Catchment Approach to Managing Soil Erosion in Kaligarang Catchment of Java, Indonesia

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INTRODUCTION

The Indonesian population is estimated to reach 270 million in 2025 and this translates to an increase in food demands of about 30%. For rice alone, this means a requirement for 17 million tons increase from the current 53 million tons annual consumption. To be self-sufficient in rice (which is politically and socially important), Indonesia must intensify agriculture by implementing at least medium-input rather than low-input technologies (Eswaran, 1998) and protecting the soil from degradation to ensure sustainability. The fact remains that erosion-prone hilly and mountainous areas are being used intensively for agriculture by the rural poor. This results in aggravation of land degradation brought about by soil erosion. The implementation of soil conservation has been accorded low priority among most farmers because most conservation technology options do not promise direct and short-term profits. Moreover, past recommendations for soil conservation have focused on expensive investments which contradict the reality of the rural poor (Garrity and Agus, 1999; Agus *et al.,* 1998). In addition, policy-makers as well as researchers have not successfully developed on-farm technologies that can address the urgent needs of poor farmers and secure upstream as well as downstream natural resources.

Past research related to these problems and other soil constraints to food production focused on biophysical aspects and technical solutions aimed at improvement and generally were designed without regard to the farmers' conditions. Sites were selected without carefully considering the possible geographical extension of the results. Consequently, farmers' adoption, if any, has been low, slow, and oftentimes unsustainable.

Recognition of this failure led to a re-examination of approaches to research on sustainable land management. Participatory catchment management research using an integrated and interdisciplinary approach has evolved and has been adopted by IBSRAM-MSEC in its research network, including the work in Indonesia. This report covers technical progress on biophysical and socioeconomic aspects of MSEC Indonesia as of September 2000.

GOAL AND OBJECTIVES

The objectives of this long-term research (aimed for at least 10-year period) are to:

- Develop sustainable and acceptable community-based land management systems that are suitable for the entire catchment.
- Quantify and evaluate the biophysical, environmental, and socioeconomic effects of soil erosion, both on and off sites.
- Generate reliable information and prepare scientifically-based guidelines for improvement of catchment management policies.

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Expected outputs include:

- Better understanding of the on- and off-site effects of soil erosion.
- Improved soil erosion control technologies that are socially, and institutionally acceptable to the communities in the catchment areas.
- Methodology for obtaining the participation of farmers and other stakeholders in the management of catchments.
- Appropriate policies that will improve the management of catchments by the local government and the communities and will induce the farmers to adopt improved land management technologies.

METHODOLOGY

Site selection

The site (model catchment) was selected based on the representativeness of its land use, topography, socioeconomic condition of the region (main watershed), accessibility, and possible collaboration with existing (research) institutions. In addition, the suitability of the site for hydrological monitoring was also set as a criterion.

Preliminary discussion about prospective research sites was conducted jointly by CSAR and IBSRAM scientists. Three general sites were visited and evaluated based on the aforementioned criteria. These were in Pasaman, West Sumatra, Tulang Bawang Watershed in Lampung, Sumatra, and the Kali Garang Watershed in Semarang, Central Java. The advantages and disadvantages of the different sites were evaluated for the final selection. After so much discussion, the Babon catchment at Keiji village in Kali Garang Watershed was finally selected (Figure 1).

Biophysical and socioeconomic inventory and characterization

Initial survey was conducted in September 1999 to identify the biophysical condition, farming practices, rainfall pattern, and natural resources (soil, water, and vegetation). The socioeconomic survey was conducted to understand the social, cultural, and institutional problems and potentials. A more in-depth farmer profile survey, including mapping of farm ownership, was conducted from July to August 2000. A combination of open ended and semistructured surveys was used. Biophysical site characterization, which includes contour mapping, soil mapping, and site geological characterization were conducted from December 1999 to April 2000. A digitized map at the scale of 1:5,000 was produced for contour, land use and soil information. Soils were classified according to the Soil Taxonomy Classification (Soil Survey Staff, 1996).

