Factors driving land use change: Effects on watershed functions in a coffee agroforestry system in Lampung, Sumatra

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Abstract

Forest cover in Sumberjaya declined from 60% to 10% over the past three decades; current land uses are a mosaic of smallholder coffee fields on slopes, and rice paddies and vegetables in the valleys. While deforestation was continuing at the forest frontier, farmers were already ‘re-treeing’ the landscape and many monoculture coffee gardens were gradually transformed into mixed systems with shade trees. In this case study we illustrate that the factors driving deforestation were strong, interconnected and generally outside the forestry domain. The current agroforestry landscape generates a significantly higher discharge than in the past, allowing a hydropower dam to revise its power-production targets upwards. One of the main reasons given to justify the eviction of farmers in the watershed, based on claims that the past land use change would negatively affect the discharge and the dam’s power generation, proved wrong. In this area, various myths about watershed functions – already dismissed in other parts of the world – still dominate the thinking of many foresters and policymakers; this paper illustrates how and why this situation came about.

Keywords: Deforestation; Shade coffee; Perceptions; Watershed functions; Driving factors

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1. Introduction

Tropical deforestation has been a prominent issue over the past few decades. A common perception, often held by national and international policymakers, attributes deforestation to a rapidly growing population of poor shifting cultivators who are hungry for new land, while another view, often held by environmentalists, blames corporate greed (Lambin and Geist, 2003). Land-cover change has long been viewed as being continuous, but in fact it is a disjointed process, with periods of rapid change, often triggered by a shock effect (Lambin and Geist, 2001). An example is the unprecedented economic crisis in 1997 that struck Southeast Asia, with Indonesia among the countries most badly affected.

Deforestation is often blamed for having tremendous negative impacts on watershed functions. The watershed functions delivered by forests are often understood to be reduced peak flows, greater dry season flows, landslide prevention, improved water quality and reduced sedimentation of reservoirs and waterways. These functions are commonly used as the main justification for classifying large areas of land as ‘protection forest’. In Indonesia alone, protection forest covers almost 15% of the total land area or 20% of the 143 million ha designated as State Forest Land, despite the fact that much of the forest cover has already disappeared. In Indonesia, the classification of land as protection forest is based on criteria such as slope, altitude, rainfall and soil, but not on criteria directly linked to the above-mentioned watershed functions.

Communities that live in the upper areas of watersheds are frequently blamed by government agencies for causing a loss of watershed functions and are asked to alter their land-use practices or to give up their land altogether. In the worst cases, farmers have been evicted when large-scale reforestation projects have been implemented, e.g. when dams are constructed. Conventional wisdom prescribes reforestation as the solution to deforestation and the perceived loss of watershed functions. In accordance with this, significant amounts of (scarce) public or donor funding have been spent on tree-planting programs. Yet, such programs are not always based on a sound understanding of the cause–effect relationships that exist between land use and watershed functions.

The aim of this paper is to demonstrate that the hydrological consequences of deforestation can only be understood by taking into account the land use systems that replaced the forest, and which were often developed by local communities.

Three hypotheses are therefore proposed:

(a) The process of deforestation is a first step in land use change;
(b) Deforestation and the development of subsequent systems are driven by various proximate and underlying factors;
(c) The hydrological impacts of deforestation are not necessarily negative, as they depend to a large extent on the nature of the systems that replace the forest.

