptions that forests generate rainfall. Yet, hard evidence of a change in documented rainfall as a consequence of deforestation still hardly exists, and the causality of the association between forests and rainfall (rainfall => forest) is generally the reverse of what is perceived (forest => rainfall). A recent re-analysis of rainfall patterns for Indonesia (Kaimuddin, 2000; Rizaldi Boer, pers. comm.), for example, indicates shifts in the isohyets (zones of equal rainfall) in Indonesia, that are not obviously related to local land cover change: some areas that lost forest cover became wetter, other areas that lost forest cover became drier; for Indonesia as a whole average rainfall did not change, despite the considerable loss of forest cover, but there may have been a change in the overall circulation pattern that affects local rainfall. Although at local scale real changes in rainfall may have coincided with real changes in forest cover, there is no convincing evidence to support hypotheses about causal relationships. The way a landscape 'processes' the incoming rainfall, however, does directly depend on the land cover, and the total amount of water, the regularity of the flow and the quality of the water in the streams can be directly affected by changes in cover.

A final quote on this historical section: "Formerly the view was generally accepted, that forests had the tendency to increase rainfall to a large extent. Nowadays this view is combated by many investigators, who deny any appreciable influence; others support the view that the distribution is changed by the forest, and not the total amount of rainfall...." Braak (1929).

Widely held perceptions of the overriding importance of forest cover for the maintenance of watershed functions in source areas have been questioned over the last decades in hydrological research, and rather than using a 'forest' <=> 'non-forest' dichotomy, have lead to the recognition that the types of land use that follow after forest conversion can make a lot of difference. Land use (including but not restricted to the protection of existing forest cover) in such source areas thus has local as well as external stakeholders and beneficiaries, and increasing demands for water in the lowlands have often lead to an increased sense of conflict over what happens in the source areas. Yet, upper watersheds in much of the tropics provide a living for large numbers of farmers and rural communities, who have often remained outside of the main stream of development. The consequences of this is an 'upland' - 'lowland' distinction with a strong perception of a conflict of interest: people living in the upper watershed are perceived to 'destroy the watershed functions', where in fact there is no recognition or reward mechanisms for all those situations where their land use protects water resources.

Criteria and indicators

Major aspects of river flow (the total annual water yield, the regularity of flow, frequency of flooding of wetlands, alluvial plains and other areas along the course of the river and availability of water in the dry season) are dominated by rainfall, rather than by the way watersheds operate hydrologically. In order to focus more clearly on the role of the watershed functions per se, we need to tease apart what the contributions of rainfall and terrain (and other site characteristics that are not directly influenced by land use change) are, and what role land cover (that is under direct human influence) plays. We propose a set of criteria for watershed functions that expresses 'outcomes' of measurable properties of rivers relative to inputs of rainfall. The criteria thus focus on 'watershed functions' as modifiable by land cover and land use, given the site characteristics and rainfall pattern that differ from location to location and from year to year, but are not likely to respond to human decisions and actions. The functional relevance of these criteria to stakeholders will vary with their location, role and perspective (Fig. 2). Quantitative indicators of the various criteria can

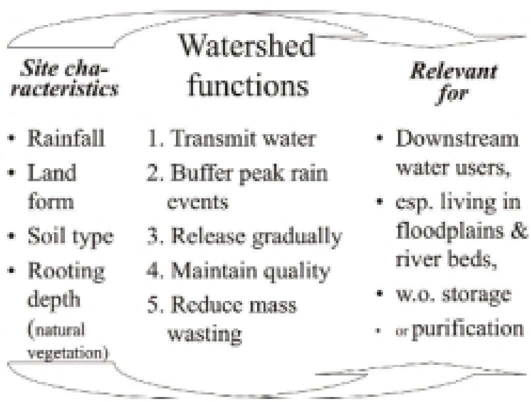

Figure 2. Five criteria for watershed functions that relate site characteristics to aspects of river discharge that are relevant to specific groups of downstream stakeholders

help inform the stakeholder negotiation process, but not directly lead to a selection of the 'most desirable' or 'least undesirable' scenario.

The criteria can be directly linked to a quantitative understanding of the way the precipitation P is partitioned over river discharge Q and evapotranspiration E in the water balance (Fig. 3). This coupling helps in understanding the logical relationships and inherent tradeoffs between changes in transmittance, buffer and gradual release functions.

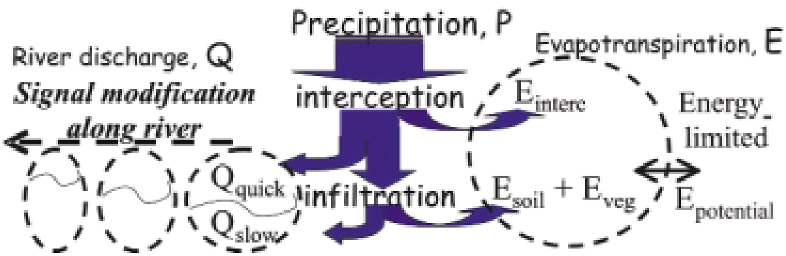

Figure 3. Schematic representation of the partitioning of precipitation in its passage through the canopy, when it reaches the soil surface and after infiltration into the soil

By analyzing the various controls that land cover exerts on the process of canopy interception of incoming rainfall, infiltration of the soil surface and use of water temporarily stored in the soil for evapotranspiration at the soil surface or transpiration by plants, we can understand the outcomes at the level of annual water budgets (Fig. 4).

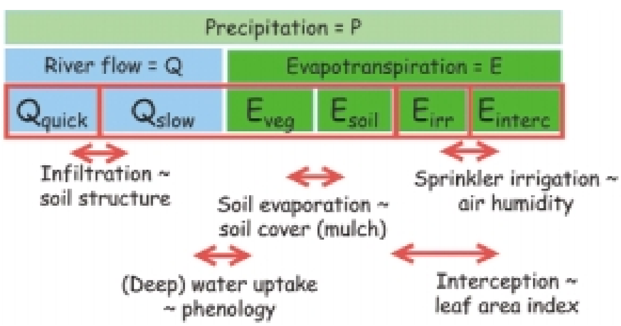

Figure 4. Five controls exerted by land cover and land use on the partitioning of precipitation over river discharge and evapotranspiration

A set of quantitative indicators was developed for the first three criteria (Table 2), that can make use of long term records of rainfall and river flow, and / or be used to summarize results of simulation models. The application of these indicators to data for the Sumberjaya area in Lampung is discussed by Farida and van Noordwijk (2004).

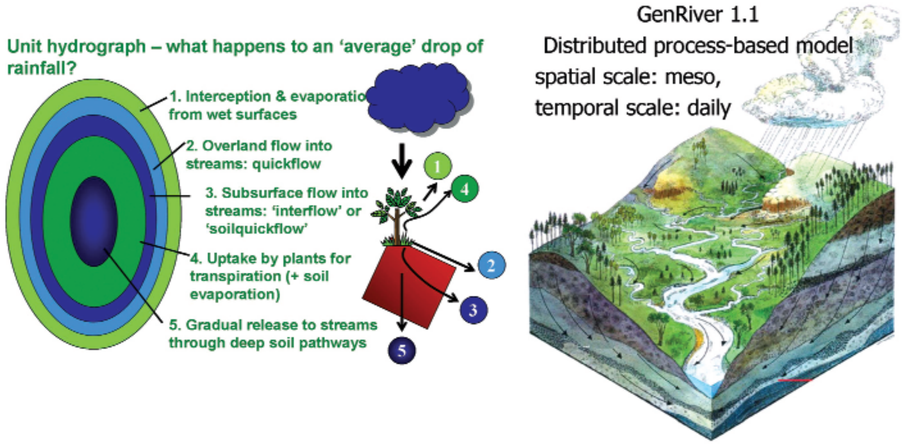

Figure 5. Basic processes represented in the GenRiver model developed at ICRAF and available from www.cgiar.icraf.org/sea

Table 2. Criteria and indicators of hydrological functions as developed by the ASB consortium for assessments in the (sub)humid tropical forest domain.

Criteria	Indicators	Stake-holder relevance	Empirical data P = rainfall, Q = river flow	Water balance model
1. Transmit water	Total water yield (discharge) per unit rainfall	All water users, esp. below reservoirs	daily P & Q	√
2. Buffer peak rain events	2.1a Buffering indicator for peak flows given peak rain events 2.1b Relative buffering indicator, adjusted for relative water yield 2.1c Buffering peak event 2.2 Highest of monthly river discharge totals relative to mean monthly rainfall 2.3 Fraction of total river discharge (1.1) derived from a. overland flow (same day as rain event) b. soil quick flow (1 day after rain event) (compare 3.2)	People living in & depending on river beds and flood-plains	daily P & Q daily P & Q daily P & Q daily P & Q (hydrograph segregation) (pathway tracers)	√ √ √ √ √ √

Criteria	Indicators	Stake-holder relevance	Empirical data P = rainfall, Q = river flow	Water balance model
3. Release gradually	3.1 Lowest of monthly river discharge totals relative to mean monthly rainfall 3.2 Fraction of discharge (1.1) derived from slow flow (> 1 day after rain event) (compare 2.3a&b)	People depending on water flows in dry season	daily P & Q (hydrograph segregation, tracers)	√ √
4. Maintain water quality	4.1 River water suitability for a. untreated drinking water (incl. bacterial (Escherichia coli) counts, absence of pollutants) b. other domestic use c. industrial use d. irrigation water e. as biological habitat (incl. BOD, COD, biological indicators) 4.2 Annual net export per contributing area of a. sediment b. nutrients (N, P) c. heavy metals d. pesticide and derivatives ('active ingredient') 4.3 Difference between mean water temperature and forest baseline	Users of river, subsurface flow or groundwater, esp. those without options for pretreatment		
5. Reduce mass wasting	5.1 Fraction of steep slopes covered by deep-rooted trees ten years ago but cleared since that time and thus subject to loss of root anchoring 5.2 Fraction of annual net sediment export per contributing area (see 4.2a) that is derived from bank erosion and riverbed deposits roadside landslides non-road related landslides current hillslope erosion paddy rice fields in valleys 5.3 Effective width of intact riparian filter vegetation integrated over stream network	People living in or depending on potential path-ways for mud flows & landslides Reservoir life span		

Hydrological functions in relation to tree cover

Tree cover, whether in the form of natural forest, remnant trees left in land clearing, partial tree cover derived from planting along field boundaries of in blocks of plantation forestry, can influence a number of steps in the pathway of water:

- The tree canopy intercepts part of the rainfall and can store a quantity of water in waterfilms around leaves and stems that will readily evaporate after the rainfall event (the amount of water involved depends on the leaf area index as well as surface properties of the leaves; it can be a considerable fraction of the rainfall in small events, but is usually negligible for large rain events that are the main concern in flooding).
- The ground vegetation and litter layer has a direct protective role in reducing 'splash' effects of raindrops that can lead to a dispersal of clay particles from soil aggregates; depending on soil texture, splash impacts can lead to a sealing of the soil surface, blocking of water entry points to the soil, as well as to the entrainment of soil particles into overland flow; the protective function of surface litter is positively related to its resistance to decomposition.
- Infiltration into the soil depends on soil structure at the surface and in various layers of the soil. Soil structure is influenced by biological activity that depends on plants (surface litter, root exudation and turnover) for their energy source; year round availability of 'food for worms' is thus important in counteracting the natural process of decay and clogging of existing macropores. The structure-enhancing function of surface litter is positively related to its ease of decomposition.
- Water uptake from various soil layers throughout the year, to support the process of transpiration from leaf surfaces. Tree phenology, root distribution and physiological response to partial water stress all influence the quantities of water used. Water uptake between rainfall events influences the amount of water that can be stored in a subsequent rainfall event, and thus feeds back ion the infiltration process and influences overland flow. Water uptake in dry periods, especially from deeper soil layers will influence the amount of water available for 'slow flows'.
- Landscape drainage is influenced by surface roughness of the soil, the presence of small depressions that increase the time available for

infiltration into the soil in what otherwise would be rapid surface runoff, and the type of 'channeling' that can occur once overland flows reach a certain magnitude and stream power that allow for a self-enhancing process of soil quick flow. In natural forests animal tracks may be the main starting points for such channeling, but generally stay below the thresholds of self-enhancing effects. Human paths and especially tracks used for wheeled vehicles or pulling of logs tend to have the continuity and intensity that enhances drainage and transfers of sediment to streams. Specific enhancement of drainage to protect crops from water-logging and/or surface water to be a hygienic risk, tend to be associated with land use change after forest conversion. The existence of wetlands and areas that can temporarily store surface water by 'flooding', plays a key role in reducing the likelihood of flooding downstream. Conversely, reducing flooding frequency upstream, increases the risks downstream.

The overall impact of forest conversion and or changes in degree and spatial pattern of tree cover in landscapes can be understood from the combination of and interaction between these processes. A number of available simulation models captures the essence of these processes and allows us to test the predicted overall outcome against empirical data sets. Existing models differ in their spatial and temporal resolution as well as in the detail of land form, soil, climate and vegetation parameters that is needed to start a simulation. Agroforestry options at plot scale can be evaluated with the WaNuLCAS model that operates at a daily time step (Khasanah *et al*, 2004). The effects of land use mosaics at landscape scale are represented in the GenRiver (Farida and van Noordwijk, 2004) and Fallow model (Suyamto *et al*, 2004) at a daily and yearly time step, respectively.

'Kebun Lindung' or 'protective garden'

The Indonesian system for forest land classification recognizes a number of 'forest functions' (conservation, watershed protection and production of wood and non-wood products) as the main reasons for maintaining forests in the landscape. Restrictions to the type of forest use that is allowed vary between these categories.

'Hutan lindung' refers to active protection functions ('melindungi') relative to downstream land areas and water flows. The earlier Dutch term ('schermbos') refers to 'umbrella' functions. The 'buffer' function (criterion 2) is directly linked to this protective function, as it reduces the levels of peak flows. The buffer function can be enhanced at the hill slope scale by water use between rainfall events and maintenance of soil structure, and at landscape scale by wetlands and areas that can receive temporary excess of surface water through 'flooding'.

The 'hill-slope' aspect of this protective function can in fact be provided by many types of vegetation cover, as long as it maintains a surface litter layer, avoids channel formation and uses water in evapotranspiration. Where natural forest vegetation is gradually replaced by trees that are preferred for their productive or other functional properties, the 'protective function' can remain intact. Clear felling of areas larger than the gaps that occur as part of the natural forest regeneration cycle, will endanger the protective function - but most of the gradual transformation of 'forest' into 'agroforest' has historically avoided land clearing at that scale.

The word 'forest' has, in the Indonesian setting, become directly associated with state control and exclusion of farmers from the land. Farmers describe their 'modified forest' or agroforest, generally as a 'kebun' or garden, emphasizing the productive and functional role of the trees present.

Efforts to evaluate such 'kebuns' in terms of the hydrological criteria and indicators, so far suggest that multistrata coffee gardens, jungle rubber, mixed fruit tree homegardens and repong damar systems do (or lat least can) meet the essential 'protective' functions at the hillslope scale. They can thus be described as 'kebun lindung' - combining protective and productive functions.

Negotiation support

Seventy percent of Indonesian land area is considered to be 'state forest land', with decisions on land access and land use made by national (especially before the 1998 law on devolution of government) or local (after 1998) levels. The relation between local communities and farmers, regardless of how long they have been in the area, and this state forest zone has a long history of conflict. Often these conflicts have lead to loose-loose outcomes, where both the conditions of the forest and the local livelihoods suffered - while the gains were made elsewhere by the beneficiaries of the legal and illegal logging industry.

The 1997 forest law with its opportunities for a more direct involvement of local communities in forest management and the various events after 'reformasi' and devolution of government, have reduced the de facto authority of the state over the state forest zone and created a situation where multi-stakeholder negotiation is a necessity as well as a major opportunity to improve the track record of land management in water catchment areas.

The case study in Sumberjaya (Pasya *et al.*, 2004) has shown that recognition of forms of 'kebun lindung' is a slow process but all current evidence points at a huge opportunity for reducing conflict and improving outcomes for all parties involved.

Discussion and conclusions

Application of the hydrological criteria and indicators to the Sumberjaya benchmark area is discussed elsewhere (Farida and van Noordwijk, 2004), while the negotiation process is described by Pashya *et al.* (2004). Criteria and indicators can only play a meaningful role in the public debate and negotiation process if they are understood, transparent and open for monitoring by the various stakeholders. The set that we propose here needs to be further tested in that sense. Our current understanding of the local ecological knowledge of soil and water movement (Joshi *et al.*, 2004) suggests that the concept of 'evapotranspiration' or 'water use' by plants does not have a direct equivalent in the local system, but that issues of rainfall, overland flow and response of rivers are understood in a similar way to their representation in the models, at least qualitatively. There is a challenge to move the dialogue with the forestry officials from a focus on 'tree planting' per se, to one that is based on measurable functions. A debate on 'functions' rather than 'control over land' has a clear political undertone that can not be easily resolved - but pragmatic solutions that are acceptable to all can emerge, as the Sumberjaya example shows. An important element in the acceptability of farmer-based solutions is the broadly shared opinion of a failure of the previous approach. Where quantitative data can help to drive that message home, the debate can make progress.

An interesting challenge to the current HKM agreements is how the results will be monitored. From a 'watershed function' perspective, research suggests that 'presence of a litter layer' is more directly linked to changes in infiltration and erosion, than criteria based on trees per se (Fauzi *et al*., this volume). Local monitoring of water quality provides another entry point, and has been successfully used in northern Thailand (Thomas *et al*., 2003) and the Philippines.

Overall our conclusion is a hopeful one: it is likely that recognition of 'kebun lindung' can help resolve current conflict by refocusing the 'watershed management' debate on measurable functions rather than perceptions of an intrinsic need for 'forest cover'. The public debate on this issue needs to be stimulated to gain a broader platform for 'result-based natural resource management', to replace the current focus on unrealistic targets.

Environmental Services of Agriculture and Farmers' Practices Worth Rewarding

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Agricultural functions in producing food, timber, fiber, and various other marketable products have long been known by policy makers and the population at large. Other functions of the agricultural landscape, however, such as environmental services, food security, employment of about 40% of the 99 million labor force in Indonesia, buffer of the country's economy at times of crisis, and maintenance of rural amenities get less recognition than they deserve. This paper reviews environmental services as part of the multifunctionality of agriculture and discusses whether rewarding farmers for those services is justifiable. Discussion is focused on the major agricultural systems including lowland rice, annual upland farming, smallholder plantation, and monoculture estate, as well as on conservation practices within the systems. The main indicators discussed include soil erosion and sedimentation, flood mitigation, carbon sequestration, and biodiversity. As forest is converted to agricultural lands, some of its environmental services disappear. The nature of the succeeding agricultural systems determine the degree of recovery of the services. Further conversion of agriculture to industrial and settlement areas, results in subsequent and mostly irreversible disappearance of agricultural environmental services. Lowland rice fields can filter sediment from the surface flows in a landscape and contribute to flood mitigation; two important functions in areas upstream of flood-prone areas. Smallholder plantations, characterized by complex agroforestry systems, sustain various positive functions including erosion control, flood mitigation, carbon sequestration, and biodiversity. Monoculture tree-based systems are low in biological diversity but they can still contribute in sequestering carbon, flood mitigation and erosion control. Annual crop-based farming systems

have relatively low erosion control, flood mitigation, biodiversity and carbon stock. Intensive vegetable farming, being mostly distributed on steep slopes with high chemical inputs, threatens water quality in the area downstream and may contribute to sedimentation depending on the overall filter functions of the catchment. With the high and increasing population pressure, the demands for using the lands, including the less suitable ones for agriculture as well as for settlement and industry, also increase and the environment is more and more threatened. Therefore, the environmental services become scarcer and more precious. Farmers' services in the forms of practicing environmentally benign farming systems and implementation of conservation practices such as life fences, grass strip, and modification of micro relief (sediment pits, terraces, furrow-ridging) within a fragile environment deserve recognition and rewards from the beneficiaries. Furthermore, the government can increase effectiveness of incentives for two-pronged (economic and environment) practices, for example, by realignment of the funds of national land rehabilitation movement.

Introduction

Beyond its primary function of supplying food, fiber and other marketable products, agricultural activity can also shape the landscape, provide environmental benefits such as land conservation and preservation of biodiversity, contribute to food security and maintain amenities of rural areas (OECD, 2001; Agus and Manikmas, 2003). Agriculture is a safety net for employment and source of income of about 40% of 99 million Indonesian workforce (BPS, 2004). These additional functions (multifunctionality) are not recognized in the current market system and mostly remain external to government policy decisions. Intensification (the use of more labour, energy and agricultural inputs per unit of land to achieve higher outputs per unit area) and extensification (the use of a larger area) of Indonesian agriculture has been able to increase the production of food and fiber although the total production has not met the demands of the entire ever-increasing population, and thus import is inevitable to fill the deficits.