Evaluation of the on-site effects of erosion

Instrumentation of the microcatchments

For hydrological monitoring, six automatic water level recorders (AWLRs), five weirs, eight staff gauges distributed in a few channels and five weirs, seven manual rain gauges, and one automatic weather station have been installed. The AWLRs were installed at the inlet of the catchment (near Y3 in Figure 2), at the Parshall Flume (outlet), rambutan catchment (2 ha area), Tegalan Catchment (3.15 ha), and Kalisidi Catchment (38.5 ha), and near Kemloso dam. AWLRs became operational in March 2000, unfortunately at the end of rainy season. A list of instruments and devices is given in Table 1 and instrument/device distribution in Babon microcatchment is given in Figure 2.

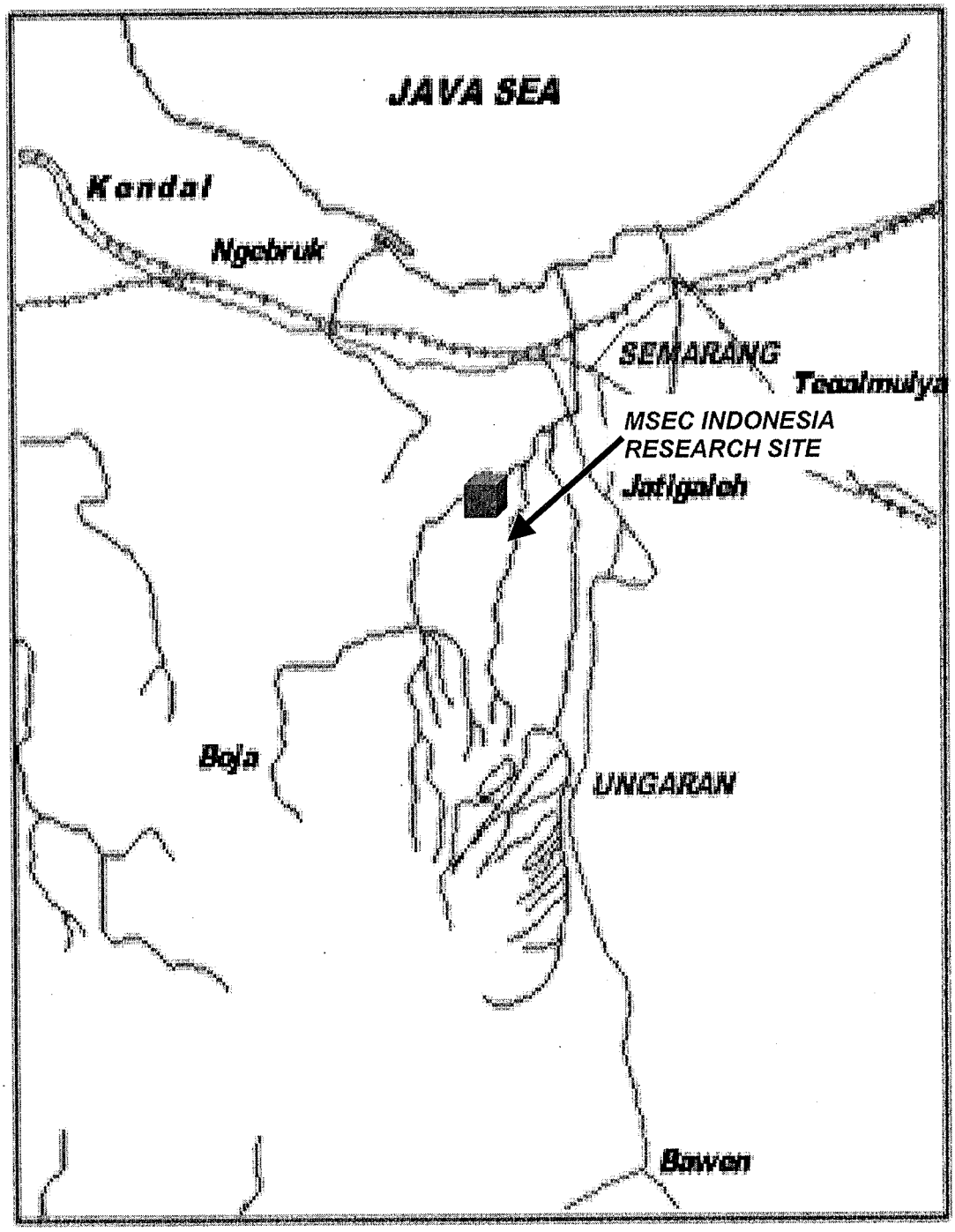


Figure 1. Location map of MSEC research site in Central Java, Indonesia.

Data collection and monitoring

The water level in each stream is recorded both manually using staff gauges and automatically using AWLRs. Water discharge and sedimentation calibration started in the last week of December 1999, but no AWLRs and rain gauges were operational before March 2000. Runoff (using staff gauges)

