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Assessing Hydrological Situation of Kapuas Hulu Basin, Kapuas Hulu Regency, West Kalimantan

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Southeast Asia

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ICRAF Southeast Asia Regional Office
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PO Box 161, Bogor 16001, Indonesia

Tel: 62 251 625415, fax: 62 251 625416
Email: icraf-indonesia@cgiar.org
ICRAF Southeast Asia website: http://www.worldagroforestrycentre.org/sea

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About the authors

Betha Lusiana (b.lusiana@cgiar.org)

Rudy Widodo (r.widodo@cgiar.org)

Elok Mulyoutami (e.mulyoutami@cgiar.org)

Dudy Adi Nugroho (d.nugroho@cgiar.org)

Meine van Noordwijk (m.vannoordwijk@cgiar.org)

Abstract

This report presents results of a 'rapid appraisal' of the hydrological situation in Kapuas Hulu Basin, Kapuas Hulu Regency in West Kalimantan (Indonesia). The main objective of this study was to assess the hydrological situation of Kapuas Hulu Basin and to provide information on what and where the payment for watershed services could be focused. In the upstream of Kapuas Hulu Basin lies Batang Kerihun National Park, one of the last frontiers of natural habitat in Kalimantan. The National Park is a hot-spot biodiversity area containing thousands of different plant and animal species, many of them endemic to Kalimantan.

Kapuas Hulu has a very wet climate, with an average annual rainfall of 4100 m/year. Rainfall is evenly distributed throughout the year with the wettest month in November or December. The dominant land cover class in Kapuas Hulu Basin is forest (90%). Lands that are managed by farmers (in form of agriculture and tree-based systems) only formed around 3% of the total area. There are three main catchments in Kapuas Hulu Basin: Sibau, Mendalam and Kapuas (Koheng). The intensity of land management varies between catchments, with Sibau the most intensive (vegetable plots, tree-systems and tembawang) and Kapuas the least intensive (gathering forest products and tembawang).

Currently, forest areas in Kapuas Hulu are under threat of being lost and fragmented due to fire, logging and mining activities. The local stakeholder (local community and policy makers) are concerned about the impact of loss of forest cover on watershed hydrological functions, particularly on water level and water quality (erosion, sedimentation and pollution). Boats are the main transportation for people in the area, thus stable and sufficient river depth is desirable. Water quality issues in the area are related to water turbidity due to erosion and sedimentation, as well as pollution.

The hotspots areas of Kapuas Hulu Basins are in Sibau Hulu village of Sibau catchment and Datah Dian village of Mendalam Catchment. These villages are the most upstream villages in the basin and the location where most land use change by local communities are occurring.

The average annual precipitation in the Kapuas Basin is approximately 4100 mm/year. The landscape water balance in Kapuas indicated that around 60% flows into the river, while 40% is used by the vegetation in interception and transpiration. According to the model, only 0.5 % of rainfall come as surface run-off, 16% as soil quick flow (interflow; reaching the river within 2 days after the rain) and 39% as base flow.

Based on existing data and the estimated water balance through a modelling approach, the Kapuas Hulu basin is currently still able to maintain its watershed function, particularly those related to maintaining river flow.

As indicated by the result of scenario analysis, reducing forest cover in the area will increase surface runoff and reduce soil quick flow. Thus, if the riparian zones are not healthy, there will also be increase of sedimentation in the river. The landscape water balance analysis also showed that up to 2004, the runoff fraction in Kapuas Hulu Basin was low. However, there were already signs of degradation at smaller scale as shown in the result of scenario analysis in the Datah Dian sub-catchment. In this sub-catchment, around 3% of total rainfall becomes surface run off or amounting to 6 times the overall basin condition.

The hydrological study also looked into the effect of the changes in forest cover into other land uses (agriculture systems, bush-fallow) to the total water balance, particularly the shift from base flow into soil quick flow or surface run off. These changes will have influence on the temporal pattern of river flow at a daily basis, but not on the weekly or monthly patterns.

Future development of reward mechanisms in the area could be linked to activities that improve the (i) tree cover along river banks as well as (ii) converting non-productive land, as these areas are contributing to sedimentation in the river. The lack of existing hydrological data shows the important part of water and river monitoring activities in the overall scheme.

To ensure that the hydrological condition of Kapuas Hulu basin can be maintained or improved, attention should be paid also to large logging activities as well as gold mining activities.

Keywords

environmental services assessment, environmental services reward mechanisms, hydrological modelling, Indonesia, local knowledge, watershed function

Acknowledgements

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We would like to thank staffs of WWF Pontianak and Putusibau office who have helped in organizing the RHA surveys in December 2006. In particular, we would like to thank Patria Palgunadi and Rudi Zapariza for their help in providing us with secondary data. We would also like to thank to Heri Mustopa for his kind assistance on LEK and PEK field survey.

Contents

Acronyms

WWF: World Wild Fund

DANIDA: Danish International Development Agency

IIED: International Institute for Economic and Development

RUPES: Rewarding the Upland Poor for the Environmental Services they provided

BAPPEDA: Badan Perencanaan dan Pembangunan Daerah (Regional Planning and Development Bureau)

RTRWP: Rencana Tata Ruang Wilayah Propinsi (Spatial Planning for Provincial Area)

PDAM: Perusahaan Daerah Air Minum (Public Drinking Water Company)

RHA: Rapid Hydrological Appraisal

CIFOR: Center for International Forestry Research

WCMC: Water Conservation Monitoring Centre

BAKOSURTANAL: Badan Koordinasi Survei dan Pemetaan Nasional (National Coordinating Agency for Surveys and Mapping)

BMG: Badan Meteorologi dan Geofisika (Meteorological and Geophysical Agency)

KIMPRASWIL: Pemukiman dan Prasarana Wilayah (Settlement and Regional Infrastructure Agency)

Introduction

Why hydrological assessment in Kapuas Hulu Basin?

Increasing degradation of watersheds has led to awareness of services that a watershed can provide and recognition of the need to maintain these functions. It is known that land use can significantly affect watershed functions such as water quality, water flow, erosion control and sedimentation in downstream areas. However, those who own or manage upper watershed land often have little incentive to maintain these services because the benefits occur downstream and because they do not receive compensation for providing them.

The increased awareness of the importance of maintaining watershed functions has triggered various form of initiatives to protect watershed including providing incentives for people in upper watershed areas to protect watershed functions. Landells Mills and Porras (2002) identified 61 initiatives on reward mechanism associated with maintaining watershed functions, mostly with goals to maintain dry season flows, to protect water quality and to control sedimentation. Reward mechanism is seen as a more direct approach in watershed conservation approach and it explicitly recognized the need to bridge the interests of landowners and outside beneficiaries through compensation payments.

Kapuas Hulu District as a potential site to develop reward mechanisms

Geographically, Kapuas Hulu District lies at 0°15' – 1°25' East and 111°39' – 114° 13' North in the northern part of West Kalimantan, bordering to Sarawak– Malaysia (Figure 2). To its east, lies East Kalimantan and Central Kalimantan Province, while in the west and south lies Sintang District. The total area of Kapuas Hulu District is around 30,800 km2.

In the northern part of Kapuas Hulu lies Betung Kerihun National Park, that is the origin of most of the island’s rivers, Kapuas, Rejang and Lupar. Kapuas is the longest river in Kalimantan. The Lupar River flows into Sarawak (Malaysia). Betung Kerihun is a recognized hot-spot of biodiversity. It has a range of habitats, including lowland Dipterocarp forest, wet hill forest, montane forest, moss forest, and swamp forest. All are extremely bio-diverse, home to thousands of different plant and animal species, many of them endemic to Kalimantan. They also represent some of the last-remaining natural habitats on Kalimantan. Currently, forests in this area are under threat of being lost and fragmented due to fire, logging and mining activities; which could cause (if not already has caused) watershed functions degradation.

Figure 1. The location of ''Equitable Payments for Watershed Services' sites in Indonesia. Atambua and Putussibau are the capital of Belu and Kapuas Hulu Regency, respectively.

The current situation in Kapuas Hulu is an opportunity to develop equitable reward mechanism, specifically in the Kapuas Hulu Basin that has 57% of its area included under the Betung Kerihun National Park. Communities living in and around the national park are potential sellers in providing service to maintain the watershed function including the forest and its biodiversity. Stakeholder with a strong interest in biodiversity could be the potential buyer of these services, as part of an overall strategy to maintain the integrity of the 'Heart of Borneo'. The local government might be an intermediary, buying the services locally on the basis of watershed protection, and selling globally as part of an integrated conservation package.

Another potential buyer for the services provided by the community of Kapuas Hulu Basin is the Public Water Service (PDAM = Perusahaan Daerah Air Minum). At present, PDAM provides drinking water to the residents of Putussibau (the capital of Kapuas Hulu District), using water from Kapuas River. Therefore, continuous supply of clean water is of interest to PDAM. According to Indonesia Human Development Report (2004), in 2002 around 80.4% of Kapuas Hulu is without access to clean water.

Reward mechanisms will have to address the poverty issue in Kapuas Hulu Basin. The Human Development Index (HDI)[1] of West Kalimantan province is 62.9, the fourth lowest among 30 provinces in Indonesia (Indonesia National Human Development Report, 2004). Within the province, Kapuas Hulu was ranked 5 (out of 9 districts including Pontianak the capital of West Kalimantan), or 276 (out of 340 districts in Indonesia). The low HDI score of West Kalimantan and Kapuas Hulu reflect the challenged livelihood situation of Kapuas Hulu Basin.

Why hydrological condition assessment?

As a consequence of landscape variability and site-specific characteristics of watershed functions, it is important that we conduct a general approach to monitor and assess the biophysical condition of a watershed, prior to developing reward mechanism. The hydrological assessment is crucial and it needs to be conducted independently and transparently. Otherwise, the development of reward mechanisms could be based on myths or general beliefs about land use and water relationship that lead to inappropriate solutions (Kaimowitz, 2001).

RUPES[2] proposed seven necessary stages in the development of reward mechanisms (Jeanes, *et al.*, 2006): (1) Scoping, (2) Awareness, (3) Identifying Partners, (4) Negotiations, (5) Action Plans, (6) Environmental Services Rewards: Support for Actions and (7) Monitoring. Hydrological condition assessment encompasses the first three stages that need to be conducted at the beginning of reward mechanisms development.

1 The Human Development Index (HDI) measures the overall achievements in a country/district in three basic dimensions of human development – longevity, measured by life expectancy at birth; educational attainment, as measured by the combination of adult literacy rate (two-thirds weight) and mean years of schooling (one-third weight); and standard of living, as measured by adjusted per capita expenditure (Purchasing Power Parity, Rupiah). The HDI is a summary, not a comprehensive measure of human development (Indonesia National Human Development Report, 2001)

2 RUPES (Rewarding the Upland Poor for the Environmental Services they provide) is a program for developing reward mechanisms in upland poor Asia. Its goal is to enhance the livelihoods and reduce poverty of the upland poor while supporting environmental conservation at local and global levels. See http://www.worldagroforestrycentre.org/sea/networks/rupes

Van Noordwijk *et al.* (2006, 2007) developed criteria and indicators of 'equitable compensation and reward' mechanisms: realistic, voluntary, conditional and pro-poor. The current report is focused on step I, the appraisal of 'realistic' relations between land use and environmental services that are of sufficient value to become the basis for reward mechanisms. Step I also requires appraisal of the degree of 'awareness' and 'shared understanding' between stakeholders, so there is necessarily interaction with activities in step II, which should run in parallel, jointly preparing for a negotiation phase. The main objective of this study is to assess the hydrological situation of Kapuas Hulu basin from the perspective of multiple stakeholders (local ecological knowledge, policymakers knowledge and ecohydrology) to assess 'whether there is a case to be made', as first step to appraisal of 'the business case', and to provide information on what parts of the area and which environmental service functions are most interesting for further exploration and development of payments for watershed service mechanisms.

Table 1. Steps in the process of developing equitable environmental service reward (payment) mechanisms that are based on a 'business case' with identified buyers, sellers and intermediaries

I. Knowledge to knowledge (K to K):	II. Actor to actor (A to A)
Scoping the knowledge systems: is there a realistic case for cause-effect relations between upland land use and downstream effects (avoided degradation and/or rehabilitation), and is there enough awareness and shared understanding of these issues among major stakeholder (RUPES step 1+2)	***a. Mandatory*** protection of environmental services, spatially explicit and general restrictions on land use. b. Options for ***voluntary*** agreements: Exploring stakeholder positions, preferences, scenarios for the future and preferences; what are their likely negotiation positions. c. Comparison of willingness to engage on the buyer side, willingness to engage on the seller side and availability of trusted intermediary – jointly defining '***the business case***' d. Differences in wealth and power between stakeholders, exploration of what '***equitabability***' implies in the local context.
III. Negotiations: (K+K ⇔ A+A) leading to (K to A) link Focus on conditionality (quid pro quo) of the agreements, the criteria for success and mechanisms for learning and step-wise improvement	
IV. Implementation and monitoring	

Specifically the objectives are:

- To identify the major forms of land cover/land use in the watershed,
- To identify the core hydrological issues and problem according to major stakeholders (including scientists),
- To identify which part of the watershed contributes the most to core problems and possible solutions,
- To estimate the water balance of the watershed, how it is affected by land use change and how it is related to the core problems identified,
- To suggest and rank options to deal with the hydrological issues, as a potential basis for payment/reward schemes.

Methodology

Hydrological appraisal methods

The hydrological condition of Kapuas Hulu Basin was assessed using 'Rapid Hydrological Appraisal (RHA)' approach[3] (Jeanes, 2006). This approach was developed to provide a rapid, inexpensive and integrated tool to assess hydrological functions of a certain watershed. It was also developed to identify the gaps in understanding between three types of knowledge on watershed function: local people, policy makers and scientific knowledge. If there are no major gaps, then we can focus on the conditionality of reward mechanism. If there are gaps, then we need to address those first.

The most important aspect of RHA approach is that it can provide clarity concerning criteria and indicators of hydrological function and thus provide clarity on: (i) how the watershed function is provided, (ii) who can be responsible for providing this service, (ii) how it is being impacted upon at present, and (iv) how rewards can be channeled to effectively enhance or at least maintain the function.

The assessment was based on the following activities:

- Spatial analysis of Kapuas Hulu Basin based on LANDSAT imageries, available maps and digital data to obtain land cover information for watershed modeling purpose
- Collection and review of existing relevant information on Kapuas Hulu Basin, including climate, river flow data and land cover maps
- Exploration of local ecological knowledge from the stakeholders of Kapuas Hulu Basin (local community and policy makers) on hydrological functions, water movement and consequences of land use options on the landscape
- Analysis of existing hydrological data
- Estimating the water balance and water use in Kapuas Hulu Basin using GenRiver[4] model.
- Scenario analyses of plausible land cover changes and their likely impacts on key performance indicators with the GenRiver model

Land cover/land cover change analysis

Image classification was conducted using object-based classification approach. The object based is a method of digital image classification based-on creation of spectrally homogenous cluster of pixels that represent real objects on the earth surface. The cluster of pixel is called image segments, which contained not only spectral information from the satellite image but also spatially related information such as area, perimeter, and neighborhood relationship. Together

3 Rapid Hydrological Appraisal (RHA) was developed by ICRAF to assess hydrological functions of a watershed and the impacts of land use change on key functions. ICRAF has also developed Rapid Carbon Stocks Appraisal (RaCSA) and Rapid (Agro)Biodiversity Appraisal (RaBA). These are three basic tools that can be used to assess environmental services of a given area. For more information see http://www.worldagroforestrycentre.org/sea/networks/rupes

4 GenRiver is a generic river flow model developed by ICRAF. For more information, see http://www.worldagroforestrycentre.org/sea/products/models

with spectral information, the additional spatial information is used to classify certain land cover/vegetation type on the satellite image.

In this study, we used two scenes of LANDSAT-TM acquired in 2001 and 2004. Landsat images have 30 m spatial resolution and 7 spectral channels. For the purpose of this study, we used only channel 3, 4, 5 and 7. Table 2 shows description of Landsat images used in this study and other additional data.

Accuracy assessment was performed with the aim to provide quantitative estimation on the quality of information from land cover map by comparing sample locations on the land cover map with reference data taken during field trip. We used Kappa methods in Arc View.

Training samples for image classification were obtained during field survey on December 2006 and a total of eight land cover classes were identified:

Forest, is an area characterized by more or less dense and extensive natural tree cover usually consisting of stands varying in characteristics such as species composition, diameter distribution, total basal area age class.

Agroforestry, refers to a mixed systems (trees and crops) managed by farmers. Often found near settlement area.

Crop land is defined as an area cultivated with annual crops or non-woody vegetation.

Shrubs are characterized by an area covered by mostly low woody-vegetation combined with grass.

Table 2. Description of data used in land classification of Kapuas Hulu Basin

Data	Description of Data
Landsat 7 ETM Scene ID: 119-60	Acquisition date: 26 November 1999 Spatial resolution: 30 m. Cloud cover: 10%. Sun elevation: 57.52
Landsat 7 ETM Scene ID: 119-59	Acquisition date: 10 July 2001 Spatial resolution: 30 m. Cloud cover: 1% Sun elevation: 53.59
Landsat 7 ETM Scene ID: 119-60	Acquisition date: 19 August 2004 Spatial resolution: 30 m. Cloud cover: 1% Sun elevation: 57.07
Landsat 7 ETM Scene ID: 119-59	Acquisition date: 19 August 2004 Spatial resolution: 30 m. Cloud cover: 1% Sun elevation: 57.77
Rencana Tata Ruang dan Wilayah Propinsi (RTRWP)	Scale: 1 : 100 000

Data	Description of Data
map	Source: Dinas Kehutanan Kapuas Hulu
GPS data	GPS data for training sample, obtained on December 2006

Grassland refers to an area dominated by *Imperata* grass. In some areas, the physical appearance of grass is almost similar to shrub. The major difference is that most of the vegetation cover is usually non-woody herbs

Rice field refers to inundated rice field include irrigated or non-irrigated rice field. These areas usually appear in light blue using visible-NIR-MIR bands combination.

Water body, an area that is inundated or flowed with water, such as lake or stream.