These hypotheses are tested through a review of relevant literature and a case study of the sub-district of Sumberjaya (West Lampung Province, Sumatra). This area is representative of many other upland areas classified as ‘protection forest’, found along the mountainous ‘spine’ of Sumatra.
2. Watershed functions and deforestation – theoretical considerations

With regard to the wide divergence between perceptions of watershed functions and the measurements made of these functions, the so-called ‘environmental issue cycle’ offers an excellent theoretical framework. The ‘cycle’ consists of seven consecutive stages (Tomich et al., 2004). During the first three stages, awareness of the seriousness of a certain environmental problem gradually grows, and the pressure placed upon the authorities to take action increases. The effectiveness of existing government policies and/or agencies is often called into question, and a debate is often begun about the validity of the available evidence of causes and effects. Once a cause-effect chain has been established unequivocally (stage 4), options for mitigation of the problem can be considered, negotiated and implemented during the remaining three stages. The latter half of the environmental issue cycle depends upon the debate on causes and effects being resolved decisively. The process can come to a halt if gaps exist in either the understanding of the problem or in the measured impacts of the problem. Different interest groups may then apply evidence selectively and advocate a position which serves their own interests (Tomich et al., 2004). Deforestation in the tropics, and particularly its effect on low flows, represent a case in point, with seemingly mutually exclusive viewpoints being expressed not only by different interest groups but also by different representatives of the scientific community.

Saberwal (1998) pictures aptly how differently this ‘issue cycle’ evolved in the USA and in India. In the 1920s and 1930s, the USA’s Forestry Service had to change its rhetoric about the link between the disappearance of forests and the occurrence of droughts and floods, when it was confronted with scientific evidence (such as evidence obtained from paired catchment experiments) presented by meteorologists, geologists and engineers. The opposition from these groups initially led to an even more alarmist discourse, but, ultimately, to the Forestry Service adopting an increasingly quantitative approach.

By contrast, in India, there was little opposition from professionals in other scientific fields such as engineering, meteorology and geology to the proclamations of the Indian Forest Department that deforestation led to erosion and ‘desiccation’. Saberwal (1998) used the term ‘desiccation’ to incorporate a larger body of ideas, centred on the connections between deforestation and increased erosion, flooding, and overall aridity. Instead, the efforts of the Forest Department to gain greater departmental control over forest land (and its revenues) were met with a great deal of opposition from the Revenue Department. Its continued opposition drove the Forest Department to use increasingly more alarmist rhetoric (which, from the Forest Department’s perspective, was politically valuable). The Revenue Department lacked the training to question the scientific rigor of the beliefs of Indian foresters, who were able to portray potentially disastrous environmental situations in the making, through selectively reporting scientific developments from the USA. Because of the potential political fallout of such disasters, the Revenue Department and the British colonial government felt forced to accept the views of the Forest Department.

Bruijnzeel (2004) reports a similar debate that occurred in Indonesia and took place on the pages of the forestry journal of the former Dutch East Indies (Tectona)
in the 1920s and 1930s. Protagonists of the ‘sponge’ theory (which stated that tree roots, forest litter and soil hold water in the wet season and slowly release it during the dry season) vigorously opposed the ‘infiltration theory’ (which stated that base-flow is governed predominantly by geological substrate rather than by the presence or absence of forest cover). Others took an intermediate position, emphasising the positive influence of forests with respect to the prevention of soil erosion and floods rather than their effect on dry season flows. A paired catchment experiment was set up in West Java in 1931, but most of the experimental results were lost during World War II, effectively halting the debate for many years. In the turbulent years after Indonesia’s independence in 1945, little scientific research and public discussion occurred on these issues. As a result, the views of the Indonesian Forestry Service were hardly challenged, receiving possibly less opposition than those of the Forestry Department in India.

It was not until 1983 that Hamilton and King (1983) challenged the traditional views of many Forestry Departments in the Southeast Asian region and took a more scientific view of the functioning of tropical forests. Because of the paucity of hard, quantitative evidence from the tropics at the time, many of these authors’ conclusions had to be based on research results from the temperate zone (notably from the USA, New Zealand, Australia and South Africa) and on their professional judgement (Bruijnzeel, 2004).