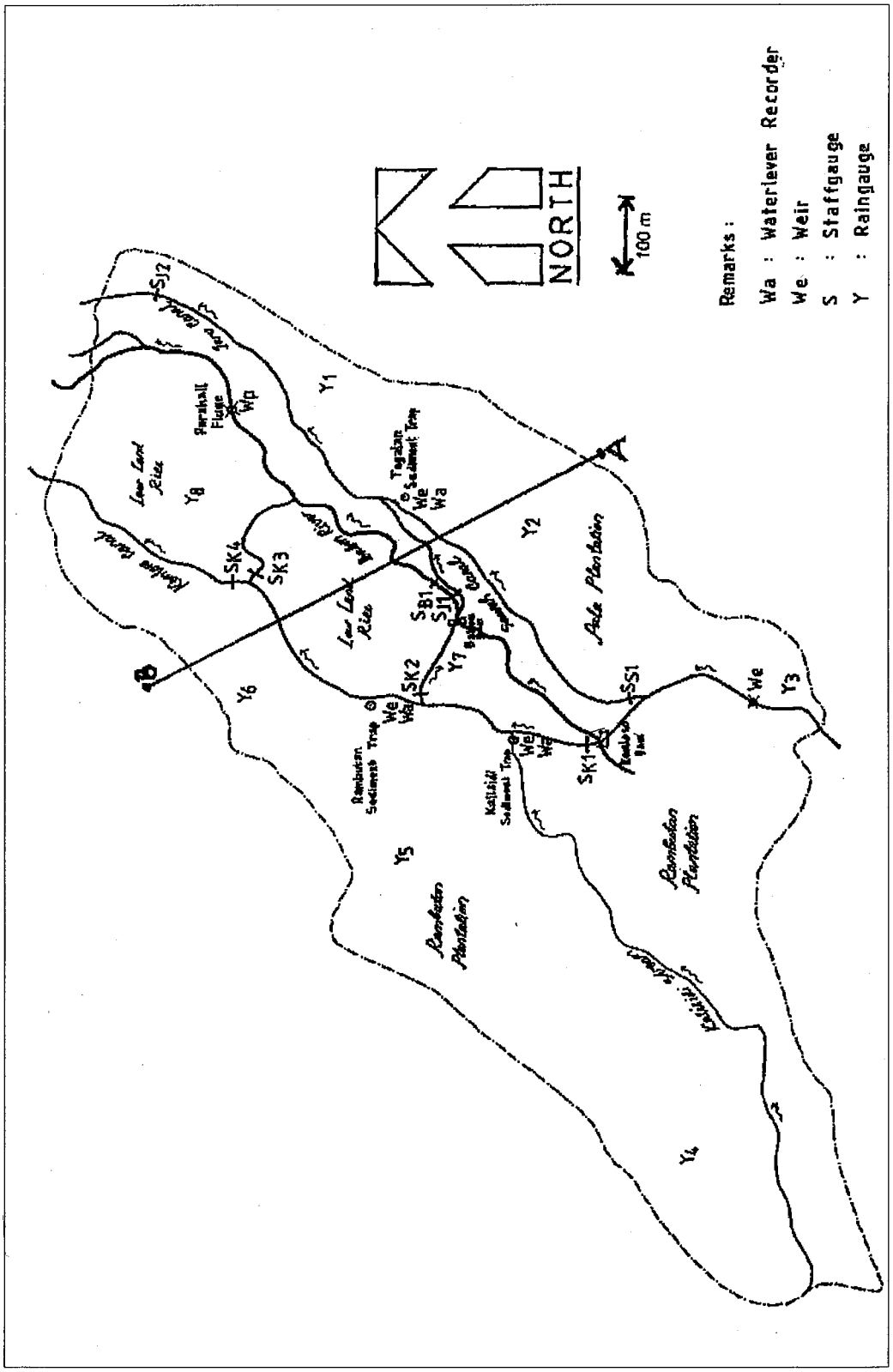


Figure 2.-Hydrological and meteorological instrument placement within Babon catchment

and suspended and bedload sediment from each sediment trap and channel is measured for every rainfall event. Water samples from traps, inlets, outlets, and channels were taken to develop rating curves of suspended sediment. Soil chemical and physical analyses are progressing at the Bogor CSAR laboratory. Sediment rating curve development for each channel and trap, was done from March to April 2000. This task needs to be continued in the next rainy season which normally starts in November. Monitoring of rainfall from the manual rain gauge is done every day at 08.00 a.m. Monitoring of the water level is conducted using automatic and manual devices. The AWLRs are set for every five-minute recording. Manual observation using the staff gauges placed on every channel is done three times daily at 08.00, 12.00, and 16.00 and less intensive observation is done for traps and weirs with AWLRs.

Table 1. Hydrological instruments and devices for Babon microcatchment.

Instrument/device	Date installed	Locatiion
1. Weirs (V-notch, outlet Parshall flume)	Feb. 2000	Catchments Tegalan, Rambutan, Kalisidi, at inlet and (entire Babon microcatchment)
2. Channel	Feb. 2000	Kemloso channel, 4 units (SKi); Sungai Jaru, 2 units (SJi); Sungai Babon, 2 units (Sbi); and at irrigation reservoir, 1 unit (R)
3. Staff gauges	Jan. 2000	8 units, installed at each weir and channel
4. Automatic water level recorder (AWLR)	Feb. 2000	At catchments Tegalan, Rambutan and Kalisidi, inlet (installed by P2SUKA), and at outlet (at Parshall Flume); 5 units
5. Automatic rain recorder (ARR)	Jan. 2000	Installed by P2SUKA (CSAR-CIRAD Agribusiness project); at the Babon Catchment inlet.
6. Manual rain gauges	Jan. 2000	7 units; spread-out in Babon catchment