Settlement represents an area used as human residential area, including main road and village

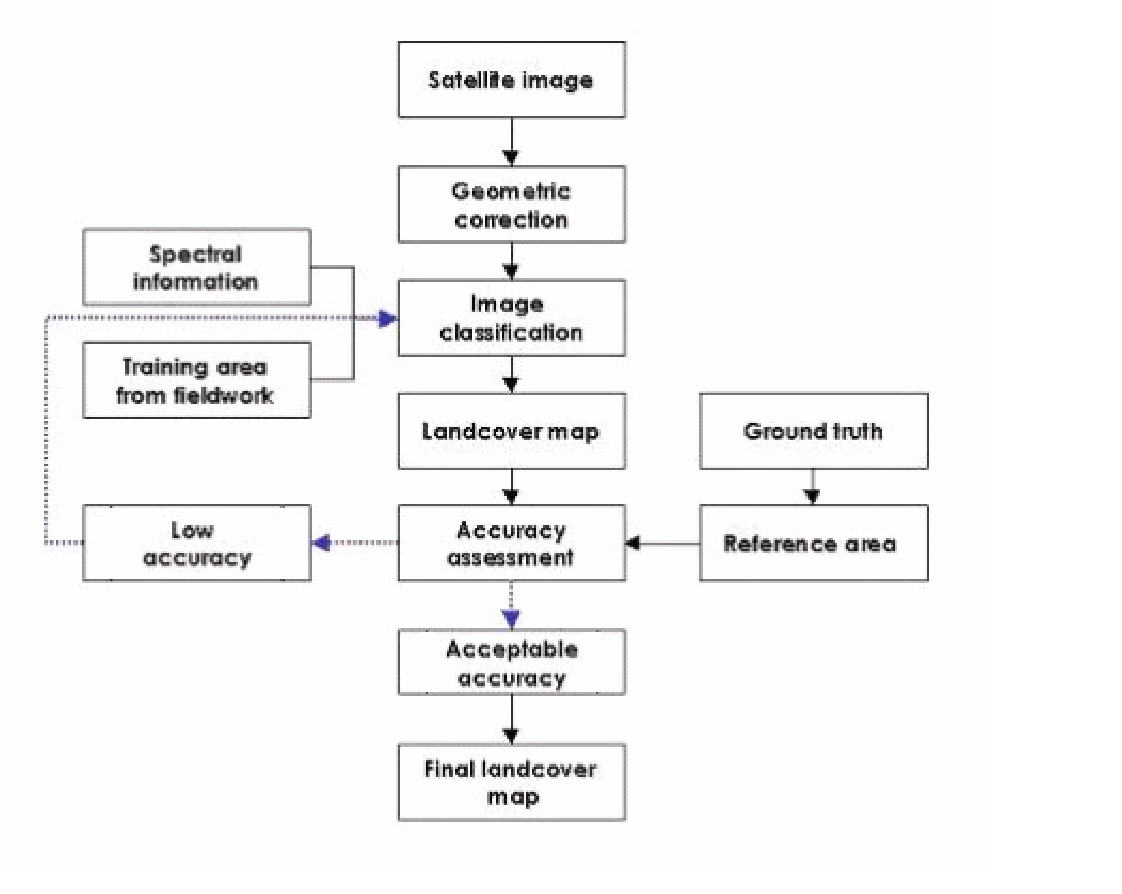


Figure 2. Flow chart of land cover analysis from Landsat image conducted in Rapid Hydrological Appraisal study in Kapuas Hulu basin (Source: Jeanes, et al., 2004).

Delineation of watershed and its sub-catchments

To delineate watershed area in Kapuas Hulu, we used DEM data from SRTM (Shuttle Radar Topography Mission), obtained from http://srtm.csi.cgiar.org//. Table 3 list the descriptions of STRM data used in this study.

Table 3. Description of STRM-DEM data used in delineation of Kapuas Hulu Basin

Product	Data File	Centre point	Year
SRTM 90m DEM	srtm_59_12	Latitude 2.50 N Longitude 117.50 E	2004
SRTM 90m DEM	srtm_59_13	Latitude 2.50 S Longitude 112.50 E	2004

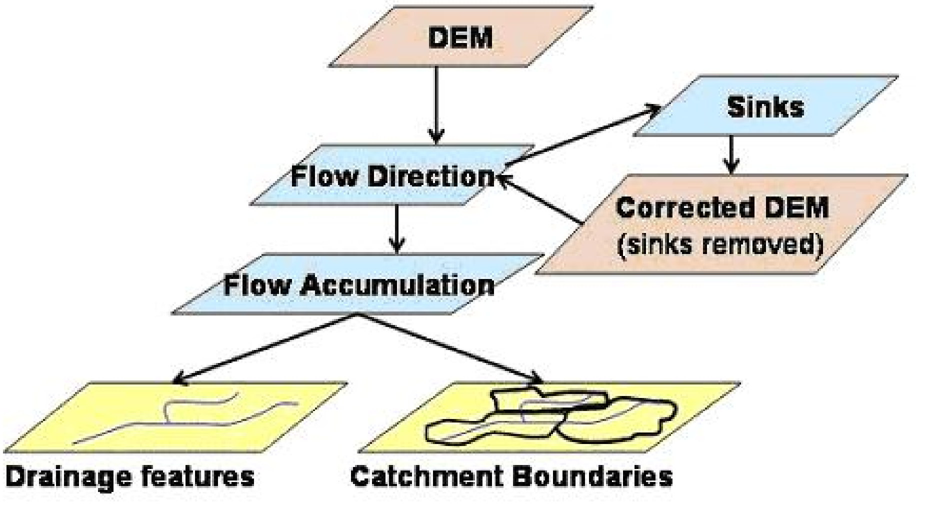


Figure 3. General work flow of hydrological features extraction in ArcView Hydro Module (Source, Jeanes, *et al*., 2004).

Notes:

Flow Direction: each cell is assigned a value denoting the direction of the flow based on the height differences of its neighboring pixels

Sink: cells identified as having no outlet, being the lowest in height compared to its neighboring cells

Flow Accumulation: each cell is assigned a value of accumulated number of cells contributing their flow to that cell

Knowledge surveys and stakeholder analysis

The objectives of these surveys are to explore the local people and policy makers' perspectives and concerns on hydrological issues in Kapuas Hulu Regency, particularly in Kapuas Hulu Basin. Perspectives from urban water users were also explored.

Local people are the actual land manager that work and interact with watershed landscape on day to day basis. Policy makers at regency and provincial level are people that have been given a mandate to control and manage the watershed areas. The policies they create will have strong influence on the future condition of a watershed. Thus, both local and policy makers views on watershed hydrological condition are very vital in this overall study.

The knowledge surveys were carried out in Pontianak, Putussibau and Sibau, Mendalam and Kapuas watersheds in December 2006. The methods used in the survey are adapted from Knowledge Based Systems developed by Dixon *et al*. (2001)[5].

Climatic, geology and hydrological data of Kapuas Hulu watershed

Up to date data on rainfall and river flow in Kapuas Hulu watershed is very scarce. There were no continuous monitoring program for water quality or quantity in Kapuas Hulu watershed, thus there are no continuous water quality or quantity data available.

The only river flow data that we were able to obtain are from Sanggau, located about 590 km downstream with a catchment area 7 times larger than that of our focus study area), and downstream of the Danau Sentarum swamps that acts as a buffer. We scaled up our modeled results for the study area to match this larger scale for the calibration set, as will be discussed later.

Table 4. List of data on climate, geology and river flow of Kapuas Hulu watershed.

Data	Type	Year	Source
Rainfall	Daily rainfall, weather station: Pangsuma, Putusibau	1996-2005	BMG Putussibau
Soil	Soil map, scale: 1:250000	-	REPPROT-WWF Putusibau
Hydrology	Daily water level, Sanggau station	1997-2006	Proyek Pengendalian dan Pengamanan Banjir Kalimantan Barat, Seksi Sumber Daya Air, Dinas Kimpraswil Propinsi Kalbar (Settlement and Regional Infrastructure Agency)

Estimating the landscape water balance of Kapuas Hulu watershed

To estimate the landscape water balance, we used modeling approach using GenRiver model (Farida and van Noordwijk, 2004, van Noordwijk *et al.*, 2003), a generic model of land use and river flow. GenRiver is a distributed process-based model that simulates river flow. It was developed for data-scarce situations and is based on empirical equations. The model can be used to explore the basic changes of river flow characteristics across spatial scales – from patch level, sub-catchment to catchment. GenRiver is a simple river flow model that aims to simulate changes in river flow due to land use change.

The core of the model is a patch level daily water balance, driven by local rainfall and modified by the land cover and soil properties of the patch. The patch can contribute to three types of stream flow: surface-quick flow on the day of the rainfall event, soil-quick flow on the next day and base flow (simulated as the gradual release of groundwater).

[5] More information on local knowledge is also available at Sinclair, FL (1998).

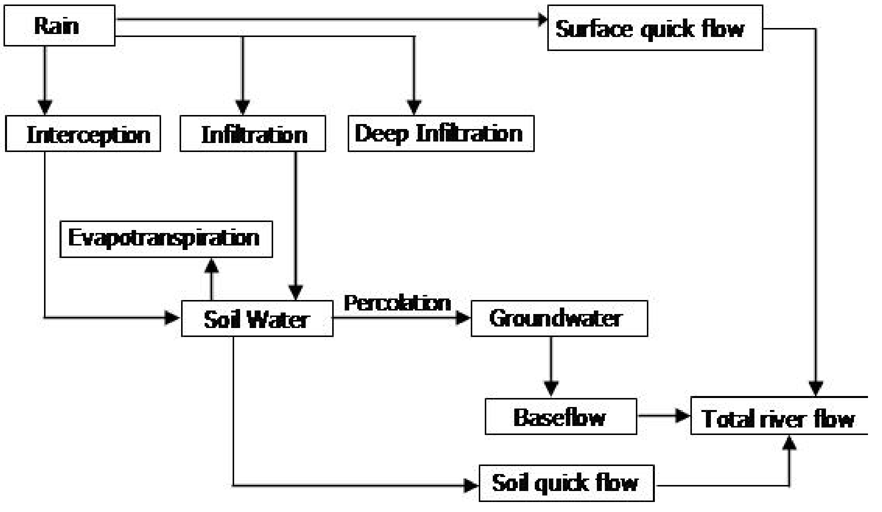


Figure 4.
Diagram flow of hydrological processes in GenRiver

The core of the model is a patch level daily water balance, driven by local rainfall and modified by the land cover and soil properties of the patch. The patch can contribute to three types of stream flow: surface-quick flow on the day of the rainfall event, soil-quick flow on the next day and base flow (simulated as the gradual release of groundwater).

The modeling activity was carried out using the following steps:

- Data preparation
- Processing spatial information resulting from spatial analysis   The activity conducted in this step includes producing hydrological features data such as sub-catchment boundary, drainage, routing distance (distance of streams within sub-catchment to main river), soil characteristics
- Model parameterization.
- Model calibration using existing data
- Scenario development
- Model simulation with plausible land use change scenarios to understand the impact of land use change on sub-catchment water balance.

Analysis on Indicators of Watershed Functions: water quantity and water quality

The assessment of hydrological situation in Kapuas Hulu basin is established mostly on criteria and indicators of water transmission (total water yield per unit rainfall), buffering capacity (relationship of peak river flow and peak rainfall, linked to flooding risk) and gradual release of (ground) water in the dry season, based on recharge in the rainy season (Table 5).   These indicators all relate the flows of water to the preceding rainfall – and by doing so; allow the analysis of the relatively small land use effects, superimposed on substantial year-to-year variation in rainfall.

As there is a shortage of reliable data on river flow, we first calibrated and validated a water balance model for the area, and then used this for further exploration of scenarios. As no data continuous data on sedimentation or erosion exist, we will assess the risk to erosion through level of runoff. This is with an underlying assumption that high run-off would lead to high risk of erosion.

Analysis of relationship between land cover and water balance

To understand the impact of land cover on landscape water balance and river flow, we will use modeling approach to simulate land cover change scenarios. The scenarios will be based on the results of both local knowledge surveys and policy makers' surveys. The simulation study will focus on (i) Sibau and (ii) Mendalam catchments where hydrological issues are most prominent.

Table 5. Criteria and indicators of watershed hydrological functions that relevant to downstream stakeholders (van Noordwijk, *et al*., 2004)

Criteria	Indicator	Quantitative Indicator	Site characteristics	Relevant for
Water transmission	Total water yield (discharge) per unit rainfall (TWY)	$TWY = \frac{Q}{A \times P}$, Q = annual river flow, A = total watershed area P = annual precipitation	Annual rainfall (mm.year-1)	Downstream water users
Buffering peak rain event	Buffering indicator for peak flows given peak rain events (BI)	$BI = 1 - \frac{Q_{abs\_Avg}}{A \times P_{abs\_Avg}}$, where $P_{abs\_Avg} = \sum \max(P - P_{mean}, 0)$ $Q_{abs\_Avg} = \sum \max(Q - Q_{mean}, 0)$	Geomorphology	Communities living along the river and in flood plains
	Relative buffering indicator, adjusted for relative water yield (RBI)	$RBI = 1 - \left(\frac{P_{mean}}{Q_{mean}} \times \frac{Q_{abs\_Avg}}{P_{abs\_Avg}} \right)$		
	Buffering peak event (BPE)	$BPE = 1 - \frac{\max(Daily\_Q - Q_{mean})}{A \times \max(Daily\_P - P_{mean})}$		
	Fraction of total river discharge derived from surface quick flow (run off)	Direct output from model		
	Fraction of total river discharge derived from soil quick flow	Direct output from model		
Gradual water release (water availability during dry season)	Lowest of monthly river discharge totals relative to mean monthly rainfall		Soil type and characteristics	Communities who do not own water harvesting/ storing systems (lake, embung)
	Fraction of discharge derived from slow flow (> 1 day after rain event)	Direct output from model		

Note: Q (mm.day-1) = {[(m3.sec-1) x24 hourx3600 sec.hour-1]/ [A (km2) x106 m2.km-2)]} x103 (mm.m-1)

Land use/cover analysis of Kapuas Hulu Basin

The study site

The hydrological study was conducted in December 2006, focusing on three main catchments of Kapuas Hulu Basin: Sibau, Mendalam and Kapuas (Koheng), with a total area of about 9800 km^2 and each catchments covers 19%, 16% and 65% of the whole basin, respectively. The three main rivers in each catchment meet in Putussibau, the capital of Kapuas Hulu Regency, West Kalimantan Province.

Geographically, the area lies at 112° 50’ 00’’ – 114° 12’ 00’’ East and 0° 23’ 40’’ – 1° 28’ 00’’ North, administratively under Putussibau and Kedamin District, bordering to Sarawak–Malaysia in the north, to Manday and Embaloh Hilir District in the South, East Kalimantan and Central Kalimantan in the east and Embaloh Hulu District to the west.

The topography of Kapuas Hulu Basin encompasses plain, hill and mountainous area, with elevation ranging from 30 – 2000 m above sea level. The upstream of this area is part of Muller Mountain range and Kapuas Hulu Mountain range.

Embaloh Group (85%) dominates the geological unit of the area and the rest falls under the category of Kapuas Complex, Sintang and Selangkai Stones and Lapung Volcanic. The soils of Kapuas Hulu belong to Ultisol (Podsolic), Inceptisol (cambisol), Histosol (organosol), Gleysol (Glei humus), and Entisol (Alluvial).

Af-aw climate (Koppen) is the typical climate of the area, which is isothermal tropical rain climate with hot dry season. The average temperature is around 22º C and average rainfall of 3500-4500 mm per year. Wet months (or total monthly rain of above 200 mm) normally occur for 10 – 12 months every year.

The river flow pattern varied, from dendritic, parallel and trelis pattern in the northern part and southern part of Muller Range, as well as anastosomic pattern in the alluvial plain (inundated areas).

The local community living in the area are mainly of Dayak tribes; Dayak Iban, Taman, Kantu', Kayan, Bukat, and Punan. According to their livelihood options and community structures, the Dayak tribes can be categorized into three main groups. Bukat and Punan are hunter gatherers, living in small groups and leader structures are based on seniority and skills. Orang Iban and Kantu’ are farmers; they are egalitarian being more open and democratic. Orang Tamambaloh and Kayan are also farmers with more complex leadership structures.

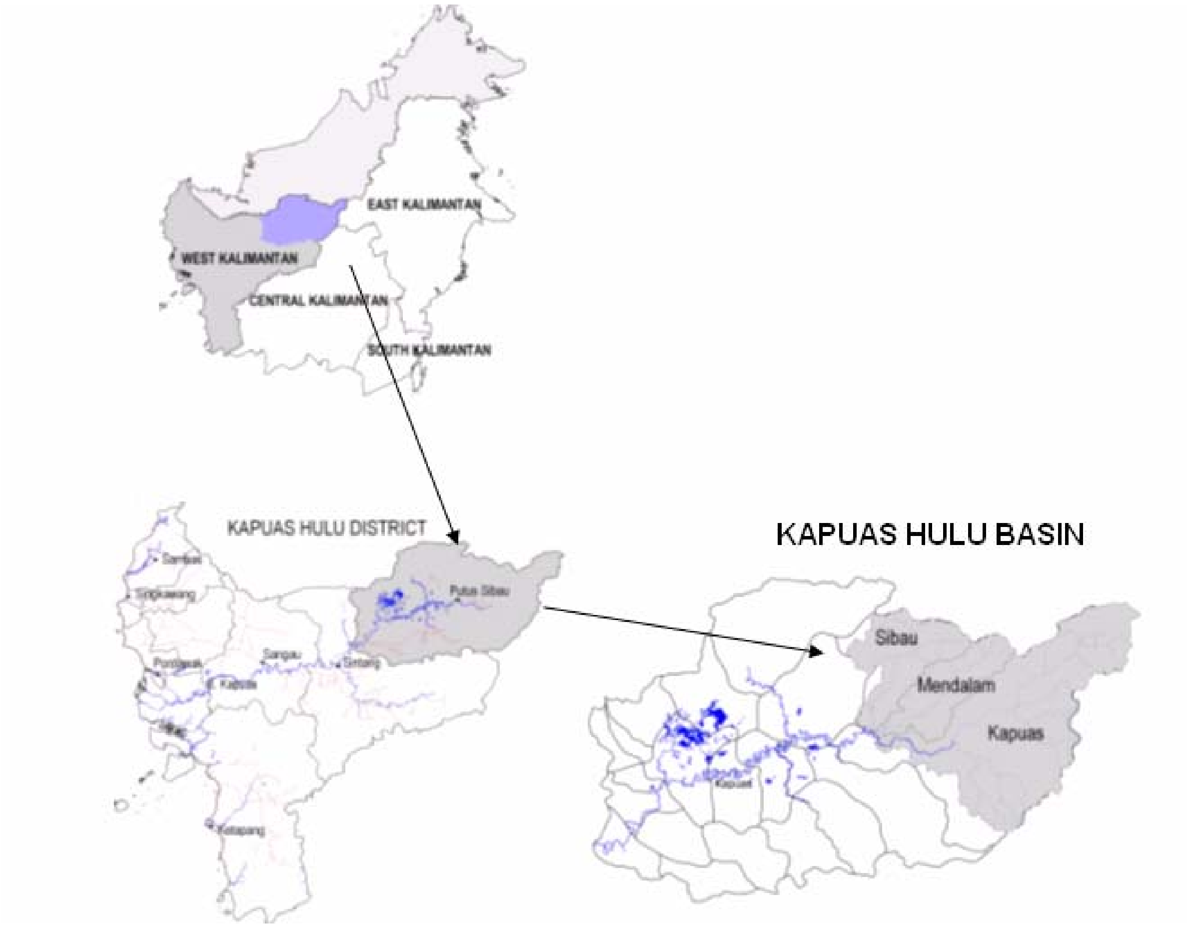


Figure 5. Location of Kapuas Hulu Basin.

Land use/cover change analysis

The result of land cover classification analysis on 2001 and 2004 Landsat imageries are presented in Table 6 and Figure 6. The land cover map has an overall pixel-level accuracy of 77% (see Appendix 1).

The Kapuas Hulu Basin has an area of approximately 9800 km^2. The main land use system in Kapuas Hulu is forest, covering more than 90% of the area. Only about 3% of the area is managed by farmers (crop land and agroforestry). The land cover patterns of the three main sub-catchments (Kapuas, Mendalam and Sibau) are similar.

Based on the RTRWP (Rencana Tata Ruang and Wilayah Propinsi = Provincial Landscape and Area Planning) map, around 56% of Kapuas Hulu Basin is part of a National Park, 36% under protected forest, 6% under production forest (limited and permanent) and only 214 km^2 (2%) is free for other land uses including settlement and agricultural cultivation (Table7 and Figure 7).