In terms of watershed functions, the type of land use that replaces forest is more important than deforestation itself: if the infiltration and water-holding capacity of the soil are reduced, it is likely that dry-season flows will be affected. As forests have higher evapo-transpiration rates than most other land use types, including agroforestry systems, the balance between reduced evapo-transpiration on one hand, and lower infiltration on the other, will determine the final outcome of deforestation and land-use change (Calder, 1998; Bruijnzeel, 2004). According to Calder (1998), deforestation has probably only a slight effect on large-scale flooding and regional rainfall. He states that landslides and water quality, including its sediment load, are the result of various processes, and are not due to land use alone. In many places, urbanization and the construction of roads generate more sediment in the rivers than agricultural activities (Enters, 1998; Nagle et al., 1999).

With regard to land use change in the tropics and the factors driving such change, the conceptual framework developed by Geist and Lambin (2002), based on the analysis of 152 case studies of tropical forest cover loss, is probably the most comprehensive (Fig. 1). These authors concluded that tropical forest decline is determined by different combinations of various “proximate” and “underlying” driving forces. So, a universal policy for controlling tropical deforestation will not be effective.

Geist and Lambin (2002) define proximate causes of deforestation to be human activities at the local level, that originate from intended land use and that have a direct impact on forest cover. Examples of such proximate causes are agricultural expansion, wood extraction and infrastructure expansion. They also define another category “other factors”, that can also play an important role in driving deforestation; these factors include pre-disposing environmental factors (e.g. the characteristics of land, including soil quality and topography), biophysical drivers or triggers (e.g. fires,
droughts, floods and pest outbreaks) and social trigger events (e.g. revolution, social disorder and economic shocks). Of the 55 Asian case studies considered by Geist and Lambin (2002), agricultural expansion was the leading land-use change associated with all cases of deforestation. Wood extraction was the second most frequent proximate cause of deforestation (89% of cases), followed by infrastructure expansion (66% of cases) and other factors (31% of cases). In Asia in particular, these factors do not operate in isolation: in only 4% of the cases a single factor (agricultural expansion) alone explained the deforestation. In 30% of the cases two factors were found to occur (mostly agricultural expansion and wood extraction), while in 45% of the cases three factors were found, and in 22% of the cases all four factors were related to deforestation.

Geist and Lambin (2002) define underlying driving factors associated with deforestation as fundamental social processes, such as human population dynamics or agricultural policies that underpin the proximate causes, and which either operate at the local level or have indirect impacts that are felt at the local level (e.g. national or global policies). The following five underlying driving factors were distinguished: (1) demographic, (2) economic, (3) technological, (4) policy and institutional and (5) cultural (Geist and Lambin, 2002). In Asia, the most frequent underlying driving factors reported were: institutional and policy factors (96% of cases), technological factors (89%), cultural socio-political factors (84%), economic factors (71%) and demographic factors (62%). In none of the Asian cases was only a single factor at
play; in 11% of cases two factors were involved, in 13% three factors, in 40% four factors, and in 36% of cases all five factors were involved (Geist and Lambin, 2002).

It needs to be mentioned that in most of these studies, deforestation has been regarded as a unilinear process, whereby little or no attention has been given either to the land use types that were replacing the forests, or to the factors driving that replacement. As stated above, in terms of watershed functions, the land use that replaces forest is more important than deforestation itself.

Against this theoretical background we tested the three hypotheses outlined in Section 1.

3. Description of the study area

In the Sumberjaya area, a hydropower dam was constructed in the late 1990s and is now operational. The population density is now 150 people per km². The first people (the Semendo ethnic group) started to settle in the area around 1900. In the early 1950s the government stimulated the economic development of the area by settling many mainly Sundanese (from West Java) and Javanese veterans of the independence war. Spontaneous migration of more Sundanese and Javanese began in the late 1970s.

The rapid expansion of smallholder coffee gardens in the 1970s worried many forestry officials and was seen as the major cause of deforestation in the area, and thus as having a negative impact on watershed functions. In 1980 the production of a forest land use map (or ‘Tata Guna Hutan Kesepakatan’ [TGHK], which literally means ‘system for forest use based on agreement’) was initiated. Ten years later, in 1990, the map was published. About 40% of the Sumberjaya area was classified as ‘protection forest’ to preserve watershed functions (Fig. 2). Soon it became clear that the above-mentioned ‘agreement’ existed among foresters, but not so much with other government departments or with the local population.