Evaluation of the off-site effects of soil erosion

Identification of potential off-site impact

Evaluation of the off-site impacts of soil erosion is accomplished through four steps, namely appraisal of potential off-site impacts; measurement (data analysis) of key water quality and quantity indicators downstream; estimation of the contribution of agriculture to the off-site impacts, and translation of the agricultural on-site contribution into economic terms. The identification of potential off-site impacts was carried out by discussion (participatory appraisal) with related agencies including Municipal Drinking Water Supply Company (PDAM), Municipal Fishery Service, Provincial Food Crop Service (Diperta), Provincial Irrigation Service (PU Pengairan), Provincial Environmental Impact Control Board (BAPPEDALDA), and Regional Planning Board (BAPPEDA). Scale-wise, this appraisal was not limited to the Babon microcatchment but it covers the entire Kaligarang Catchment. Information on the utility of rivers, history of floods, land use changes, river discharge, sedimentation, pollution, and problems related to water quality was collected from respective agencies in September 2000.

If the appraisal indicates convincing correlation of on- and off-site impacts, then the modality for water sampling for the three tributaries of Kali Garang River will be developed. The economic contribution of on-site impacts will be estimated based on biophysical measurements, but estimation of the farming contribution on the off-site impacts will be necessary before the economic analysis can be done. Estimation of the farming contribution to the off-site impacts will be the main challenge in this analysis because virtually no published studies have been conducted in Indonesia in this connection.