Table 6. Area of Kapuas Hulu Basin in 2001 and 2004 under various land cover

Land cover Class	2001		2004	
	Area in km2 (Proportion in %)		Area in km2 (Proportion in %)	
Forest	9001	(91.9)	8873	(90.5)
Agroforestry	252	(2.6)	279	(2.9)
Crop land	7	(0.07)	17	(0.2)
Bush	38	(0.4)	102	(1.0)
Grassland	2	(0.02)	11	(0.1)
Rice field	21	(0.2)	26	(0.3)
Settlement	9	(0.1)	22	(0.2)
Water Body	25	(0.2)	26	(0.3)
No Data (cloud, shadow)	445	(4.5)	445	(4.5)
Total	9800			

Table 7. Area of Kapuas Hulu Basin under designated land use categories (based on RTRWP map)

Designated Land Use	Total area	
(according to RTRWP)	Km	%
National Park	5502	56
Protected Forest	3487	36
Limited Production Forest	409	4
Permanent Production Forest	152	2
Dry land Agriculture	214	2
Water body	37	0
Total	9800	100

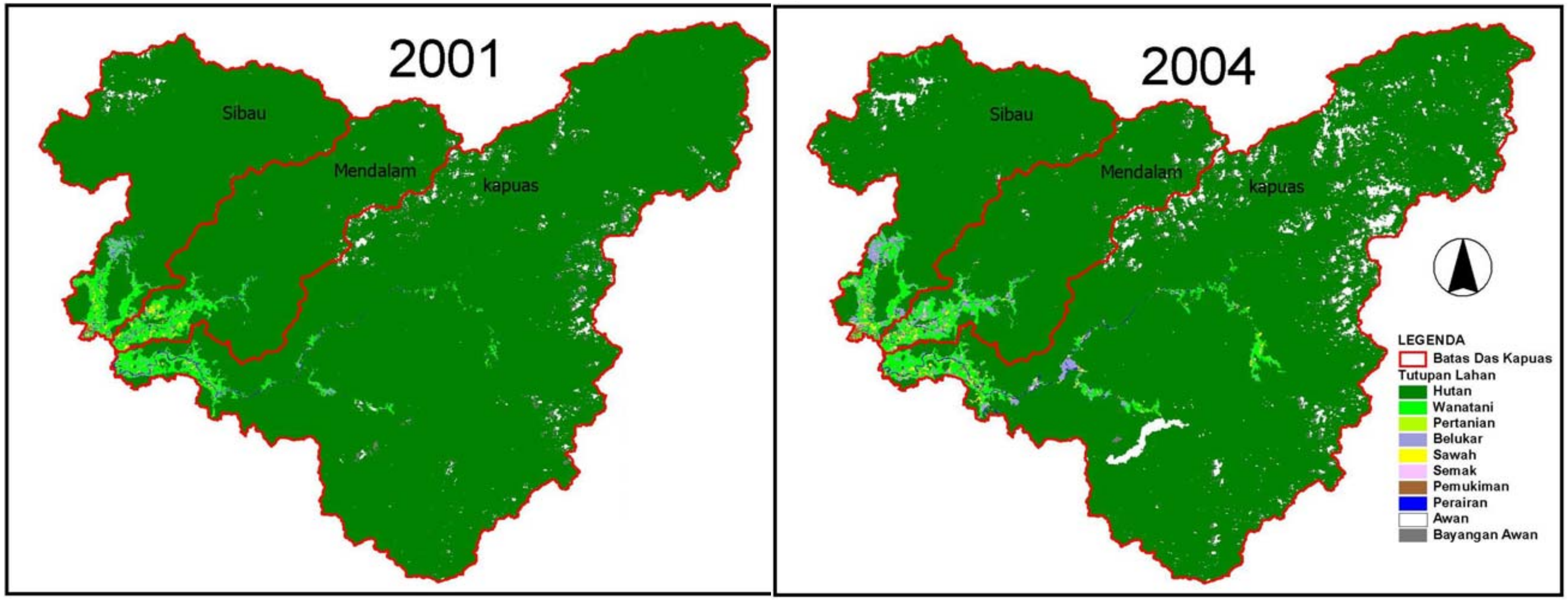


Figure 6. Land cover map of Kapuas Hulu Basin based on classified image of Landsat in 1001 and 2004.

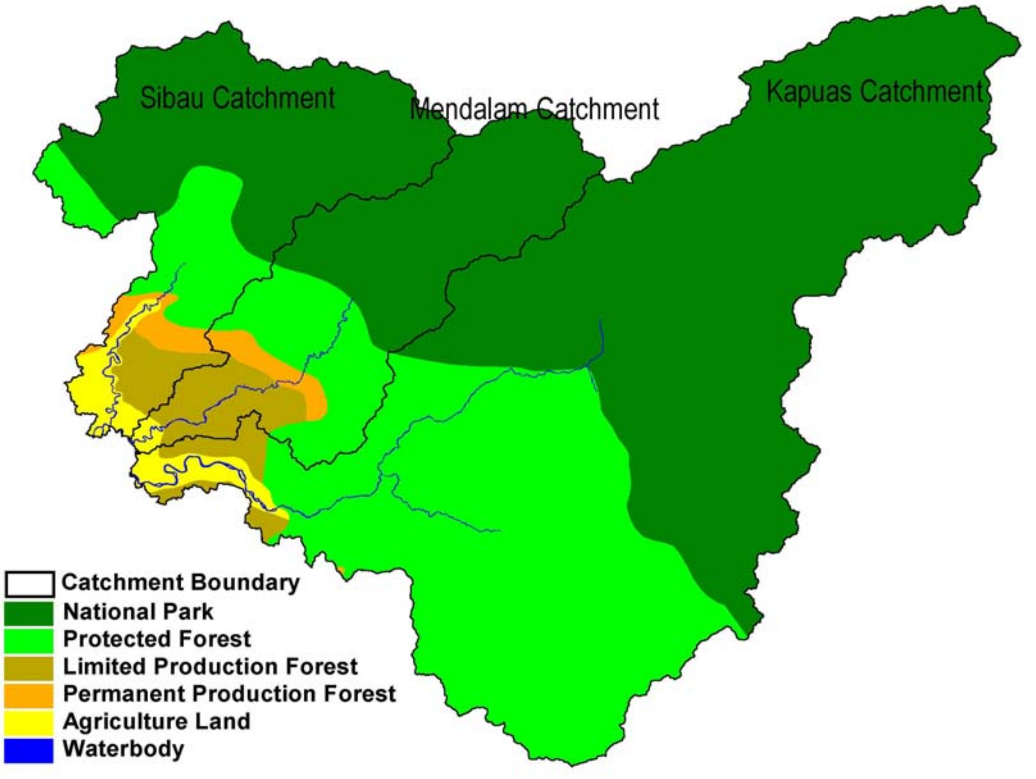


Figure 7. Map of Kapuas Hulu area under different land use designation based on RTRWP map.

Between 2001 and 2004, forest area in the Kapuas Hulu basin was reduced by around 130 km^2, while the total area managed by farmers increased by around 42 km^2. Both are insignificant changes in terms of percentage to the total basin area, but they represent a substantial relative increase in the agriculturally used area. Settlement area has more than doubled within this period. These changes mostly occurred in the designated 'Dry Agricultural' land area.

Further analysis showed that most of the land changes occurred along the river (Figure 8). Areas highlighted in green refer to changes from forest into tree-based systems, while changes in yellow refer to changes from forest into non-tree systems (crop, shrubs, bush or settlements). None of the land use changes occurred in the National Park area, showing quite good protection of the area as well as good stewardships by the people living surrounding the area. Nevertheless, changes that had occurred along the river, could affect the stability of the river banks. Direct field observation showed that the riparian condition of Sibau and Mendalam area are more open compared to Kapuas catchment (Table 8).

Table 8 presented a general overview of the landscape condition in each of the main catchments. In terms of intensity of land use management, farmers land seems to be the most intensive in Sibau catchment, where farmers planted many types of vegetables. On the other hand, Kapuas is the least intensive, where basically farmers still carried out gathering activities.

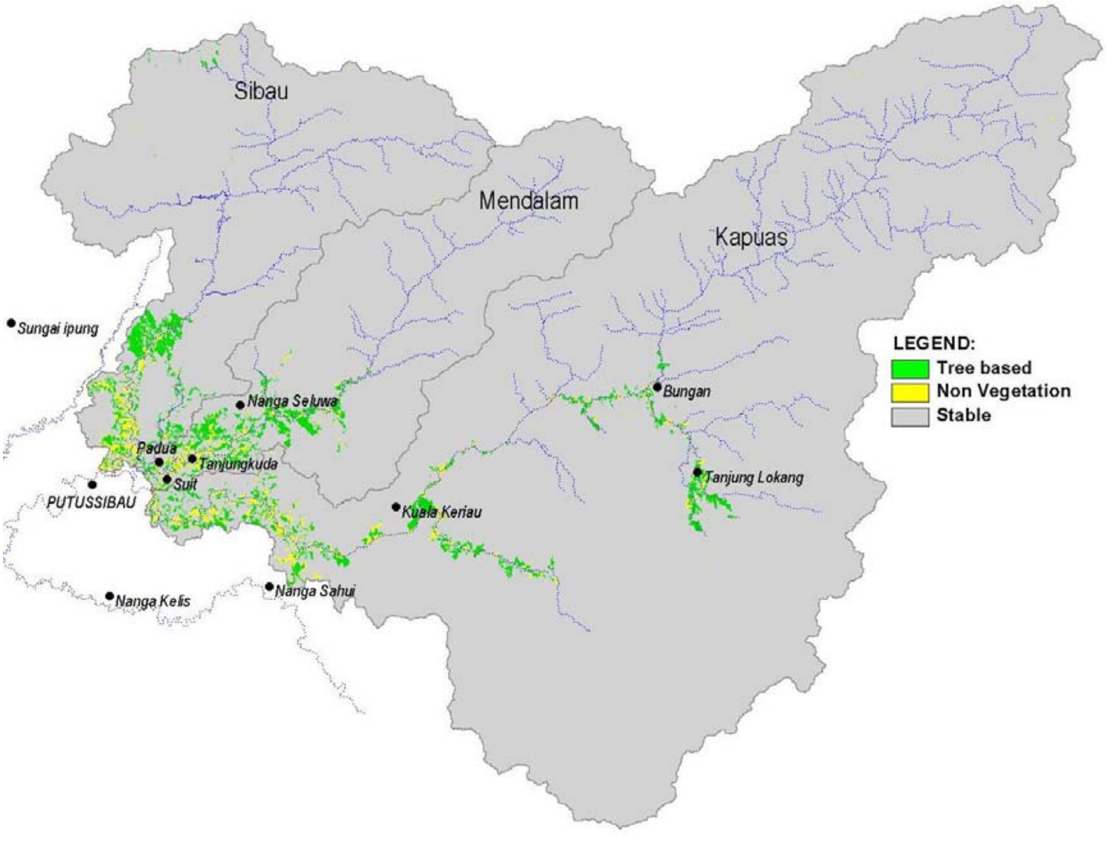


Figure 8. Map of location where land cover changes occurred between 2001 – 2004. Yellow color refers to area that has changed from forest to non-tree vegetation, while green color refers to changes from forest to tree-based vegetation.

Rice Field

Grassland

Water body

Settlement

Shrub

Cropland

Agroforestry (*Tembawang)*

Forest

Figure 9. Example of land use systems found in Kapuas Hulu Basin (Photo by: RHA Team, World Agroforestry Centre/ICRAF)

Table 8. Landscape situation in Sibau, Mendalam and Kapuas catchments

		Sibau	Mendalam	Kapuas
Catchment area (km2)		1907	1579	6315
Land form		P L A I N – U N D U L A T I N G		
Slope		F L A T - S T E E P		
Land use		Forest, tembawang, rubber systems, mixed-tree (rubber, cacao and fruit trees) systems, dryland agriculture, shrubs	Forest, tembawang, rubber systems, mixed tree systems, shrubs, dryland agriculture	Forest, shrubs, fruit tree systems, dryland agriculture
Riparian condition		Many open areas	Many open areas	Good condition
Villages	Upstream	Nanga Potan	Nanga Hovat	Tosoing Loing, Marang, Berarang, Na. Bungan, Nanga Lapung
	Mid-region	Tanjung Lasa, Tanjung Pandan	Pagung Uma', Suling, Teluk telaga	Metelunai, Nanga Keriau, Nanga Balang, Nanga Erak, Nanga Enap
	Downstream	Bua Manik, Panggilingan	Tanjung Karang, Semangkok, Nanga Sambus	Pulau Lunsara, Lunsara Hulu, Siut, Ingko Tambe, Malapi, Suai
Tribe		Bukat, Kantuk, Taman, Melayu, Iban	Bukat, Kayan, Taman, Melayu	Punan, Bukat, Suru, Taman, Melayu
River use		Transportation, fishing, drinking water, communal toilet and wash facilities (MCK)		
Source of water		River		River, rainfall, springs
Farmers group		KSM Tangke sio mambele, Kelompok Lumut Berdaun	Bukit balio	None
Main cultivated plants		Vegetables: sawi (*Brassica juncea*), maize (*Zea mays*), cucumber (*Cucumis sativus*), kangkung/ water spinach (*Ipomoea reptans*), egg plant (*Solanum* sp.), kacang panjang/long bean (*Vigna sinensis*) Tree-based systems: cacao (Theobroma cacao), rubber (Hevea brassiliensis), pepper (Piper nigrum), tengkawang (Shorea spp.), kayu belian (Eusideroxylon zwageri) Tembawang: durian (Durio zibethinus), rambutan (Nephelium lappaceum), langsat (Lansium domesticum), cempedak (Artocarpus integer), nangka (Artocarpus heterophyllus) and kelengkeng (Dimocarpus longan)	Vegetables: cucumber, maize, groundnut, long bean cacao (Theobroma cacao), rubber (Hevea brassiliensis) Tembawang: tengkawang (*Shorea* sp.), durian (*Durio zibethinus*), langsat (*Lansium domesticum*) rambutan (Ne*phelium* sp.), kelengkeng (*Dimocarpus longan*)	Kebun: pepper, rubber, tobacco, rubber, tengkawang, fruits, ginger (*Zingiber officinale*), turmeric (*Curcuma domestica*) **NTFP:** rattan, damar (*Shorea* sp.), asam kandis (*Garcinia urophylla*), sengkuang (*Dracontomelon dao*)

Delineation of sub-catchments of Kapuas Hulu Basin

The size of Kapuas Hulu is very large. To enable us to have a good and thorough assessment on the impact of land cover on water balance, we need to divide the basin into smaller sub-catchments. Thus, for the purpose of modeling, we divided Kapuas Hulu basin into 16 sub-catchments.

The focus areas of the study are Mendalam and Sibau catchment, in particular Sibau Hulu village (sub-catchment 4) and Datah Dian village (sub-catchment 9). These villages are the most upstream villages and the surrounding landscapes are where land use change by local community is occurring.

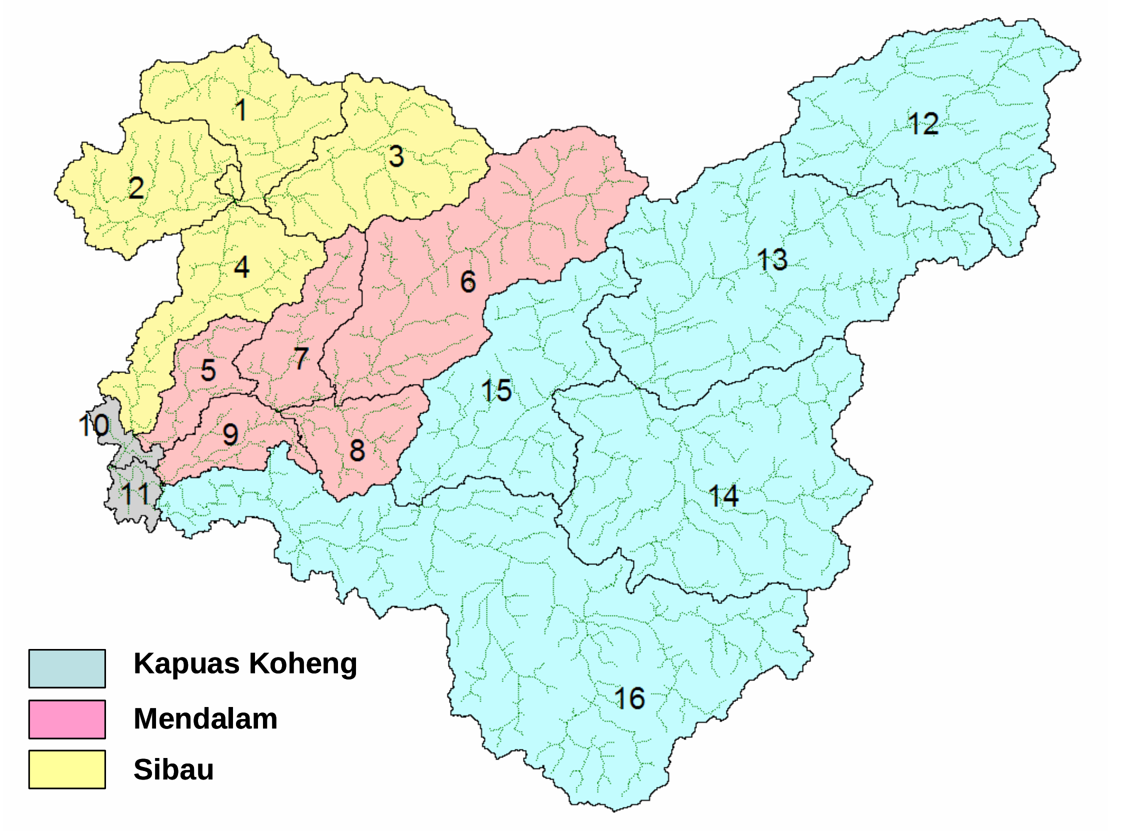


Figure 10. Map of sixteen sub-catchments within Kapuas Hulu Basin.

What are the main hydrological problems in Kapuas Hulu Basin? local community and policy makers' perspectives

Local Community Perspectives and Knowledge

People and land use pattern

The majority of the people living in Kapuas Hulu Basin are *Dayak* people and few are from *Melayu* origins. The Dayak tribes are mainly Pukat, Kantu, Tamambaloh, Taman and Iban. Each tribe has its own culture and livelihood, depending on the history of their arrival to the area[6].

The location of their settlements in the landscape are strongly linked to the land use systems and livelihood options, and influencing their perceptions and attitude in managing natural resources (Table 9). Land use pattern also changes along the river. In the upstream area, the land use systems are less permanent, subsistence in nature and use less technology. In terms of livelihood options, upstream community also carried out hunting and gathering activities. These activities provide higher income but at the same time higher uncertainty.

Table 9. Characteristic of the community in Sibau, Mendalam, and Kapuas Koheng Catchments based on their geographical position.

	Upstream	Mid-region	Downstream
Villages	Nanga Potan, Nanga Hovat, Nanga Bungan,	Tanjung Lasa, Padua, Nanga Balang, Matalunai	Sibau Hilir, Nanga Sambus, Semangkok, Dalinge
Ethnic group	Pukat and Punan	Kayan and Taman	Kayan Taman, and Melayu
Land use	Traditionally managed complex agroforest and dryland field	Rubber systems and semi-permanent upland systems (dryland and wetland)	Rubber systems and semi-permanent upland systems (dryland and wetland), Vegetable patch
Livelihood	Hunter and gathering NTFP: eaglewood (Aqauilarria sp.), swiftlet nests, gold mining (Kapuas Hulu)	Upland rice (fallow systems), Livestock breeding Trader	Upland rice (fallow systems), Livestock breeding Trader
Accessibility	Limited access to market High transportation cost	Medium access to market Medium transportation cost	Good access to market Low transportation cost

Source: interview and observation during LEK Survey (December, 2006)

Local knowledge

Dayak people believe that nature provides signs and guidance to direct them in managing their life and natural resources. For instance, bird singing is an indicator that it is time to harvest.