Between 1991 and 1996 ‘protection forest’ boundaries were enforced and thousands of people were evicted to ‘rehabilitate’ watershed functions (Kusworo, 2000). This happened with often violent confrontations between the local population and government officers. For Sumberjaya, the boundaries of the State Forest land were the same as those delineated by the Dutch in 1935, which had been practically abolished following independence (Verbist and Pasya, 2004). Many villagers, often veterans of the independence war who had obtained legal land titles during the tenure of the Sukarno government in the 1950s, found their land suddenly classified as State Forest land.

The land use change study was carried out on an area of 730 km² comprising the sub-district of Sumberjaya (541.9 km²) in the district of West Lampung. It is situated in the largest coffee-producing area in Indonesia and it has a large variety of coffee systems and comprises the upper watershed (about 400 km²) of the Way Besai River, upstream of the hydropower dam.

The area is situated between 4° 56'6" and 5° 11'25" South and 104° 17’ 52” and 103° 33’51” East. The elevation ranges between 720 m.a.s.l. at the hydropower dam and 1718 m.a.s.l. at the summit of Gunung Sekincau. Average rainfall is
2500 mm/year, often with high rainfall intensity (Budidarsono et al., 2000). The rainy season lasts from November until April.

4. Methodologies

4.1. Land use change

Trends in land use change were analysed using available historical land use maps, past studies and satellite image interpretation. The land use map of 1970 made by the National Land Administration Board (BPN) with scale 1/100,000 was digitised. Not all map sheets of the other maps of 1978, 1984 and 1990 (all with scale 1/25,000) could be retrieved, but the results of the study of Syam et al. (1997) with data from 1970, 1978, 1984 and 1990 were available in table format.

Multitemporal Landsat satellite imagery (MSS 1973, MSS 1986 and ETM 2000) was used to update and visually crosscheck the classifications from the land use maps. The ETM2000 was classified using the maximum likelihood classification algorithm with a pixel-based approach and its classification accuracy was assessed by collecting ground truth data on field visits in 2001.

4.2. Factors driving land use change

The framework established by Geist and Lambin (2002) was used to analyse the various proximate and underlying causes of deforestation. Data were obtained from the

Fig. 2. The forest land use plan of 1999 of Lampung province, Sumatra. The black rectangle corresponds with the Sumberjaya area, which contains the Way Besai watershed. Reg 46 B around Gunung Sekincau is National Park, while Register 39, 44 B, 45 B with Bukit Rigis are classified as ‘protection forest’.
literature, from an ongoing research project and from discussions in open and closed meetings with the various stakeholders during field visits between 1998 and 2004.

To assess the effects of coffee prices on land use change, indicator prices for robusta coffee (USD/kg) on the world and Indonesian market were compiled from International Coffee Organisation (ICO) reports at [http://www.ico.org](http://www.ico.org) and Karanja (2002). Nominal prices were deflated to real prices (USD/kg) using the United States Consumer Price Index (CPI) with reference year 1998. Average annual coffee prices paid to robusta growers in Indonesia were deflated to real prices in Indonesian rupiah (Rp) using the general CPI with reference year 1998 and currency exchange prices ([http://strategicasia.nbr.org](http://strategicasia.nbr.org)). The rupiah price series is also based on ICO data. Due to market deficiencies these prices tend to be higher than those obtained by farmers in reality.

**4.3. Watershed functions and perceptions**

In the theoretical section the different perceptions of foresters, engineers and policymakers were mentioned. A generally overlooked group are farmers, who often are the main actors responsible for the land use changes described above. In 2002, Schalenbourg (2004) interviewed 60 farmers, a number of foresters, and also engineers who worked at the hydropower dam in Sumberjaya, to assess their knowledge and perceptions with regard to erosion and watershed functions.