RESULTS AND DISCUSSION

Site selection

While the watershed in Pasaman, West Sumatra was the best choice from the biophysical point of view, it was disqualified because of poor accessibility. The Tulang Bawang Watershed in Lampung also had poor accessibility although it would have been a good link with the International Center for Research in Agroforestry (ICRAF). As earlier mentioned, the Kali Garang Watershed in Central Java was finally selected as the site for MSEC-Indonesia. Institutional links were made with the Assessment Institute of Agricultural Technology (AIAT) in Ungaran, Central Java, and Agri-business Project (P2SUKA), a collaborative project between CSAR and CIRAD. AIAT conducts mostly on-farm agronomic and socioeconomic evaluation of promising technologies and P2SUKA concentrates on meteorological and hydrological aspects of agri-business on meso-catchments of Kaligarang Watershed. The various land uses of Babon microcatchment, including perennial tree crops, annual upland crops, and lowland rice fields (*sawah*) is the strength of this catchment, but the catchment's steep slopes may be an extreme case in northern Java.

The Babon Catchment was further identified within the Kali Garang Watershed for the more detailed catchment study. The site is described as follows:

Province: Central Java
District/subdistrict: Semarang/Ungaran
Village: Keji
Catchment name: Kali Garang (220 km^2)
Sub-catchment (mesocatchment): Babon (139 ha)
Latitude: 07° 20'; S; Longitude: 110° E
Slope: 15–75 %

The catchment is located about 3 km west of Ungaran and about 20 km south of Semarang, the capital of the province. Accessibility to Keji village is relatively easy and the farmers are under the influence of the urban areas.

Biophysical and socioeconomic characterization

Biophysical description of Kaligarang Watershed

The general description of Kaligarang Watershed is adapted from CSAR (1999). The watershed extends from south to north, from the summit of Mount Ungaran (2,050 m asl) to the coastal line of the Java Sea. Kaligarang River empties into the Java Sea through Semarang city, the capital of the province of Central Java. The total area of the watershed is about 220 km^2. Three tributaries contribute to the Kaligarang River. These are Kali Kreyo (west), Kali Kripik (centre) and upper Kaligarang (east). Geographically Kaligarang Watershed can be divided into three areas:

- The highlands, with elevations between 400–2,050 m asl. are the steep slope area of Mount Ungaran, with an ancient volcano dating back to the Pleistocene era. The geological substratum mainly constitutes basaltic lava. Slopes range from 15–40% and become steeper closer to the summit. Drainage patterns (hydrological networks) are composed of concentric narrow valleys formed by rapid flows due to torrential rains. Forest still covers the steepest slopes, but annual food crops and various estate crops (rubber, cloves, and tea) dominate the area with 400–1000 m elevation.
- The Intermediate Plateau, with elevations between 50–400 m asl., corresponds to a hilly region with the geological substratum constituting volcanic breccia, tuff, and sandstone. The hydrological network spread out in three tributaries that pass through winding and narrow

valley bottoms. The river beds are overlaid with stones indicating the occurrence of flash floods. The landscape is covered by a mosaic of agroforestry gardens, villages, and rice fields.

- The 10-km wide coastal plain, which used to be swampy alluvial plain, is now widely built up, including fishery and pond areas. The three tributaries merge into Kaligarang River near the border of the coastal plain and the intermediary plateau and the Kaligarang River is canalized from Simongan reservoir to the sea.

Geology and parent materials

Based on a geological map (Magelang-Semarang sheet), at a scale 1: 100,000 (Thaden *et al.*, 1975) the study area belongs to the formation of Central Ungaran lahar (cinders) and volcanic rocks from the Pleistocene-Holocene (Quarternary) age. The lahar and lava consist of andesite and basaltic rocks.