6 Further detail on Dayak community around Taman Nasional Bentuang Karimun is available in Ngo M (1998).

(a) Forest

Local people believe that forest has economic and ecological function. Forest functions as water reservoir and can prevent floods and landslide. Forest also the source for human basic need such food (hunter and gather the food), timber for construction, and also for religious or ritual process.

The Dayaks use their own customary law in managing forest. Timber harvesting is allowed only for household need with the leader permission. Only certain trees and animals are allowed to be harvested.

(b) Vegetation, erosion and river bank collapse

Local people knew the type of trees that has high ecological function as well as high economic value. They refer to *meranti*, *tengkawang* and *durian* as trees that have strong roots. *Bayuan*, *tebelian air*, *sengkuang*, *rabug* and *ensurai* are good trees to prevent river bank collapse. *Bungo* tree and *araso* grass are good for landslide prevention.

In local perception, erosion and landslide along the river are caused by logging activities in upstream area and riparian zones and it has caused high economic loss.

(c) Soil

The local typology of soil types is based on observable characteristics and is related to implications of soil conditions for plant growth. To get good yield from their farming systems, farmers need to practice a fallow rotation systems, in which they move their plots after two-years and leave plots to fallow for 5 years.

Fertile soils are black, normally found along the river and upstream. They will produce 'white' (clear) water. This type of soil is called *tulin* soil and *bengkinai* and *meranti* trees are normally found in fertile soil. Soils that have stones and that are reddish or yellow in color are not fertile as they lack of water and 'fertilizer'. Peat land is not fertile and produces dark reddish black water. It is normally found downstream. Another type of infertile soil is *gugup* soil, which is normally covered with ferns or grasses. It has dry and hot characteristics and difficult to cultivate.

Table 10. Soil classification based on local perception and knowledge

Soil type	'black-reddish' (peat) soil	'liat' (clay) or 'white' soil	'black' soil
Indicator (vegetation)	Hardwood species, e.g. Rengas, Jelutung	Cashew, Resam,	Softwood species,e.g. Manyam, Bungur, Bengkirai, Leban, Bongut, Mahang, Keniung,
Color	Black reddish	White yellowish	Black or dark brown
Characteristics	Low water content, high quantity of humus	Sandy, stones, low water content	Porous, high water content, landslide prone
Fertility	Less fertile	Not fertile	Fertile
Location	-	Upland areas	Flat areas
Appropriate vegetation	Rubber	*Tengkawang*	Dry land agriculture

Source: interview and observation during LEK Survey (December, 2006)

(d) Flood

Local people perceived that reduction in forest cover and high intensity of rain caused flooding. Nevertheless, they also accepted that flooding is part of their life, even before logging activities occurred.

Flooding occurred once a year, normally between October to December after the *tengkawang* fruiting season.

Hydrological issues

Table 11 presented the various concerns of local people within the three main catchments. In general, the hydrological concerns among them are more or less similar, related to quantity and quality of river flow and particularly on river flow fluctuation, water turbidity, pollution, soil erosion and river bank collapse.

The people perceptions on the main reason for the hydrological problems in general is similar with slight variation between catchments. In Sibau and Mendalam, people blamed the establishment of shortcut (*pintas)* as causing sedimentation. The Mendalam people also concerned about a recent establishment of forest concession company in the area (http://www.kompas.com/ver1/Dikbud/0703/26/174657.htm). In Kapuas, mining and small-scale logging are considered to be the main factors.

Table 11. Hydrological problems as perceived by local people in Sibau Watershed

	Sibau	Mendalam	Kapuas
Hydrological issue	river flow (water depth) fluctuation, turbidity, pollution, soil erosion and river bank collapse, sedimentation		
	increasing river width		
Causing Factors	logging, high intensity of rain, over fishing (poisoning)		
	domestic and logging trash	river shortcut construction	Gold mining (jack machine)
	soil structure (sandy soil), degraded riparian zones	degraded riparian zones	Soil structure (prone to erosion)
Impact	Transportation problem, decreasing amount and diversity of fish, people having water related stomach problem,		
	water turbidity, sedimentation in the river	widening of river, bank collapse,	widening of river, bank collapse, lack of clean water
Efforts made	agreement of forest as protected area	formation of 'community adat forum of Mendalam watershed' declaring Sadong Lake as protected lake banning on fishing using electricity and poison. community of Melayu	-

	Sibau	Mendalam	Kapuas
		Sambus agreement to ban (i) the use of pesticide and insecticide when opening land, (ii) outsiders to open and exploit land around the community area.	
What they would like to do/have	Planting Belian trees (*Eusideroxylon zwageri*), establishing rubber mixed-systems (cacao, banana, coffee), ban cutting trees in *Tembawang* systems and riparian zones, planting trees in riparian zones and establishing 'barao' to prevent bank collapse no forest concession in the area, re-enactment of community law	planting trees in riparian zones ban cutting trees in *Tembawang* systems and riparian zones, no forest concession in the area, re-enactment of community law ban on the use of poison in fishing community group development forest and water watch	Community development, clean water, Better collaboration with National Park and compensation from National park Rubber planting More information from government related to rules and regulation

Figure 11. Sadong Lake area as protected lake area.

Policy makers at district level: perception and knowledge on watershed function

Stakeholder analysis: interest and position

The stakeholder analysis showed the lack of working intergratedly between the various institutions that manage Kapuas Hulu basin. Table 12 presented the various institutions in Kapuas Hulu, including their roles and interests.

Table 12. Stakeholder interest and role in watershed management

Stakeholder	Role on watershed management	Watershed function position in stakeholder interest	Stakeholder role in watershed management	Score
Water resource agency (Direktorat Jenderal Sumber Daya Air) - Kalimantan Barat Province	Supporter	3	4	7
Regional Development Planning Agency (Bappeda) – Kalimantan Barat Province	Supporter and Policy maker	3	4	7
Environmental Impact Management Agency (Bapedalda) – Kalimantan Barat Province	Controller, Supporter and Policy maker	4	4	8
Natural Resource Conservation Agency - Kalimantan Barat Province	Controller	4	4	8
Kapuas Watershed management centre (BPDAS Kapuas)	Controller, supporter	4	5	9
Forestry Agency - Kalimantan Barat Province	Controller, supporter and organizer	4	5	9
Mining Agency – Kalimantan Barat Province	Controller, supporter	3	4	7
Environmental service provider	Provide	5	5	10
Environmental service user	User	3	5	8
NGO's	Organizer	3	4	7
Public water service (PDAM) Kapuas Hulu District	User	5	3	8
Regional Development Planning Agency (Bappeda) Kapuas Hulu District	Supporter and Policy maker	3	4	7
Transportation and communication agency Kapuas Hulu District	User and controller	4	4	8
Energy and Mineral resource agency (ESDMLH) Kapuas	Controller and Policy maker	3	5	8

Stakeholder	Role on watershed management	Watershed function position in stakeholder interest	Stakeholder role in watershed management	Score
Hulu District				
Forestry and plantation agency Kapuas Hulu District	Controller, organizer and policy maker	3	5	8
Agriculture and irrigation agency Kapuas Hulu District	Controller, supporter and organizer	4	4	8
Public works agency Kapuas Hulu District	Supporter	3	4	7
Tourism and Cultural agency Kapuas Hulu District	Supporter	-	-	-
Balai Taman Nasional Betung Kerihun	Supporter and organizer	4	5	9

Note: 1= not important, 2 = less important, 3 = moderately important, 4 = important, 5 = very important. Source: literature and interview

Hydrological issues

The following are the main hydrological concerns of policy makers that related to quality and quantity of river:

(a) Water flow fluctuation, erosion and sedimentation

Similar to the findings in local community knowledge, the main hydrological issues that the local stakeholders (provincial and district) found are the fluctuation of water level (water flow). They indicated that logging activities had caused this problem in two ways (i) decreasing amount of river flow and (ii) increase river sedimentation (due to erosion), thus decreasing river depth.

The problem in decreasing water level had caused serious transportation problem in the area as boat is the main transportation to go up and downstream (http://www.kompas.com/ver1/nusantara/0610/06/ 165140.htm).

Department of Transportation reported that during the time when water level decreased, boats with tonnage capacity of above 10 tonnes cannot reach Putussibau. This caused problem in distribution of goods, particularly food and fuel, thus price increase and electricity shortage (http://www.kompas.com/ver1/nasional/0608/01/185031.htm).

Policy makers attributed the problem to logging and mining activities as well as conversion of forest to other land uses. Establishment of 'shortcuts' (*pintas*) on the river had also added to the problem. Shortcuts' on river way that is established naturally or artificially has made transportation by river shorter (thus reducing fuel cost) and reduce flooding incidence. But, it has caused river banks unstable and collapsing, adding sediments to the river.

Table 13. Erosion and sediment concentration measured around Betung Kerihun National Park

Catchment	Catchment size (km2)	Erosion (Mg/ha/year)	Sedimentat concentration (mg/l)
Mendalam	1685	Year 1986-2004: 2	Year 1986-2004: 25
		Year 2005 : 3	Year 2005: 31
Sibau	1472	Year 1986-2004: 2	Year 1986-2004: 6
		Year 2005 : 4	Year 2005: 9
Kapuas Koheng	5992	Year 1986-2004: 1	Year 1986-2004: 5
		Year 2005 : 2	Year 2005: 9

Source: Dinas Kehutanan, 2006

Table 13 presented various point measurements on soil erosion and sedimentation in Kapuas Hulu. The current measured sedimentation rate around the National Park is much lower than threshold that WHO recommended, which is 1500 mg/l (Widjarnarto A.B. et al, 2005). This could well be because the point of measurement was taken adjacent to the National Park. Thus, this value revealed that until 2005, the National Park was able to function well in protecting the watershed function. Overall, there is an increase of erosion and sedimentation from 2004 to 2005.

It estimated that on certain location, bank collapse could have a size of 3 m, with vertical depth of 1– 2.5 m. (Dinas Kehutanan, 2006). Loss of forest cover is considered to increase sedimentation and erosion and decrease river flow.

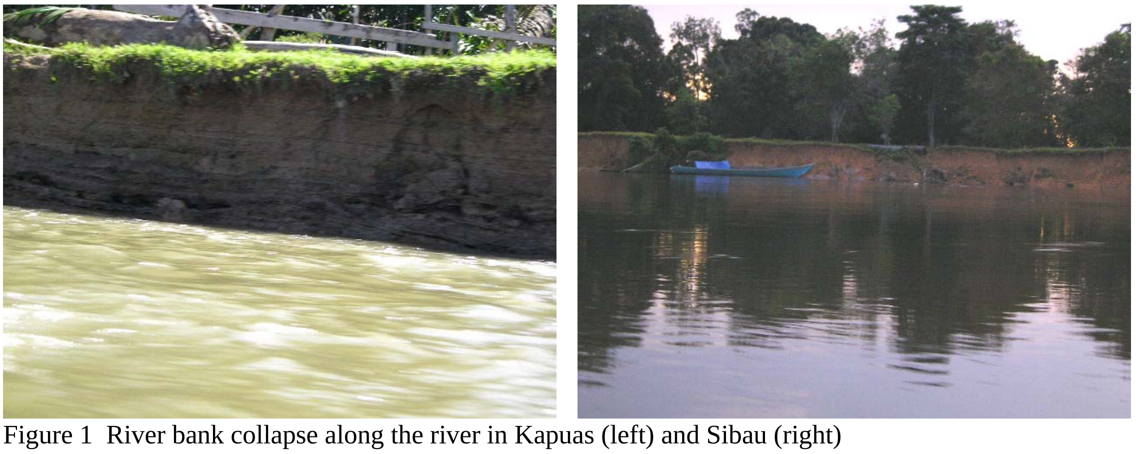


Figure 1 River bank collapse along the river in Kapuas (left) and Sibau (right)

(b) Water Turbidity

The quality of water is also a big issue for policy makers in Kapuas Hulu, particularly for PDAM. In Sibau and Mendalam catchments, water turbidity problem is quite prominent. It was considered that logging activity had caused high runoff and bringing sediments to the river. Logging activities in Sibau and Mendalam had been carried out since 1980. Mining activities that produced mud and directly run to the river is also considered to cause high concentration of sediments in the river (Figure 13). The observed condition of river turbidity, around Putussibau area, particularly after heavy rain, is not reflected in the low sediment concentration measured by Dinas Kehutanan (Table 13). Again, point of measurement and time when the measurement was taken could well be influencing the low value.

Figure 13. Accumulation of unused timber log in riparian areas contribute to unstable river flow (left). Semi mechanic gold mining activity at riparian areas potentially increased turbidity and pollution (right).

(c) Pollution: Mercury and Poison

Mercury pollution is quite high particularly in the downstream of Kapuas river. In Pontianak, the capital of West Kalimantan around 750 km downstream of Putussibau (KOMPAS, Jum’at 04 Agustus 2006) the lowest concentration of mercury is 3 ppb (part per billon) and up to 40 – 100 ppb in other points. It is higher than recommended threshold of 1 ppb (Peraturan Pemerintah No. 20/1990). (KCM, Kompas, Kamis, 02 Desember 2004, Equator online, 20 November 2000). The PDAM in Pontianak had already provided warning to its consumers not to use its water for drinking or cooking. Most people in Pontianak buy water or harvest rainfall for drinking water.   In Putusibau, the mercury concentration was measured to be 0.5 – 1 ppb (Widjarnarto A.B. et al, 2005).

Gold mining activity was thought to be the cause of mercury pollution. Survey conducted by Tanjungpura University shown that the fish in the areas (lais, belidak, toman, gabus and baung) were already polluted and no longer safe to consume.

Other source of pollution is fishing by poison. This often occurs in Kapuas Hulu area. Besides causing loss of fish population, poison fishing has also caused disease for the people along the river that uses the river for consumption and wash facilities. Diseases such as diarrhea occurred very often throughout the year.

Figure 14 summarizes the stakeholder perceptions on the hydrological problems in Kapuas Hulu and the causing factors. They have also suggested activities that could be done to solve the problems and who can be responsible for that. This issue is discussed further in the next session.

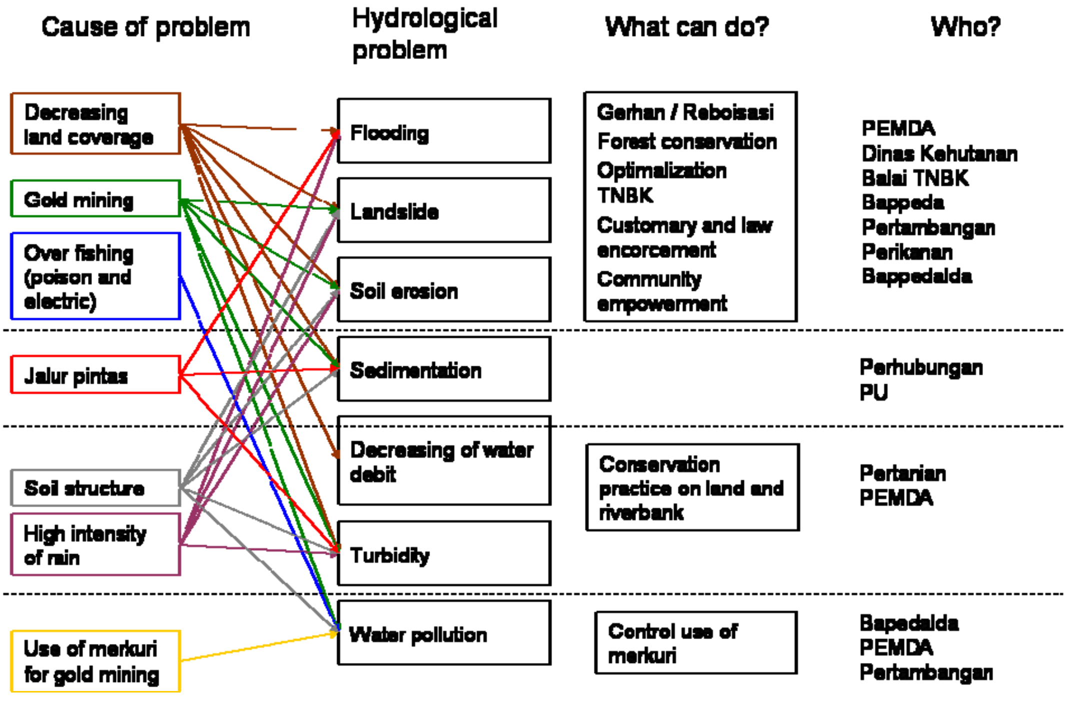


Figure 14. Diagram summarizing Provincial and District policymakers on hydrological problems in Kapuas Hulu, the causes and what can be done

Payment of environmental service: publics and policy makers' perception

All stakeholder agreed that the main issues in environmental service payments are 'what are the urgent hydrological problems' and 'who are the provider'. They felt that payment should be directed to the provider and the payment mechanism should be transparent.

Table 14 and Table 15, presented the policy makers perception on the potential PES that can be developed in Kapuas Hulu Regency. These are a very broad view from the policymakers in the area on what their basin can provide in terms of environmental services. It showed that the staffs of local government are somewhat already aware of ES and potential of PES in this area.

Table 14. List of potential hydrology-related PES as described by Policy Makers of Kapuas Hulu

Provider	Beneficiaries	Activities	Environmental Services	payment/reward mechanisms
All community along the river	All community along the river	Good land management with conservation No logging in riparian zones	Riparian zones to prevent erosion and maintaining good water quality	capacity building on knowledge for good land management practices, program to enhance the productivity of *tembawang* systems, collaborative programme to manage 'adat' areas
All upstream community	PDAM, water consumers	Protecting the river from 'harmful' activities, such as	Continuous supply of clean water	payment from PDAM/water consumers

Provider	Beneficiaries	Activities	Environmental Services	payment/reward mechanisms
		mining, logging and use of poison for fishing Rehabilitation of riparian zones		
All community along the river	Dinas Kehutanan dan Perkebunan	Rehabilitation of degraded land with economically and ecologically beneficial vegetation Rehabilitation of river banks and sloping areas	Maintaining protection function of the landscape Supporting government programme in rehabilitating degraded areas	capacity building on rubber and other tree-systems and
All community along the river	Dinas Perhubungan	Rehabilitation of river banks and sloping areas	Protecting the river from sedimentation	payment from water transport systems
All community along the river	Balai Taman Nasional Betung Kerihun	conservation of protected flora and fauna around community (in addition to already existing national park areas)	biodiversity and land protection local community added value to ecotourism flora and fauna protection	not mentioned
Kapuas Hulu	West Kalimantan	not mentioned	clean river	payment from the downstream province
Kapuas Hulu	World	Protection Natural forest	carbon stocks, biodiversity	CDM

Some respondents felt that it is better if the compensation is in form of infrastructures such as establishing schools, mosque/church or providing clean water. It could also be in form of capacity building for farmers on better farm management including environmental-friendly technology that can conserve the landscape.

The stakeholders also understand the importance of keeping the watershed for conservation area. They stressed the importance of keeping the local community involvement in this subject, through re-enactment of local traditional law. A better collaboration between the communities of various tribes is also important to avoid conflicts in the area.