Agriculture produces positive environmental functions - at least in many cases environmental degradation is not as severe as it might be, although these positive aspects are usually not recognized and rewarded as such. Policies in natural resource management systems that enhance the positive and minimize the negative functions are the key to the sustainable use of natural resources.

Environmental services and other functions are essentially contributions made to society at large free-of-charge by farmers, the majority of whom still remain among the poorest and marginalized communities. There are many disincentives in farming in the forms of recurrent market failures, policies biased towards non-agriculture, unavailability or unaffordability of agricultural inputs, and problems with infrastructure and marketing. Farmers also face hardships because of unpredictable weather and pests and disease problems.

So far, there has been limited documentation on environmental functions of agriculture in Indonesia. Deeper and more convincing research-based knowledge is necessary to increase awareness among policy makers as well as the entire communities on the multifunctionality of agriculture. Comprehensive study and policy papers on the improvement of positive functions and reduction of negative externalities will hopefully lead to a more judicious and unbiased policy formulation, i.e. the policies that can promote practices for both economic and environmental improvements. This paper discusses environmental services of different agricultural systems and practices and systems that deserve rewards.

Environmental services of agriculture

There are many kinds of environmental services that agriculture can provide. These include the functions of erosion control, flood mitigation, water preservation, heat mitigation (Agus *et al.*, 2001), preservation of biodiversity, and carbon sequestration. The following section will discuss selected functions.

Erosion and sedimentation under different land management systems

Sutono *et al.* (2003) used the universal soil loss equation (USLE) to calculate annual soil loss under different land use systems in the Citarum River Basin (Table 1). Please note that the results of this equation apply to a particular scale of measurement and cannot be directly used to estimate net soil loss from larger areas, as landscape-level deposition in 'filter' areas can reduce the net soil loss per unit area. The plot-level prediction used primary and secondary available data in the river basin area and as such, not only land use and management systems (soil cover and management systems, the C and P factors) differed but also other factors such as slope, rainfall erosivity, and soil erodibility depending on the spatial variation of the latter properties. In general, it was shown that the annual upland crop system has the highest soil loss, followed by intercropping of annual upland crops with trees.

The annual upland crop system in general is a rotation or a relay planting of food crops such as cassava, maize, peanuts, soybean and upland rice or intensive vegetable farming systems that usually coincides with steep slopes. Because of minimum soil protection by crops most of the year, these annual upland farming systems are very prone to erosion. Tea plantation gives rather high soil loss because of incomplete soil cover which lead to a high crop factor, the 'C' factor, apart from the fact that it is also usually found on steep slope areas. Paddy fields and forest have the lowest soil loss because of terrace and dike systems of the former and the thick and multi-storeyed vegetation of the latter.

Van Dijk (2002) reviewed literature data on catchment scale erosion research (Table 2) that show a general agreement with the predicted values in Table 1. In general, forest catchments have the lowest sediment yield except for teak forest (with almost clean understorey). Vegetable based system have the highest sediment yield. The systems associated with intensive annual cropping on steep slopes also contribute to a high bed load in the streams and rivers due to a limited filter function of the catchment.

The role of trees and grass strips

Under similar rainfall amount and pattern (the research catchments were within 1 km radius), Agus *et al.* (2002) derived sediment yield data from Tegalan (a 1.1 ha catchment dominated by annual upland crops), Rambutan (a 0.9 ha catchment covered by 10 year old Rambutan, Nephelium lappaceum trees), and Kalisidi (a 13 ha catchment also covered by rambutan but with some annual crop planting on the lower part of the catchment) (Figure 1). The total sediment yield for Tegalan, Rambutan, and Kalisidi catchments were 20, 1.7, and 2.9 Mg ha^{-1} under annual rainfall of 3800 mm indicating that orchard farming can substantially reduce soil loss.

Because of the high sediment yield under intensive annual upland crop the use of fodder grass in conjunction with cattle fattening activity was introduced in December 2001 and the result shows a reduction of sediment yield for Tegalan in 2002 compared to 2001 (Figure 1). Total annual rainfall was slightly lower in 2002 than 2001 (3100 mm vs 3800 mm). As the grass cover develops, its effectiveness in controlling erosion is increasing. On the other hand, cassava planting on the part of the floor of Rambutan orchard in Kalisidi catchment (because of encroachment by local villagers) loosens soil aggregates and exposed it to rain and canopy drops and thus contributed to the increase in sediment yield.

Similar to the case of Rambutan, coffee also contribute in decreasing soil loss. Based on plot-scale experiments, Pujiyanto *et al.* (2001) showed that soil loss was very high for plots without any conservation measures in the first two years after coffee planting because the canopy cover is relatively limited. During the first two year period, conservation practices such as bench terrace and hedgerows were effective in reducing erosion. Beginning in the third year, however, soil loss became negligible due to effective canopy closure and conservation measures did not give any effect whatsoever (Table 3).

Table 1. Predicted soil loss of different land use systems in Citarum River Basin.

Land use	**Catchment**		
	Saguling (uppermost)	**Cirata (upper)**	**Jatiluhur (lower)**
	Mg ha^{-1} yr^{-1}		
Forest	0.1	0.2	0.1
Intercropping of annual crops with trees	8.4	15.4	36.9
Rubber plantation	-	8.8	11.4
Paddy field	0.3	0.4	1.4
Shrub	1.1	1.6	0.5
Annual upland crops	22.0	61.3	40.1
Tea plantation	23.1	26.9	9.6

Table 2. Runoff coefficient (RC), Sediment yield (SY) and bed load percentage observed from different catchments in Indonesia as cited by van Dijk (2002) from several references.

Land use	Catchment Size	Period of measure-ment	RC (%)	SY Mg $ha^{-1}yr^{-1}$	Bed load %
Forested					
Rainforest	45 km^2	3 years	-	7	-
Rainforest	1-45 km^2	-	-	4-7	-
Rainforest	-	-	-	4	-
Mixed plantation forest	3-12 km^2	3 years	2-6%	0.4-4	1-10%
Pine plantation	18 ha	-	-	0.4-2	-
Agathis plantation forest	20 ha	-	-	4	10%
Teak forest	79 km^2	1 year	-	73	-
Other land uses					
Vegetables on steep terraces	10 ha	3 years	17%	42-75	-
Vegetables on steep terraces	3 ha	4 months	12%	87	5-10%
Logged pine plantation forest	32 ha	-	-	34	-
Logged rainforest	-	-	-	51	-
Mixed (agriculture, forest)	12-22 k km^2	3 years	3-10%	10-12	8%
Agriculture on bench terraces	8-20 ha	1 year	3-9%	19-25	5%
Agriculture on bench terraces	18 ha	-	-	12-14	74-80%
Agriculture on bench terraces	0.1-125 ha	6 years	6%	40	30%

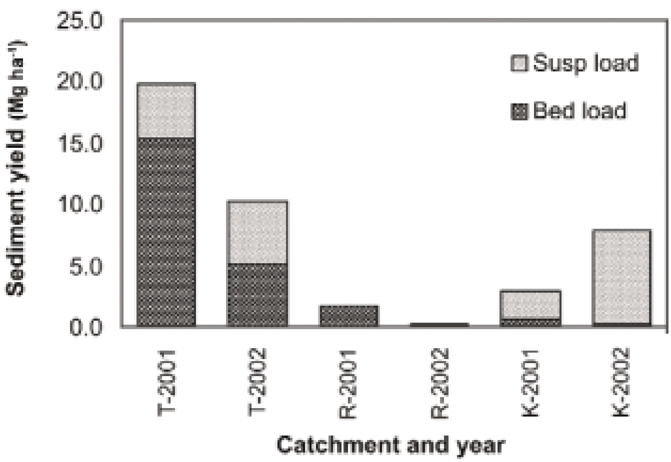

Figure 1. Suspended load and bed load yielded in 2000/2001 (denoted as 2001) and 2001/2002 (denoted as 2002) rainy seasons for Tegalan, T (annual upland catchment); Rambutan, R (rambutan orchard catchment); and Kalisidi, K (rambutan orchard catchment with some cassava on the floor). (Agus *et al*., 2003).

Table 3. Effects of bench terrace and hedgerow planted along terrace lips on soil loss at coffee farm in Jember, East Java on land with slope of 31% and annual rainfall of 2,768 mm during the first four years after coffee planting).

Treatment	Soil loss (Mg ha^{-1} year^{-1})			
	Year 1	Year 2	Year 3	Year 4
Control (no terrace)	25.80 ab)	17.75 a	0.55 a	0.88 a
Bench terrace	1.51 b	1.17 b	0.35 a	0.82 a
Terrace + L. leucocephala	3.03 b	1.19 b	0.28 a	0.82 a
Terrace + V. zizonioides	1.90 b	0.61 b	0.28 a	0.83 a
Terrace + M. macrophylla	0.33 b	0.88 b	0.21 a	0.83 a

a) Source: Pujiyanto *et al*. (2001).
b) In one column, numbers followed by common letter are not significantly different as tested using the Tukey test at the 5% significance level.

Widianto *et al*. (2002) based on erosion measurement in Sumberjaya, West Lampung, evaluated soil loss under forest and different stages of coffee development. This plot-scale measurement was conducted at scattered location and therefore, the effect on soil loss is not only determined by land use and coffee growth stages, but could also be by variation in rainfall amount and soil properties. Nevertheless, the trend in soil loss as found by Widianto *et al*. (2004) is in agreement with that of Pujianto *et al*. (2001) (Table 3).

In Sumberjaya sub district, Lampung, Dariah *et al*. (2004) recorded similarly negligible (less than 2 Mg ha^{-1} yr^{-1}) soil loss under 3 year coffee cover and annual rainfall amount of 2400 mm and the slopes of 50-60%. As such, different conservation techniques they tested did not give significant effects. Earlier on, Gintings (1982) measured soil loss at the same sub district for six month period with the rainfall of 1338 mm on slopes reaching 60%. The author found that soil losses for the six month period were 1.9, 1.6, 1.3, and 0.3 Mg ha^{-1} respectively for land covered by 1, 2, and 16 year old coffee and by virgin forest. The whole year soil loss is expected to be no more than twice as much since average annual rainfall is about 2400 mm.

These research findings consistently show that tree-based systems is an effective erosion control measure. Coffee and rambutan cases, above, exemplify the systems that are not only environmentally save, but also relatively profitable.

Paddy Field as a sediment filter

Soil loss measurement from terraced paddy field system in Ungaran, Central Java, on land with major slope of about 25% revealed that sediment leaving the paddy system is very small (<1.5 Mg ha^{-1} $season^{-1}$) and more than 50% of the erosion occurred during and shortly after tillage operation (Table 4). During the erosion observation, mud (particles and aggregates suspended during tillage) transported to only a few terraces downward and this means that particles reaching the stream originate from only a few series of plots / terraces above the streams. Water flow only occur when the water level in the plot exceed the normal water level of 5 cm during the vegetative stage of rice plant. If water level during and shortly after tillage operation can be controlled such that no or only little outflow of water is allowed, erosion from paddy field could further be minimized. Table 4 also shows a net sediment deposit in the paddy field. This means that paddy field can function as a landscape filter.

Table 4. Amount of sediment entering and leaving a series of 18 terraced paddy fields (ranging in size between 12 to 358 m^2, with a total area of 2515 m^2 in two rice seasons (first season was 31 October 2001 to 31 January 2002 and second season from 16 March to 1 July 2002).

Variable	**Rice season**	
	First	**Second**
Duration of observation (day)	62	69
Sediment budget:		
Total sediment entering the system from irrigation canal (Mg ha^2)	3.4	6.2
Total sediment leaving the system (Mg ha^2)	1.4	0.8
Total sediment leaving the system during tillage operation (Mg ha^2)	0.7	0.6
Net sediment deposition (Mg ha^2)	2	5.4

Source: Adapted from Kundarto *et al.* (2002).

Water retention

Agus *et al.* (2001) estimated water retention capacity of several land use systems in Citarum watershed in West Java and Agus *et al.* (2003) evaluated the flood mitigation role of paddy farming for the same case study area using the replacement cost method and the travel cost method.

Water retention capacity (Buffering capacity, BP) is the watersheds capacity to absorb and hold (rain) water. Only rainfall in excess of this water retention capacity will flow as runoff water during and shortly after every rainfall event (Nishio, 1999). The water retention capacity includes water that can be absorbed by soil pores, water that can be stored by ponding on the soil surface, additional water that can be stored by paddy fields, dams, etc. and water intercepted by plants. In essence, this property indicates the flood mitigation capacity of each land use systems. Agus *et al.* (2003) found that tree-based farming systems maintain most of the flood mitigation capacity exerted by forest. Paddy fields, with their terrace and dike system behave like small dams in collecting and ponding water and thus have similar water retention capacity as tree-based agricultural systems (Figure 2).

Furthermore, Agus at al. (2003) discussed that the marketable products of the 157,000 ha paddy field within the 696,000 ha total area of the watershed represented a total value of around $181 million annually and the value of flood mitigation role accounted for about 10% of this amount (about $18 million per year). The total values of flood mitigation, conservation of water resources, soil erosion control, organic waste disposal, rural amenities, and heat mitigation accounted for about 51% of the marketable rice value (about $92 million per year). The current market system only recognizes rice as the product of agriculture and ignores the by-products (externalities).

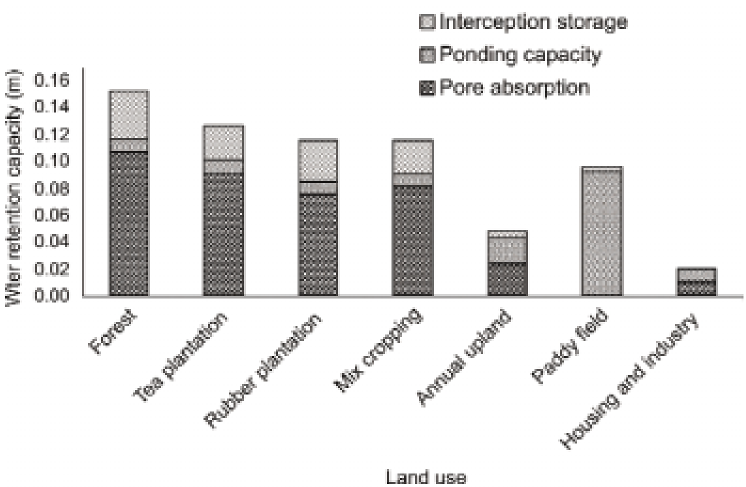

Figure 2. Water retention capacity (capacity of the system to hold water temporarily before runoff occur) of different land use systems in Citarum River Basin (Agus *et al.*, 2003).

Carbon sequestration and biodiversity

The main source of CO_2 in Indonesia is forest conversion which, in many cases, involves burning (Ministry of Environment, 1999). CO_2 emission from forest conversion is much higher than from fossil fuel combustion.

Among agricultural land uses, tree-based farming systems have the highest while annual food crop system have the lowest carbon stock (Table 5). Efforts to maximize carbon storage include diversification of food crops with trees or the adoption of agroforestry system. For coffee system in Lampung Sumatra, the mean annual increment of C-stock of mixed coffee systems is about 1.9 Mg ha^{-1} yr^{-1} during a typical production cycle, and that of a monoculture coffee system was about 1.0 Mg ha^{-1} yr^{-1} (Tomich *et al.*, 2001; van Noordwijk *et al.*, 2002). Combination of various crops in complex agroforestry systems are common under smallholder farmers not only in Sumatra and Kalimantan where the so called "rubber agroforest" or "rubber jungle" is common, but also in Java where the annual food crop are planted in association with various species of perennial tree crops.

In the forest margin of Sumatra, plots of traditional agroforestry systems can inhabit plant species approximating the number of species in forest. As agriculture intensifies it is dominated by monoculture farming system that, in many cases, have negative impacts in sustaining biodiversity (Table 5).

Practices worth rewarding and mechanism for technology selection

Land us systems differ in the environmental services they provide, depending on the specific management practices used. Practices that deserve rewards are those producing services needed by the community. For example, if flood is the recurrent and growing problems in the downstream, then every practices for increasing or at least maintaining the water retention function of the landscape, deserve rewards. In this case, linking the problems with the farmers' practices that can maintain or increase services to solve such problems is an essential process. This process include identification of watershed-specific problems, identification of interventions that have been or could be done by the farming community to solve or alleviate the problems, selection of most do-able practices and provision of guidance and incentives for implementing new practices. Location-specific solutions developed by farmers themselves, with or without external support, are superior to the conventional blanket recommendations. The 'extension' challenge is to facilitate and speed up the process of local learning.

Table 5. Carbon sequestration and biodiversity for the Forest Margins of Sumatra

Land use	Carbon sequestration	Biodiversity
	Time averaged C stock (Mg ha^{-1})	Plant species/ standard plot
Natural forest	254	120
Community- based forest management	176	100
Commercial logging	150	90
Rubber agroforest	116	90
Rubber agroforest w/ clonal planting material	103	60
Rubber monoculture	97	25
Oil palm monoculture	91	25
Upland rice / bush fallow rotation	74	45
Continuous cassava degrading to Imperata	39	15

(adapted from Murdiyarso *et al*., 2002)

Participatory rural appraisal - a survey technique in which farmers and extension workers communicate iteratively about the local farming systems, including the prospects and constraints - has officially become a standard procedure in the technology-selection process of development projects in Indonesia. However, in practice, recommendations found in many demonstration units or development projects have not reflected the diverse biophysical and socio-economic backgrounds of farmers but appear to be still dominated by standard recommendations. For example, slope gradient has been regarded as the main criterion for determining the number of trees per unit area. Lands with slopes gentler than 25%, between 25 and 40%, and steeper than 40% are 'reinforced' with 100, 200 and 400 trees ha^{-1} to give 25%, 50% and 100% tree canopy cover, respectively (unpublished 1996 Regreening and Reforestation Guidelines issued by the Central Guidance Team of Regreening and Reforestation). Wider issues, such as existing tree stands, subsistence mode of farming, insecure land tenure that forces farmers to invest in activities with fast returns, and inaccessibility to markets, have not been fully considered in technology selection. Tree planting is acceptable to farmers as long as it does not distort existing annual crop based farming. For those with insecure land tenure, however, getting a fast return on their investment is a lot more important than any other consideration (Agus, 2001).

Management options should address the main issue at stake, and thus start from thorough analysis of cause-effect relations, but should also be viewed from their effect on farmers' basic necessities. Thus, it's very important to have an open and transparent dialogue or negotiation among stakeholders to analyze the problems, possible causes, and problem-solving or alleviating options (van Noordwijk at al., 2004; this volume). Examples of links between watershed problems, causes and management options are given in Table 6. Some of the causes of the problems are natural. These include untypical long dought or excessive

Table 6. Selected watershed problems, causes and management options

Problems	Possible Causes	Problem solving or alleviating options
Significant reduction of water volume (subsidence of water level) in lakes	Long drought	Implementation of drought mitigation measures
	Artificial increase of volume of water output from the lake, such as through dredging of river bed or tunneling water out of lake for hydroelectricity, industry and irrigation.	Increasing inflow into the lake by reducing evapotranspiration in the lake catcment. Sparing water use
Decreased capacity of lakes and dams	Erosion (including stream bank erosion) from the watershed, followed by sedimentation.	Improving plant cover in the catchment Grass strips Establishment of riparian zone Protection of unstable stream bank
Flood	Excessive rainfall	Construction of flood mitigation structures such as dam and flood canal
	Reduced water retaining capacity, reduced infiltration capacity	Enhancement of infiltration and percolation through construction of water retardation ponds and pits Increasing water consumption in the catchment, for example, by tree planting Protection of soil aggregate breakage by mulching, plant cover, and maintenance of plant litter on soil surface
	Clogging of or insufficient drainage system	Maintenance and construction of new drainage system.
	Sedimentation	Improvement of landscape filter through plant cover, life fences, agroforestry, paddy field systems, etc.

rainfall. Some causes are anthropogenic, including improper land use, artifical intervention of ecosystem balances such as by channelling water out of lake.

Conclusions and policy implications

With a high population pressure and growth of 1.6% per year, there is a strong pressure for intensifying agricultural systems and for extending agriculture even to unsuitable steep slopes and marginal lands for producing enough food, wood and fiber and for providing income opportunities. At the same time, land is also needed for settlement, industrial and infrastructural developments. As land from forest is converted to agriculture and agricultural lands are converted to other non agricultural uses, many environmental services tend to disappear and thus the services will become more precious necessities.

Different agricultural systems provide also different environmental services. Smallholder plantations, characterized by complex agroforestry systems, sustain various positive functions including erosion control, flood mitigation, carbon sequestration, and biodiversity. Monoculture tree-based systems lose numbers of species although it can still contribute in sequestering significant amount of carbon, mitigate flood, and control erosion. Intensive paddy farming system has been able to control erosion to a level as low as that of forest. Monoculture annual crop-based farming systems have a low erosion control, low biodiversity and carbon stock but techniques to develop the systems into a more environmentally-benign practices are available, although are not necessarily affordable by farmers.