A 24-year timeseries (1975–1998) of rainfall data from three stations in Sumberjaya, and discharge data from the Way Besai (the main river in Sumberjaya) were available from the Research Centre for Hydrology, Bandung. Discharge data were collected using a water level logger and rating curve. Discharge data for the years 1982 and 1989 were omitted from the analysis as the data were incomplete. The discharge data were measured 6-km upstream of the hydropower dam. The dam has a small storage lake and is designed to operate 4 h per day, when the target of 25 m³/s average daily discharge is met, while the lake would slowly fill up during the other 20 h per day. An increased discharge can be used to generate more power on a daily basis.

The number of days per year that a target discharge was met was calculated using a spreadsheet. Trend lines were fitted to explore how many days per year a certain target discharge had changed, on average, over the years.

**5. Results**

**5.1. Land use change**

A visual check of the MSS1973 and MSS1986 satellite imagery corroborated the results published by Syam et al. (1997) whereby maps of the National Land Administration Board (BPN) of 1970, 1978, 1984 and 1990 were compared.

The results of Syam et al. (1997) and our classification of 2000 are presented in Fig. 3. There was a steady decline in forest cover from 60% in 1970 to 12% in 2000 (Fig. 3). The 10-fold increase in the area of coffee, from 7% of the total land
area in 1970 to 70% in 2000, is striking. In a first wave of forest conversion, coffee was mainly planted without shade trees (‘sun coffee’). Since the mid-1980s, however, some sun coffee was converted to simple shade coffee systems, in which *Erythrina* spp. and *Gliricidia sepium* were used as shade trees.

### 5.2. Factors driving past land use change

The proximate and underlying causes of land use change are discussed below one by one. The causal diagram (Fig. 4), adapted from the theoretical framework of Geist and Lambin (2002), also shows feedback loops between the various factors.

Agricultural expansion was significant as, over the past 30 years, the area of coffee gardens increased at the expense of the forest (Fig. 3).

Interviews with farmers showed that wood extraction was an important source of income until the late 1970s, when forest was still abundant. The income provided by logging supported farmers while they cleared the land for coffee and during the first 2–3 years of the coffee plants’ development, when coffee could not be harvested.

Local infrastructure extended dramatically when Sumberjaya was connected with the Trans-Sumatra highway in the east in the 1950s. This was a major reason for a drop in transportation costs and an increase in the area’s accessibility. In 1987, 10,000 coffee planters from the slopes of the Sekincau volcano in the western area of Sumberjaya hired a private company from Jakarta to enlarge the 40-km access road to their villages in order to allow access by four-wheel drive vehicles (Mougeot, 1990). The subsequent decrease in transport costs made coffee production even more attractive, and this led to further in-migration and clearance of more forest, even inside the borders of Bukit Barisan Selatan National Park.

A major pre-disposing environmental factor is that the area is very suitable for growing coffee: the volcanic soils are among the best in Lampung Province. Furthermore, rainfall is ample and regular, and the area’s altitude is suitable for coffee-growing.
A major social trigger for deforestation was the breakdown of the formerly high level of control exerted by the government. When Suharto gave up his presidency in 1998, this caused a 'land race' in many areas of Indonesia (Sunderlin et al., 2001).

Local and world market coffee prices are a major underlying driving factor. The infamous frost in Brazil in 1975 severely affected world coffee production and prices, as Brazil then had a 35% world market share. The coffee agreement of 1976 managed to keep world prices relatively high until 1989. Then overproduction led to the suspension of the quota system and world coffee prices dropped to 50% of their former level and have generally been decreasing ever since (Fig. 5). Coffee prices in Indonesia are affected by world coffee prices. For example, the high coffee price in 1975 triggered a wave of spontaneous migration to the area (see additional information in section on demographic factors). The export-stimulating macro-economic policy of the Indonesian government, including devaluations of the rupiah, was also important: coffee prices obtained by producers did not follow the downward trend occurring in the world market. Apart from increased export earnings, the stimulation of exports by the central government also led to an expansion of the coffee area and thus to greater conversion of forest land. The yearly price fluctuations on the Indonesian market are much larger than on the world market (Fig. 5).