Table 15. Environmental services scheme based on hydrological problems from stakeholder perspective

Environment services	Activities	Provider	Indicators	User
Water Supply	Riverbank protection and replanting	Mendalam, Sibau, Kapuas	Good quality and quantity of water	PDAM Putussibau, Urban community, Transportation
Watershed conservation	Conservation practices, protected forests and lakes	Upstream Mendalam, Sibau, Kapuas	Decreasing sedimentation Increasing infiltration Soil fertility Stabilization of water flow	Forestry Department, Downstream farmers, Local government, PDAM, TNBK
Landscape	Forest conservation Customary law re-enactment	Sibau and Kapuas Hulu	Ecotourism	Local government, tourism board, scientist, global community, TNBK
Biodiversity	Protected forest, protected lake, Customary law re-enactment	Sibau and Kapuas Hulu	Flora dan fauna Recreation (Ecotourism)Conservation of rare species	Forestry department, tourism board, local government, TNBK
Carbon	Agroforestry system Forest conservation Customary law re-enforcement	Mendalam, Sibau, Kapuas Hulu	Land cover	Forestry department, tourism board, global community, TNBK

Source: observation and interview

Ecotourism is a potential PES that the policy makers are keen to develop. They realize the economic potential of ecotourism and they also realize that their area has a lot to offer in terms of biodiversity and nature attractions. Nevertheless, they recognize that at the moment they are still lacking knowledge on how to start this activity and that there are a range of issues that they need to develop and tackle, such as security, clean water, strengthening local capacity in providing place to stay and local industry.

Figure 15. Water purification systems are set up by community (top) and PDAM (bottom) to solve problem in decreasing water quality.

Estimating landscape water balance of Kapuas Hulu basin

Calibrating river flow data

Data for validating the model the flow of Kapuas River are based on records of the water level in Sanggau, which is 590 km downstream of Putussibau. By expressing river flow per unit contributing area, a comparison can be made between the Kapuas at Sanggau and the Kapuas Hulu Basin, as there are no strong gradients in rainfall. The steps in validating river flow estimates can be seen in Appendix 2.

Climatic condition of Kapuas Hulu Basin

Based on rainfall data from Pangsuma Putussibau weather Station in 1996 - 2005, the annual rainfall in Kapuas Hulu basin is high, varying between 3300 - 4700 mm.year^{-1} with an average of 4100 mm.year^{-1}. The average monthly pattern of rainfall also shows that Kapuas Hulu basin is relatively wet throughout the year (Figure 16), with the comparatively high monthly rainfall in November and December. The lowest monthly rainfall occurred in March at around 300 mm.year-^{1}.

The monthly average air temperature ranged from 26-27^{o}C. The estimated potential evapotranspiration is 1720 mm.year^{-1} (Figure 17).

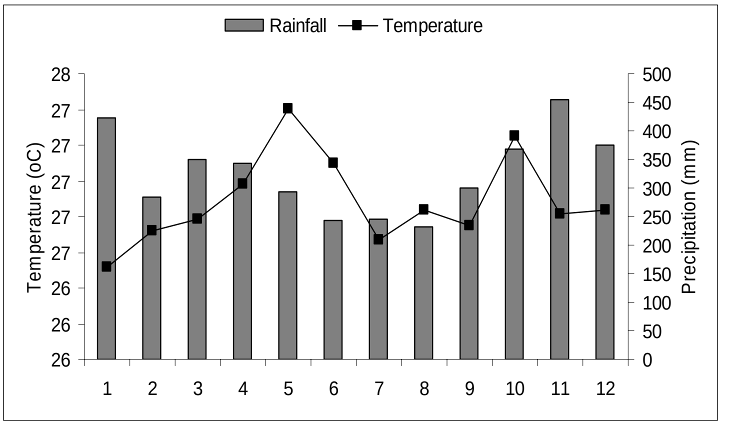


Figure 16. Monthly rainfall pattern in Kapuas Hulu basin during 2001 – 2005 period.

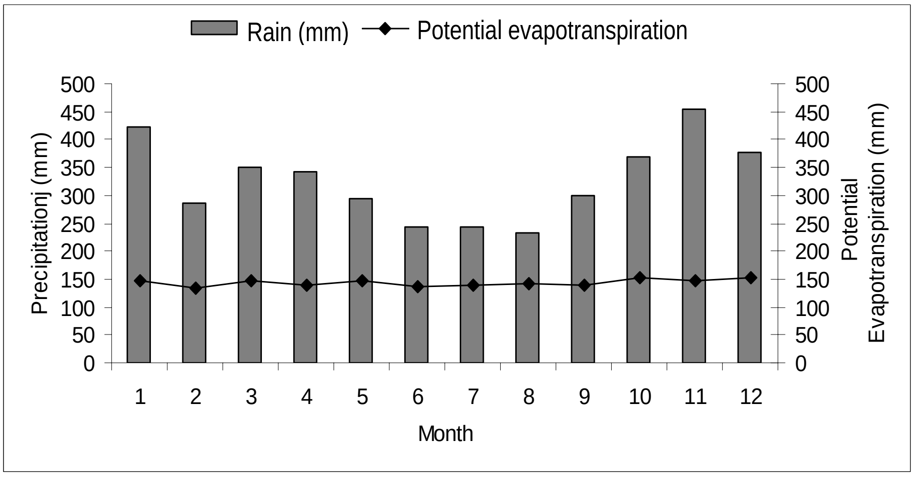


Figure 17. Monthly rainfall and potential evapotranspiration estimates in Kapuas Hulu Basin

Riverflow and rainfall pattern in Kapuas Hulu Basin

Figure 18 presents the rainfall and river flow pattern. The rainfall pattern is inverted (with high values on the bottom of the graph), to enable direct visual comparison on the dynamics (fall and rise) of river flow and rainfall. The rainfall pattern (light blue) of Kapuas Hulu is evenly distributed throughout the year. Dry spells occurred in July – August where river flow stabilizes. High rainfall directly followed by peak flow in the river flow.

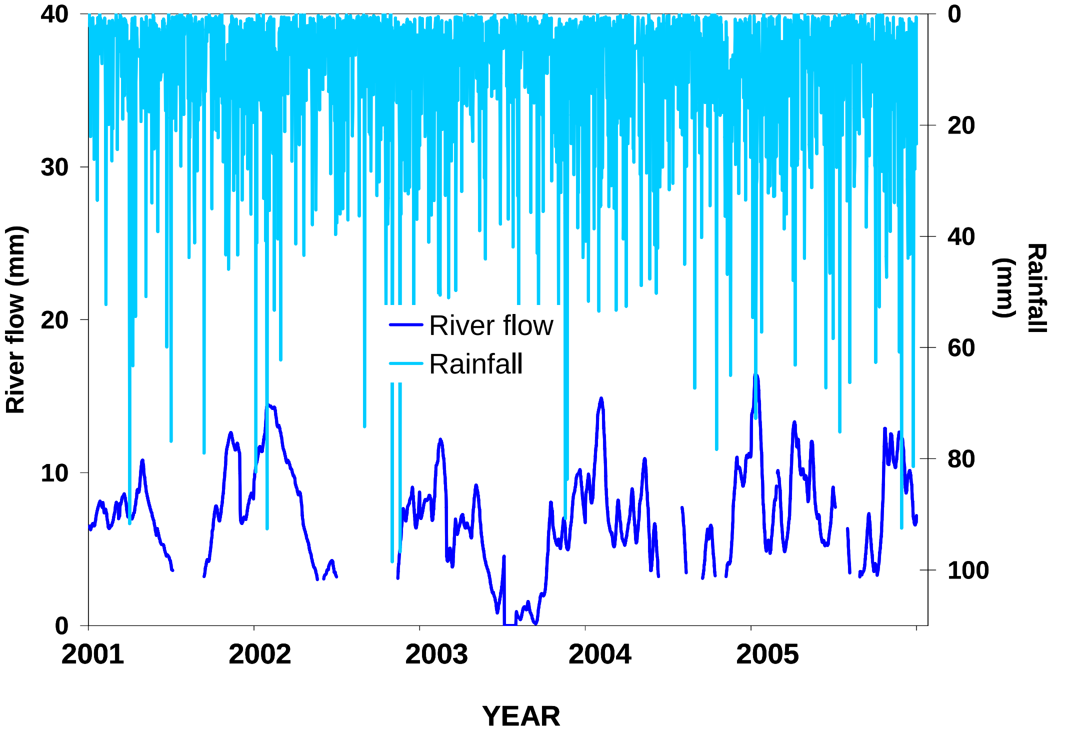


Figure 18. Daily rainfall and river flow pattern of Kapuas river in 2001 – 2005

Figure 19 showed the persistence curve of river flow, where current river flow is plotted against river flow of the day before. The purpose of this graph is to gain an understanding of how persistent the river flow is, especially on days without new rainfall, when flow is a fraction of flow the day before. The Kapuas river downstream of Danau Sentarum is well buffered, with the majority of flows at least 95% of flow the day before. Interestingly, only few days have flow more than 5% above flow the day before. The almost 1-1 line of persistence curve indicated that Kapuas Hulu river flow downstream of Danau Sentarum is stable. Even when there was no rainfall, the river flow will only reduced at the most by 5% of the previous day.

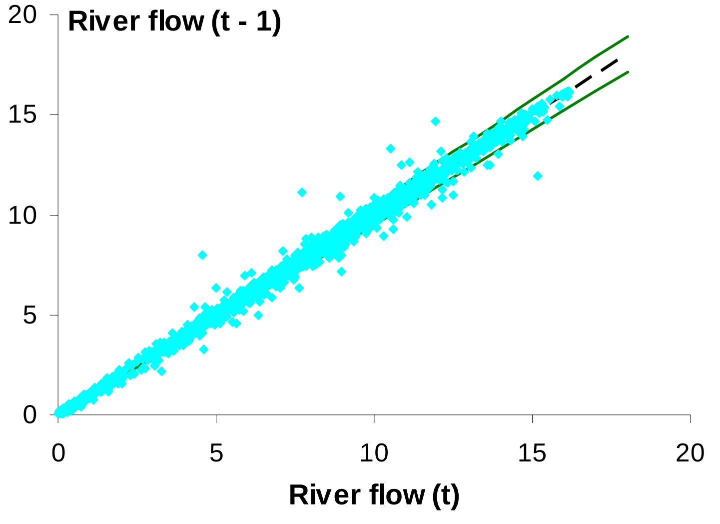


Figure 19. Flow persistence of Kapuas river in 1996 – 2005 period, plotted against 1:1 line and between the 95% - 105% range.

Calibrating GenRiver model for the Kapuas Hulu condition

A modeling approach was used to estimate the water balance of Kapuas Hulu Basin. The first step was to parameterize and calibrate the model to simulate Kapuas Hulu conditions.

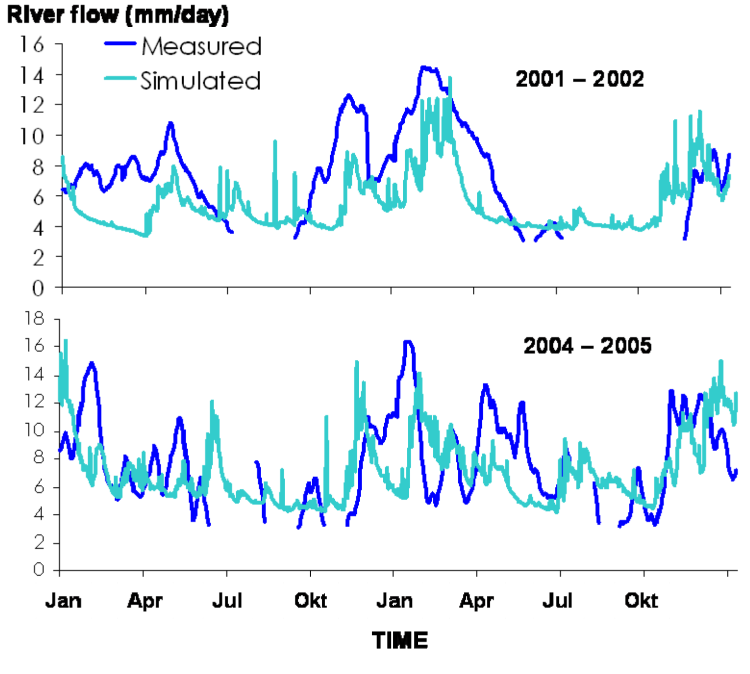


Figure 20. A hydrograph of Kapuas River in 2001 – 2002 and 2004 – 2005: measured vs. simulated. Calibration result showed GenRiver model was able to capture the trend of Kapuas river flow.

Simulation result showed that the GenRiver model captures the seasonal trend in river flow (Figure 20 and Figure 21), but the modelled behaviour (above Danau Sentarum) is less buffered than the measured behaviour (downstream of Danau Sentarum). Example was taken for the period of 2001-2002 and 2004-2005, where land cover data exist. Seasonal trends of simulated river flow match actual data across this period. Overall, the model gave a slight underestimation of peak flow. There is a 2-3 day lag time between peaks of rain in the basin and peaks of river flow at Sangau, consistent with the distance and a speed of about 10 km/hour.

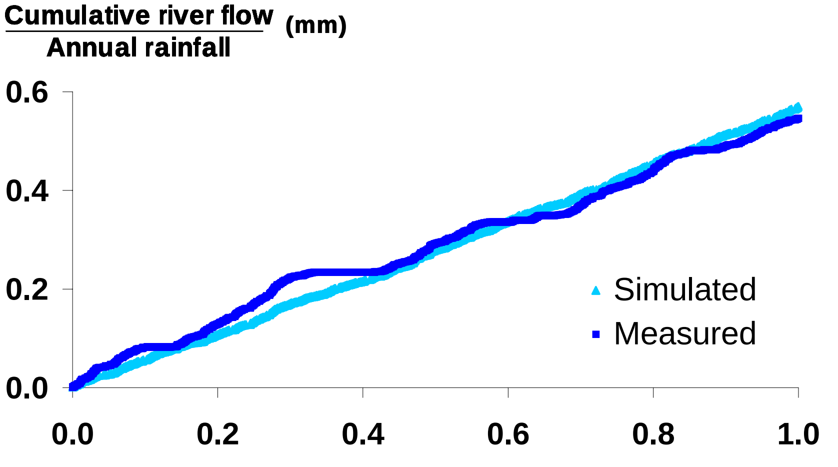


Figure 21. Plot of rainfall vs. river flow of Motabuik sub-catchment: measured vs. simulated. Simulated result slightly underestimated peak flows.

Landscape water balance of Kapuas Hulu Basin

Figure 22 and Table 16 presented the estimated water balance of Kapuas Hulu Basin in an 8-year period. Evapotranspiration in the area is roughly 40-50% of annual rainfall and base flow is stable at 35 – 40% of annual rainfall. Run off in the whole catchment area of 9800 km^2, is low of less than 1% of annual rainfall. Thus, overall the water balance of Kapuas Hulu basin indicated an area with good watershed function.

The estimated low run off is in line with the low sedimentation concentration measured in the river (Table 13) but not with what people observed in various points along the river. Thus, a water balance assessment at a smaller area (sub-catchment) was carried out to capture the finer detail.

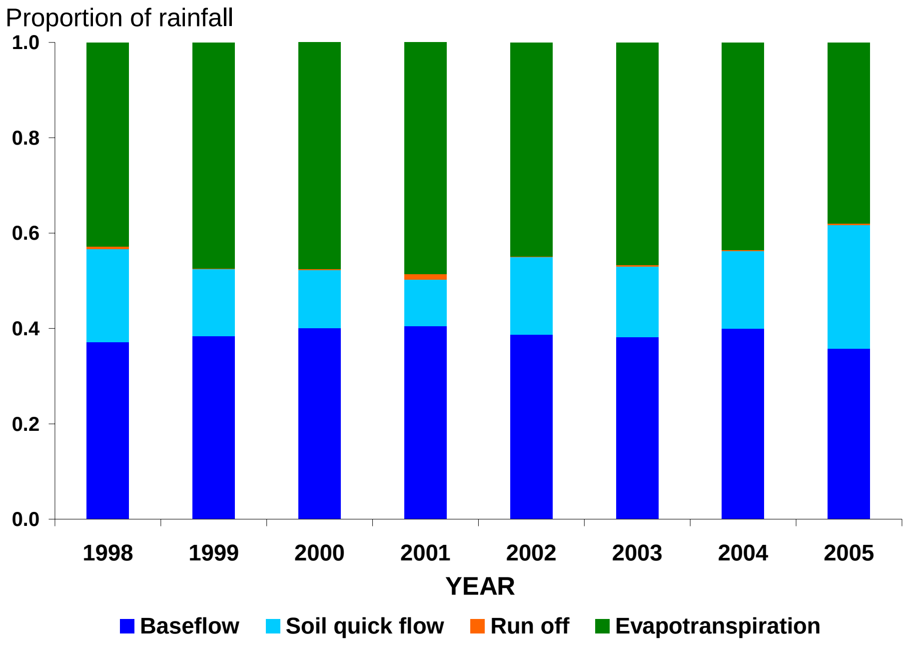


Figure 22. Estimated annual water balance in 8-year period of Kapuas Hulu Basin as proportion of total rainfall

Table 16. Estimated annual water balance of Kapuas Hulu basin.

		mm	%
Annual Rainfall		4100	100
Evapotranspiration		1582	39
River flow	Run off	660	16
	Soil quick flow	15	0.4
	Base flow	1842	45

Hydrological condition of Kapuas Hulu Basin

With the model, we explored how the year-to-year variation in rainfall translates to variations in hydrological behaviour, with potential co-variation among the indicators of watershed function.

Figure 23 presents the variation of watershed function indicators with changes in total discharge fraction. Overall, the total discharge fraction of Kapuas did not vary much within the 10 year period (ranging within 0.5 – 0.57). This value indicates that the river flow is quite stable throughout the year. Given this condition, the buffering capacity and gradual water release function are stable as well within this period.

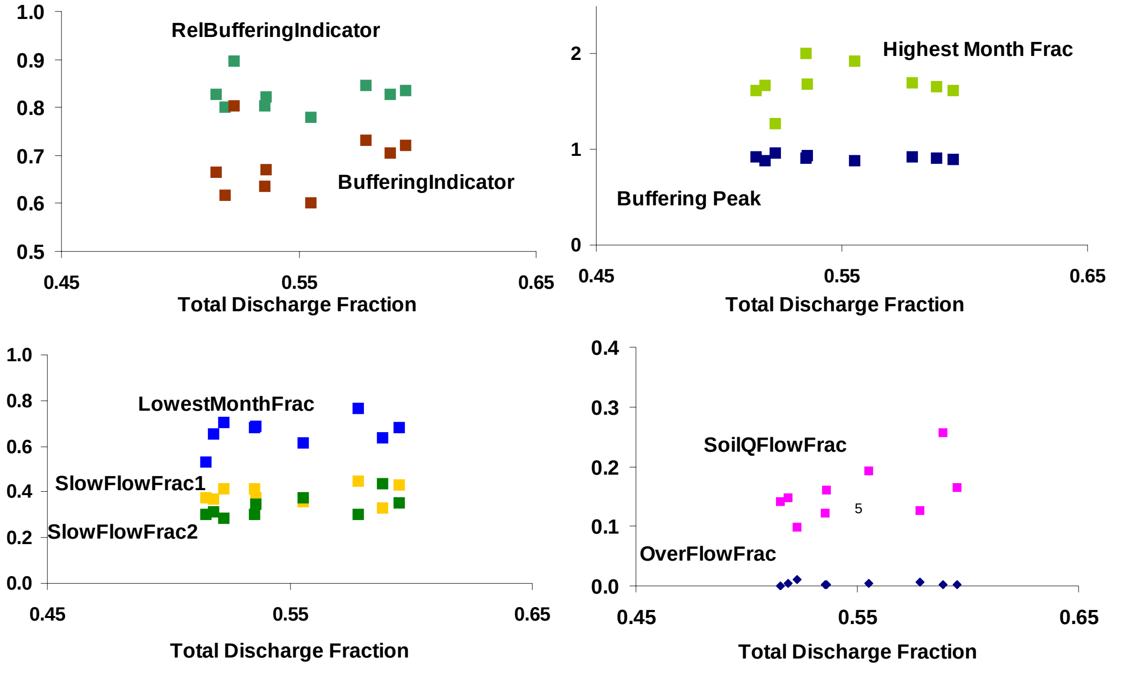


Figure 23. Indicators of watershed function of Kapuas Hulu Basin, expressed in relationship with the total discharge fraction (which is positively correlated with annual rainfall), over a 9- year period. See Table 5 for the definition of each watershed-function indicators.