Traditional agricultural systems and practices maintain significant services, but farming faces lots of disincentives related to supplies, marketing and infrastructures. Since the needs for agricultural products and environmental services are increasing and both are not mutually exclusive, rewarding the farmers, as the environmental service providers, is indeed justifiable. The beneficiaries of the services and government should participate in this endeavor. Government support could be realized through realigning of the current budget of land rehabilitation and conservation to a more problem solving and people oriented approach such that it can contribute in increasing environmental services while providing a better livelihood for farming communities.

Criteria and indicators of watershed management used for the National Movement for Land and Forest Rehabilitation (GNRHL) in Indonesia

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Flood and drought do not occur only in watersheds in which forests have been cleared. They also occur in watersheds with good forest cover, because the forest has limitations to store water during heavy rain. On the other hand, the conversion of land from natural forest to a tree plantation has the potentials to decrease the water supply in the downstream, especially in the dry season. Therefore, forest management must be linked to the watershed management.

To estimate the success of forest and watershed management, criteria and indicators are needed in conducting the monitoring and evaluation processes. This paper aims to illustrate the criteria and indicators of watershed management currently used in Indonesia and their connection with the criteria and indicators of the sustainable forest management and also the influence of land and forest rehabilitation on the watershed performance.

Three main criteria, referring to land, water, and humans, respectively, are used in the monitoring and evaluation process of watershed management. Sustainable forest management has three types of criteria: production, environmental services and social welfare. Although the criteria and indicators used in sustainable forest management have included the criteria of environment, the management and evaluation units have not yet been decided. Forest management using watershed as management units will simplify the management as well as monitoring and evaluation processes. Based on the criteria and indicators of watershed management, the current

program of land and forest rehabilitation can potentially improve the watershed condition by 67% using the numerical indicators that will be explained in this chapter.

Introduction

Floods and drought come alternately, depending on the rainfall and the characteristics of the watershed. Both are usually signs that damages has occurred in the watershed. In a damaged watershed, the proportion of rainwater transformed into overland flow will increase and only a little rainwater will infiltrate. The potential result is that only a little water becomes available to flow in the dry season.

The capability of the watershed to retain rainwater and to release it in the dry season depends on its biophysical condition. One of the factors that influence it is the land cover. Forest cover can reduce the speed of overland flow and increase infiltration, so that a lot of water will be saved under the soil surface and will be available for slow flows. This could maintain the continuity of the flow for the whole year.

However, flood also occurs in areas in which the upland is covered with forests, such as Jambi, Bohorok, and Pacet. Research shows that forests have limitations in preventing flood. When a long and intensive rain occurs, a forest can no longer absorb additional water. According to Sudjoko *et al.* (1998), when a rain has duration of 5.5 hours and has an intensity of 114 mm / hour, the capacity of the forest as a flood preventor will be exceeded.

Moreover, droughts also often occurred in uplands covered with forests such as the ones occurred in Kebumen, Cilacap, and Purworejo. The forests in those areas are pine plantations. Generally, the upper lands were teak forests and mixed jungle. After being replaced with pines, a shortage of water emerged in the downstream. It occurred because those areas have a dry climate with a rainfall of lower than 2000 mm yr^{-1} and they were planted with trees that have high water need (evapotranspiration) so that the remaining water is decreased. The result is that the people downstream suffer the shortage of water especially in the dry season.

The success of the watershed and forest management can be seen from the result of the monitoring and evaluation process with the use of fixed criteria and indicators. This article aims to illustrate the criteria and indicators of the watershed management and to what extent the Land and Forest Rehabilitation Movement (GNRHL) can potentially improve the watershed performance.

Criteria and indicators of watershed management

Watershed management is an effort of the people to control the mutual connection between the natural resources and human beings in the watershed and all their activities, with the purpose of establishing the preservation and the harmony of the ecosystem and to continuously increase the usefulness of the natural recourses for the people (BTP DAS 2001). The role of natural resources in the form of land and water is so important in human existence that the usage should be regulated so that it can be optimal and long lasting. The watershed is a collection of land units. The managers of the natural resources need to consider all the functions of the units. Watershed management comprises planning, implementation, and monitoring and evaluation steps.

In monitoring and evaluation, criteria and indicators that can reflect the watershed condition should be set. The criteria used in the monitoring and evaluation of the watershed management can be classified into three: land management, water management, and human resources management in connection with the natural resources. The percentage of each criteria and indicator depends on the objective of the watershed management in a particular area. In the current practice of prioritizing watershed for management interventions the following percentage are used: a land criterion is weighed for 40%, a water criterion for 40%, and a human resources criterion is the remaining 20%.

Land management

Land management is very influential in affecting watershed functions. The land criteria have a percentage of 40% in the overall prioritization. The main indicator in the land management category is the evidence of current erosion processes. The overall land condition as derived from soil conservation interventions and the cropping systems that are being practiced is considered as additional factor. The percentage of each indicator can be seen in Table 1.

Table 1. Weights of each indicator of land criterion.

Indicator	Weight	Total Weight
1. Current erosion		25
2. Land Condition		5
a. Soil Conservation Interventions	2.5	
b. Cropping System and Pattern	2.5	
3. Land use plan		10
a. Index of Land Use Planning	5	
b. Index of Permanent Land Cover	5	
Sub Total of Land Criteria		40

Water management

Water management is reflected in the output of a watershed. This water criterion has a percentage of 40%. The indicators in the water management comprise flood and drought, sedimentation, water quality, and the fluctuation of the ground water surface. The percentage of each indicator can be seen in Table 2. The ratio of maximum and minimum daily flow is used as indicator of the flow regime. The smaller this ratio, the more the river approaches the ideal continuous flow. The coefficient of variation is the comparison between the standard deviation of the annual total flow and the average annual total flow. The water use index is the comparison between the water needs for irrigation, domestic and industrial uses and the water supply. The smaller the score for this index, the less critical its condition is.

Sedimentation is measured in lakes or reservoirs. Water quality is measured for its physical, chemical and biological aspects. Indicators of physical quality include color, total suspended load and turbidity. The chemical characteristics include pH, Electrical Conductivity (EC), NO_3^-, SO_4^{2-}, PO_4^{2-}, K^+, Na^+, and Ca^{2+}. Finally, the biological characteristics include Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD).

Table 2. Weights of each indicator of water criterion.

Indicator	Weight	Total Weight
1. Flood and Drought		15
a. Ratio of maximum and minimum river flow	7	
b. Coefficient of inter-annual variation of river flow	5	
c. Water Use Index	3	
2. Sedimentation in lakes and reservoirs		12
3. Water Quality		9
a. Physical quality	3	
b. Chemical quality	3	
c. Biological quality	3	
4. Fluctuation of Ground Water		4
Sub Total of Water Criteria		40

Human resources management in correlation with the natural resources.

Human resources management is one of the criteria that determine the success of watershed management. The human resources criteria have a percentage of 20%. The indicators in the human resources management includes the level of dependence on land use, land ownership, institution of the watershed management, conservation adoption, and the people's income. The percentage of each indicator can be seen in Table 3.

Table 3. Weights of each indicator of human resources criterion.

Indicator	Weight	Total Weight
1. Dependence on land		5
2. Land tenure		3
3. Institutionalization of watershed management		4
a. Community Organizations	3	
b. Conflict	1	
4. Culture		7
a. Conservation norms	3	
b. Adoption of conservation technology	4	
5. People’s income		1
Sub-total of human resource criteria		20

Evaluation standards

Measurable parameters for each indicator are specified in Table 4. For each parameter a qualitative score was defined as good (= acceptable), fair (=problematic) or poor (= critical), to make them comparable in the overall indicator of 'critical watershed' condition.

Table 4. Parameters used as indicator of the condition of a watershed and the qualitative score assigned (1 = acceptable, 2 = problematic, 3 = critical watershed condition)

Criteria	Indicator	Parameter	Evaluation Standard	Score
Land	Erosion	Slope class (%)	<8 8-25 >25	1 2 3
		Solum depth (cm)	>50 20-50 <20	1 2 3
		Visible signs of erosion	None Some Much	1 2 3
		Quality of soil conservation practices	Standard Below standard None	1 2 3
	Soil Conservation Interventions	Fraction of land with soil conservation practices (%)	>70 50-70 <50	1 2 3
	Cropping system and pattern	Crop cover as percentage of total agricultural lands (%)	>80 60-80 <60	1 2 3
	Index of Land Use Planning	Match between land use and land capability	>70 50-70 <50	1 2 3
	Index of Land Cover	Vegetated land relative to total watershed area (%)	>40 30-40 <30	1 2 3
Water	Ratio of maximum and minimum river flow	Maximum flow divided by minimum flow	<50 50-120 >120	1 2 3
	Coefficient of inter-annual variation of river flow	Standard deviation of annual flow total divided by the mean	<0.1 0.1-0.3 >0.3	1 2 3
	Water Use Index	Water demand for extraction divided by water supply	<0.5 0.5-0.9 >0.9	1 2 3
	Sedimentation	Sedimentation (mm $year^{-1}$)	<1 1-2 >2	1 2 3

Criteria	Indicator	Parameter	Evaluation Standard	Score
	Physical water quality	TDS (total dissolved sediment) (mg L^{-1})	<250 250-400 >400	1 2 3
	Chemical water quality	pH	6.5-7.5 5-6.5 or 7.5-8.5 <5.5 or >8.5	1 2 3
		Electric conductivity (EC) (ì mhos cm^{-1})	<500 500-2000 >2000	1 2 3
	Biological water quality	Biological oxygen demand (BOD) (mg L^{-1})	<5 5-10 >10	1 2 3
	Fluctuation of ground water level	Difference in ground water level in dry and wet season (m)	<5 5-10 >10	1 2 3
People	Dependence of income on agri-cultural land use	Contribution of farms to total household income (%)	<50 50-75 >75	1 2 3
	Land tenure	Cultivator as Owners (%)	>75 25-75 <25	1 2 3
	Community organization	Institutions involved in local soil conservation efforts	Functioning Not functioning None	1 2 3
	Conflict	Conflict of Natural Resources Utilization	None Handled Not handled	1 2 3
	Norms	Social norms in soil and water conservation	Clear Not clear None	1 2 3
	Adoption	Farmers understanding & action in soil conservation	Done Not Done Don't know	1 2 3
	People's income	Total income divided by BPS poverty standard	>BPS standard =BPS standard <BPS standard	1 2 3

Criteria and indicators of forest management

Forests are considered to be regulator in the hydrological cycle and as such are an important component of the landscape. The general expectation is that forests can prevent floods (except for exceptional rain events) and drought. Moreover, the forest is also a wood producer that for several decades contributed the second largest foreign exchange earnings of Indonesia after oil. If it can be well managed, it will have two functions: as a foreign exchange supplier and as the regulator of water. To manage the forest well, management steps such as planning, harvesting, monitoring and evaluation are needed so that they can be the basic of further planning.

Several institutions, local and international have established criteria and indicators for 'sustainable forest management'. Generally, in the sustainable forest management, there are three criteria: production, environment, and socio economic condition of the people living in the area.

The Ecolabel Institute for Indonesia (LEI, 1999) has developed criteria for ecosystem stability which consist of eleven indicators. They are:

1. The proportion of protected area that is functioning properly, as confirmed and/or recognized by relevant stakeholders.
2. The proportion of well-designed protected area that is protected and has already been delineated in the field.
3. The intensity of damage in protected areas
4. The condition of floral and/or faunal diversity in protected areas in various forest formations/types within the management unit
5. The intensity of damage to forest structure and plant species composition
6. The intensity of damage to soil caused by management activities
7. The intensity of damage to water management caused by management activities
8. The effectiveness of management on stand/forest structure and composition
9. The effectiveness of management activities on soil quality
10. The effectiveness of management activities on water
11. The effectiveness of education and extension on importance of forest ecosystems as support systems and the impact of overharvesting activities on forest ecosystems

ITTO have written indicators of the health of the forest ecosystem as follow:

1. Extent and percentage of total forest area managed primarily for the protection of soil and water.
2. Extent and percentage of area to be harvested for which off-site

catchment values have been defined, documented and protected before harvesting.

3. Extent and percentage of area to be harvested which has been defined as environmentally sensitive (e.g. very steep or erodible) and protected before harvesting.
4. Extent and percentage of area to be harvested for which drainage systems have been demarcated or clearly defined and protected before harvesting.
5. Percentage of length of edges of watercourses, waterbodies, mangroves and other wetlands protected by adequate buffer strips.
6. Existence and implementation of procedures to identify and demarcate sensitive areas for the protection of soil and water.
7. Availability and implementation of guidelines for forest road lay-out, including drainage requirements and conservation of buffer strips along streams and rivers.
8. Availability and implementation of harvesting procedures:
   (a). to protect the soil from compaction by harvesting machinery, and
   (b). to protect the soil from erosion during harvesting operations.
9. Existence and implementation of procedures for assessing changes in the water quality of streams emerging from production forests as compared with streams emerging from the same forest type kept free from human intervention.

From the above items we can see that the criteria for sustainable management of the forest stresses on the environmental aspects, especially the watershed environment and impacts on the soil condition. The management of forests that is influential in the watershed management among others are: the proportion of the forest area in a watershed, the spatial distribution of forest in a watershed, and the matching of tree species and forest types to the environment.

The proportion of forest and spatial distribution in a watershed

The Forestry Law No.41 1998, article 18, states that the minimal proportion of forest in a watershed is 30%. Although this number is not supported by the research results in tropical countries, it is considered to be sufficient, as long as the forest is of good quality.

Several results of research show that the annual water yield changes when the vegetation changes in a watershed. Land use change that causes the decrease of evapotranspiration will increase the water yield. Evapotranspiration can decrease along with the conversion of the structure and composition of the vegetation in a watershed (Brooks *et al.*, 1991). Research results on the effect of partial forest clearing on water yield in Malaysia, summarized by Bruijnzeel (1990), showed that a decrease in forest cover generally will increase the water yield. We can expect the same for conversion from forest to agriculture. However, these research results only show changes in annual water yield, not the pattern of daily or monthly distribution of flows. The desirable degree of forest cover in a watershed is very much influenced by the purpose of the watershed in a particular area.

The fraction of forest cover only gives the first indication of the function. The spatial distribution of forest in a watershed also determines the degree of protection of water resources. Forests will be most effective if they are situated on steep slopes and in riparian zones on both sides of the river (LEI, 1990 and ITTO, 1992).

Matching tree species and forest types with the environment

Forests differ in their effects on the water balance. Conversion of natural forest into tree plantation of Eucalyptus creates many problems like the ones reported from India, Thailand and Indonesia. Another example is the conversion of natural forest into pine forest in southern part of Central Java which also created shortage of water for the people downstream. The people started to complain after the planting of pine forest.

If we look at it in details, forest will influence the pathway of water from the rain through the canopy of trees until it is absorbed by the soil and finally reaches springs or rivers, as discussed in Chapter 1. According to Priyono and Siswamartana (2003), the influence of forest on hydrology can be classified into 4:

- A concentration of interception, throughfall, and stemflow,
- The change of soil humidity and the change of ground water.
- The change of the physical character of the soil. The soil under the forest has a higher infiltration, and better soil structure.
- The change of characteristics of the river flow. The river flow that comes out from forest is likely to have low fluctuations between maximum and minimum volume.

Evapotranspiration of various kinds of plantation forest vary. Therefore, in large scale planting of new plantation forest (exotic) it is advisable that we take into account the local climate condition, especially the rainfall. If the trees to be planted has a higher evapotranspiration level than the previous vegetation it replaces, there is a possibility that the area will suffer from lack of water. *Pinus merkusii* forest is better grown in areas that have an annual rainfall of >2000mm.

Forest and land rehabilitation

Forest and land rehabilitation activities

The rate of forest damage and the increase in area of degraded land in Indonesia is alarming. The general illustration of the condition of a damaged forest shows that from the 105 million ha of forest area in Indonesia, 57.7 million ha (55%) is damaged (Baplan, 2001). In 1984 degraded lands occupied 9.7 million ha; in 1994 it increased to 23.2 million ha, of which 15.1 million ha is outside the forest area and 8.1 million ha is within forest area. Meanwhile, the ability in rehabilitating the forest and degraded lands is only 300,000 ha yearly.

Based on these alarming figures, the government has initiated the National Movement of Land and Forest Rehabilitation (GNRHL). The policy is the result of a cooperative endeavor of the Environment Improvement Coordination Team through the National Rehabilitation and Reforestation effort. The team was formed by the coordination of three ministers: the Coordinating Minister of Politics and Security, the Coordinating Minister of Economics, and the Coordinating Minister of the Livelihood of People signed on the 31st of March, 2003.

The GNRHL aims to conduct integrated and well planned forest and land rehabilitation effort with the participation of all related government, non-government, and community institutions so that the uplands will recover as good watershed. According to the agenda, the GNRHL will be implemented in five years in a target area of three million ha. The details are: 300,000 ha in 2003, 500,000 ha in 2004, 600,000 ha in 2005, 700,000 ha in 2006, and 900,000 ha in 2007. The movement will be implemented in forest and lands with watersheds as implementation units, in 68 degraded watersheds in Indonesia.

The strategies adopted in the GNRHL are:

1. To combine the capabilities in the national-level institutions, utilize the ability of regional government, and encourage the participation of the community, private sectors, with the pioneering efforts of the national army.
2. Match reforestation with the effort to suppress the rate of forest and land damage.
3. The priority lies on the degraded forest and land that creates large damaging effects.
4. A monitoring and evaluation system will be applied transparently and consistently using satellite image analysis.
5. Tree species will be selected that match the livelihoods of the local community.

In general, there are two main activities in the GNRHL:

- The activity of Seed Development (seedling supply, renovation and building of seedling production centers),
- Planting activities (reforestation, community forestry, and roadside planting) and soil conservation (check dam, retaining dam, absorbing well and gully plugs).

How do the forest and land rehabilitation movement improve watershed conditions?

As mentioned earlier, there are three criteria and twenty indicators to evaluate the success of watershed management. The forest and land rehabilitation is expected to improve the conditions of watersheds. It covers not only planting trees but also soil conservation construction. Indirect effects on the 'people' criteria may also be possible. All together 67% of the total score of 'critical' watersheds could be influenced by the efforts currently undertaken (Table 5).

Table 5. The potentials of forest and land rehabilitation impacts based on the criteria and indicators in Table 4.

Criteria	Indicator	Parameter	Weight (%)	Forest & Land Rehab	Relative impacts on watershed conditions (%)
Land	Erosion	Slope class (%)	10	Terracing	10
		Solum depth (cm)	5	-	
		Morphoerosion	5	Soil conservation	5
		Quality of soil conservation practices	5	Soil conservation	5
	Soil Conservation Interventions	Fraction of land with soil conservation practices (%)	2.5	Soil conservation	2.5
	Cropping system and pattern	Crop cover as percentage of total agricultural lands (%)	2.5	Increasing use of trees in agricultural lands	2.5
	Index of Land Use Planning	Match between land use and land capability	5	Growing trees	5
	Index of Land Cover	Vegetated land relative to total watershed area (%)	5	Reforestation	5
Water	Ratio of maximum and minimum river flow	Maximum flow divided by minimum flow	7	Tree planting and conservation	7
	Coefficient of variation	Standard deviation of total annual flow divided by annual flow mean	5	Tree planting and conservation	5
	Water Use Index	Water demand divided by supply	3	-	
	Sedimentation	Sedimentation (mm $year^{-1}$)	12	Tree planting and conservation	12
	Physical water quality	TDS (total dissolved sediment) (mg L^{-1})	3	Tree planting and conservation	3
	Chemical water quality	pH	1.5	-	
		Electric conductivity (EC) (ì mhos cm^{-1})	1.5	-	

Criteria	Indicator	Parameter	Weight (%)	Forest & Land Rehab	Relative impacts on watershed conditions (%)
	Biological water quality	Biological oxygen demand (BOD) (mg L^{-1})	3	-	
	Fluctuation of ground water level	Difference in ground water level in dry and wet season (m)	4	Growing & promptly	4
Socio-economic	Dependence on land	Contribution of farms to total household income (%)	5	-	
	Land tenure	Cultivators as owners (%)	3	-	
	Community organization	Institutions in land rehabilitation and soil conservation	1	-	
	Conflict	Conflict of Natural Resources Utilization	3	-	
	Norms	Social norms in soil and water conservation	3	-	
	Adoption	Farmers understanding & action in soil conservation	4	-	
	People's income	Total income divided by BPS poverty standard	1	planting	1
		T O T A L	100		67

Conclusions

The criteria and indicators currently used for sustainable forest management in Indonesia has included a number of environmental criteria, although the management and evaluation units had not yet clearly defined. Using the watershed as a management unit, makes the management as well as the monitoring and evaluation processes easier.

The criteria and indicators used in forest management especially concerning the environment should also refer to the criteria and indicators used in watershed management.