Migration has been the most important demographic factor. During the period 1978–1988, the population in Sumberjaya doubled from 37,500 to 78,500. The

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**Fig. 4.** Causal relationship diagram for the Sumberjaya area with the proximate and underlying factors of deforestation (after Geist and Lambin, 2002).
annual population growth rate in Sumberjaya at that time was extremely high: 7.5%. The prospects of very high returns attracted many Javanese migrants (in fact, Sum-ber Jaya means ‘source of wealth’). After 1976, many Javanese, who initially arrived in the area to work as seasonal coffee harvesters, set up their own farms and opened large tracts of forest. That steep population increase coincided with extensive deforestation and a sharp increase in the area of sun coffee (Fig. 3).

From 1988 until 1998, the number of inhabitants only grew from 78,500 to 79,500, despite the population being very young. This is a clear indication that Sumberjaya has evolved to become an area of out migration. Recent field interviews reveal that because of scarcity of land in the late 1990s many young families migrated further north, to Bengkulu Province, where more forest remained for conversion to coffee.

As the population increased, and more labour became available, coffee-growing became more labour- and capital-intensive in the 1970s, with widespread use of new technological factors such as pruning and fertilisers.

Since the late 1980s farmers have planted more shade trees in older coffee gardens where land tenure was secure. Thus, at the landscape level, ‘re-treeing’ occurred. Trees such as *Erythrina* spp. improve soil fertility and, through shading, also reduce the weeds present and thus the time and labour required for weeding. Schalenbourg (2004) showed that farmers are also knowledgeable about the positive effects of (shade) trees on watershed functions. These off-site benefits are driven by on-site benefits. Currently, there is considerable farmer interest in fruit tree species such as *Citrus* spp., durian (*Durio zibethinus*), but also in nutmeg (*Myristica fragans*) and clove trees (*Syzigium aromatica*). In addition, cacao (*Theobroma* sp.) has recently been promoted by the government.

From a policy perspective, official taxes are relatively low. The Indonesian Coffee Exporters’ Association (AEKI) charged exporters 15,000 Rp (1987 price) for every
tonne of exported coffee (Mougeot, 1990). This is less than 1% of the value paid to the growers, but in return AEKI also invested in equipment in an attempt to improve the quality of coffee at the farm level. On the other hand, where coffee is grown on disputed State Forest Land, coffee farmers have to pay up to 20% of the profits from their coffee as an ‘unofficial tax’ to officials from various government offices, including officials from the provincial forestry unit (Observer, 1999 in Suyanto et al., 2000). This created the perception among farmers that it was acceptable to grow coffee in the protection forest.

On the institutional side, land tenure and legislation are characterised by a great deal of ambiguity, uncertainty and controversy (Verbist and Pasya, 2004). Forest legislation has so far proved to be ineffective in halting deforestation. Many laws and decrees originate from different levels within the government (Central, Provincial and District), and also from different Ministries (including those of Agriculture and Forestry). These laws are often conflicting and inconsistent. After the fall of Suharto in 1998, and at the beginning of the period of reform (reformasi) which followed, there was a sense of land tenure security. Local communities felt they had more power and could stand up to the government, and so again started to clear forest at the forest frontier.

Cultural factors are important, as the Semendo people had a reputation for their extensive farming techniques. Employing hired labour (mainly Javanese) allowed Semendo groups to convert vast areas of land relatively rapidly and to increase their incomes, as well as to occupy a large area of land (and claim land rights) while moving south (Benoit, 1989). The later Sundanese and Javanese migrants also cleared forest or old fallows to grow coffee.