The relationship of land use and hydrology in Kapuas Hulu Basin

Land use scenarios

Based on local knowledge and policy makers knowledge surveys, the main hydrological issues that emerge are (i) reduction in water level during dry season which affect transportation and (ii) water quality that relates to turbidity as well as pollution (poison from fishing and mercury from mining).

Most stakeholders (local, regency and provincial level) considered that reduction of forest cover and degradation of riparian zones contributed to the water quantity and turbidity problem. They also agreed that increasing tree cover in degraded area could solve the problem. Knowledge surveys also revealed that community living upstream feel that planting trees in degraded areas could solve erosion and sedimentation problem and at the same time benefiting them economically.

Based on the above observation, we developed land use scenarios that would enable us to see the impact of land use changes on the water balance and watershed hydrological functions if (i) the basin is further degraded and (ii) current degraded areas are converted into tree systems. The areas that will be highlighted are (i) overall Kapuas Hulu Basin and (ii) forest concession. Thus, the following scenarios were simulated to get a sense of the extremes between which real scenarios will operate:

- All land in Kapuas Hulu basin are converted to forest.
- All forest cover in Kapuas Hulu basin are converted to (i) agroforestry systems, (ii) well managed crop field and (iii) deforested
- All forest cover in forest concession area are deforested and converted into degraded land (shrubs).

Scenarios on the hotspots area of Kapuas Hulu Basin will be discussed in the next section.

Impact of land cover change on water balance

Scenario 1 and 2: All areas are in forest condition and conversion of all forest.

Figure 24 and Table 17 showed the impact of land use change on the water balance of Kapuas Hulu basin. The baseline condition is almost similar to the ‘All Forest’ condition, with less that 1% of run-off. Changes started to show when forest cover area were converted into agroforestry systems, where run-off increased by 13% and soil quick flow reduced by 5%. However, the base flow was more or less intact. Further loss of forest cover due to conversion to crop systems or deforestation, will further increase run off and reduced soil quick flow.

The shift of soil quick flow into run-off as simulated in condition where all forest converted to crop land could have caused extreme variation of water level during long dry season, as currently observed by local people during long dry periods. The water level will quickly increase and decrease within 1 day after rain occurred. But as the current land cover situation is not as extreme as simulated yet, it is not yet clear as to why currently the water level changed quickly within a short period. Indeed, good data collection is required.

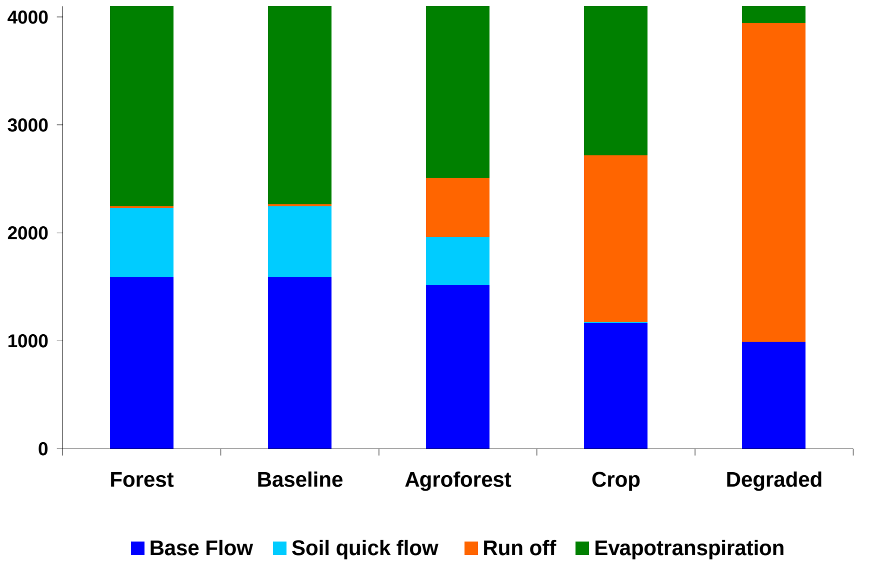


Figure 24. Water balance of Kapuas Hulu basin at baseline condition, when all land (i) become forest, existing forest cover are converted into (ii) agroforestry systems, (iii) well managed crop systems and (iv) degraded land

Table 17. Estimated water balance of Kapuas Hulu at various land use scenarios.

		Forest	Baseline	Agroforest	Crop	Degraded
Rainfall (mm)		4100				
Evapotranspiration – mm (proportion)		1853 (0.45)	1836 (0.45)	1591 (0.39)	1381 (0.34)	153 (0.04)
River flow	Run off – mm (proportion of rainfall)	12 (0.00)	16 (0.00)	544 (0.13)	1544 (0.38)	2951 (0.72)
	Soil quick flow– mm (proportion of rainfall)	647 (0.16)	657 (0.16)	444 (0.11)	11 (0)	0 (0)
	Base Flow – mm (proportion of rainfall)	1588 (0.39)	1591 (0.39)	1521 (0.37)	1164 (0.28)	996 (0.24)

Scenario 3: converting forest in concession area in Mendalam catchment

The designated forest concession area falls under six different sub-catchments (Table 18). In sub-catchments 6 and 16, the percentage of area under forest concession area compared to its sub-catchment size is very low, only less than 1%. Thus, the scenario study will focus on sub-catchment 5, 7, 8 and 9.

Among the four sub-catchments, sub-catchment 9 has the lowest forest cover (41%), similar to the size of land managed by farmers (42% as crop land, agroforestry and paddy field). Shrub/bush covered 13% of the area. The other three sub-catchments still have good forest cover, mostly almost 100% except for sub-catchment 5 with 80% forest cover.

Figure 26 presented the estimated water balance of forest concession area at baseline condition and when forest in the concession area are deforested and converted into shrubs. A shift from soil quick flow into run off occurred in all sub-catchment, significantly in sub-catchment 9.

In sub-catchment 9, at baseline condition, around 3.5% of annual rainfall flows to the river as run-off. This is above the overall Kapuas Hulu condition (1%). Conversion of forest cover in sub-catchment 9 will triple the amount of runoff into almost 11% of annual rainfall. The conversion also caused a slight reduction in base flow.

Overall, the conversion of forest in forest concession area could increase run-off from 0.5 – 3% to 1 – 11%. This could potentially lead to increase in erosion as well.

Table 18. The forest concession area of PT TORAS

Sub-catchment	Concession area (ha)	Percentage to overall size of sub-catchment (%)
5	4248	25.4
6	135	0.2
7	4685	18.5
8	7289	33.2
9	4850	27.9
16	1052	0.5
Total	22261	-

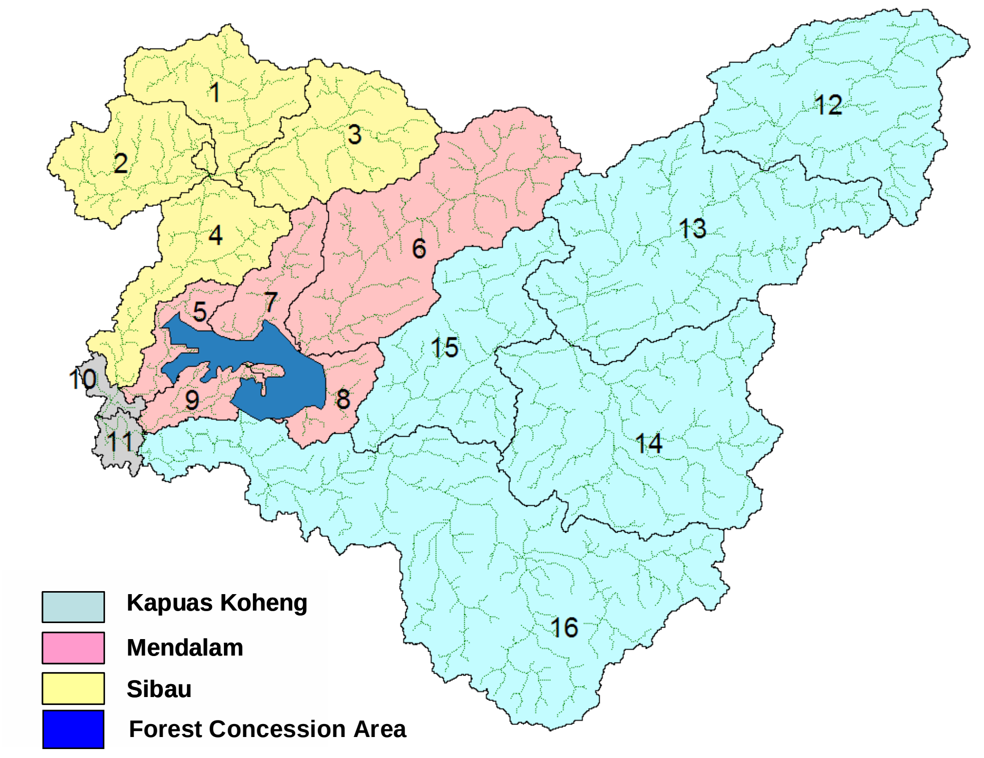


Figure 25. Designated location of forest concession area

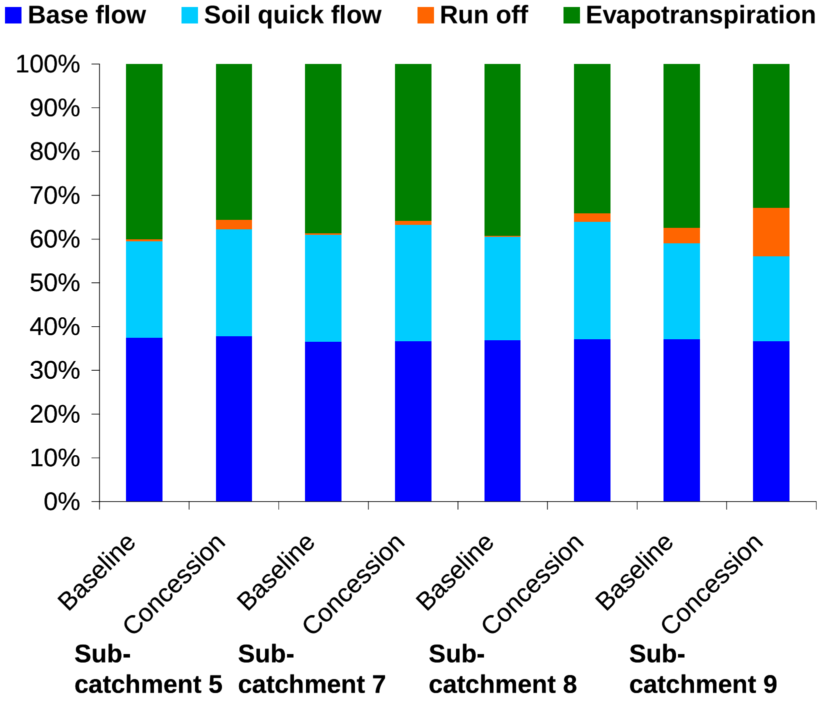


Figure 26. Estimated water balance of forest concession area, baseline condition and when forests in concession area are deforested (converted into shrubs)

Hydrological situation in Datah Dian and Sibau Hulu: the hotspots area in Kapuas Hulu basin

This section will specifically describe in more detail the hydrological situation in two villages in Kapuas Hulu Basin: Datah Dian village – Mendalam catchment and Sibau Hulu village – Sibau catchment.

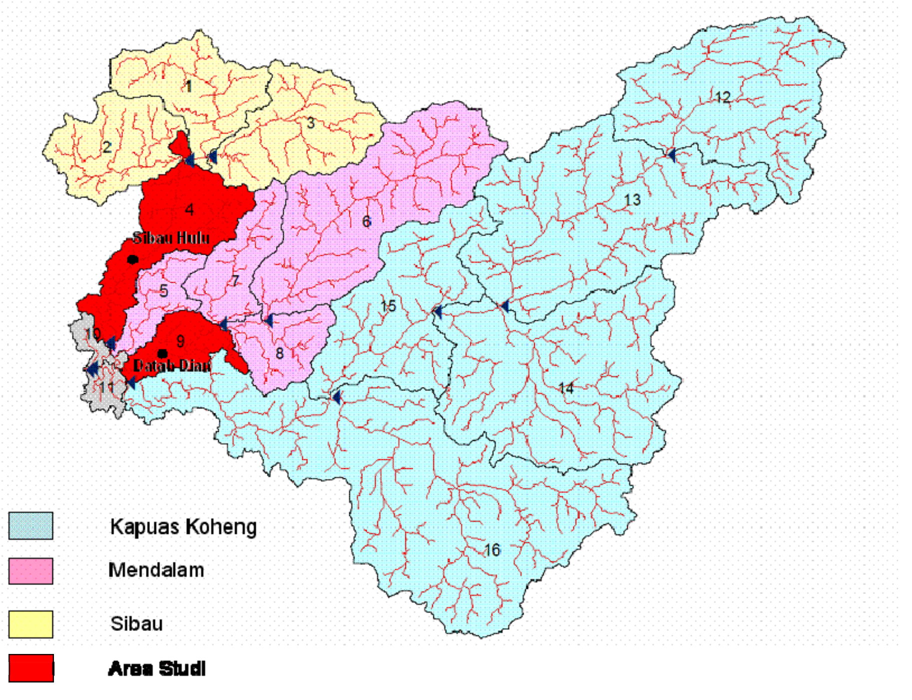


Figure 27. Location of Sibau Hulu (Sibau Catchment) and Datah Dian (Mendalam Catchment).

Landscape situation of Datah Dian and Sibau Hulu

Sibau Hulu and Datah Dian sub-catchments have size of 433 km^2 and 174 km^2 respectively, or 4.4% and 1.8% of Kapuas Hulu Basin area.

Sibau Hulu landscape is still intact compared to Datah Dian. More than 80% of Sibau Hulu landscape is covered with forest, while Datah Dian only has around 40% of forest area remaining (Table 19). Most of forest areas in Datah Dian have been converted into other land uses. Agroforestry covered around 36%, while agriculture (crop and paddy filed) covered almost 6% of the area. Considering that land cover class of shrubs and bush could actually be the fallow phase of agricultural land, additional 14% of Datah Dian area could actually be a part of agricultural land. Thus, around 20% of the area is agricultural land. Between 2001 to 2004 period, shrubs have increased by three fold, while bush has increased by seven fold. This situation indicated that farming activity in Datah Dian is quite dynamic.

Table 19. Distribution of land cover in Sibau Hulu and Datah Dian sub-catchment (in percentage of sub-catchments area)

Land class	Sibau Hulu		Datah Dian	
	2001	2004	2001	2004
Forest	86.8	82.1	46.6	40.8
Agroforest	8.7	8.9	38.7	36.5
Shrubs	2.4	5.6	4.1	12.5
Crop land	0.2	0.7	1.5	2.6
Paddy field	0.8	0.6	5.6	2.8
Bush	0.1	0.5	0.2	1.5
Settlement	0.3	1.0	0.8	1.4
Water body	0.7	0.7	2.5	1.8

Figure 28. Settlement in Nanga Hovat, Datah Dian (Mendalam Catchment) with productive systems in their home garden.

Figure 29 showed the transect map of Datah Dian (A) and Sibau Hulu (B), depicting the land use pattern in the area. Crop fields are normally planted with rice, maize, cassava and maybe some vegetables, while *bawas* are planted with rubber, durian, aren, and maybe cacao.

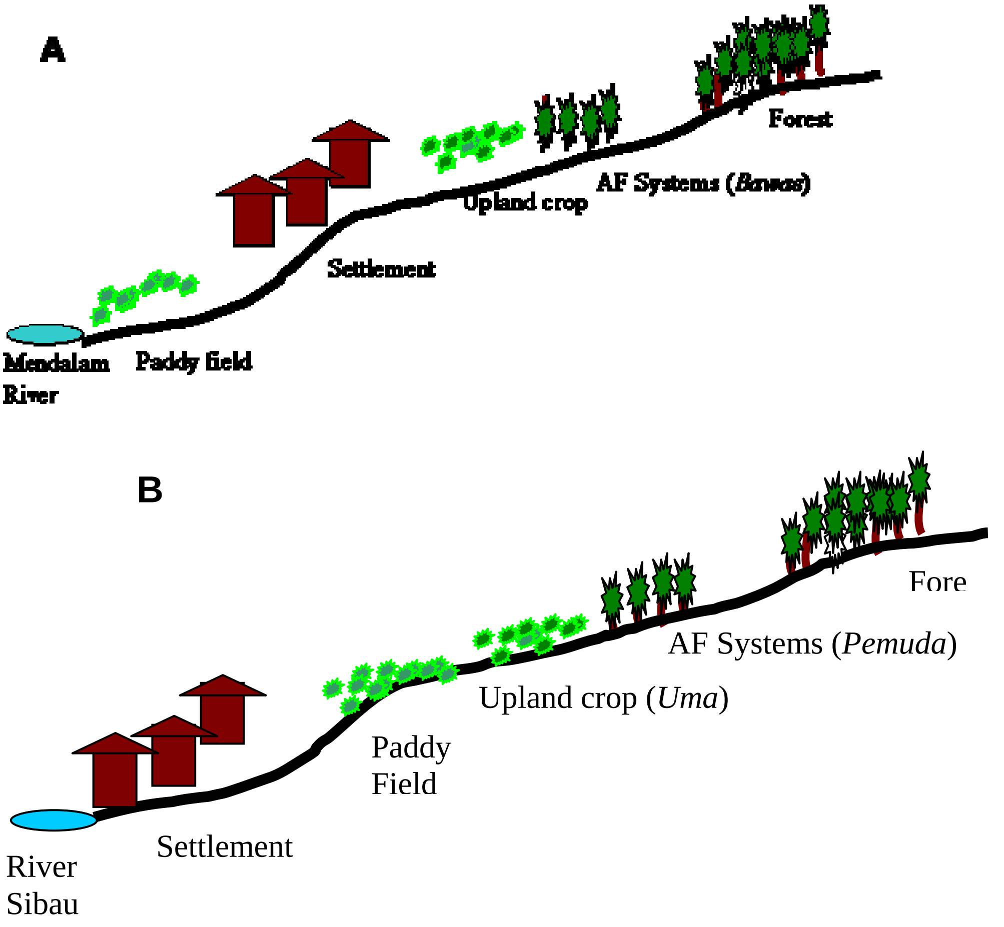


Figure 29. Transect map of Datah Dian (A) and Sibau Hulu (B) villages.

Hydrological issues

The main hydrological concerns of the local community living in Sibau Hulu and Datah Dian are more or less similar to the concerns of people living in Kapuas Hulu Basin, that are issues on:

- river turbidity after hard rain, thus water no longer good for consumption,
- river bank collapse and erosion
- transportation problem when water level of the river appears to get lower
- fishing using poison, causing illnesses (stomach problems).

The local community indicated that protecting the forest and areas along the river could partially solved the problems.

Impact of land use changes on water balance of Sibau Hulu and Datah Dian village

The estimated water balance of Sibau Hulu and Datah Dian sub-catchments are depicted in Figure 30 and Table 20. The land cover condition of Datah Dian that has only around 40% forest cover has turned 3% of the rainfall into run-off. The run-off in Datah Dian is 15 times larger than in Sibau Hulu, that still has more than 80% forest cover. However, the soil quick flow and base flow is similar. Thus, the difference in run off indicates the amount of water that could be intercepted and taken up by trees.