Recognizing and Rewarding the Provision of Watershed Services

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Increasing demands for and widening fluctuation of water quantity and declining water quality are contributing to a serious decline in the available water that many see as an unalienable right. Linked to supply of water is the protection of the watersheds that provide the water and with the scarcity of supply comes conflict and competition to own, use and manage the sources of water. Conventional solutions have been left in the hands of government who have not always been the most efficient or appropriate managers. Conversely being left entirely to market forces has resulted in unfair distribution and often misuse and degradation of environmental attributes associated with water. Both approaches have suffered from market failure - the failure for the full economic value of water - indirect and direct, use and non-use, to be fully accounted for. Using market mechanisms can provide protection of watershed resources (securing supply) as well as meeting demands. It will mean that development of market mechanisms must account for the total economic valuation as well as ensuring that there are fully aware, knowledgeable and capable stakeholders in the process, that property rights are clearly defined and that an enabling and supportive policy and institutional environment is in place.

The trend towards decentralization of natural resource management in Indonesia has opened the door for development of market mechanisms for watershed services. A few cases have already started and there is certainly more ready to explore the challenges. The lessons learned from other places, like Costa Rica, where payments for watershed services have been in place and are now being reviewed will provide valuable insights for Indonesia as it moves forward in providing rewards and recognition for watershed services to those that provide the services.

Ensuring an adequate supply of clean water

2003 marked the UN International Year of Freshwater and highlighted the increasing concern over the supply of water to the world's growing population. More so than oil, water is now thought to be the resource that will be in the scarcest supply for our planet's future.

Contributing to the scarcity of supply are increases in population, agricultural development, industrialization, urban expansion, and demographic changes. The increased demand for and the declining amount of clean, usable water means that there have been increasing pressures on water resources and as such increasing levels of water scarcity. When water becomes scarce, the competition for how it is owned, used and managed becomes greater. This has often led to conflict and growing local, national and international concern. This increasing pressure for water is felt in the watersheds that provide the water and other watershed services.

Confounding the arguments over the supply of water and watershed services have been the debate on whether water is a right - that is, a necessity of life and so to be provided without prejudice or favour or whether water is an economic commodity to be allocated based on market mechanisms.

In response there have tended to be two major approaches or solutions - the first being government intervention whereas the government has the responsibility for the provision of the goods and services associated with water. The second approach has been treating water as an economic commodity and letting the market determine the most efficient use and appropriate price for water and watershed services.

The UN Committee on Economic Social and Cultural Rights affirmed the human right to water in 2002, which puts an obligation on governments to progressively extend access to sufficient, affordable, accessible and safe water supplies and to safe sanitation. Where there is a specific barrier to access to water, such as when people are refused access on the basis that they live in illegal settlements, governments have a responsibility to remove the barrier or ensure access by other means, for all their citizens, without discrimination.

On the other hand, private sector management of water supply systems is not a new phenomenon and there are examples of private water supply companies operating in many cities (e.g. Buenos Aires, London, Paris, Seville) in the 19th century. However in these instances it was typically the wealthy areas that received the benefits. Over the past decade there has been significant growth of private sector involvement in water markets. From 1987 to 2000, 183 water and sewerage projects with private corporate participation were initiated in developing countries with a total investment of over $33 billion USD (Bakkar, 2003).

A major point of debate during the negotiations on the 'right to water' was its relationship with 'water as an economic resource' (outlined in the Dublin Principles). The UN Committee on Economic and Social Rights have emphasized that supporting the right to water does not imply that water should be provided free of charge. There is no such assumption about food, medical care, housing and social services. Consequently, the recognition of water as a right is not in conflict with water being understood as an economic good. The difference now is that states are legally obliged to ensure that water for the purposes of drinking and sanitation are affordable for everyone and that pricing of water does not compromise other basic needs. The right to water suggests that any group or person denied the right to adequate water should have access to legal remedies and compensation (Freshwater Action Network, 2004).

The answer to the most efficient and effective provision and distribution of the benefits of water lies in a mixture of both government control and market mechanisms.

But can markets help?

Some may justify government control of water because it is a "fundamental human right." Yet there is increasing evidence that governments cannot provide clean water to poor people, and have their own failings associated with imperfect knowledge, misaligned incentives, inefficient bureaucracies and rent seeking. Furthermore, as pressure mounts on governments to curtail spending and cut budget deficits, their ability to invest adequately in the provision of public goods and services is called into question. And if governments interfere with pricing and profitability, it can result in a distortion of the market.

Efforts to transfer responsibility for environmental services out of the public sector have relied on a combination of regulation and market-based approaches, though the latter have become more prominent in recent years. Market approaches aim to alter incentives facing forest owners and users so that they act in ways consistent with government policy.

However, markets typically fail to compensate those who produce positive externalities due to the absence of property rights or other legal means to require payment for services rendered. A positive externality is any uncompensated benefit. Positive externalities associated with forest protection include, for example, erosion control, reduced risk of flooding downstream and water quality maintenance. Watershed services can be considered a public good when the consumers of the services cannot be prevented from enjoying the good or service in question, even if they do not pay for the privilege. For instance, it is difficult, if not impossible, to exclude downstream communities from benefiting from improved water quality associated with forest regeneration upstream (Landell-Mills and Porras, 2002).

The failure of markets also means that the better off are able to capture the greatest benefits at the expense of the poorest. This insight has been brought out by Byron and Arnold (1997) who have shown that even though it is the poorest that tend to be most dependent on forests, it is often the better off who benefit most from forest use. This is due to a variety of factors including the latter's greater access to complementary assets (e.g. machinery and skills), better training and education, preferential access to markets, and informal arrangements which allow them rights to the most valuable forests (e.g. through connections with those with authority over the resource).

The markets have failed in the past in equitably distributing benefits due to a number of reasons. Often watershed services can't be bought and sold and so the market doesn't get the correct signals to ensure adequate supply. In addition there can be interference with the market and incorrect and incomplete valuation of watershed services.

The value of water and watershed services

Watershed functions are attributed to the natural capital available (climate, geology, soil structure, land form) as well as to land use and management (either through guardianship of protected areas or stewardship activities that provide livelihoods while still protecting the environment). Although not the only ecosystem that provides watershed functions, forests and agroforests are key components in providing watershed services in the developing world.

However, watershed functions cannot be considered "services" unless they also have some form of economic significance for identifiable stakeholders. Although services need to be defined in a site-specific context, they can be generally classified in two broad categories, those that have a use value (either direct or indirect) and non-use value.

Direct benefits can take the form of timber and food they provide, or indirect through their contributions to production processes, e.g. the protection of valuable agricultural land. There is also an option value associated with watershed functions in providing future opportunities that are both direct and indirect. Non use values are often intangible and include the value of leaving opportunities for future generations (bequest value) and the value from knowing that the watershed function exists (existence value). Recognition of all the values of a watershed is capture as their "Total Economic Value".

However, in most cases today, the cost of protecting water at its source is not included in the price paid and water prices typically only reflect the costs of delivery, at best. In other words, the hydrological benefits, and therefore, the economic value of watershed protection, are not fully appreciated nor reflected in the pricing of water. The failure to understand and value the watershed services provided by healthy ecosystems results in land-use choices that degrade watersheds. With little economic incentive to protect natural ecosystems upstream, land users are likely to adopt practices offering the most tangible, direct and immediate economic benefits to them, for example, converting forests for grazing and farming (The Conservation Alliance, 2003).

However, experience has shown that well-designed market-based instruments can achieve environmental goals at less cost than conventional "command and control" approaches, while creating positive incentives for continual innovation and improvement (Landell-Mills and Porras, 2002).

In the forestry sector, governments around the world have heeded this advice and taken responsibility for forest protection in areas high in biodiversity, landscape beauty or critical for their watershed protection functions. For the most part governments have taken direct control for forest protection through public ownership and often elaborate regulation of extractive uses.

Using market mechanisms - opportunities and pitfalls

Forest conservation advocates support market approaches because it is thought that capturing the financial value of forest services will promote good stewardship and discourage more degrading uses of forests. Market approaches have gained prominence as frustration has increased with regulatory approaches - often thought to be inefficient, expensive and inequitable (Forest Trends, 2002).

It is worth pointing out that although the costs of identifying potential trading partners, negotiating to implement a trade, monitoring and analysing service delivery, documentation and record keeping and administration of trades exist in all commodity and service markets, they are particularly high in markets for watershed protection. This is partly a reflection of the nature of the product and the large numbers of participants involved, but it is also the result of an underdeveloped market infrastructure.

There are lots of stakeholders involved in watershed markets making it a complex activity. The intermediaries need the right set of skills to be cost effective and it becomes costly if a new group has to be set up and trained. In most cases insecure tenure remains the principle constraint to market creation.

So why use market mechanisms? Because, unlike financial incentives, which depend on government subsidies, markets require that beneficiaries pay for the service provided. In addition because markets determine the "price" of a good or service by equating demand and supply, they are thought to offer important efficiency gains over government set "prices". Good market development will promote recognition of the economic and ecological value of watersheds and ensure that producers of watershed services are compensated -

Table 1. Potential advantages and disadvantages of using payment for watershed services mechanisms

Potential Advantages	**Potential Disadvantages**
• Improve or maintain water quality • More efficient allocation of water supplies • Maintain or re-establish natural flow regimes • Reduce secondary costs of filtration and sediment control • Reduce secondary health costs • May be able to provide essential services to industrial and residential users more efficiently and at lower costs than regulatory command and control approaches • Potential for sustainable source of financing to protect large areas that include critical ecosystems • Promotes recognition of the economic and ecological value of watersheds • The benefits and costs of watershed services are more equitably shared • May begin to reduce urban-rural disparities and increase equity • Provides an opportunity to develop more participatory and cooperative institutional arrangements that are of broader social benefit • May result in improved regulations and legal structure for protection of water and watersheds • Improved communications between stakeholders • Producers of ecosystem services are compensated. This may improve livelihoods of the rural poor by providing new sources of income – if their rights are recognized and tenure security is increased • Capacity building in rural communities through the development of skills in sustainable land-use practices, project management and through new business opportunities that may be presented • Increased political representation for the rural poor. • Improved scientific understanding • Protection of cultural heritage • Improved recreation and cultural opportunities • Improved delivery of watershed services • Potentially large markets for hydrological services	• Complexity of watershed management problems makes it difficult or impossible to obtain complete information linking causes and effects and to measure impacts • The development of markets and other institutional arrangements is a slow and iterative process that takes time • High transaction costs associated with the development of markets for public goods that may include: • Planning & Negotiation • Monitoring & Enforcement • Multiple stakeholder agreements and collaboration to overcome free-riding • Gathering of scientific and other information needed to support decision-making • Informing stakeholders and making them aware of uncertainties so as to avoid unrealistic expectations • Clarification of property rights • Strengthening of legal and regulatory framework • Development of intermediary organizations • Overcoming barriers to market access that include: • Low education • Geographic isolation • Lack of property rights • Unequal bargaining power • The cost of implementing protection measures • Inequity may be increased – existing inequities may be reinforced if they are not explicitly addressed in the design of the initiative • Opportunity costs of forgone land uses • Water users may lack ability to pay • Potential for loss of informal use rights as a result of increased competition and use restrictions • Complicated economic valuation procedures of the services

Source: Conservation Alliance 2003 and adapted in part from Landell-Mills and Porras, 2002 contributing to improving the livelihoods of the rural poor by providing new sources of income (if their rights are recognized and tenure security is increased). In addition, there is opportunity to develop more participatory and cooperative institutional arrangements that are of broader social benefit and secure sustainable sources of funding to protect critical ecosystems. Expected cost savings and efficiency gains have meant market development is receiving unprecedented attention from policy-makers.

Different types of market mechanisms

In the same way that ecosystems and watersheds vary, so to will economic, social, political and ecological context will determine the most appropriate market mechanism.

These can broadly be categorized as self-organized (often voluntary) private agreements, public payment schemes and open trading schemes. The following categorizes different types of market mechanisms by the level of public involvement.

Self-organized private deals

This approach includes direct, usually closed, transactions between those who benefit from forest services and those who provide them. This includes deals such as voluntary certification and eco-labeling schemes, direct purchases of land and purchases of development rights to land, as well as direct payment schemes between offsite beneficiaries of watershed services and landholders responsible for the services.

Private deals, typically limited in scope and transparency, benefit from clear property rights and enforceable contracts, although clear rights and enforcement mechanisms are not always necessary. In most cases, little other public involvement is warranted.

Contractual agreements tend to work better at smaller scales. This allows for face-to-face negotiations, and enables stakeholders to know what they are getting, because there is less uncertainty about the links between watershed management actions and their consequences. A smaller scale also allows agreements to be more complex and more tailored to local conditions (Conservation Alliance, 2003).

Public payment schemes

Because watershed services are often considered a "public good," public payment schemes are the most common financial mechanism used to protect watershed services (Conservation Alliance, 2003). This approach is used when a government provides the institutional foundation for a program and directly invests in it as well (Powell *et al.*, 2002).

In a public payment scheme, the government or a public sector organization can generate funding through some type of fee or tax. The government may also create an institutional arrangement to provide or maintain watershed services. This has been done in a variety of ways: at the agency level, such as the department of forestry, fisheries, or environment; a contract with an NGO; working with a university; or quite often a combination of all of the above.

In almost all cases there has been a need to make changes or additions to legislation or policy. These policy decisions can be made at the local, municipal, or regional level; whichever is most appropriate for the geographic scope of the watershed. Examples of new policies include:

- creation of or increases in water fees;
- the ability to apply water fees directly to watershed protection;
- means to provide incentives to land owners
- the ability to apply and enforce environmental easements
- establishing oversight, monitoring and regulation compliance mechanisms
- implementing fines for non-compliance to with agreements on land use or discharge limits by either "buyer" or "seller."

Prices paid by governments are often determined by political or budgetary considerations, rather than strict economic evaluation of the environmental benefits involved. As with private schemes, public payment schemes often require intensive upstream/downstream negotiations to establish the amounts that will be paid to private landowners and/or private or public resource managers. Payments may be used to fund management activities such as the purchase of conservation easements or development rights, or to pay landowners/ resource managers to change land-management practices (Conservation Alliance, 2003).

In China, ecological degradation has become recognized as a major obstacle to their socioeconomic development, and forest loss is believed to be closely associated with ecological degradation. Consequently, forest conservation has gained increased attention. In particular, the Natural Forest Protection Program and the Sloping Farming Lands Conversion Program signify a fundamental transition from valuing solely forests' economic benefits toward valuing their economic, ecological and social benefits. It was against this general context that China 's Forest Ecological Benefit Compensation Scheme was developed. This public payment scheme was established under law and has an established legal framework with a specified state budget as the primary source of capital. A total budget of 1 billion Yuan has been earmarked under this fund for the pilot implementation for the FEBSF to begin in 24 state- level nature reserves and 658 counties of 11 provinces (Changjin Sun, and Xiaoqian Chen, 2003).

In addition to the state component there are also local initiatives where general funds are raised from local budgetary allocations (Guangdong) and charges / fees collected on beneficiaries (organizations, enterprises and individuals) of forest ecological benefits according to the whoever-benefits-pays principle, such as in Hubei and Xinjiang. The FEBCF is usually carried out by various levels of fiscal departments and specifically used for ecological forest construction and wildlife protection by the forest department.

Open trading schemes

Trading schemes are the least common of these three market mechanisms, and tend to be used more in developed countries. The government defines and sets the limits on the environmental service commodity to be traded and then devises regulations to create demand. In these cases a strong regulatory framework is required. In addition any market-based system of trading credits requires a transparent framework, accurate accounting and verification systems (Powell *et al.*, 2002).

In New South Wales, Australia, the government is piloting proposals for salinity credit trading rooted in broader basin-wide salinity targets. Based on these targets, the government has allocated licenses to dischargers of salinity. The idea is that those wishing to exceed their salinity quota can do so if they purchase salinity credits from those who have taken action to reduce salinity, e.g. by protecting and managing native vegetation. Other examples include tradable development rights pioneered in urban areas of the U.S., the trading of wetland mitigation credits and emerging nutrient trading schemes in some U.S. states.

What's needed to make market mechanisms work for watershed protection

As has been noted earlier, markets, like government interventions can be prone to failure if a number of factors are not considered. In designing the project "Rewarding Upland Poor for Environmental Services they Provide " (RUPES), the World Agroforestry Centre recognized that there are a number of steps and processes that have to be undertaken to put in place successful watershed services agreements. These include identification and confirmation of the environmental service(s) being provided, the providers of the services and the users. It also entails finding the appropriate reward mechanisms - be that financial or otherwise, as well as creating a supporting and enabling institutional and policy framework that can encourage effective environmental transfer schemes.

Watershed services - separating the fact from the fiction

Disentangling facts from fiction, and establishing cases where forests play a positive role in the provision of watershed services must be the point of departure for market development. In a recent study on what has been learned from the Costa Rica experience with PES (arguably one of the most advanced countries in the developing world on PES), it has been shown that development of markets and payments systems that are based on sound underpinnings stand the greatest chance of thriving and being replicated. This is followed by those that rely on facts as generally accepted (conventional wisdom). Where markets and payments are developed on demonstrably false or inherently unreliable estimates of the importance of ES, not only is there potential for failure and disenchantment of those involved, but eventually for the larger process of market development and, indeed, the larger environmental agenda to be discredited (Rojas and Aylward, 2003).

In the development of sites for the RUPES Program, it has been learned that the cause and effect links between land use/management and provision of environmental services is in many cases not clearly understood. Disaggregating the man made influences on a watershed (deforestation, grazing, slash-and-burn agriculture, soil compaction, road building and other construction activities) from natural conditions is a challenge.

It is not only difficult, but may not always be necessary to undertake a precise measurement of all the various linkages between land use practices and their impact on water-related services, as long as there is a common understanding between upstream and downstream stakeholders on the most significant linkages. However, users need to be made aware of the range of natural variability and uncertainty in watershed processes, and that results may not appear immediately, so that expectations remain realistic. This implies a need to conduct site-specific assessments, so that management plans can be developed that are based on the best information obtainable using available resources (The Conservation Alliance, 2002).

Providers

Sellers or providers of watershed services tend to be the land use decision makers. The distinguishing characteristic of land-use decision-makers is their ability to support the hydrological services of a watershed by engaging in sustainable land-management practices, or to diminish those services, through activities that lead to land degradation (The Conservation Alliance, 2003).

However, the providers of the ES are not a homogenous group. Depending on their current wealth, access to land, land title, availability to provide ES (due to land capability e.g. soil structure, slope) they may have a different view of the service being provided. It is important to ensure that the providers are aware and knowledgeable about the service they provide and that there is a market for the service. To ensure the markets work for the providers they must be able to deliver the service (and so know what it is and how they contribute to its creation and maintenance). They must also be involved in monitoring the watershed functions for without this level of accountability, the relationship with the buyer can become strained.

Users

In their review of markets for watershed protection, Landell-Mills and Porras (2002) noted that the majority of buyers for watershed services were local in origin. This is not surprising given the constraints associated with geographically dispersed markets. In larger catchments not only are hydrological linkages between upstream actions and downstream water impacts increasingly tenuous, but also perceived links by beneficiaries and suppliers are less likely. Ultimately, unless downstream communities believe they gain from upstream watershed protection, they will not be willing to pay for supply. Furthermore, even where there exists a willingness to pay, where watersheds span political boundaries (e.g. national or even state borders), the risks involved may prevent payments emerging.

Demand is the main driver behind watershed market establishment, accounting for over 50% of the cases reviewed by Landell-Mills and Porras. The perception that forests play a critical role in maintaining water quality and ensuring supplies is the major factor behind growing demand for forest management in key catchments. Willingness to pay is growing amongst government and private entities responsible for providing clean drinking water and managing hydropower plants, downstream farming communities that wish to guarantee continued water for irrigation and broad groups of industrial and domestic users willing to pool payments.

However, it is also important to understand that different stakeholders in the watershed will have their own unique requirements. Domestic water supply, irrigation, hydropower, navigation, fisheries and ecosystem maintenance are just a few uses - each with their own requirements of water quality and water quantity. Even in hydropower use - a run-of-river plant is interested in maximizing water retention in the watershed and providing a regular flow of water throughout the day - a peaking hydropower plant with daily storage facility is more concerned with maximizing daily inflows during the dry season - an inter-annual storage reservoir is most interested in maximizing total annual water flow given its ability to store water across seasons (Rojas and Aylward, 2003).

Ultimately, users need to be confident that funds raised for improving watershed management are actually maintaining or enhancing the watershed and the quality of watershed services. They need to remain confident that the water source will remain reliable and that the implementing organization is acting fairly and equitably.

Supporting institutions and policies

Establishment of watershed reward and recognition schemes depends on the existence of an adequate legal and regulatory framework. For any environmental service transfer mechanism to work, it is essential that the overall policy environment is conducive and in order for systematic transfers of rewards to communities for the environmental services they provide to take place, constraints that inhibit such transfers must be identified and addressed. These constraints can take the form of a lack of political will, institutional capacity, lack of a supportive legal framework, financial resources and even limited community interest and commitment. Institutional constraints, such as conflicting and competing government agency jurisdiction over the regulation of the environment services that upland communities are providing will be examined.