5.3. Watershed functions and perceptions

Schalenbourg (2004) concluded that the understanding and perceptions of watershed issues in Sumberjaya did not differ greatly among the different stakeholder groups (foresters, engineers and farmers). Foresters, however, placed a higher weight than farmers on the importance of forest in providing beneficial watershed functions. Farmers agreed that forest was important, but they also valued the positive effects that trees may have in terms of soil conservation, namely in increasing infiltration and the soil’s water-holding capacity (because of the presence of a litter layer). All parties concluded that peak flows are now greater, and that dry season flows had decreased, and attributed that to deforestation (Schalenbourg, 2004). Claims were made that the reduced dry season flow hampered the operation of the Way Besai dam.

On the basis of rainfall data for the period 1975–1998, we concluded that average annual rainfall remained almost constant over the years, although there is large year-to-year variation (Fig. 6). The average yearly runoff ratio discharge/rainfall shows a statistically significant increasing trend. The chance that the slope of the regression is different from 0 was significant at the 99% confidence level ($\alpha = 0.001$), which we attribute to the increase in the area of coffee gardens in the landscape, as these gardens have lower evapo-transpiration rates than forested areas.
The average yearly runoff discharge also showed an increasing trend, but this was not significant at the 95% confidence level.

Fig. 7 shows how many days per year a certain target discharge was met. As was mentioned by the farmers and the engineers, peak flows increased and the dry season low flows decreased over time (Fig. 7). Table 1 illustrates the results of a standard linear regression or the fitted trend lines. The lowest flows (discharge lower than 5 m$^3$/s) show a significant decreasing trend. Over the 24 years the number of days with a discharge lower than 5 m$^3$/s increased on average by 8%. The number of days with a discharge between 10 and 20 m$^3$/s does show a trend, but not a significant one. The number of days per year that the dam can operate 4 h per day at its target discharge of 25 m$^3$/s has increased on average by 16% from 1975 to 1998; this trend is significant at the 95% confidence level. The hydropower dam is now able to generate significantly more power. Thus, a relatively simple analysis can help to dismiss some of the claims made to justify the evictions of the farmers in the 1990s.

The lower dry season flows in the 1990s did indeed decrease, but, in our opinion, cannot be entirely attributed to deforestation. In the ‘El Niño’ years of 1994 and 1997, rainfall was historically low (less than 2000 mm) and that certainly had an impact on the low flows (<5 m$^3$/s) (Fig. 7). Further analysis is therefore needed to separate the effects of rainfall from those of land use change.

The conversion of sun coffee into shade coffee since the mid 1980s with its higher ‘surface roughness’ and infiltration capacity suggests that rehabilitation might already be going on. However, it should be noted that a significant area of shade coffee is still young (so tree cover is not yet very dense), and regeneration of soil physical properties is generally slow.
6. Discussion

In this case study, not just some but all the proximate and underlying causes listed by Geist and Lambin (2002) are present. This fact, in combination with all the mutual feedback loops occurring among these factors, provided a very strong impetus for deforestation. The complexity and the strength of these driving factors were clearly not understood when the decision was made to evict farmers in the early 1990s.

The 1997 economic crisis strengthened many of those driving factors. Farmers increasingly operated as agents of deforestation during the crisis: as stated by Sunderlin et al. (2001), many farmers who suffered a loss of income (despite the
higher commodity prices) would turn to logging to compensate for that loss, while those who gained would invest in further agricultural expansion.

On the positive side, the Asian crisis and the subsequent reformasi in Indonesia have also created new opportunities to change conventional thinking and the institutional status quo. Since 1998, greater regional autonomy and a shift in the balance of power opened the way for negotiations about land tenure and access to State Forest Land. The Forestry Department at the local level now admits that the ‘heavy-handed’ approach did not work. Community Forestry Management schemes (Hutan Kemasyarakatan) have been set up in a few so-called pilot areas, of which Sumberjaya is one. Farmer groups are now able to obtain land tenure rights in some protection forest for a 25-year period, after they complete a 5-year trial period. The conditions are that these groups must protect the remaining forest and plant trees on their coffee farms. However, there is still a lack of clarity about the criteria and indicators needed to evaluate progress, and much discussion is still ongoing between (and among) forestry officials and farmer groups about what trees would be suitable and how many of them should be planted, in this recent attempt to balance economic and watershed-protection objectives. It is an interesting policy experiment, which needs to be evaluated for its potential application in larger areas.