Visual field observation shows that the soil in the study area on the middle volcanic slopes is derived from intermediary tuff, volcanic ash, intermediary volcanic rocks (andesite), and mafic rocks (basalt) while the valley bottom developed from alluvial and colluvial materials resulting from gravitational translocation. Soils derived from the volcanic tuff and ash have a bulk density of 1.0 g cm^{-3}, light colour, and contain volcanic glass (Puslittanak, 1995). The intermediary volcanic rocks (andesite) generated dark coloured soils and a relatively high soil pH (>6.0). Part of the lava and cinders in the form of boulders and rocks protrude on the steep slopes.

The study catchment consists of a middle volcanic slope from the Ungaran volcanic system and valley bottom in the middle of the catchment (CSAR, 1997). The land was formed as a result of Mount Ungaran activity that yielded lava and lahar flows, tuff eruption, and volcanic ash. The volcanic activity also resulted in hill formations stretching from south to north. The secondary process resulted in valley formation between the hills in which Kalisidi River and Babon, Jaru, and Kembloso streams flow.

Land use

Agroforestry (a mix of perennial tree crops and annual food crops) and lowland rice fields (*sawah*) dominate the land use of Kali Garang. Homesteads and industry occupy about 4,500 ha (20%) of the land (Table 2) and the change toward this land use from agricultural purposes has been very rapid. Moreover, homesteads and industries extend from the steeplands to the city and this has been attributed by local officials as a contributing factor to frequent floods. Despite the rapid development of industry and housing, agriculture will remain an important field of employment, especially because it needs a large labour force. Agricultural commodities diversify from food crops to fruits and animal products as a response to urban demands and more competitive benefits from nonrice commodities. Meanwhile, off-farm employment has become increasingly important.

Table 2. Land use type and area in Kaligarang Watershed.

Land use	Area (ha)
Irrigated lowland rice fields	6,000
Agroforestry garden	7,500
Forest and estate crops	3,500
Homesteads and industries	4,500
Miscellaneous	500
Total	**22,000**

Source: CSAR (1999).

Biophysical conditions of Babon microcatchment

Topography

The study area is located at an elevation between 390–510 m asl. Around 55% of the area is steep to very steep (25–75 % slope) and only a small portion of the valley bottom has plain and undulating slopes (Table 3 and Figure 3). Most of the land, including parts of the upland and the lowland rice fields, has been bench terraced.

Table 3. Slope classes of the Babon Catchment.

Symbol	Slope class %	Area ha	Area %
A	0–3	6.8	5
B	3–8	26.9	19
C	8–15	2.9	2
D	15–25	23.6	17
E	25–45	40.8	30
F	45–75	34.1	24
G	>75	3.7	3
Total	**139.0**	**100**	