Watershed management in Indonesia and the Philippine is a good example. In each country several government agencies are responsible for maintaining or regaining watershed environmental services, potentially complicating the reward negotiation process. Another example is potential opportunity costs will be forfeited by some or all of these institutions whose staff at times depend on rent seeking activities to supplement incomes. An extension of this example is the lack of institutional transparency in the management of financial rewards leading to a lack in confidence in the process. Other institutional questions may concern the lack of capacity of community-based institutions to manage the rewards in a transparent and equitable way. Political constraints can take the form communities receive rewards for services provided only in exchange for support on Election Day.

Environmental services agreements involving rural communities may be most likely to be successful when they are created and administered at the supra-village level. This is due to the presumed high transaction costs of implementing separate agreements with large numbers of local units. Bodies that are set up at the supra-local or even national level may be effective in bundling investments from national or global stakeholders and distributing them through to communities under the terms of the agreements. Such an approach is being implemented in Costa Rica.

It is important to point out that these policies can take time to develop and will need to be made at various levels.

Markets for watershed services in Indonesia

Stages in developing watershed markets

Developing markets for forest services is, in many senses, similar to developing any new market. However, as outlined by Powell *et al.*, (2002) the process differs in some key aspects. It is similar in that entrepreneurship, local constraints and opportunity will decide the speed and extent to which a market is developed. Because most forest services are currently treated as free goods, it is perhaps most different in that developing a market often requires converting these freely-accessed goods and services into commodities and property. This is inherently a political process, whereby different stakeholders' rights and responsibilities are questioned, new rules are established, and new entitlements are established. This process occurs in three broad phases.

In the first phase, the linkages between forest actions and their consequences are emerging and gaining attention. In all cases, an entrepreneur operating either in the public or private sector, and operating as an individual or an entity, shows leadership and mobilizes action by informing stakeholders of the existing problems and opportunities. This action generates willingness to pay for protection from the problems and provides a basis for interested stakeholders entering into negotiations.

In the second phase, the structure is defined. Supporting rules and processes begin to emerge.

Except in purely private deals, drafting regulations requires a political process. The regulations define the service, settle the particular rights and duties of the stakeholders and provide a platform for negotiating payments.

In the final phase, the market becomes live. Transactions take place and money changes hands. Service contracts and agreements are established, along with supporting institutions, such as accounting standards, monitoring and certification mechanisms.

In reality, this clear-cut pattern is clouded by the many stakeholder interventions and activities happening within the different phases. Moreover the process is iterative, progressing at different speeds in different contexts, and in some cases involving setbacks (Powell *et al.*, 2002).

Case studies in Indonesia

In a recent review of watershed markets in Indonesia (Suyanto *et al.*, 2004, in prep) it seems that the development of environmental services in Indonesia is still in its early stage. There are very few cases studies where an environmental service market has been implemented. Similarly, the studies that proposed the environmental service initiatives are also rare. However, there are increasingly many more initiatives, emerging projects and research related to the development of market of environmental services.

Contributing to this exploration of market mechanisms for environmental services in Indonesia is the change in national policy in several sectors to provide a more supportive setting for locally based natural resource management and financing. In April 1999 the Government of Indonesia formulated the Letter of Sector Policy and Policy Reform Matrix, which forms the basis of the ongoing Indonesia Water Resources Sector Adjustment Program (WATSAP). The reform of Law no 11/1974 on water resources, and relevant regulations deriving from that law, will re-align the role of the government. Most fundamentally, the devolution of many decision-making and budget control functions from central government to district governments (Otonomi Daerah) since 2000 - one of the most ambitious decentralization exercises ever undertaken by any country - facilitates local solutions to natural resource management problems. In the water sector, the ongoing policy reform process has as its center the theme of integration in water management - integration among sectors and among stakeholders. In the forestry sector, central government is beginning to invest in its stated commitment to community-based forest management (Munawir, 2003 unpublished).

Four examples of watershed payment schemes are presented as an indication of the growing trend in Indonesia.

Annual fee paid by PT INALUM to the North Sumatra District Government for conservation of land around Lake Toba

PT Indonesia Asahan Alumunium (INALUM) - an aluminum refining and power generation corporation - is a Japanese overseas investment in North Sumatra, Indonesia. The electric power is produced in Asahan Hydropower Plant using the water from Toba Lake. The supply of electric power is for use in the aluminum industry and for sale for public use (80% from the total production in North Sumatra). Starting in 1985, INALUM contributed to the conservation costs of Lake Toba yearly through Dana Konservasi Alam Danau Toba (Nature Conservation Fund for Toba Lake). The focus of the fund provided by INALUM is to rehabilitate critical lands in five districts on the catchments areas of the Toba Lake and on the watershed areas in Asahan and Tanjung Balai.

Four components of annual fee are put aside to conserve the Lake Toba. The first three components are fixed payments of as much as 2.6 million US Dollar; those are Pajak Bumi dan Bangunan (land and building tax), Iuran Jasa Air (retribution of water service) and other taxes both from provincial level and district level governments. The fourth component is an additional one as the result of the difference between the exchange value of Rupiah and US Dollar in selling the products of PT INALUM.

In 2002, the additional payment was 23 billion rupiah. Accordingly, the total fund from PT INALUM was 49 billion rupiah. Despite this large amount, there is no real cost-benefit measurement of the environmental impacts of this company as its cost in consuming the water is very cheap (Rp. 5.18 per cubic meter) compared to regular tariff that is Rp 75 - Rp 100 per cubic meter). In one year, Asahan Hydropower Plant uses approximately 2,9 billion cubic meter of water.

Land lease of state land to the local community for providing watershed functions in the upper Besay watershed of Sumberjaya, Lampung

In this area, there are four state forest zones that form part of the upper watershed ecosystem. Population pressure on the state forestlands is high as a result of forest status disputes, poverty, lack of rural economic infrastructure, market drivers for coffee, and man-agriculture land ratio. Forest conversion has been blamed as a source of erosion and sedimentation to Way Besay, affecting the hydropower plant downstream. There is also distrust by the local communities of the government as a result of previous governmental repressive policies used to evict people from the forest.

In 2000, ICRAF and a local NGO, Watala, collaboratively began developing mutual trust and dialogue between local people and government to build social capital and create space for dialogue, negotiation and collective action (Negotiating Support System for Integrated Natural Resource Management. The Hutan Kemasyarakatan (HKm), in English 'Social Forestry' program - a program promoted by the government - was used as policy entry point for reconstructing mutual trust based land tenure conflict resolution.

The most current policy on Community Forestry (HKm) from the Indonesian Forestry Service is Surat Keputusan No. 31/Kppts-II/2000 which allows permits in gaining the HKm Initial License. This policy obligates forming community groups among the communities who are willing to gain the HKm License. The process followed includes formulation of the group rules and working plans. These community groups then determine the management area though participatory mapping. After completing these requirements, the community group can make a proposal to the Forestry Service.

In operating the HKm, some constraints are caused by inconsistency of policy and limited resources. The national level of Forestry Department has not approved legal locations of HKm proposed by district/province. In addition, the Forestry Department admits that currently they only have very limited human and financial resources in developing the HKm. From the community perspective, there is still limited socialization about the HKm policy and the process in applying the license is considered too long and tedious. Supports from external parties such as research centers or NGOs are still needed. In term of monitoring and evaluation process of HKm, no participative process is in operation yet. ICRAF and its partners are working on how to develop the mechanism of participative monitoring and evaluation process of this HKm including its criteria and indicators.

Some initiatives in supporting the development of HKm have been done by the government (the Forestry Service) and the communities. The government has started to do some socialization of this HKm and provides supports by supplying the multi purpose tree species (MPTS) seedlings. The communities response these efforts by actively joining in forest rehabilitation under HKm either using the seedling from the Forestry Service or initiatively obtaining seedlings in groups. Currently there are 12 HKm groups (about 1035 farmers as members) facilitated by ICRAF and Watala. Three groups of them had have HKm Initial License valid for 5 years issued by Bupati Lampung Barat and become the first HKm groups licensed by Bupati in Indonesia under Ministry of Forestry Decree No. 31/Kpts-II/2001.

Preserving natural spring water through cultivating local varieties plants

In Bandung, West Java, almost half of the 23 water springs are vanishing because of water pollution as well as excessive draining and exploitation. Decreases in water biodiversity, low quality of water and high water pollution dominantly caused by farming chemicals and domestic waste indicate that the deteriorating quality of water is already at an alarming stage. In addition, there is insufficient information on how to use and manage the water resources.

The project intends to conserve spring water sources involving the communities surrounding the springs as well as to give additional income for their livelihood. It would increase the level of information and awareness of the importance to conserve the environment among the communities. As an indication of the success of the program, there has been replication of the activities in several areas in West Java.

The potential buyer, in this case the state-owned water supply enterprise (PDAM) and its consumers, would provide a reward to the communities surrounding the spring in the form of in-kind rewards, such as training in how to increase their income through agroforestry and to apply simple technology in maintaining the environment. Nine farmer groups (total of 125 members) have been formed in five locations of the project. They have been encouraged to plant productive perennial plants such as fruit trees, coffee, cocoa and clove, combined with shade tolerant medicinal herbs and food crops, using organic manure. An efficient system of 'longyam' (balong ayam), putting poultry cages above fishponds was introduced to eliminate water pollution from the poultry waste and excessive evaporation of the water pond. Other activities included building infrastructure such as sanitation and clean water system, and to purify organic liquid waste using simple methods. In line with these activities, the communities were trained not to throw away their domestic waste to the rivers or water bodies.

Action-learning to develop and test upstream-downstream transactions for watershed protection services: a diagnostic report from Segara River Basin, Indonesia

The overall goal of this project is to promote maintenance of water services that support local livelihoods. It is aimed at increasing the understanding of the potential role of market-based approaches in promoting the provision of watershed services for improving livelihoods in Indonesia, especially in Segara River Basin, Lombok.

Despite its early stage and lack of accurate hydrological information, the mechanisms for linking downstream water users to upstream land managers in the Segara Watershed exist. For example, a number of payment schemes to finance irrigation infrastructure (Sawinih, Irrigation Service Fees, and operational fee) contributed by farmers with irrigated land are already managed by the six associations of irrigation water users, but nothing yet is transferred to upstream communities.

PDAM pays a land tax to the local government of the Bantek village to compensate the individual landowners that are affected by its water pipeline. Together with the Lombok Inter-Rafting Company, some financial payments are delivered to contribute to village development through the village administrators. The amounts transferred from PDAM are Rp 2 million in 2001 and Rp 5 million in 2002, while the Lombok Inter-Rafting Company contributes Rp 600,000 / village / year. Basically, the funds are used to cover forest guard salaries, to plant trees and to subsidize various social activities in the village.

Community tradition in Bentek shows their strength in protecting forest. The community holds regular ritual celebrations through Sedekah Gumi Paer. This activity stems from both customary law and religion, which aims to protect community members from natural disasters and diseases. Both the Muslim and Hindu communities of Bentek participate in this occasion.

Bentek Village has adopted its own long-standing customary law as a basis for drafting local law on natural resources management, which is commonly called "awiq-awiq" to protect the watershed. Furthermore, this effort also intends to develop good relations between upstream land managers and downstream water user in synergy with the programs of the local government, as they have not involved in current developed mechanism.

Conclusions

The role of markets and market mechanisms to ensure a fair and equitable distribution of benefits and costs for watershed services will depend on a number of factors, and government's role in funding watershed protection will remain an important one. Many of the broad social benefits provided by water resources may never be fully captured through the use of market mechanisms. However, given the constraints under which government finds itself and the move towards more local governance of natural resources - including watershed goods and services - what will be important is ensuring that all stakeholders are involved, engaged and capable in the process of finding the most appropriate mechanism and institutions.

Institutional Development of Water Resource Management for the Ombilin-Singkarak Sub Basin in West Sumatra, Indonesia: A Study on Role Sharing for River Basin Management

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Conflict over water and other problems of water management like floods, water pollution and drought are common problems that exist almost at all parts of Indonesia. In this regard, the government of Indonesia has announced a reformation of water policy by adapting the concept of Integrated Water Resource Management (IWRM) that recognizes river basin as a unit of management. However, there is still a big question of how to translate this concept into practice. One of the approach is by establishment of Balai Pengelolaan Sumber Daya Air (Balai PSDA or the center for water resource management) at the provincial level.

In West Sumatera, there are two Balai PSDA established in 2001, and one of them is Balai PSDA Kuantan Indragiri. One of the main issues within the region of Balai PSDA is the role sharing of water management for the Ombilin-Singkarak sub basin. As a new institution, there is still a question of what would be the model of working operation and how the roles should be shared among stakeholders for effective water management in the sub basin. This paper discusses the issues of water management and role sharing in the management and propose an institutional improvement to enhance the role of the Provincial Water Council, Balai PSDA, as well as all other stakeholders.

Introduction

Physically, conflict over water as a common resource is mainly caused by a lack of supply compared to demand, in quantity and/or quality. When the amount of water is not enough to satisfy all users, conflict will occur among them if there is no regulation controlling water use. Powerful users, in terms of their socio-economic status, can easily manipulate the use of water for their own benefits, while the rest may have to do with poorer or no service.

In the case of river water use, conflict over water may occur between upstream and downstream users at international, national, regional or even local levels. In terms of the users, conflict may occur between the government and local communities, between different groups within local communities, or between the government, local communities, industries and environmentalists. Issues on river basin management include water pollution, land degradation of catchment area, floods and the maintenance of infrastructures along the river. Conflict over water and related problems in water management occur mainly in the absence of consistent regulations, responsible institutions and also the role-sharing pattern of all stakeholders (Febriamansyah, 2003).

In West Sumatera, Indonesia, among the efforts to improve the water resource management at basin level was the establishment of two institutes for water resources management in 2001, namely Balai PSDA Kuantan Inderagiri and Balai PSDA Batang Hari. Moreover, the Water Council for Provincial level (namely Dewan Daerah Sumberdaya Air or DDSDA) has also been established in September 2003. However, these two institutions are still questioning their mandate and responsibilities in water resource management in this province. A study on "Water Resource Management and Role Sharing in the Region of Balai PSDA Kuantan Inderagiri, Sumatera Barat" has been done to explore the real issues of water resource management and role sharing at the region of BPSDA Kuantan Inderagiri. Based on the existing issues in the region and the current capacity of Balai PSDA, the main recommendation from this study is to rationalize the activity of Balai PSDA for one sub basin, that is Inderagiri Subbasin.

This paper will explore the issues of water management and role sharing in one sub basin within the region of Balai PSDA Kuantan Inderagiri, that is the Ombilin-Singkarak sub-basin, and propose an institutional improvement to enhance the role of DDSA, Dinas PSDA, Balai PSDA dan other government agencies.

Overview of the region of Inderagiri Subbasin

The region under Balai PSDA Kuantan Inderagiri management covers four river basins, i.e. Rokan, Kampar, Inderagiri and Anai Sualang. Figure 1 shows the geographic position of those four subbasins. Although the Inderagiri river basin is the second largest in the region (> 7,500 km^2), this basin consists only of one main river that flows down to Riau province. There are five districts (Agam, Limapuluh Kota, Solok, Sawahlunto/Sijunjung, and Tanah Datar) and five municipalities (Payakumbuh, Bukittinggi, Padang Panjang, Sawahlunto and Solok) within the Inderagiri Basin.

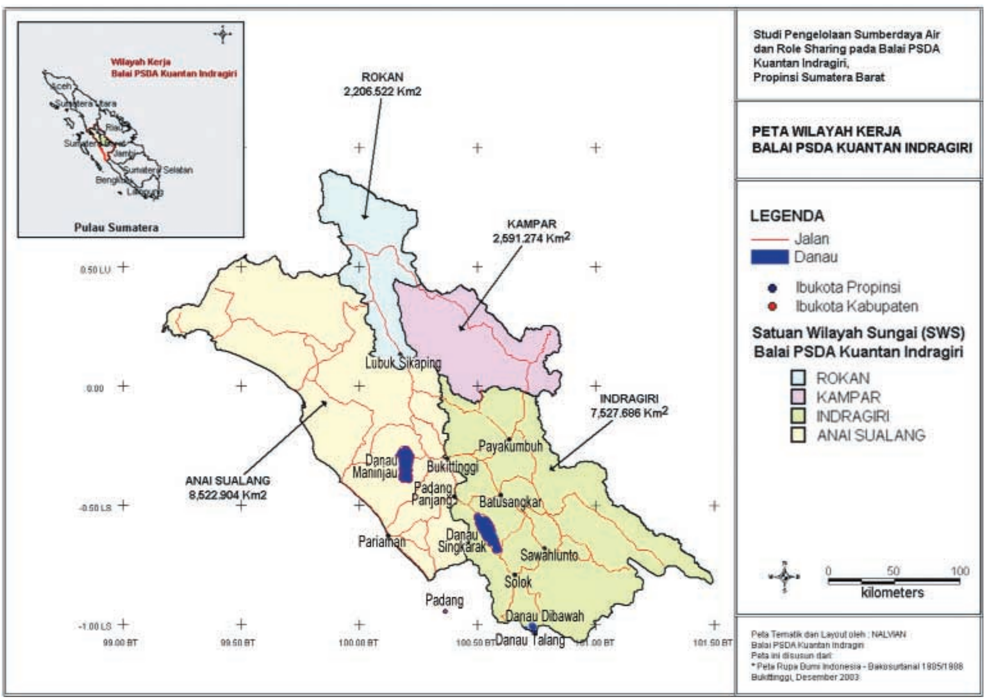

Figure 1. The working region of Balai PSDA Kuantan Inderagiri

Demography and employment

The total population occupying the subbasin area in 1997 was 662,425, with an average population density of 408 persons per square kilometer. The urban-rural population ratio is 0.28. In 1997 there were 150,466 households in the basin area with an average household size of 4.59 persons. It is estimated that only around 12.56 percent (or some 18,898) households are served by pipe-born water. Aside from households, there are also some industries, offices, and social facilities that are served by piped water.

Around 68 percent (94,508 of 139,831) of households were categorized as farm households in 1993. The number of farm households in the basin area for 1997 is estimated as high as about 98,000. This number indicates that the majority of households in the basin area are engaged in agriculture as their main occupation. It is reasonable enough to expect that water demand for agriculture-related activities will be one of the major issues in the basin area.

The subbasin and its area

The Inderagiri River originates from the highlands of West Sumatra and flows to the east coast of Sumatra Island. The upper subbasin of the Inderagiri River Basin in West Sumatra Province consists of three major rivers, Lembang/Sumani, Sumpur, and Ombilin, and two lakes, Danau Dibawah and Singkarak (see Figure 2). The altitude in the upper subbasin rises from 164 m above sea level at the lowest point (near the confluence of the Ombilin and the Sinamar rivers) to 1,200 m at the point where the Lembang River originates from the Dibawah Lake, which is about 363 m above sea level. Water from the Lembang/Sumani and Sumpur rivers flows into the Singkarak Lake, while the Ombilin River originates from the Singkarak Lake and flows eastward to the Kuantan River, Riau.

The total area of the upper Inderagiri subbasin was estimated at 3,060 square kilometers. The basin area includes 400 desa (villages) within three districts and three municipalities. The distribution of this area within each individual basin of the rivers in the subbasin is approximately as follows: around 43 percent in the Lembang/Sumani River subbasin, 14 percent in the Sumpur River subbasin, and 43 percent in the Ombilin River subbasin.

Climate

The basin area generally falls under the typical humid tropical climate. Average rainfall in the subbasin area was 2,026 mm yr^{-1}. The subbasin area of the Sumpur River is the wettest, with average rainfall of 2,484 mm yr^{-1}. This is slightly higher than the Lembang / Sumani river subbasin with annual average rainfall of 2,201 mm. The Ombilin River subbasin is the driest, with annual average of rainfall of 1,789 mm (Oldeman *et al.*, 1978). The climate of Singkarak Lake catchment, however is a semiarid tropical climate, which is an exception of humid tropical climate of western part of Indonesia (Boer, this volume)

Issues on water resource management

The construction and operation of a hydroelectric power plant (HEPP) at Singkarak Lake in late 1997 diverted (transferred) water from Singkarak Lake to the Anai river subbasin, which flows to the west coast of Sumatra. Water was diverted to Anai River to obtain sufficient head to generate power. In the Anai area the altitude is around 10 meters above sea level. The diversion changed the water supply for the Ombilin River and affected users along the river.

In order to fulfil water requirements for power generation by Singkarak HEPP, the outflow from Singkarak Lake to Ombilin River was regulated to be between 2 - 6 m^3 per second. This was a significant reduction from the earlier average outflow of around 49 m^3 per second. At the Ombilin River (especially along the 70 km length of the river under study), water is used for irrigation, industry, electric power generation, and domestic water supply. The operation of Singkarak HEPP has affected the availability of water for various uses along Ombilin River, which indicates the competition between Singkarak Hydro Electric Power Plant and water users along the Ombilin River.