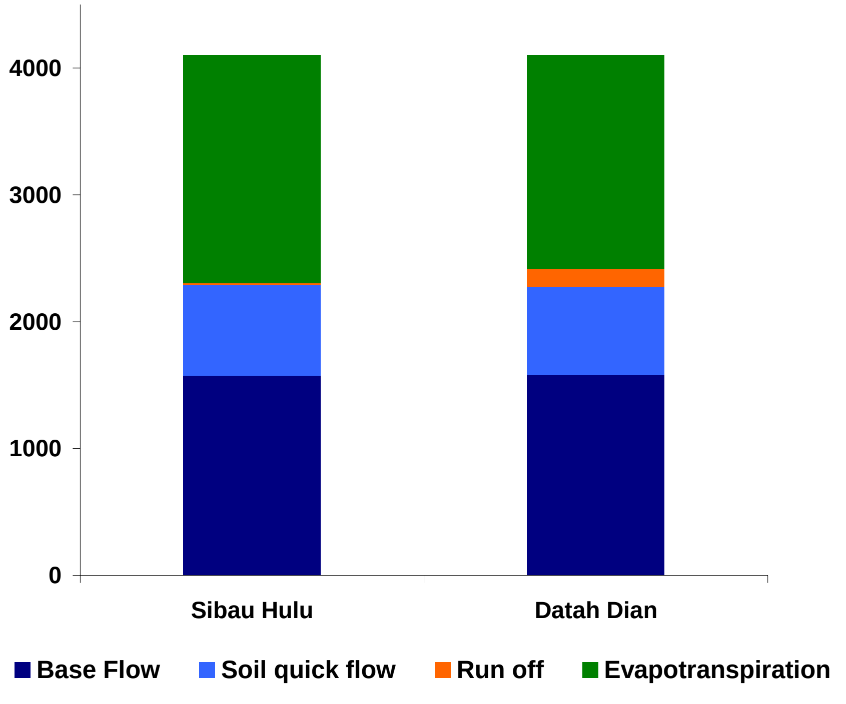


Figure 30. Estimated water balance of Sibau Hulu and Datah Dian sub-catchment at baseline condition

Table 20. Estimated water balance of Sibau Hulu and Datah Dian sub-catchment at baseline condition

		Sibau Hulu		Datah Dian	
		Amount (mm)	Proportion to rainfall	Amount (mm)	Proportion to rainfall
Rainfall		4100		4100	
Evapotranspiration		1797	44	1683	41
River flow	Run off	9	0.2	140	3
	Soil quick flow	717	17	698	17
	Base Flow	1577	1557	1578	1558

To see the impact of land use changes on the sub-catchments water balance, we conducted several scenario analysis:

- converting forest areas into agroforestry, crop, pioneer (shrubs/bushes) or degraded condition (settlement)
- converting shrubs/bushes into forest, agrofretsry, crop and degraded condition (settlement)

The result can be seen in Figure 31 and Figure 32.

Converting forest areas in Sibau Hulu and Datah Dian into agrofrestry systems will increase run off by 10% and 9%, respectively (Figure 31). Increase in run-off implies an increase in soil erosion and if riparian zones are degraded, there will be high risk of sedimentation in the river. Converting all forest that still exist (80% for Sibau Hulu and 40% for Datah Dian) will increase run-off by 50% and 30% for Sibau Hulu and Datah Dian respectively. The increase in run off occurs along with reduction in soil quick flow, implying more water from the rainfall will directly reach the river within 1 days. During heavy rain events, this will lead to flash floods.

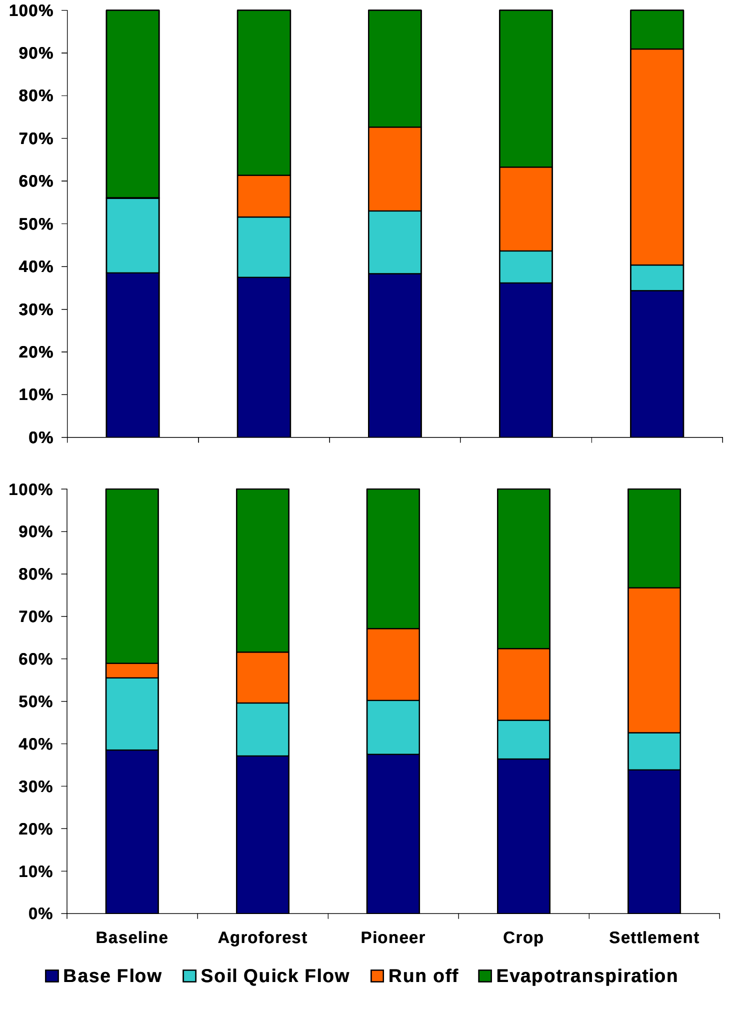


Figure 31. The impact of converting forest areas into other land uses on the water balance of Sibau Hulu (top) and Datah Dian (bottom)

Rehabilitation measures appears not to be needed yet in Sibau Hulu, as the non-productive land (bush and shrub) in the areas are low covering only 9.5% of the sub-catchment. Thus, reforesting the areas, nor conversion to other systems, hardly have any effect to estimated water balance (Figure 32, top). On the other hand, land rehabilitation in Datah Dian through reforestation of bush and shrubs land classes, will reduce run off by half (Figure 32, bottom). Converting bush and shrubs into agrofretsry systems or crop appear not to change the water balance at all.

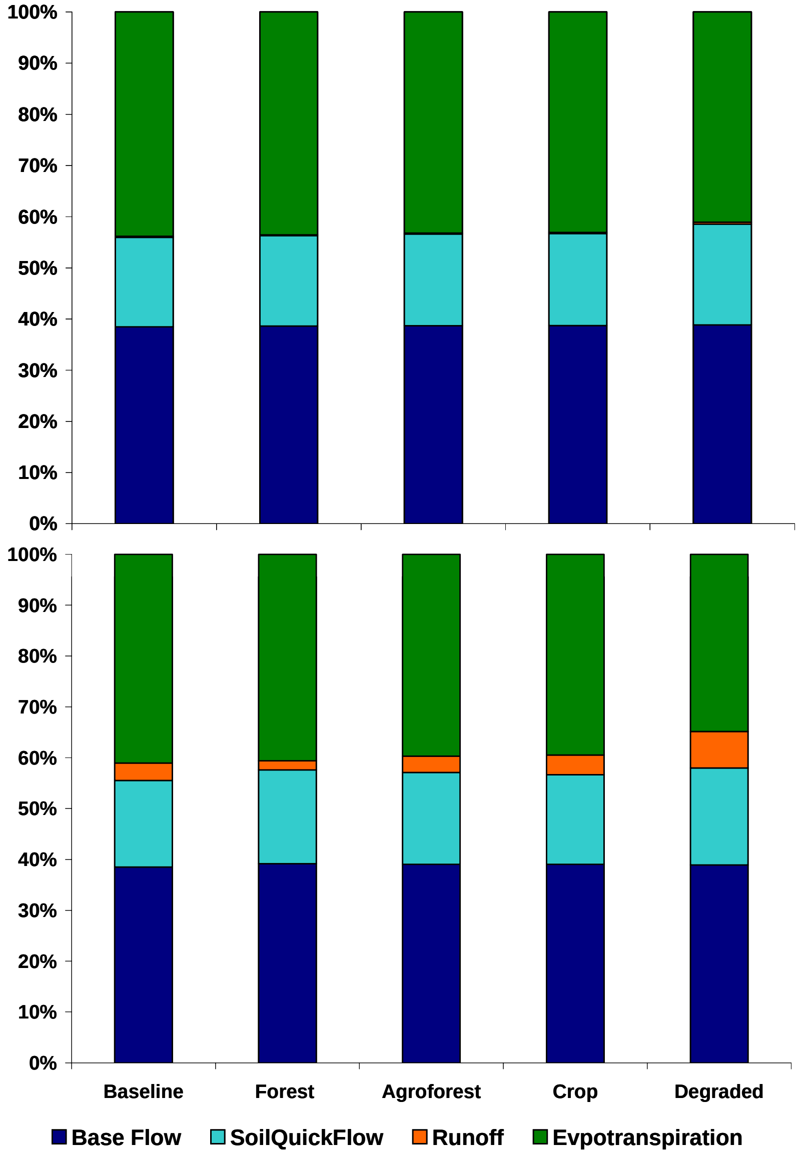


Figure 32. The impact of converting bush/shrubs areas into other land uses on the water balance of Sibau Hulu (top) and Datah Dian (bottom)

Conclusion

Can we develop reward mechanisms in the area? A hydrological perspective

The Environmental Kuznetzs[7] Curve hypothesizes the relationship between environmental quality with economic development (Stern, 2004), where economic development normally correlates with time. The curve describes that environmental degradation increases as income rises up to a threshold level beyond which environmental quality improves with higher income per capita (Figure 33).

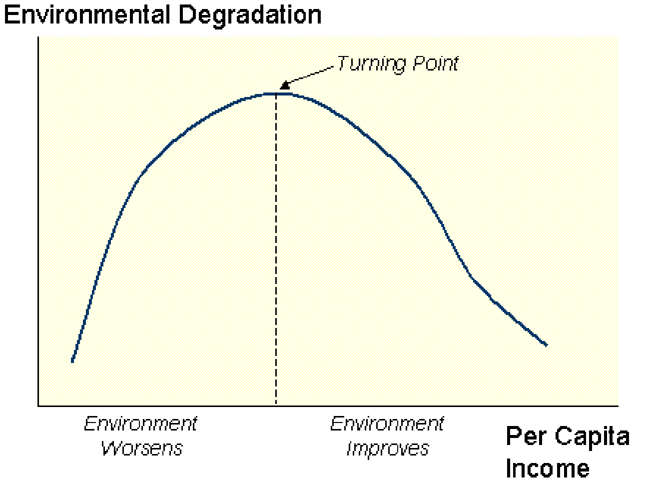


Figure 33. The environmental Kuznets curve

From the Environmental Kuznets Curve, we can derive five phases of environmental condition for a particular landscape (Figure 34). During the initial stages of economic development, environmental degradation will inevitably (and unfortunately) increases because high priority is given to increase material output, using existing natural resources. The landscape degradation will continue up to a certain point when people then realized that they need to do something to prevent further degradation. This dynamic largely due to the time lags involved in getting a sufficient part of stakeholders to realize that they have or are facing a problem, and that action is opportune to them. As prevention is better than cure, it is therefore 'avoided degradation' efforts are as important as 'rehabilitation' activities.

The Kapuas Hulu case represents a typical Stage II 'frontier' in opening up a forested landscape, on the edge of the 'Heart of Borneo'. Environmental degradation in previous locations of the frontier has been the result of the interactions between the logging industry, mining, influx of migrants related to both industries, processes of urbanization without proper pollution control,

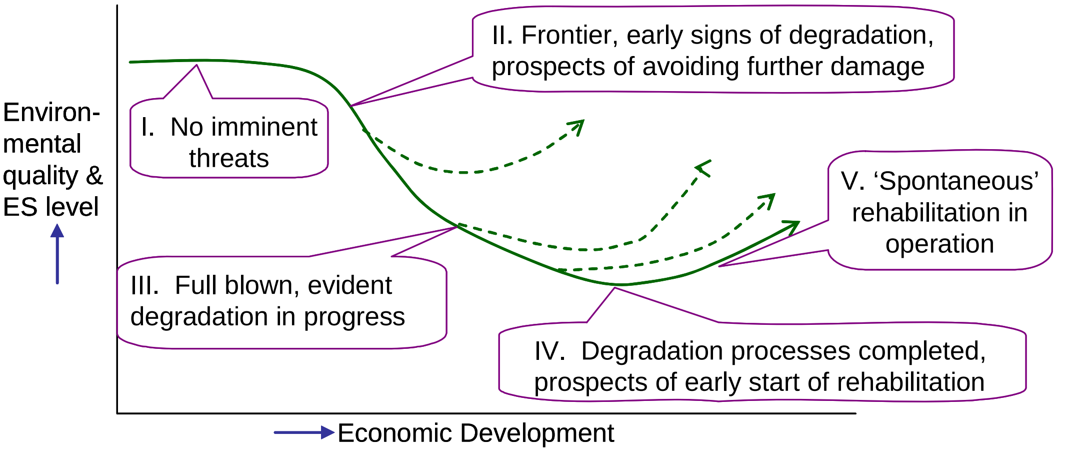
7 Application of Kuznets curve on various environmental indicators can be read Bhattarai and Hammig (2004) and Culas (2006) on deforestation, Aldy (2005) on CO2 emmision, Deacon and Norman (2004) on air pollutants and Paudel, et al. (2005) on water pollution.

as well as intensification of agriculture. This phase is characterized with contesting legal frameworks, shifting power relations and abilities to enforce 'rights', complex relationships between different layers and sectors of government, as well as between private and public sector.

The Kapuas Hulu site shows the signs of experiencing this pattern – and yet it could become the place where the negative impact of 'development' comes to a halt. That is, if we can find a potential policy programs that can move the economy to a sustainable pathway. We believe a combination of new incentives and institutions can effectively alter the process of interactions. Will "Payments for Watershed Services" turn the situation around? Probably ***not***. Can "Payments for Watershed Services" be part of a package that makes a difference? Probably ***yes***.

Knowledge surveys and direct observation in the field revealed there are early signs of watershed degradation, such as erosion and sedimentation in the river. Local community has already been affected by changes in the river flow, when they can no longer use the river for transportation during long dry spells. But, various sediments measurements that has been conducted in the area has not yet reached alarming results and the estimated water balance showed that Kapuas Hulu basin is currently still able to maintain its watershed function in term, particularly at maintaining river flow. In terms of water quality, at smaller scale in Datah Dian sub-catchment, there were already signs of degradation.

Therefore, future development of reward mechanisms in the area could be link to activities that improve the water quality in the area, such as (i) tree cover along river banks as well as (ii) crop land and non-productive land. Monitoring river flow and quality should also be part of the activities.



	Current ES level + evidence	Threats	Prospects to ES reward mechanisms
I.	Good	No imminent threats; low accessibility and/or institutional protection is sufficient	No imminent need, low 'project additionality'
II.	Good, but degrading; early signs of degradation	Frontier setting, interaction of multiple actors; changing in institutions;	Slowing down degradation, stabilizing at higher level; potentially high project + ES additionality, but WTP and WTA may be low as yet

III.	Declining; evidence starts to accumulate	Full blown degradation in progress,	Slowing down last phases of degradation, early start of rehabilitation; potentially moderate project + ES additionality, but WTP and WTA are increasing
IV.	Low, historical decline evident	Degradation processes completed, prospects of early start of rehabilitation	Triggering and/or speeding up rehabilitation; moderate but 'easy to show' project + ES additionality, WTP and WTA may be high
V.	Low but improving; 'trends' may be unclear	'Spontaneous' rehabilitation in operation	Speeding up degradation or increasing the restoration levels attainable; low-to-moderate project + ES additionality, WTP higher than WTA?

Figure 34. Five stages of environmental degradation and rehabilitation in relation to 'willingness to participate/pay' (WTP) and 'willingness to act/accept' (WTA), derived from Kuznets curve.

Environmental services rewards: potential scheme

The proposed activities focus in Mendalam and Sibau catchments where degradation was observed to be more prominent and existing local institutions are already strong. However, these activities could also be potentially developed in Kapuas catchment.

Revitalization of riparian zones

The purpose of this activity is to prevent and reduce river banks collapse, thus reducing sedimentation in the river. Sedimentation is currently seen as part of the reason in low quality of drinking water in Putussibau. The degraded riparian zones in Kapuas Hulu basin has the size of roughly 412 ha or 105 km in river length (Table 21).

Table 21. Size of riparian areas in APL zone of Kapuas Hulu Basin. (Based on 2004 land cover maps)

Land cover class	Sibau		Mendalam		Kapuas	
	Area (ha)	Length (km)	Area (ha)	Length (km)	Area (ha)	Length (km)
Grass-shrub	23.6	5.9	31.0	7.6	35.9	9.9
Bush	39.0	13.1	72.3	13.4	103.2	24.9
Crop and	17.9	7.9	63.2	15.1	26.1	7.1

Note: Riparian area is defined as 200 m adjacent to river banks.

Hairiah, *et al.* (2006) described that to maintain river banks stability required combination of trees that have deep roots (anchoring function[8]) and shallow roots (binding function). Examples of trees that have moderate - deep roots are durian (*Durio zibethinus*), petai (*Parkia speciosa*), jati kertas (*Gmelina arborea*), candlenut (*Aleurites moluccana*), pasang (*Quercus lineata*), and mahagony (*Swietenia macrophylla*). Examples of trees that have shallow roots are bamboo, semantung (*Ficus padana*), surian (*Toona surenii*) and gamal (*Gliricidia sepium*). Wild coffee (*Coffea canephora var. robinson*) have both properties of roots.

8 Hairiah et al (2006) developed two indicators that quantify the fucntion of trees on slope stability: (1) Index of Root Anchoring (IRA) and Index of Root Binding (IRB)

Thus, good species to plant along the river banks in Kapuas Hulu could be based on the above criteria and farmers preference.

Developing agroforestry systems and enriching existing *Tembawang* systems.

This activity focuses on providing farmers with good planting materials of tree species that could provide additional economic benefits to the local farmers. Farmers have indicated their interest on rubber (*Hevea brasilliensis*) and sugar palm (*Arenga pinata*). The area potential for this activity is in non-productive land (shrubs and bush) and in existing crop land (Table 22). This potential area is not yet based on distance to settlement.

Table 22. Potential area for development of agroforestry systems in APL zone of Kapuas Basin.

Land cover class in 2005	DAS Sibau (ha)	DAS Mendalam (ha)	DAS Kapuas (ha)
Grass-shrub	300	400	400
Bush	3600	3000	3600
Crop land	700	500	400

Note: The potential area estimated is purely based on land cover class, and not yet based on distance to settlement.

Community based watershed management and river monitoring.

A potential scheme that can be developed, specifically in Mendalam area is community based project that focuses on good land management and water monitoring. In this scheme local community are provided with financial payments to conduct activities that can protect the riparian zones from collapsing. Full payment will be given on condition that over a certain agreed period, the riparian zones and the river banks are intact. Thus, river monitoring is part of the activities. A similar scheme is currently being applied in Sumberjaya, Lampung – Indonesia (Suyanto, 2006).