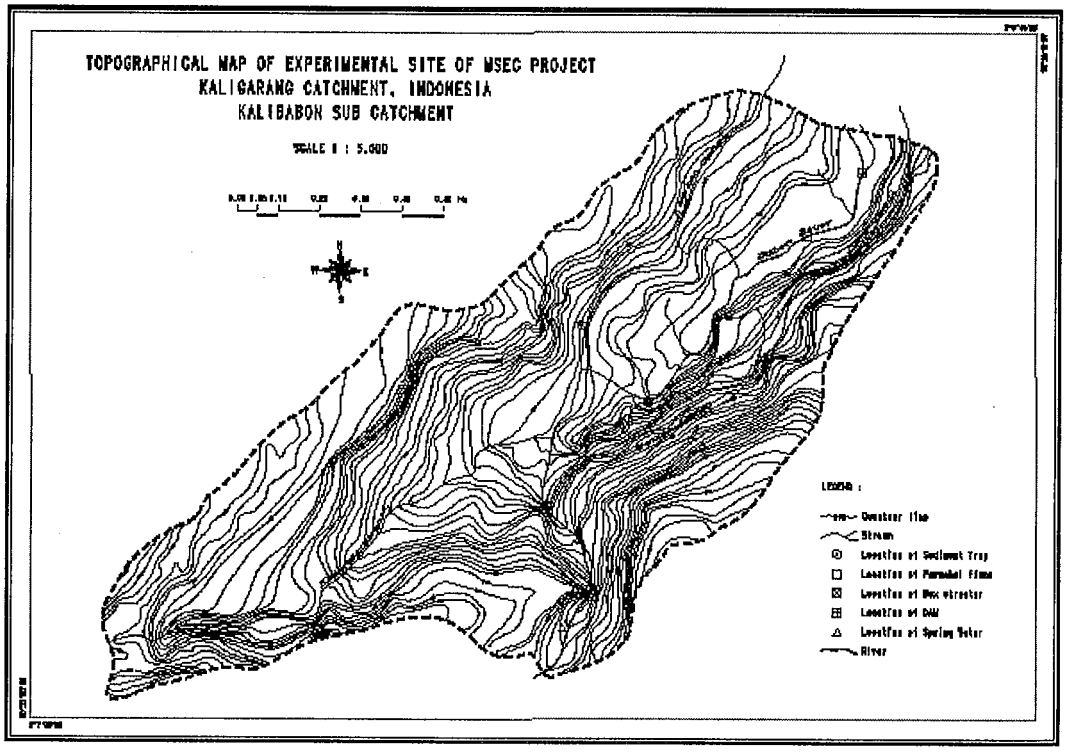


Figure 3. Topographic map of Babon catchment.

Soil

Soils in the area are determined primarily by parent materials, while other soil-forming factors did not really affect the soil type. Soil families and main land uses are given in Table 4. The soil map (Figure 4) consists of 15 land units as listed in Table 5. Grouping of land units was based on soil family, slope classes, and land phases. The presence of an aquic moisture regime and the existence of streams in the catchment enable lowland rice (*sawah*) production.

Table 4. Soil family and dominant land use for Babon Catchment.

Soil family	Main land use/vegetation
Fine, mixed, isohyperthermic, Aeric Epiaquepts	Lowland rice, 2 crops per year
Fine, mixed, isohyperthermic, Typic Endoaquepts	Lowland rice, 3 crops per year
Fine, mixed, isohyperthermic, Andic Eutrudepts	Upland, mixed crops of cassava with coffee (Coffea robusta), coconut (*Cocos nucivera*), durian (*Durio zibethinus*), rambutan (*Nephelium lappaceum*), and peanuts (*Arachis hypogaea*).
Fine, mixed, isohyperthermic, Aquic Eutrudepts	Lowland rice (*Oryza sativa*) or root crops, corn (*Zea mays*), or peanuts.
Fine, mixed, isohyperthermic, Humic Eutrudepts	Nutmeg (*Myristica fragrans*)
Fine, mixed, isohyperthermic, Andic Dystrudepts	Rambutan (*Nephelium lappaceum*),
cassava	(*Manihot esculenta*), *Imperata cylindrica*, and American gooseberry (*Melastoma malabatricum*)