In this regard, there are three issues related to water management in the subbasin: a) inter-basin water transfer; b) impacts of the construction of Singkarak Hydro Electric Power Plant on irrigated agriculture and c) impacts of the HEPP on other users.

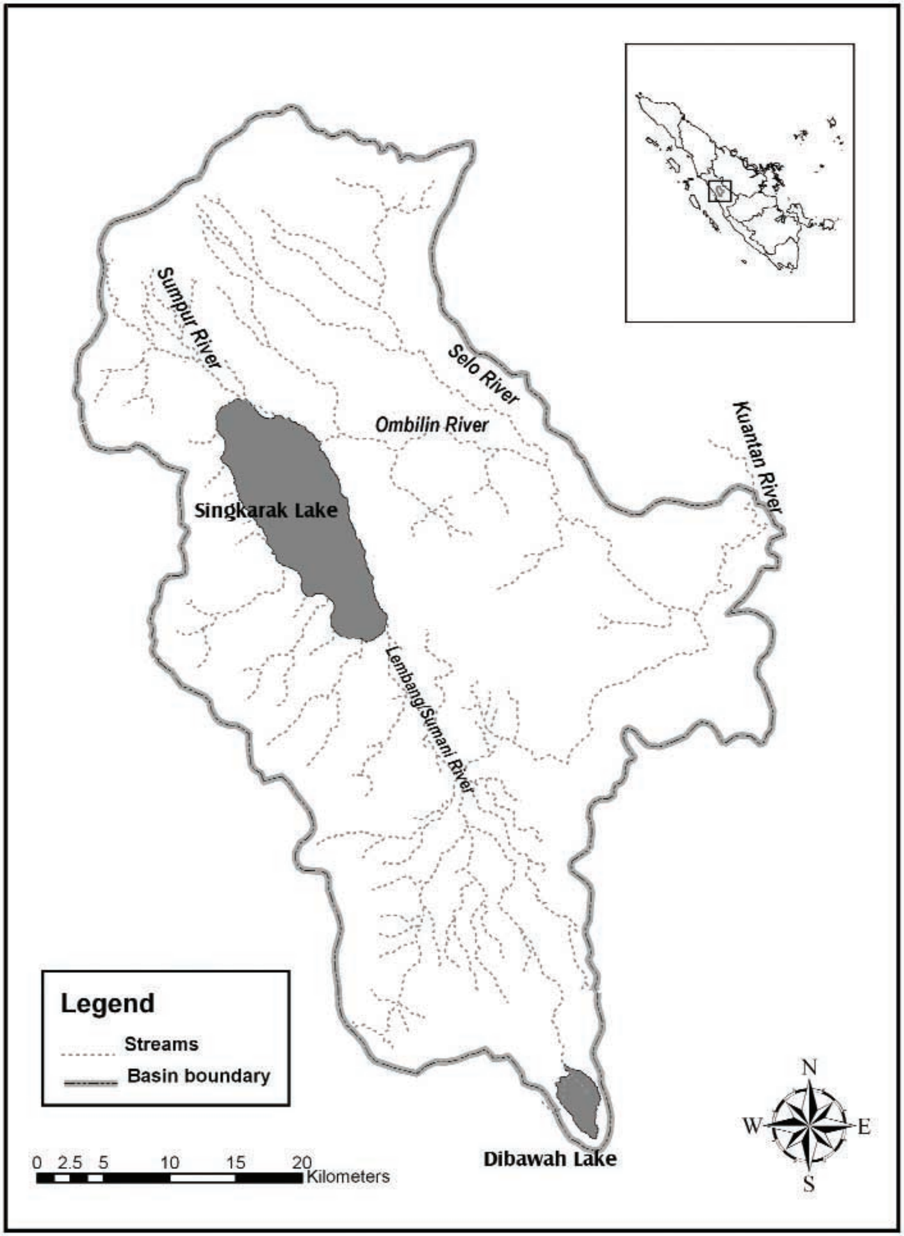

Figure 2. The Ombilin-Singkarak sub basin

Interbasin Water Transfer

As mentioned earlier, the water used by the Singkarak hydroelectric power plant does not return to the Ombilin River (which flows to the east coast of Sumatra). In order to gain sufficient head, the water is channelled (by a tunnel through the mountain range) to the Anai River, which flows to the west coast of Sumatra. This transfer to the Anai River reduces the availability of water for the users along the Ombilin River. The fragmentation of water management responsibilities among a number of government agencies makes coordinated action among them a constraint. The tendency is that when any particular government agency has developed any particular water sources, the control of water uses is assumed to be in their hand. Other users are expected to adjust themselves to the changes in water availability.

Impacts of the Singkarak Hydroelectric Power Plant

Reduction in the number of water wheels and irrigated area

Irrigation has been severely affected by reduced discharge in the Ombilin River. The number of waterwheels, command area, and number of farmers served during the period after Singkarak HEPP development have declined markedly. The number of currently existing waterwheels is only around half of that in 1996 before the operation of the Singkarak HEPP started. Current irrigated area is approximately 61 percent of that in 1996. Table 1 shows changes in the number of water wheels, service area, and farmers at the Ombilin River during the period of last 5 years (1996-1999).

Table 1. Number of waterwheels, service area, and farmers in the Ombilin River from 1996 to 2000.

Year	Number of water wheel	Total service area (ha)	Total number of farmers involved
1996	366	549	729
1997	296	470	621
1998	237	405	556
1999	195	343	478
2000	184	333	463

Increased operation and maintenance costs of waterwheel irrigation systems

Beside its impact on the number of waterwheels, the operation of HEPP have also influeced the operation and maintenance (O&M) cost of the irrigation systems. The operation system of HEPP had Increased the intensity of damage to traditional weirs and waterwheels. The increased damage means more labor and capital costs if systems are to be repaired. Results of the socioeconomic survey show that, on average, the intensity of waterwheel damage increased from once per season before the operation of Singkarak HEPP to 2.5 times per season (Table 2).

Table 2. Damage intensity, and average rehabilitation costs of water wheel and weir before and after development of Singkarak HEPP

	Before HEPP	After HEPP	% increase
Frequency of damage (times per season)			
Waterwheels	1	2.5	150
Weirs	1	4.5	350
Rehabilitation costs			
Waterwheels	Rp 150,000	Rp 1,100,000	633
Weirs	Rp 50,000	Rp 425,000	750

Source: Socioeconomic survey

Unreliability of irrigation water and decline in rice yield

Higher intensity of damage to waterwheels has created problems for irrigation water supply. Most farmers reported that their irrigation water supply has been unreliable after development of the Singkarak HEPP due to the above-mentioned problems in system O&M. As a result, the growth and yield of rice on land irrigated by waterwheels declined markedly, from an average of 4.2 Mg ha^{-1} in the period before the development of Singkarak HEPP to 3.1 Mg ha^{-1} in 1999.

Decreased Performance of Irrigated Agriculture

The performance assessment suggested that irrigated agriculture has declined during the last five years. Seven indicators measured performance: (1) output per unit of cultivated area; (2) output per unit of command area; (3) output per unit of irrigation water; (4) output per unit of available water; (5) relative water supply; (6) relative irrigation supply; and (7) financial self-sufficiency. Most performance indicators for waterwheel irrigation systems have declined. The overall performance of irrigated agriculture declined markedly. This condition can be attributed to the lack of effective water management institutions in the Ombilin River Subbasin under conditions of growing inter-sectoral competition for water. With regard to irrigation water management, a major point is that the existing irrigation technology (particularly traditional water wheels) is no longer suited to the recent condition of water scarcity.

Impacts on Industry and Domestic Water Supply

The decline in the water quality in the Ombilin River brought about some problems for the domestic water suppliers and consumers. The pollution comes from the Selo River, which transported sediment especially during rainy season, and from coal washing. Water quality in the downstream portion of the Ombilin River declined after the operation of the Singkarak HEPP began. This is shown by an increase in electric conductivity. When records in 1994 and 2000 are compared, soluble solid material rose from 104 mg L^{-1} to 176 mg L^{-1}, pH from 7.2 to 8.4, nitrate content from 0.26 mg L^{-1} to 0.35 mg L^{-1}, chloride from 4.62 mg L^{-1} to 8.4 mg L^{-1}, and sulfate from not detected to 10.3 mg L^{-1}.

The decline in water quality increased O&M costs of the domestic water suppliers. The manager of a water company estimated that water treatment cost increased by almost 100 percent. However, at the time when raw water quality is very low, the domestic water suppliers do not perform water treatment since it would not yield any improvement in the quality of water. Under such conditions, the domestic Water Company distributes raw water directly to the customers without treating it.

Issues on role-sharing in water management

Conflict of interest among stakeholders of water resource management within the basin related to the existence of regulations, institutions and role sharing pattern among them. Basically, the idea to perform the management system on the basis of one river has been explored nationally. Moreover, a new paradigm to shift the pattern of development from centralism to decentralism system has been accepted and declared legally in Act No. 22/1999. At present, although the Law about Water

Resource Management has not been formally accepted, some points with regard to the river basin management has been agreed by all fractions at the People Representative (DPR RI).

Following the paradigm of decentralization, the existing Balai PSDA Kuantan Inderagiri as a technical unit of Dinas PSDA Sumatera Barat that was established in 2001 based on the Kepmendagri No.179/1996 has also been considered to be developed for better water management in this province. However, as the conflict of interest still occurs with regard to the decentralization processes from the provincial to the district governments, all stakeholders in this basin are still questioning the role of Balai PSDA.

According to Kepmendagri (Decree of the Minister of Home Affairs) No.179/1999, the role of Balai PSDA includes 9 (nine) aspects of water management: (1) inter district irrigation management, (2) water allocation for all users, (3) river management, (4) lake, reservoir and springs, (5) flood and drought control, (6) swamp, (7) water pollution control, (8) coastal, and (9) delta and estuaries. These nine aspects are too broad for a new institution like Balai PSDA that still lack human resources. It is hard to expect the Balai to work for all aspects in the short term.

In case of conflict of interest among stakeholders within the basin, this study has also collected the identification of conflict from stakeholders' opinion. Table 3 presents the conflict of interests among stakeholders in the Inderagiri sub basin.

Based on those identifications this study found a challenge to construct an institutional development for Inderagiri river basin by rationalizing the role of Balai PSDA and empowering the role of Provincial Water Council (DDSDA) into an integrated institutional development.

The institutional development for the Ombilin-Singkarak subbasin management

Basically, the concept of role sharing in water resource management is a practical concept of "water governance". According to UNDP (2001, as cited by Helmi, 2003) and GWP (2002, in Helmi, 2003), conceptually "water governance" is the exercise of economic, political and

Table 3. Conflict of interest in water resource management within the Inderagiri river basin

No.	Issues	Conflict of interest (role)
1.	Inter-district irrigation management	Kepmendagri 22/2003 presents the role sharing between farmers and government agencies (provincial and district level), but did not present explicitly the role of Balai PSDA as the technical unit of Provincial Agency of PSDA.
2.	Water allocation	a. New National Policy on Water Resource Management has declared to use the concept of “one river one management”. However there has not identified yet a responsible institution for water allocation along a river courses. b. Groundwater management and its exploitation permission are still under the authority of the Department of Energy and Mineral Resources.
3.	Management of hydrological data	a. There are four institutions collect the hydrological data; BMG, Agriculture, Kimpraswil and PLN (electric power company), and there is no coordination pattern among them. b. They collect and manage the data for their own benefit and interest, not for the interest of water resource management within the basin
4.	River	The current regulation about river managemenf (PP No, 35/1991) has not explicitly present the role sharing between provincial and district government.
5.	Catchment management	BPDAS (under the Depart. of Forestry) has responsibility for the catchment management, while Balai PSDA (Dept. Of Kimpraswil) have also responsibilities for surface and groundwater management from the upstream to downstream section.
6.	Water pollution control	a. Conflict of role between Balai PSDA and Bapedalda (The Regional Body for Controlling the Environmental Impact) and Health Department. b. There is no integrated approach for water pollution control among those institutions. Each institution collect the data of water quality for their own purposes not for water management in general within the basin.

administrative authority to manage a country's affairs at all levels. Here, the concept of governance is larger than the concept of government as the entity of political decision-making. It comprises the mechanisms, processes and institutions, through which citizens and groups articulate their interest, exercise their legal rights, meet their obligations and mediate their differences.

By bringing in the above conceptual framework on water governance and considering the existing issues of water management and conflict of interest among stakeholders within the basin, there are three points of the institutional development for the Ombilin-Singkarak sub basin proposed below:

(a) Linkage among stakeholders in water management

(b) Rationalisation the role of Balai PSDA

(c) The principles of role sharing in water management within the basin

Linkage among stakeholders in water management

The concept of new policy of water resources was explicitly explored in one specific program called Water Sector Adjustment Program (WATSAP) that basically follows the concept of Integrated Water Resource Management (IWRM) (Sudharta, 2002; Anshori, 2003). In order to facilitate all stakeholders in decision-making process of water resource management within one river basin, the institutional framework of water management is drawn as seen on Figure 3.

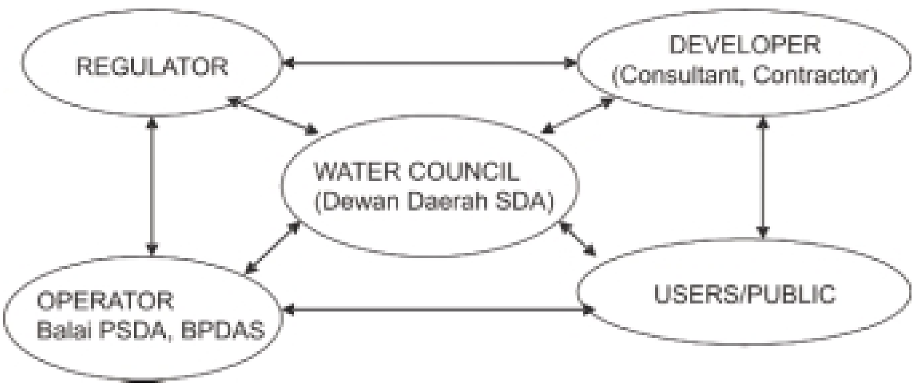

Figure 3. Institutional framework for all stakeholders of water resource management

The national policy of this institutional framework is the main reference for the institutional development at each province. The Provincial Water Council or Dewan Daerah SDA should perform its existence by facilitating all stakeholders (including users, developers, regulators and operators) in the decision making process before it was formally stated by the regulator (Governor, District Headman, or Head of Dinas PSDA). The Balai PSDA should only perform as the operator of each regulation made by the regulator.

Therefore, the institutional development activities needed to enforce effective water governance are:

(a) Establishing Water Council for sub basin level or called Dewan Daerah Wilayah Sungai that facilitate all stakeholders within this basin in the decision making process related to water resource management and development.
(b) Since the area of this sub basin is relatively large, sub committee could be established at each hot-spot issue within the basin. These sub committees are representative members at the Dewan Daerah Wilayah Sungai.
(c) District government within the basin should be enforced to declare their regional regulations related to this institutional development.

Rationalization the role of Balai PSDA

As mentioned earlier, the existing Balai PSDA could not function effectively for all aspects of duties as stated in Kepmendagri 179/1996. Considering the current issues of water management in the region and the availability of human resources, for the short term, the Balai PSDA should prioritize its activities on:

(a) The management of inter-district irrigation systems
(b) The management of water allocation along the river courses
(c) The management of hydrological data

This rationalization was also considered in the last workshop (Lokakarya) conducted by the Directorate General of Water Resources, Department of Kimpraswil in Bogor, 13 December 2003. The workshop recommended the function of Balai PSDA as follows:

(a) the information center of water resources
(b) the prime mover of coordination among stakeholders
(c) public services for water resource management

The concept of role sharing in water resource management

In general, there are two principles toward effective water governance (see Helmi, 2003):

(a) from approach side: it must be transparent, inclusive and communicative, coherent and integrated, equitable and ethical, and
(b) from the operational side: accountable (executive and legislative), efficient (economically, politically, socially and environmentally), responsive and sustainable.

These two principles are applied to specifically identify the basic concept of role sharing of water management for the Ombilin-Singkarak subbasin.

1. The basic concept of role sharing in inter-district irrigation management
   a. Balai PSDA is responsible to give the technical recommendation for any efforts of inter-district irrigation development that may influence the condition of water supply and demand, the quality of water, and changes of river infrastructures.
   b. Although the authority for infrastructure development of inter-district irrigation systems is at the provincial level (Dinas PSDA), the technical implementation of the development must be given to the relevant agencies at the district level. Dinas PSDA may act as the coordinator of this technical implementation.
   c. The Legal Permissions for new exploitation of irrigation water are given after having the technical recommendation from the Balai PSDA. The relevant government agencies at the district level prepare the documents to be considered.
   d. In term of irrigation water allocation and management, Balai PSDA may assign its own field officer tobe responsible to control and record the water withdrawal pattern at the irrigation headwork.

2. The basic concept of role sharing in water allocation systems
   a. Balai PSDA is the prime mover in facilitating the establishment of sub-sub committee of water council within the subbasin.
   b. Dinas PSDA is responsible to assist any efforts done by Balai in facilitating the regional regulation at the district level.
   c. The Legal Permission for new water resource exploitation from the river or other water sources within the basin is given after having the technical recommendation from the Balai PSDA. The relevant

government agencies at the district level prepare the documents to be considered.

d. The Legal Permission of the resource exploitation at the catchment area within the basin is given after having the technical recommendation from the Balai PSDA and the Badan Pengelola DAS (under the Department of Forestry).

3. The basic concept of role sharing in hydrological data management
   a. Balai PSDA as a technical unit of Dinas PSDA should be given a full responsibility for hydrological data management.
   b. Balai PSDA should be functioned as the center of information of water resources.

Agenda for Further Studies

Considering the existing condition of Balai PSDA Kuantan Inderagiri as the center institution for promoting Integrated Water Resource Management for four river basins, including Ombilin-Singkarak sub basin, there are several specific agenda for further studies to assist Balai PSDA.

a. Action Research for Institutional Development, especially in creating the regional regulation to establish the consensus of role sharing among stakeholders within the subbasin and facilitating the establishment of sub-sub committee of water council.

b. Modelling of Water Allocation System within the sub basin. This study should be done in a collaborative work with the personnel of Balai in the "Learning Process" pattern. It includes database management, hydrological analysis for multiple purposes, and creating a computer program for water allocation model.

c. Study of Economic Value of Water for promoting the economic perspective of water resource management within the basin.

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Challenges and Opportunities to Implement RUPES Program at Singkarak Catchment

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Singkarak Lake, located in the central part of West Sumatra, is very important not only for people who live surrounding the lake but also for other people who live outside the catchment. The function of the Singkarak Lake to produce hydropower electricity and irrigation water is deteriorating, and this have been perceived as one of the effects of increasing rate of forest/land degradation surrounding the Lake. During the dry season, water level at the Lake could go down to 2 m from the normal level and this could cripple the PLTA (the Hydroelectric Power Plant) and can cause drought in many rice growing areas. During the wet season the water level increases and often causes floods.

The local government and local community are now trying to rehabilitate the degraded land surrounding the lake to reduce such unfavourable conditions. However, due to lack of funding and lack of incentives for the upland poor to rehabilitate the land, the progress of the rehabilitation program is very slow.

Rewarding the local community for the environmental services that they provide (RUPES) will encourage them in maintaining their natural resources and assist them in accelerating the rehabilitation program. However, such reward system and institutional mechanisms for the reward distribution have not yet been established in Singkarak. Initiative to establish such system is now underway not only in Singkarak but also in other province, i.e. Banten Province. The challenges are how to develop local stakeholder capacity to identify potential activities that provide environmental services, what regulations that should be made to facilitate the process of rewarding the upland poor for the environmental services that they provide, what institutional systems that should be in place, and how the local institution could be connected to national system who facilitate and regulate environmental services programs.

"Wali Nagari" Paninggahan, Solok District, West Sumatera Province in collaboration with Bogor Agricultural University and the Cooperative for the Improvement of Technology and Welfare of Agroforestry Community (*Induk Koperasi Peningkatan Teknologi dan Kesejahteraan Masyarakat Pertanian Kehutanan*) and other local stakeholders (Andalas University, WARSI, BPDAS-Dinas Kehutanan) is carrying out RUPES project (2004-2007). The objectives are to identify a range of environmental services (ES) and methods or approaches to measure the ES as well as constraints for the implementation of the RUPES, to establish appropriate institutional arrangements for transfer payment, and to compile and disseminate best practices and lessons learned from these projects to raise awareness at all levels on how the transfer of payments in delivering environmental services can benefit upland communities.