However, we are still far away from a situation where a (participatory) water monitoring program is set up, and as part of which, watershed functions themselves are being assessed and used as criteria. A better insight into the functioning of the watershed (through assessment of the major sources of sediment and pollution, for example) will increase the probability that improved watershed functions will benefit more stakeholders, while still ensuring the livelihoods and acceptable incomes for farmers.

One could wonder why it took so long to challenge the ‘myths’ in India or by extension in Indonesia, which were already debunked in the 1920s and 1930s in the US. In our opinion, an explanation is that, as mentioned above, (a) foresters tend to narrow down land use change to deforestation and show little interest in the subsequent land use and (b) as illustrated in the introduction, many scientifically unfounded perceptions about hydrological impacts of land use change, and deforestation, in particular, remain. Another important explanation could be that conditions had changed dramatically. Saberwal (1998) states that the research conducted in the USA in the 1920s and 1930s was carried out within the context of a continuing battle over the apportioning of flood-control funds, whereby the Corps of Engineers got the upper hand over the Forest Department: an editorial in American Forests in 1937 points to the huge discrepancy in the funding for flood-control works allocated to the two main agencies involved. Just US$ 2.5 million was allocated for the purchase of forest lands located at the headwaters of large rivers; by contrast, US$10 million was allocated in 1937 for surveys and planning by engineers, in addition to US$310 million for the building of levees, reservoirs, spillways and dams along the Mississippi (Saberwal, 1998). It seems that at a later stage in India and Indonesia (and probably in many more countries besides), the foresters and engineers had concurring rather than conflicting interests. The question was no longer whether public funds should be
allocated to forests or to dams and reservoirs. In fact, the need to make large investments in dams (for hydropower and irrigation, for example) was accepted by central governments, and dams were being constructed at a rapid pace between the 1960s and the late 1980s, especially in Asia (World Commission on Dams, 2000). There was nothing to be gained by questioning the rhetoric of the Forestry Department, a Department which in Indonesia is (and probably in many surrounding countries) well-connected to the policymakers. The main beneficiaries of further research on how land use change affects watershed functions would have been the upland farmers. However, given the farmers’ general lack of influence and power, none of the existing agencies felt compelled to call for further research on this topic.

7. Conclusions

The evidence presented here supports our first hypothesis, which states that deforestation is only the first phase of land-use change. In 30 years, forest cover declined from 60% to 10%, with forest mainly being converted into monoculture sun coffee. However, after a time lag of about 15 years, a ‘re-treeing phase’ occurred, with the conversion of much of the sun coffee into (mainly simple) shade coffee systems.

All categories of proximate and underlying driving forces of deforestation as listed by Geist and Lambin (2002) are present and interconnected. The most important factors influencing deforestation and the conversion to the subsequent coffee systems are outside the domain of forest policy; this calls for solutions beyond the scope of the Forestry Department’s activities, and therefore a multisectoral framework is needed.

Regarding the third hypothesis, it was illustrated that the hydropower dam in Sumberjaya can now operate significantly more days per year at its target discharge than it would have been able to 30 years ago. The hydrological impact of conversion from forest to agroforestry systems is positive from this perspective. Peak flows increased and dry season flows decreased over the years, although one must add that the current analysis does not explain how much of these low flows should be attributed to the effect of deforestation or to the dry ‘El Niño’ years in the 1990s.

Last but not least, this paper does not aim to give ‘carte blanche’ for more deforestation, but is a plea for better diagnosis and consideration prior to reforestation for rehabilitation of watershed functions.

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