Conclusion

The current situation of Kapuas Hulu where the landscape hydrological condition are still intact, and yet signs of degradation already appearing (Stage II in Kuznets curve) warrant for further activities that relates to 'avoiding degradation' activities. In stage II ongoing degradation is hard to prove, as the 'anthropogenic' aspect may as yet be less than the 'natural variation', especially where quantities of water and regularity of flow is concerned. In stage II/III we typically have multiple agents responsible for degradation as there still are substantial gains to be made in extractive use of the natural resources (logging/mining) for medium-to-large scale actors. In this kind of situation, it is not easy to develop reward mechanism that is based on activities by smallholder in protecting the environmental services. Smallholder agriculture may be (perceived to be) the dominant driver of environmental degradation only at a later stage. However, a 'project' that aims to avoid degradation, actually has potential 'additionality' that is relatively high compares to a restoration project, as rehabilitation of watershed services tends to be a much slower process than degradation is. In a recent review of the time lags involved in restoration of watershed services time lags of 10 – 100 years were found to be common (Dillaha *et al.* http://www.worldagroforestry.org/sea/portals/2/lombok/material/presentation/Day1/session2/TheoDillaha.pdf).

The RUPES program has developed a list of twelve ‘prototypes’ of environmental services worthy of rewards (van Noordwijk, 2005). A recent workshop (January 2007) in Lombok reviewed the evidence and experience with a range of ‘reward’ mechanisms for environmental services that include but are not restricted to ‘payments’. In Table 23 the emerging evidence and ‘good practice’ or ‘avoidable errors’ are listed. The ‘Kapuas Hulu’ case may fit the prototype 2 in its emphasis on ‘regularity of flow’. Other IIED/CARE/WWF project sites may relate to prototypes 1 or 3. The opportunity for the project to adjust the ‘PWS instrument’ to the reality of a typical ‘Type II’ setting, complementing type IV experience is exciting, and will be of benefit to the project.

Table 23. Summary of lessons learnt on the twelve prototypes of environmental services (van Noordwijk, 2005), based on working groups at the Lombok workshop (23 January 2007; www.worldagroforestry.org/sea/rupes)

Environmental Service Type	Providers/ sellers	Users / buyers	Main issue	Do (ready for use)	Try (good ideas)	Avoid (dead alleys)	Research
1. Total water yield for hydro-power/ irrigation via storage lake	Impacts on total water yield small; reservoir sedimentation issue may dominate the debate; option for sediment traps and landscape filters	Consumer satis-faction depends on continued functioning; high project in-vestment costs, little subsequent management flexibility	Intercepting sedi-ment flows rather than avoiding them is generally easier to accom-plish; sediment flows out of well-managed upper catchments may still be high be-cause of geolo-gical and geomor-phological processes	RHA for problem identification, Link upstream + downstream stakeholders, Focus on risks for all involved Identify 'hot spots' Value opportunity costs Analyze data: rainfall => use	Link 'pay' to actual change in sediment load of streams Group level re-wards, not indi-vidual sellers, but note 'free riders' 2-way accoun-tability of perfor-mance	Solution bias ('plant trees' as pre-set standard) Avoid PES where WTP is low Perverse in-centives to degrade so as to qualify for support	Optimal land use mixes and role of trees Lag times of ES response Match form of PES to setting & history of interactions Info tradeoffs vs. cost Impacts on poverty & gender equity
2. Regular water supply for hydro-power via run-off-the-river	A change from soil quick flow (saturated forest soils) to overland flow will have some effect on buffering of river flows and hydroelectric operation time	Consumer satis-faction depends on continued functioning; high project in-vestment costs, little subsequent management flexibility	Interventions in-fluencing the speed of drainage (linked to paths, roads and drains) have the most direct effect on buffering at larger scales	RHA for problem identification, River-care groups with result focus & rewards Prepare for variable hydropower performance	Performance based conditional reward system Stimulate micro hydropower for internalizing externalities	Expectations that 'extreme' events can be avoided	Low-flow hydrology Replicable primary indicators to replace compliance proxies
3. Drinking water provision (surface or groundwater)	Intensive agriculture and horticulture will cause rapid pollution of surface flows and slow but persistent pollution of	Willingness to pay for drinking water depends on quality assurance from medical perspective, as well as taste	Slow response of groundwater flows to changes in the pollutant status make 'regulation' a more effective solution than results based markets	Analyze eco-geohydrology & sources of water Education & awareness raising Enhance direct local benefits of land stewardship	Support for low-emission agricul-ture Use of locally validated biological water quality indicators	Idea that CSR is sustainable and sufficient Short-term focus & commitment of buyers Expectation that PES cam solve	Time lags for surface and groundwater quality response Acceptable range of land uses & emissions Rewards for avoided damage in relation to 'buyer efficiency'

Environmental Service Type	Providers/ sellers	Users / buyers	Main issue	Do (ready for use)	Try (good ideas)	Avoid (dead alleys)	Research
	groundwater flows with nitrogen and pesticides; people residing around streams cause pollution E.coli and diseases			Use bundling of buyers via public sector actors Enhance transparency at all levels		all issues	Relationship between 'good' (saleable water) and 'service'
4. Flood prevention	Land use effects strongest for flow buffering of small-to-medium sized events, with saturation dominating the large events	Relevance of upland land use depends on location ('flood-plains') and engineering solutions (dykes, storage reservoirs)	Risk avoidance for the rare category of large events	RHA for problem identification, Flood alerts & early warning Focus on rivers, roads & channels Focus on soil cover (infiltration) rather than trees/forest Landslide damage prevention Analyze risks, incl. rainfall variability	Shift from 'input' to 'outcome' based rewards Transforming existing 'reforestation' programs to become conditional, voluntary & realistic	Solution bias and expectations that risks will be zero Short-term & unsustainable rewards/ payments Use of (tree) monocultures as solutions	Acceptable ranges of land use and mosaics Impact analysis of integrated approaches Poverty & gender analysis of impacts Suitable primary indicators for monitoring Tradeoffs in mosaics Time lags for rehabilitation and relations between specific and general concerns
5. Landslide prevention	Mortality of deep-rooted trees ('anchors') causes tempo-rary increase in landslide risk	Relevance depends strongly on location in the flow paths	Deep landslides are little affected by land cover				
6. General watershed rehabilitation and erosion control --	Promoting tree cover and permanence of litter layer protecting the soil is a good precaution	'Holistic' perception of watershed func-tions survives despite the lack of clear impacts on specifics	Communication gap with scientists who try to enhance clarity				
7. Biodiversity buffer zones around protected area -- Bcons_1	Use value of buffer zones depend on hunting restrictions,	Flagship species still dominate the public perception of value	Push and pull factors in human land use; livelihoods operate at larger scales	Output-based rewards for removal of invasive species in early stages Analyze local costs,	Bundling with other service rewards and direct profitability of land stewardship in	Rewards based on short-term fund availability	Relevance of proxies and simple indicators Biodiversity science for landscapes with

Environmental Service Type	Providers/ sellers	Users / buyers	Main issue	Do (ready for use)	Try (good ideas)	Avoid (dead alleys)	Research
	presence of human-life threatening species		than most conservation plans acknowledge	risks and benefits of biodiversity Awareness raising on multiple perceptions Build in critical evaluation into all reward designs	local context Basic 'habitat' con-servation rewards + target species outcome bonus		agricultural use Time lags in degradation & rehabilitation
8. Biodiversity landscape corridor -- Bcons_2	Still new concept in agriculture/forest land use mosaics in the tropics; use value of patches in the 'stepping stones' similar to the buffer zone case	Relevance depends on dispersion pro-perties of the species of main interest; some-times higher connectivity not desirable; relevance in-creases with climate change concerns	Ex ante impact assessment of effectivity is still difficult				
9. C restocking degraded landsca-pes -- Crehab	Options for profitable tree restocking primarily depend on policy reform	Demand is for Certified Emission Reduction (CER) rather than carbon	Additionality issues in CDM; high transaction cost	CDM-type standards for use in voluntary markets Enhance/ local capacity to monitor aboveground stocks	Bundling of bio energy, C-stocks & biodiversity Account for belowground C stocks Standardization	Use of mono-cultures as solutions Over-using scarce water for low-value C stocks	Options to reduce transaction costs by standardization Tradeoffs with water use
10. C protecting soil and tree stocks -- Ccons	Road construction (accessibility) is main determinant of 'opportunity costs' for non-conversion	Demand is for Certified Emission Reduction (CER) rather than carbon	Not (yet) recognized as part of CDM or UNFCC) Kyoto protocol) mechanisms	Full carbon ac-counting at (sub)regional scale Focus on peatlands	Low-impact logging and rewards for similar partial emission reductions	Perverse incentives & leakage in small scale reward schemes	Institutions for avoided emission rewards Relevance of sub national scales of C accounting
11. Gua-ranteeing produc-tion land-scapes meet en-	Where the 'ecolabel' process starts	Consumers with high sense of personal	Relevance of global standards in the face of	Use ecolabel as means to educate consumers of options	Shift from initial 'product' focus to shared respon-	Expectations of large price premiums for	

Environmental Service Type	Providers/ sellers	Users / buyers	Main issue	Do (ready for use)	Try (good ideas)	Avoid (dead alleys)	Research
vironmen-tal stan-dards -- Ecolabel	from the consumer side, there can be a substantial gap in communication and trust, leading to high transaction costs	responsibility; gradually replaced by the introduction of standards and the raising of baselines of 'acceptable' behaviour	variation in local conditions; transparency of the standards and compliance monitoring; transaction costs	and tradeoffs producers face Start with niche market to influence the big market to make it the norm Willingness to pay studies in early stages for pioneer users	sibility of for production system Reduce transac-tion/ certification costs by standar-dization	producers Ecolabel without promotion & consumer education	
12. Providing gui-ded access to landscapes of beauty/ heritage/ recreational value -- Ecotour	The local and international appreciation for landscape beauty depends on culture and time (fashion); rewards are for roles as guide and provider of accommodation, food, transport and handicrafts ; gender aspects of provider roles may be promi-nent	The appreciation of landscape beauty and cultural traditions does not reduce the need to provide security and comfort to potential tourists	Global ecotourism is a highly volatile market where security and political concerns can interfere	Willingness to pay studies graduated for foreign and local tourists Believe that high fees can work Invest in information and promotion Provide institutional transparency & build trust Get direct feedback from clients Invest in training	Build on domestic tourist as more stable market segment and foreign as add-on	Unrealistic estimates of # of visitors New mining and other changes in land use zoning Underestimate opportunity costs for displaced users Expectation of high local net benefits	Multiplier effects on overall economy Impacts (+ and -) on poverty, gender & cultural integrity

Appendix 1. Accuracy of Landsat image classification result

Land use class	Accuracy (%)
Forest	85
Agroforestry	86
Crop land	23
Bush	77
Grassland	98
Rice field	87
Water body	67
Settlement	94
Average	77

Appendix 2.

River flows at Putussibau outlet were estimated from water level data at Sanggau outlet. The following steps were carried out:

1. Estimating river flow at Sanggau outlet

We used the following rating curve that relates water level with river flow:

h =-3 x 10-7 * Q2 + (0.0034*Q) +0.6631

Where:

h = water level (m)

Q= river flow (m3/second)

This equation was obtained from Dinas Sumber Daya Air Propinsi Kalimantan Barat. The R2 of this equation is 99%.

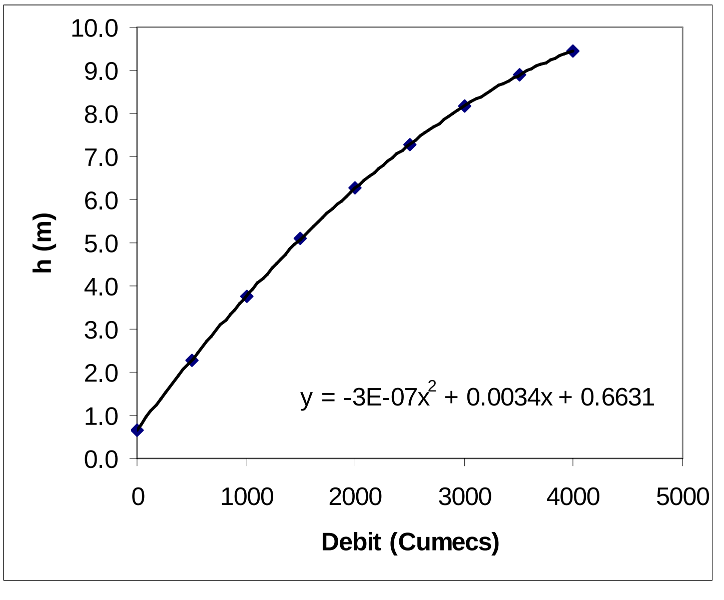


Figure Appendix 2.1. Rating curve at Sanggau outlet.

2. Estimating river flow at Putussibau outlet

The river flow at Putussibau outlet was estimated using the following equation:

Q2=(A2/A1)*Q1

Where:

Q1= river flow at Sanggau outlet (m3/second)

Q2= river flow at Putussibau outlet (m3/second),

A1= size of Sanggau catchment area (km2)

A2= size of Putussibau catchment area (km2)

The total catchment area of Sanggau is 70865 km2, whilst Putussibau catchment area is 9800 km2. Therefore, the estimated conversion factor for Putussibau outlet is 14% of Sanggau outlet (Figure Appendix 2.2).

Wijanarto et al. (2005) measured river flow at Putussibau outlet on September 2005. He obtained a value of 674 m3/second or around 40% of estimated river flow at Sanggau (1554 m3/second). Thus, this is the conversion factor that we used to estimate river flow.

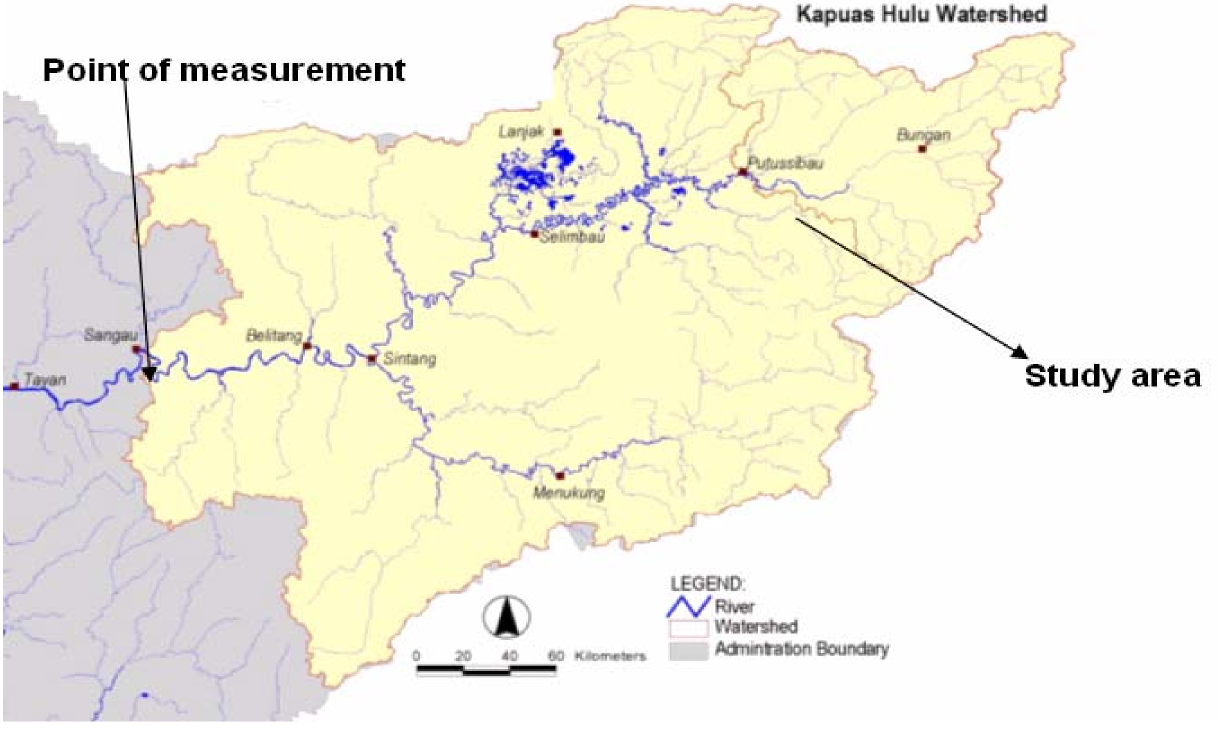


Figure Appendix 2.2. Location of Sanggau station where hydrological data were obtained

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Glossary

Base flow: the part of stream flow that is attributable to slow release of groundwater to the stream and not related to current or recent rainfall.

Buffering capacity is the ability of a system to reduce the impact of external variation on internal properties, e.g. reducing the variation in stream flow relative to variation ion rainfall

Buffering indicator is derived from the ratio of above-average stream flow and above-average rainfall

Buffering for peak events is the ‘buffer’ function demonstrated at peak rainfall events

Evapotranspiration: The combined processes of evaporation from soil surfaces, open water or water films attached to plants and transpiration from living plants.

Flash floods: floods caused by heavy or excessive rainfall in a short period of time, generally under 6 hours, leading to stream flow and water levels that rise and fall quite rapidly

Gradual water release: gradual release of (ground) water in the dry season

Ground water discharge: is the release of groundwater to streams or subsurface flows

Low flow: flow through a watercourse after prolonged absence of rainfall

(Bank) overflow: flow of water outside of the regular river bed during conditions where recent inflow minus outflow has exceeded the storage capacity

Peak flows: maximum flows through a watercourse

Precipitation: water that falls to earth in the form of rain, snow, hail, or sleet.

Relative buffering indicator: the ‘buffer’ function adjusted for relative annual water yield

River flow: the flow of water in the river channel

Run off or surface quick flow: streamflow that derived from rainfall by overland flow and that occurs quickly in response to precipitation events

Soil quick flow: streamflow that occurs shortly (e.g. 1 day) after a rain event but that passed though the soil for at least part of the pathway

Storage capacity: The total amount of water that can be stored in a reservoir before overflow occurs

Streamflow: Water flowing in the stream channel. The term is often used interchangeably with discharge.

Surface runoff or Surface-quick flow or run off: streamflow that derived from rainfall by overland flow and that occurs quickly in response to precipitation events

Total discharge fraction: Total water yield (discharge) per unit rainfall, usually on an annual basis

Water balance: The comparison over a certain time period (e.g. month or year) of inflow of water (precipitation) and outflows by evapotranspiration, streamflow and subsurface flows

Water quality: The chemical, physical, and biological characteristics of water with respect to its suitability for a particular use.

Water storage: The volume of water that can be (temporarily) withheld from evapotranspiration, streamflow or subsurface flows, either above ground in lakes, rivers, and other waterways or below ground as ground water

Water transmission: The functions of a watershed to transmit incoming precipitation to streamflow

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Who we are

The World Agroforestry Centre is the international leader in the science and practice of integrating 'working trees' on small farms and in rural landscapes. We have invigorated the ancient practice of growing trees on farms, using innovative science for development to transform lives and landscapes.

Our vision

Our Vision is an 'Agroforestry Transformation' in the developing world resulting in a massive increase in the use of working trees on working landscapes by smallholder rural households that helps ensure security in food, nutrition, income, health, shelter and energy and a regenerated environment.

Our mission

Our mission is to advance the science and practice of agroforestry to help realize an 'Agroforestry Transformation' throughout the developing world.

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United Nations Avenue, Gigiri - PO Box 30677 - 00100 Nairobi, Kenya
Tel: +254 20 7224000 or via USA +1 650 833 6645
Fax: +254 20 7224001 or via USA +1 650 833 6646
Southeast Asia Regional Programme - Sindang Barang, Bogor 16680
PO Box161 Bogor 16001, Indonesia
Tel: +62 251 625 415 - Fax: +62 251 625 416
www.worldagroforestry.org