Introduction

Singkarak Lake is located in Tanah Datar District. Like in other district, the main problems faced by the local government at present are poverty and unemployment in the region. These problems have negative impact on environment through the increase of forest exploitation by the community. According to the report (Bapeda, 2000), number of shifting cultivators surrounding Singkarak Lake were about 4,559 families with total areas of shifting cultivation of about 10,624 ha. The direct impact of decreasing forest cover, as perceived by the stakeholders, is an increase in water supply during wet season that may increase flood risk and a decrease in water supply during dry season that may increase drought risk.

A mechanism called rewarding upland poor for the environmental services that they provide (RUPES) may be an effective way to increase community participation in maintaining its natural resources and increasing forest cover. The emergence of global carbon market is one of the rewarding mechanisms for upland poor that participate in carbon project such as in the National Movement of Forest and Land Rehabilitation. However, up to now institutional mechanisms to distribute the rewards have not been developed. There are a number of challenges and opportunities to develop such system. This paper discusses the environmental problems surrounding Singkarak Lake as well as challenges and opportunities to implement RUPES.

The Catchment and Lake Setting

Singkarak Lake is located in the central part of West Sumatra and is the heartland of the former Minangkabau Kingdom. The lake has an area of about 13,665 ha with length of about 21 km, width of about 16 km, and depth of about 160 m. The elevation of the lake is about 360 m above sea level. Total catchment area of the lake is about 129 thousand ha and about 39 thousand ha (30%) of this land is covered by *alang-alang* (*Imperata*) grassland. The catchment area is situated at 0^{0}14'S - 0^{0}45'S and 100^{0}19'E - 100^{0}51'E and the elevation varied between 360 and 1500 m above sea level. Its climate is characterized by a semi arid tropical, which is an exception of the wet climate for most western part of Indonesia. Annual rainfall ranges from 1,660 mm to 1,860 mm with three dry months (month with rainfall of less than 100 mm). The other months have rainfall of more than 100 mm (Oldeman *et al*., 1979).

The Southern part of the catchment area belongs to Solok District, and the northern part belongs to Kabupaten Tanah Datar. Catchment area surrounding Singkarak Lake covers about 58,460 ha (Kusuma *et al*., 1990). Of the 58,460 ha, about 32% is considered "critical land" (mostly covered by imperata grassland) while other area is used for rice paddy (21%), upland crops (17%), and other uses (30%). Most of these critical lands and 9,773 ha of uplands belongs to the clan (*Ulayat Kaum* or clan land) and local community (*Ulayat Nagari*). Only small part (less than 2,000 ha) belongs to the state. Most (about 90%) of these lands have slopes of between 26 and 75%.

Water of the Singkarak Lake comes from at least five main rivers (*batang*). From the western part of the lake (Tanah Datar district), the water comes from Batang Malalo, while from the southern part (Solok district), it comes from Batang Ondoh, Batang Paninggahan, Batang

Saning Bakar and Batang Sumani. The outlet of the lake is Batang Ombilin. Aside from this natural outlet, the PLTA (Hydropower Electricity Company) constructed an artificial tunnel in 1997. Water from Ombilin river is the source of irrigation water of rice paddy area in four downstream districts, i.e. Kabupaten Solok, Padang Pariaman, Tanah Datar and Sawahlunto Sinjunjung. While, the streamflow from the artificial tunnel is used for generating the electricity servicing West Sumatra and Riau Province, and flows to the west coast of Sumatra. Installed capacity of Singkarak Hydropower Electricity is about 175 MW (Ahmad, 2004).

The People and Institutions

Number of people living surrounding Singkarak Lake is about 400.000 people or about 205 people per km^2 and about 42% with age of between 18 and 55 years old (BPS, 1999). About 10% of the population lives under poverty line and about 4,559 families are shifting cultivators covering about 10,624 ha of shifting cultivation area (Bapeda, 2000). This community normally opens the forest without following proper water and soil conservation techniques, such as alley cropping, terracing (Yunizar, 1996) and tree planting. The current local practices has been attributed by local stakeholders as the cause of critical lands such as grasslands particularly in steep areas.

After the "reformation", the Governmental system in Indonesia has changed from centralization to decentralization system. Local Regulations on the implementation of autonomy system have been developed. West Sumatra Provincial Government has issued a Government Regulation number 9/2000 about village government system (*Pemerintahan Nagari*). With this regulation, the districts, sub-districts and village governments have autonomy to manage their own resources and to develop their own regulation in managing their resources. After this regulation was issued, the role of informal leaders and "adat" system is becoming dominant again.

The Adat system has its own hierarchical system. Lowest level is called Kaum, headed by a *Datuak* (*Ninik Mamak*). Between four or five Kaum will form Suduik. The Suduik is headed by *Datuak Tuo*. And, between three and four '*Suduik*' will form '*Suku*', coordinated by '*Datuak*

Pucuk'. A body representing a number of *Sukus* is called KAN (*Kerapatan Adat Nagari*), headed by *Ketua KAN* (Chairman). The member of *KAN* is not only the *Ninik Mamak* but also intellectual and religious leaders.

Land conflicts are normally settled using the "*adat*" system, where in the past this "adat" system was not properly used (more repressive approach). Actually, the *tanah ulayat* or clan land has been acknowledged by law since long time back, however, before the reformation this law was not well taken into consideration.

There are three types of clan land tenurial systems namely: (i) Tanah Ulayat Nagari (Nagari Land) which is under responsibility of KAN; (ii)) Tanah Ulayat Suku (clan land) which is under responsibility of all datuks under that clan and coordinated by datuk pucuk and; (iii) Tanah Ulayat Kaum (sub-clan land) which is under the responsibility of the member of Kaum and coordinated by Datuk. Other people could cultivate those lands by sharing the benefits with owner of the land (*Nagari, Suku and Kaum*).

Environmental Issues

Due to deforestation, area of critical land at Singkarak Lake increases from time to time. This condition may reduce the quality of environmental services delivered by the Singkarak watershed. Among the services perceived to be affected include:

1. River flows. Water level of the Singkarak lake during the dry season could drop down to 2 meters compared to the normal level. Under this condition, the electricity generators of the Singkarak hydroelectric power plant (PLTA Singkarak) cripples and many rice areas do not receive enough irrigation water, thereby creating big problems not only for electricity users, but also water users in the downstream of Ombilin River (See Febriamansyah *et al*., this volume). Singkarak Lake, through Ombilin River, has been providing irrigation water for rice paddy areas in Solok, Padang Pariaman, Tanah Datar and Sawahlunto Sijunjung Districts. Since the establishment of PLTA Singkarak in 1997, PLTA Singkarak has been providing most of electricity of West Sumatra and Riau Provinces. On the other hand, during wet season, the water level at Singkarak increases and causes floods, especially in rice planting areas. It is expected that by rehabilitating the "critical" land surrounding the lake, the maximum

water discharge could be reduced while the base flow could be slightly increased.

2. Water quality. Based on past studies, soil loss from part of steep slope areas in the Singkarak Lake Catchment that has been converted into agricultural land was estimated as high as 471 to 530 Mg ha^{-1} yr^{-1} (Hermanto *et al*., 1996). This level of soil loss is classified as very high and potentially causes sedimentation in the river and the Lake. During the dry season, the PLTA closes the outlet of water to Ombilin river (in order to maintain the water level at the lake), and thus decreases not only the quantity, but also the quality of water in the river due to lack of replenishment of water from the lake and heavy uses of water (for bathing and washing) along the river. It is perceived by the local communities that by rehabilitating the lake catchment area, the volume of water in the lake during the dry season could be higher, and thus good quality water and sufficient quantity of water could still be supplied for the water users in the downstream areas.
3. Maintenance of aquatic habitat. The main (involving 76.5% labor force) sources of income of the people in Singkarak Lake are agriculture and fishery. The main fish for consumption and for generating income is a local fish called '*ikan bilih*'. The population of 'ikan bilih' is now decreasing as result of high harvesting rate and perhaps also because of the decrease in water quality.

Possible Mitigating Interventions

Government and local stakeholders are now more aware of the importance of maintaining and increasing forest cover in the catchments area of Singakarak Lake. It is believed that increasing forest cover surrounding Singkarak Lake will reduce the said environmental problems. At present there are a number of initiatives from the governments and local communities to reforest the degraded land and forest. For example, the government has launched a program called a Million Trees Planting (*Penanaman Sejuta Pohon*). This program was started in February 2003 at Junung Sirih sub-district, Kanagarian Paninggahan. It was targeted that about 540 ha of the critical land will be rehabilitated every year through this program. Local community using their own fund has conducted many small scale rehabilitation activities using agroforestry system under the coordination of *Wali Nagari*. Up to early 2004 the total area that has been rehabilitated by the community using the community fund was only around 30 to 40 ha. It seems that without support from other funding, it will be difficult for the local community to rehabilitate all the critical lands.

Rewarding the local community for the environmental services that they provide (RUPES) will encourage them in maintaining their natural resources and assist them in accelerating the rehabilitation program. However, such reward system is not yet well established. At present, the regulations that relate to this issue are Undang-Undang Number 34/2000 on Tax for Surface and Sub-Subsurface Water (*Pajak Air Permukaan dan Bawah Tanah*) and Government Regulation Number 65/2001 on Regional Taxation (*Pajak Daerah*). For implementing this regulation, the local government has issued Local Government Regulation or PERDA Number 4/2002 on Tax for Utilization of Surface and Sub-Subsurface Water (*Pajak Pemanfaatan Air Permukaan dan Bawah Tanah*). According to this PERDA, the allocation of the tax money would be 30% for Provincial Government, 35% for the district that produce the tax, and 35% for other districts of West Sumatra Province. However, further regulation on how this tax should be used or distributed to the community is not available. For this year, water tax collected from PLTA Singkarak was about 2.2 billion rupiah (250 thousands US$) and about 777 million rupiah (88.3 thousand US$) has been distributed to Solok and Tanah Datar districts. Nevertheless, there is no strong basis in defining the amount of tax that should be paid by the PLTA in relation to the watershed functions, and there are no agreed criteria at present on how to monitor the level at which the watershed services are provided.

On the other hand, the global carbon market is now growing either via CDM (Kyoto mechanisms) or non-Kyoto mechanisms (such as Bio Carbon Fund). In these mechanisms, developed countries can purchase carbon benefits generated by projects that reduce carbon emission or increase carbon sequestration and/or conserve the carbon stock in forest. The communities who participate in such projects will get income from selling the carbon. From the National level, Strategic Studies on Clean Development Mechanism was conducted by the Ministry of Environment (2003). Singkarak Lake has been identified as one of the potential site for the implementation of forest-carbon projects. This payment mechanism may also be one of the potential funding sources to accelerate the degraded land/forest rehabilitation program. The challenge is how to develop capacity of the local stakeholder (human resources and institutional capacity) to participate in such mechanisms.

Proposed Mechanism of Reward

Availability of laws and regulations is very important in developing reward mechanisms for the upland poor who provide environmental services. However, the existing laws and regulation have not mentioned anything specific about rewarding the upland poor. Although there are a number of regulations relevant to this issue. Among others are UU No. 34/2000 on the amendment of UU No. 18/1997 about Local Government Tax and Revenue, PP No. 25/2002 related to rehabilitation fund, PERDA Number 4/2002 related to water services, and Government Regulation Number 34/2002 (PP34/2002) related to carbon services.

In regards with Tax for Surface and Sub-Subsurface Water (PERDA Number 4/2002), there is no agreed distribution system of the surface water tax from local government to local community. *Wali Nagari* expect that most of this tax should be given directly to local community through Nagari. Therefore, the community requested the district governments to issue a regulation on tax distribution. There have been an informal agreement among the local stakeholders to form an institution called Management Body for Singkarak Lake (*Badan Pengelola Danau Singkarak* or *BPDS*). It is expected that this body could play important role in establishing rewarding system for the upland poor who provide the environmental services.

The BPDS should represent all stakeholders from the two (Solok and Tanah Datar) districts including the Peoples Representatives (DPR), head of the two districts, Wali Nagari, other community leaders, and representatives from Buyers. The body may consist of two components, i.e. Steering Committee and Secretariat. The Steering Committee will act as Focal Point and Liaison with Governor and the National Authorities for Environmental Services. This body will provide inputs for local government on policy setting and the establishment of new local regulations as necessary related to the rewards system. The secretariat will take care the daily activities of the Body, i.e. to implement and coordinate the SC meetings, to establish system for transfer payments process following the policy formulated by the SC, and coordinate the implementation of environmental services activities surrounding the lake. The possible institutional arrangement is presented in Figure 1.

In the case of CDM project, the Authority Bodies for the ES would be DNA (Designated National Authorities) which is now being established.

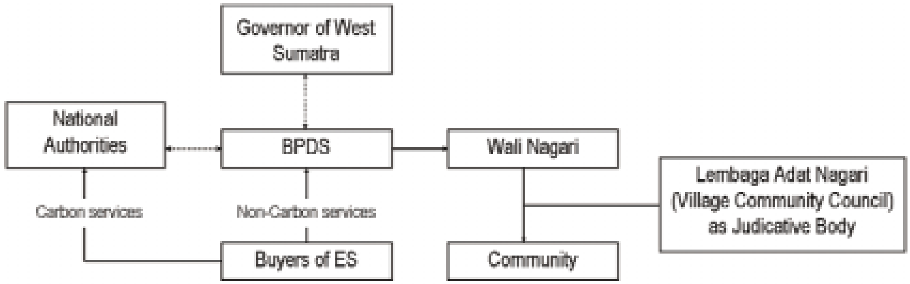


Figure 1. Institutional Arrangement for Transfer Payments in Danau Singkarak.

CDM is unique in the sense that it has to follow sets of rules governed by an international agreement. It has not only economic perspectives but also political, legal, and social implications. For these reasons, the existing institutional arrangements without some adjustments may not be able to deal with requirements and various issues to be addressed under CDM projects and a DNA is needed. The DNA is an independent institution representing government agencies and other stakeholders. This would be an ideal entity to bring CDM project into Indonesia. At present, Government of Indonesia through the Ministry of Environment is in the process of establishing the DNA. It is expected that the DNA will be available in the end of 2004.

As a learning comparison, at Banten Province, institutional mechanism to distribute reward to forest managers has been established (Figure 2). Downstream community pay the water retribution to government of Cilegon City and the retribution is distributed to upstream local government (Pandenglang and Serang districts). The upstream local governments then give the retribution funding to forest managers for managing the watershed.

In Japan, similar system has been implemented. A profit-sharing system was developed through agreement between upstream and downstream city authorities (Figure 3). Benefits from wood are shared between the two cities and then downstream city pays some amount of funding to the upstream city, as agreed in the agreement, for managing forest in the upstream watershed. The funding is managed by forest association.

Considering the above aspects, the challenges to implement RUPES program would be (i) how to develop local stakeholder capacity to identify potential activities that provide environmental services as well as approach to quantify the environmental services provided by the upland poor, (ii) what other government regulations that should be made to facilitate the process of rewarding the upland poor for the environmental services that they provide, (iii) what institutional systems that should be in place at local level to facilitate all the process, including distribution of

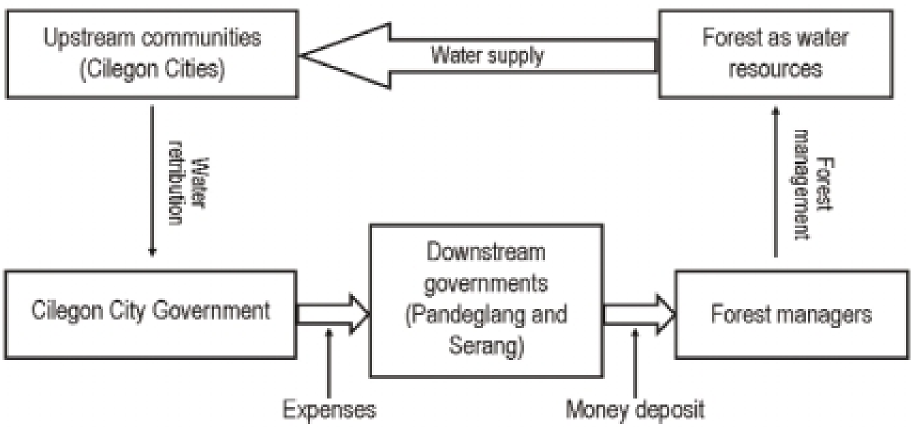


Figure 2. Financial mechanism for managing Cidanau Watershed at Banten Province (Santoso, 2004)

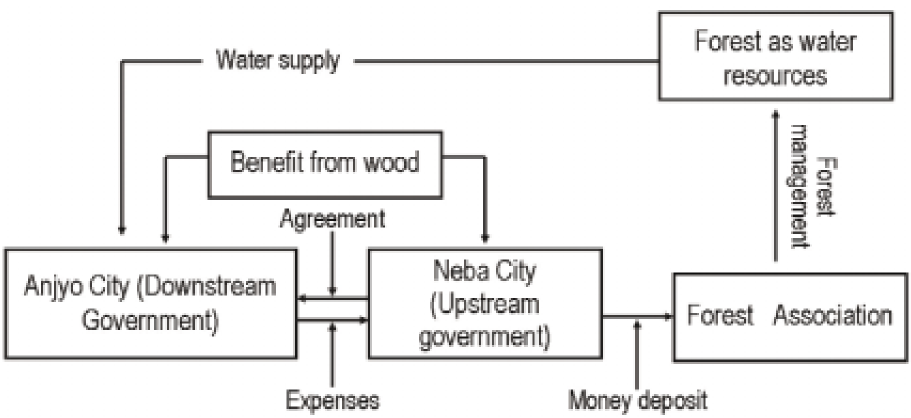


Figure 3. Watershed management with profit-sharing system in Japan (Santoso, 2004)

the rewards, and (iv) how the local institution could be connected to national system who facilitate and regulate environmental services programs.

RUPES Project at Singkarak

"Wali Nagari" Paninggahan, Solok District, West Sumatera Province in collaboration with Bogor Agricultural University and the Cooperative for the Improvement of Technology and Welfare of Agroforestry Community (*Induk Koperasi Peningkatan Teknologi dan Kesejahteraan Masyarakat Pertanian Kehutanan*) and other local stakeholders (Andalas University, WARSI, BPDAS-Dinas Kehutanan) is carrying out RUPES project (2004-2007). This project is aimed to (i) identify a range of environmental services (ES) and methods or approaches to measure the ES as well as constraints for the implementation of the RUPES, (ii) establish appropriate institutional arrangements for transfer payment, agreements, monitoring system and enforcement mechanisms following the process which is now underway on the site, and (iii) compile and disseminate best practices and lessons learned from these projects to raise awareness at all levels on how the transfer of payments in delivering environmental services can benefit upland communities.

The expected short-term outputs from the project are (i) Information and capacity building in terms of increased awareness of local stakeholders on the opportunities to have economic benefits from the environmental services they provide, knowledge in recognizing and assessing the environmental services, and in developing project concepts related to environmental services, such as carbon-sink projects, and (ii) a suitable working model of best practices for successful implementation of RUPES, i.e. an appropriate institutional arrangement for transfer payment, agreements, monitoring system and enforcement mechanisms.

The expected long-term outputs are (i) local, regional, national, and international capacity to implement environmental services effectively, (ii) improved natural resource management in upland areas, (iii) improved livelihoods among poor upland communities, and (iv) additional programmes that can be proposed for new sites to promote environmental services compensation schemes ensuring flow back of benefits to poor upland communities.

The direct beneficiaries of the project would be all community in the Nagari surrounding Singkarak Lake. By having sustainable institutional arrangement to provide rewards for the poor upland communities, and ability of the local stakeholders to get environmental services projects such as carbon-sink project, the land / forest degradation in Singkarak watershed could hopefully be slowed or even diminished while the livelihood of local community be improved. The main potential buyers for the environmental services would be PLTA for watershed function, and international investors from developed countries for carbon services.

Conclusions

Rewarding Upland Poor for Environmental Services that they Provide (RUPES) may be an effective way to reduce the rate of environmental degradation surrounding Singkarak Lake. However there are a number of challenges to implement such mechanisms. The main challenges are how to develop local stakeholder capacity to identify potential activities that provide environmental services as well as approach to quantify the environmental services provided by the upland poor, what other government regulations that should be made to facilitate the process of rewarding the upland poor for the environmental services that they provide, what institutional systems that should be in place at local level to facilitate all of the processes - including distribution of the rewards, and how the local institution could be connected to the national system who facilitate and regulate environmental services programs.

At present, there are number of initiatives to develop such mechanisms. For example, Japan has developed watershed management with profit-sharing system, while Banten Province have been using water retribution from downstream community to support forest management in the upstream. Experiences from other sites, with their strengths and weaknesses, would be a good learning for Singkarak to develop reward system.

Working group brief reports

Criteria and indicators of watershed functions and mechanisms for rewarding farmers for actual hydrological services

Following the presentations and roundtable discussions of the background papers, the participants were divided into three working groups to focus the discussion on the indicators of watershed functions and acceptable criteria, and on how to improve stakeholders understanding of the hydrological services. The three groups discussed the following themes:

(i) Criteria and indicators of watershed problems from a policy and research perspectives;

(ii) Farmers' environmentally benign practices and local ecological knowledge; and

(iii) Mechanisms and pitfalls for rewarding farmers for actual hydrological services.

Brief report on these discussions is as follows:

1. Criteria and indicators of watershed problems from a policy and research perspectives

In determining criteria and indicators of watershed functions, it was considered necessary to define the purposes or objectives of criteria and indicators, and among others these objectives are based on: (i) Sustainability of watershed resources; (ii) Performance of watershed management; and (iii) Law enforcement.

From this perspective, the group commented on different criteria and indicators as presented in the workshop. Some modifications and additions were suggested to the five hydrological watershed functions presented by van Noordwijk *et al.* (this volume), to include non-hydrological functions (biodiversity) and socio-economic and institutional aspects. The recommended list became:

1. water transmission (includes collection and dispersion functions)
2. water storage (infiltration and buffering functions)

3. water quality
4. erosion, sedimentation, and landslides
5. biodiversity
6. socio-economic-cultural-institutional aspects (including indigenous knowledge)

The group thus suggests that the first five criteria in Table 1 of van Noordwijk *et al.* (this volume) can be regrouped into four, while the non-hydrological criteria need to be added.

In the assessment of watershed resources, the Ministry of Forestry (see Fauzi Mas'ud *et al.*, this volume), divided watershed into three components:

1. Land
2. Water
3. Human resource factors

The criteria in Table 6 of Mas'ud *et al.* (this volume) adequately represent these three aspects, but the weighing factors used in the subsequent prioritization process would require closer scrutiny.

According to 'land functions' as used in RUTR/W evaluation, three functional land classes are:

1. Protected lands
2. Cultivated lands
3. Buffering lands

According to 'Balai PSDA' of public works (Kimpraswil), five criteria employed to diagnose watershed problems are:

1. Drainage area (DTA/DAS)
2. Mining activities
3. River flood plain zone (sempadan sungai)
4. Storage capacity and water quality
5. Water budget.

The group noted some overlap between these different sets of criteria, but also recognized that they are used for different purposes including identifying priorities for intervention, diagnostic phases of management options within each watershed or in the implementation and monitoring of 'watershed improvement' activities.

A number of necessary conditions was identified for successful land rehabilitation such as the GNRHL program:

1. Convergence in stakeholders' perception on the relations between rainfall, land cover, soil and terrain conditions and water flows
2. Guarantee for maintenance of trees after planting to ensure survival
3. Community education since early stage, starting from primary schools
4. Institutional strengthening at the local / farmers level
5. Reliance on a participatory approach with support by NGOs and researchers, including empowerment of local community in accessing and utilizing local resources. No more 'project' approach, as this creates dependence on external resources and external setting of priorities.

Important stakeholders of watershed functions include:

- Government (BPSDA, BPDAS, Bappeda, Balitbangda, Bapedalda, relevant district-level agency)
- Community (Farmers)
- Private corporations
- NGOs
- Researchers / scientists / Universities

An analysis of the likely stakeholders' perspectives on the various indicators / watershed functions yielded:

Indicators	Gov't	Community	Private Corporations	NGO	Scientists / Researchers
Water Transmission	√	√	√		
Storage	√	√	√		
Water quality		√	√	√	√
Erosion/sediment-ation/landslides		√	√	√	√
Biodiversity				√	√
Socio-economic-cultural & political aspects	√	√		√	

Concluding remarks of Working Group 1:

1. There is a need to further discuss selection of a minimum set of criteria and indicators of watershed functions for practical purposes according to different stakeholders' perspectives.
2. From the panel discussion, it was suggested that the applicability of criteria and indicators should indicate the scale at which they can be applied; the current criteria may typically apply for watersheds of the order of 10,000 ha; for smaller or larger areas other elements will need to be considered.
3. While there is broad support for the GNRHL objectives, the underlying assumptions of the GNRHL approach need to be clarified and the modes of implementation need to be improved; where conflicts and social factors are used in the prioritization of watersheds, they should be followed by non-technical components of the program; as yet there are serious limitations in the non-technical factors related to realizing the GNRHL concept.

2. Farmers' environmentally benign practices and local ecological knowledge

The second group discussed examples of environmentally-benign practices and local ecological knowledge. The group focused on the reasons for farmers to implement such practices as well as on the hydro-logical cause-effect relationships that can be inferred from such practices.

First, the group discussed biophysical characteristics and came up with the criteria of watershed function from a users' perspective. The following Table also describes indicators of watershed function.

Since watersheds transmit water, there should be a condition that water can be retained or released in and out of the watershed. Continuity of water availability is an indicator to be measured. Continuous water availability is of great importance to people living downstream. It is important to understand how fast water flows to the stream channel, after rain events as it determines the 'flashiness' of floods, if not the total volume of water that comes down. Hydrologic flow paths (overland flow, rapid subsurface flows or 'pipe flow' or slower macropore drainage) to streams need to be distinguished to answer the question of "how the rain water generate stream flow". So far, the variability of hydrologic pathways that generate stream flow is still debatable. In addition, as

Biophysical character-istics	Watershed function	Relevant Users	Indicators
Rainfall	Water transmission	Downstream users	Water availability
Landform	Peak flow retention	Flood plain community	Water level
Soil types	Infiltration and slow release of water	Downstream community using well water Hydro-electric plant	Water level in wells
	Water quality	Community in the lowland Farmers, fisherman, Hydro-electricity	Availability of potable water
Rooting depth of natural vegetation	Land slide mitigation	Farmers and tourists	Land slide intensity
	Erosion control		Depth of litter, depth of top soil, fish biodiversity
	Micro climate stabilization		Temperature and humidity

reported by Sidle *et al*. (2000), the headwater catchments are sources of sediments, nutrients, and biota for larger streams, yet the hydrologic pathways that transport these materials remain unclear, as there is temporary storage and filters of variable longevity.

The discussion also focused on what farmers (can) do to conserve water resources and soil. A synthesis of soil conservation measures was discussed (see the following Table).

Many conservation technologies have been created, but the implementation is still unsuccessful. In most cases, technology adoption occurs only under the control of the project implementation agencies. Farmers are not able to maintain the technologies if no incentive is provided by the project, as most techniques involves tradeoffs with the directly productive use of land or labour. Meanwhile maintaining or planting grass strips as a soil erosion measure is known widely in Indonesia and it is known to significantly reduce erosion (Abujamin *et al*,

Soil conservation techniques	Benefit
Grass (and litter) strips	Forage, erosion and runoff control, farmers' income
Alley cropping	Forage, fire wood, soil fertility, erosion and runoff control, income
Mixed cropping	Income, subsistence good, diversification, erosion and runoff control, shelter
Permanently vegetated field borders	Security, ownership border, income, forage, fire wood, erosion and runoff control, composting material/litter
Terraces	Increasing infiltration, reduced erosion and runoff

1983). However, such techniques reduce the cultivated area of farms and are hard to implement for farmers with small farms (Dariah *et al*., 1998). Integrating vegetative soil conservation measures such as grass planting with cattle fattening has good prospects to become a sustainable and profitable conservation measure. Planting of lucrative tree commodities also has good prospects. Initial implementation may be difficult, however, as the revenues start only after a number of years. External help with planting materials and investment of labour can be seen as an investment into future environmental service provision.

3. Mechanisms and pitfalls for rewarding farmers for actual hydrological services

The third working group discussed the criteria and indicators of the watershed functions according to stakeholders' perspectives, especially the mechanisms and pitfalls for rewarding the services. The group felt that among the various services, the most feasible one for rewarding was the hydrological functions, although there are other functions such as landscape beauty, biodiversity, micro climate, etc. that the group recognized.

Water users as key stakeholders were grouped into Domestic, Agricultural and Industrial groups, further divided into downstream, middle and upstream parts of the watershed, with the following result:

Downstream	**Domestic**	**Agriculture**	**Industrial**
Provider	None	None	None
Beneficiary	HH Small industry	Irrigation, Fishery, Cattle	PDAM Hydropower, Tourism
Middle			
Provider	HH	Farmer/planter	
Beneficiary	HH	Farmer/planter Fishery	PDAM, water industry, dropower, factory, pulp/paper
Upstream			
Provider	HH	Farmer/planter	
Beneficiary	HH	Fishery	Factory

Mechanisms and pitfalls for rewarding farmers for actual hydrological services from the perspectives of beneficiaries and providers are as follows:

Mechanism:

- Direct transaction
- Through NGO and/or Government
- Pooled transaction
- Combination of the three above mechanisms

Possible pitfalls:

- Low awareness
- No supporting policies and/or institutions
- No supporting scientific background
- No common understanding between stakeholders

4. Final discussion

The plenary discussion came to the following conclusions:

1. Watershed functions and the way they are affected by 'development' are much debated and are nearly everybody's concern…

2. but there are many ways in which specific problems can be solved through combinations of forests, agroforestry and upland cropping…

3. once we have a common perception (criteria and indicators) of what exactly is the problem to be addressed.

4. For example the way the GNRHL tries to achieve environmental protection goal may miss opportunities to build on local participations …

5. to support the various ways in which proper land management with trees can provide local as well as national (environmental) benefits,

6. while ensuring that outside stakeholders provide recognition and rewards in ways that are transparent, effective and pro-poor.

Indonesia's current national program for reforestation and land rehabilitation is aimed at addressing widespread concern over degradation of watersheds, through a program targeted at planting X million trees per year on 500,000 ha of 'critical lands'. Assumptions that are yet to be met for the program's success are:

1. Convergence in stakeholders' perception on underlying knowledge of what the trees can actually provide to the environment and the community
2. Suitability and synergy of the supplied tree seedlings with existing local agro-ecosystems
3. Guarantee for acceptance by the local community and maintenance after planting to ensure tree survival
4. Guarantee for non-disruption of local livelihood because of changes in land use systems
5. Community education since early stage, starting from primary schools, on science based, rather than myths, of the relationship

between land uses and the environments as well as socio-economic conditions
6. Institutional strengthening at the local/farmers level
7. Application of participatory approach (as opposed to a 'project' approach) with 'pendampingan' ('facilitation') of NGOs and researchers, including empowerment of local community in accessing and utilizing local land and tree resources.

New ways to build 'hulu-hilir' (upstream-downstream) relationships that can satisfy everybody's needs, will require ways to share the benefits that lowland community enjoy from the effectively protected water resources, ways to enhance recognition and respect for upstream communities and their ability to monitor and solve problems, and means to reduce rural poverty. A combination of public and private rewards and payments is most likely to be successful in watershed management. Test sites for this new approach include the Singkarak and Sumberjaya (West Lampung District) action research sites of the RUPES (Rewarding the Upland Poor for the Environmental Services They Provide) program.

Our overall message is:

> We need to rebuild effective communication between local, scientific and public/policy perceptions and knowledge of the problems that development can cause to 'watershed functions' and try to find solutions that build on local opportunities rather than blue-print standardized solutions.

Field visit to Lake Singkarak and Lake Maninjau

Welcome to the Nagari Paningahan on Lake Singkarak. Pak Abu Bakar Bule, the Wali Nagari, chairs the meeting and explains the general condition of the village, the community controlled lands, the state forest zone and the large enclave of village land inside the protection forest.

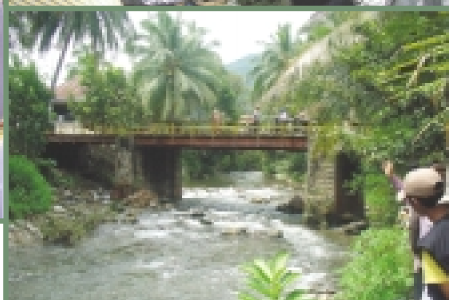
The village has developed two selections of avocado that are now recognized as 'national superior varieties' - we had a chance to taste them.

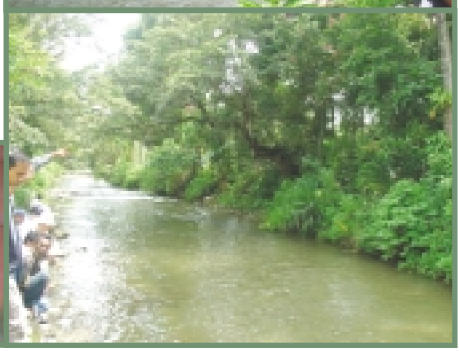
The lake (area 106 km^2, depth 160 m, 360 m asl) is surrounded by a zone of paddy rice fields with coconuts - two main components of the local food.

The foothills and lower slopes have mixed tree gardens, open field crops (maize, beans, tubers) and a substantial area of 'fallow' land, dominated by *Imperata cylindrica* (alang-alang), with low intensity grazing and frequent fire. Rehabilitating land in this zone is a priority for the community. A newly developed access road makes it feasible for small groups of farms households to jointly develop mixed tree gardens in this zone.

A group nursery in the village provides the planting material, including the special avocado seedlings

The stream coming out of the Paningahan subcatchment (the Nagari boundaries surrounding the lake are essentially hydrological subcatchments) is still clean and has a regular flow – partly due to the limestone area that allows for deep infiltration and gradual delivery to the springs, partly due to the condition of the vegetation.



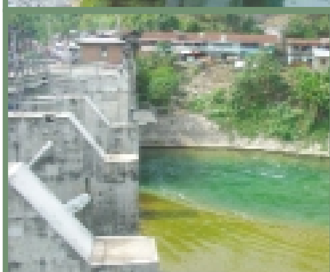


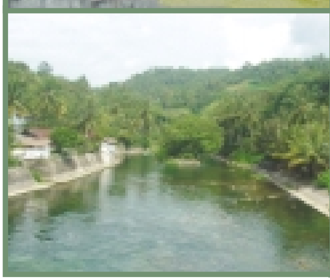
The ikan bilih, the endemic fish of Lake Singkarak that is heavily fished (if not overfished…) requires clean, flowing water over sandy river bottoms to reproduce. Nagari Paningahan has reserved a sector of the river as fish reproduction area. Dr. Bustanul Arifin, as part of the institutional analysis work of RUPES interviews to get the details on this reserve.

The Hydro Electric Power project (HEP) operated by PLTA Singkarak, has modified the regime of the lake: at its inlet it takes 49 $m^3 s^{-1}$ (leading to a drop in the level of the lake of 3 cm day^{-1} in the absence of inflow) – at least that is the target, which can not be met after dry periods.

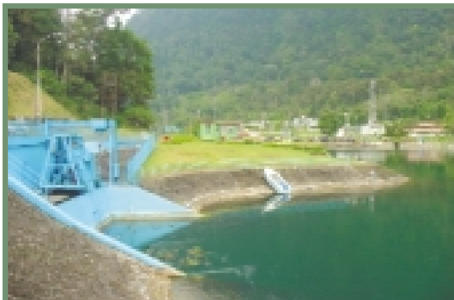
The natural outflow of the lake into the Ombilin river has been regulated. Before the HEPP scheme it had an average flow of 40 $m^3 s^{-1}$ and is now used as 'overflow' in case the incoming water exceeds the storage capacity. To avoid problems of water pollution due to domestic use of the stream, a 'sanitary; flow' of 3 $m^3 s^{-1}$ is maintained as a 'base flow'.

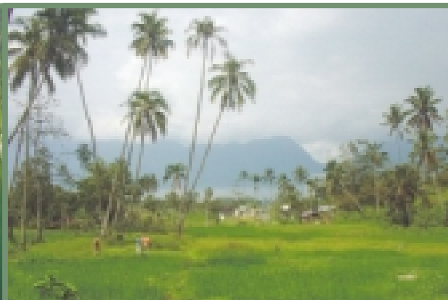
The change in river regime in the Ombilin river has consequences for the traditional water wheel irrigation systems in the valley.





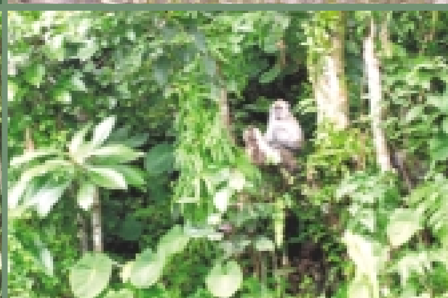
Lake Maninjau - a volcanic crater lake; the hydroelectric scheme here uses an inflow next to the natural outflow and returns the water to the same stream.



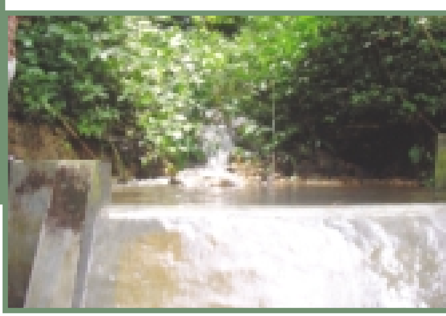


Rules - and practice

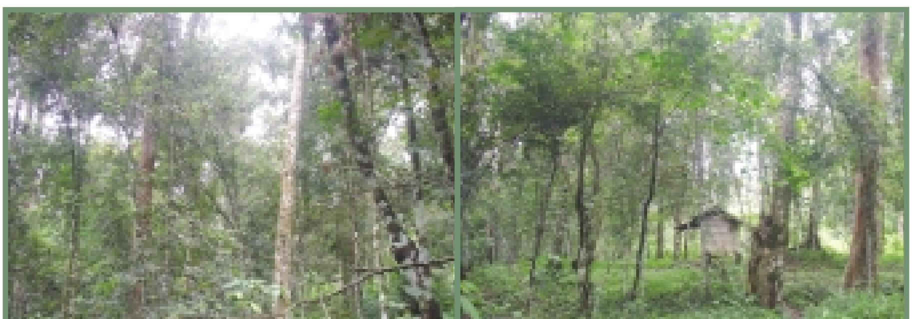
There are only a few visible streams flowing into the lake – much of the water may reach it by underground flows.

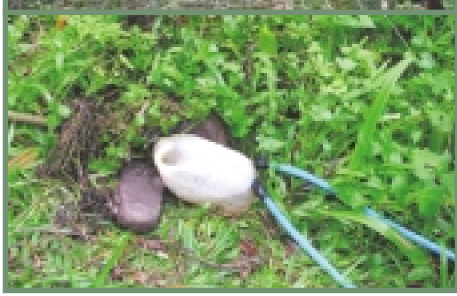


Long-tailed macaques are keeping a close watch on the winding road down to the lake.

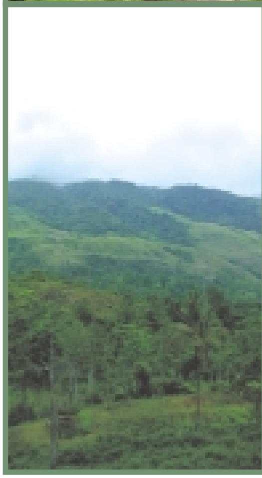


Agroforests (mixed tree stands with durian, suren and other timber trees, coffee, cinnamon, coffee, cardamon (as understorey) are the dominant land cover on the slopes surrounding Lake Maninjau, with paddy ricefields on the lowland surrounding the lake





Local benefit sharing mechanism in water supply.



Lake Singkarak – Lake Maninjau comparison

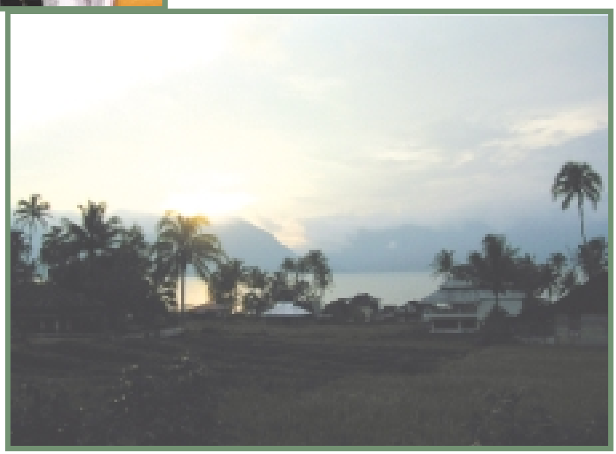
Similarities: natural lakes of volcanic origin, fertile lands, high rainfall, steep slopes, both used for hydro-electricity by PLTA, high populations density surrounding the lake

Differences: Singkarak has extensive alang-alang zone on community forest land plus a lot of deforested state forest land, low success rate of past reforestation efforts. Maninjau slopes are dominated by forms of agroforest - mixed tree system with a key role for durian, cinnamon and other fruit trees

Hypotheses: key role for different evolution of local tenure rules: community-controlled lands in Singkarak with little incentive for conversion to tree-based systems; evolution of community controlled towards privately controlled agroforests gardens in Maninjau, coffee under forest cover.

Opportunities for cross-site learning: agroforests of Maninjau can show a possible trajectory to Singkarak villagers

Meeting with village on issues arising from GNRHL implementation: "Why can't the forestry officials use tree seedlings from the local nurseries? We have suren (Toona) seedlings, the timber tree we like best – but forestry comes with seedlings of species we don't find suitable.”



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