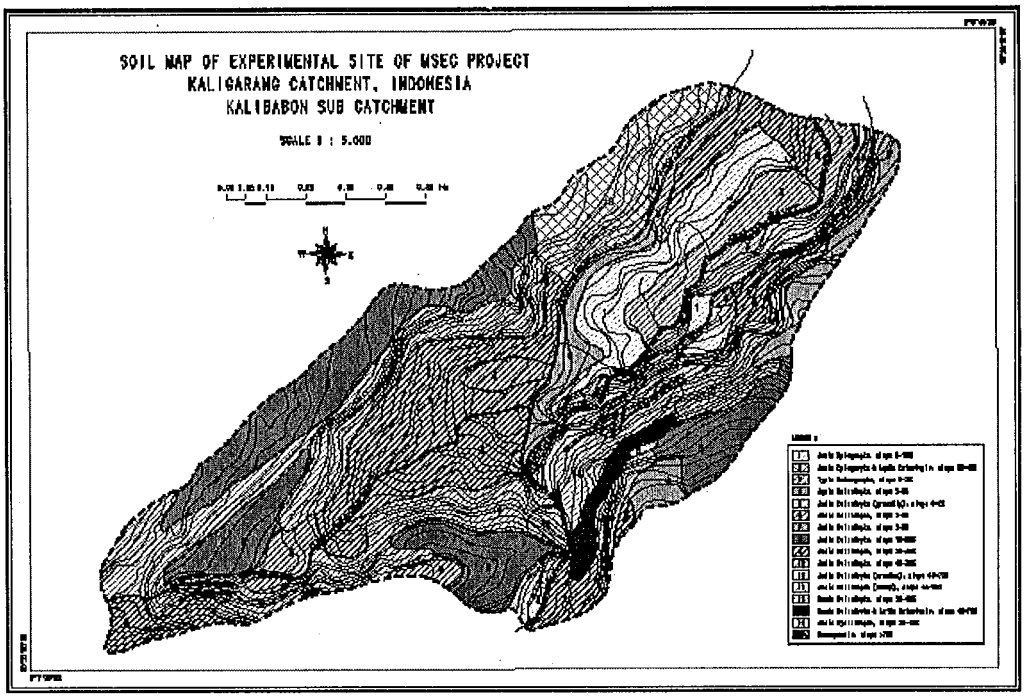


Figure 4. Soil map of Babon Catchment

Table 5. Land units of the Babon Catchment.

No.	Soil Family	Slope	Phase		Area	
			Terrace height	Surface Conditn		
		%	m		ha	%
1	Fine, mixed isohyperthermic, Aeric Epiaquepts	2–8	0.5–1.0	-	16.15	11.6
2	Complex:					
	Fine, mixed isohyperthermic, Aeric Epiaquepts					
	Fine, mixed isohyperthermic, Aquic Eutrudepts	25–45	1.0–2.0	-	2.00	1.4
3	Fine, mixed isohyperthermic, Typic Endoaquepts	0–2	<0.25	-	6.35	4.6
4	Fine, mixed isohyperthermic, Aquic Eutrudepts	2–8	0.25–0.5	-	4.75	3.4
5	Fine, mixed isohyperthermic, Andic Eutrudepts	0–2	<0.25	Gravelly	0.45	0.3
6	Fine, mixed isohyperthermic, Andic Eutrudepts	2–8	0.25–0.5	-	6.05	4.4
7	Fine, mixed isohyperthermic, Andic Eutrudepts	8–15	0.25–0.5	Eroded	2.90	2.1
8	Fine, mixed isohyperthermic, Andic Eutrudepts	15–25	-	-	23.60	17.0
9	Fine, mixed isohyperthermic, Andic Eutrudepts	25–45	-	-	26.10	18.8
10	Fine, mixed isohyperthermic, Andic Eutrudepts	45–75	-	-	29.25	21.1
11	Fine, mixed isohyperthermic, Andic Eutrudepts	45–75	1.0-2.0	Eroded	1.30	0.9
12	Fine, mixed isohyperthermic, Andic Eutrudepts	45–75	1.0-2.0	Stony	1.65	1.2
13	Fine, mixed isohyperthermic, Humic Eutrudepts	25–45	-	-	3.05	2.2
14	Complex:					
	Fine, mixed isohyperthermic, Humic Eutrudepts					
	Fine, mixed isohyperthermic, Andic Eutrudepts	45–75	-	-	1.90	1.4
15	Fine loamy, mixed, isohyperthermic, Andic Dystrudepts	25–45	-	-	9.65	6.9
x	Bank	>75	-	-	3.70	2.7
	Total				**138.85**	**100.0**

Socioeconomic setting of Babon microcatchment

History

Keji, the village where Babon Catchment is located, is a dynamic village in terms of agricultural, social, and economic conditions. A study conducted by Ungaran Assessment Institute of Agricultural Technology (AIAT) (Prasetyo *et al.,* 1997) described the time trend of land uses of Keji village. During the Dutch colonial period, before 1942, the area was dominated by kapok (*Ceiba petandra*), and rubber (*Havea brasiliensis*). In 1942 there was a promotion of castor bean planting for castor oil production. In 1952, probably due to difficulties in processing and marketing, castor was completely removed and the successive plants diversified to coffee (*Coffea robusta*), durian (*Durio zibethinus*), rambutan (*Nephelium lappaceum*), jackfruit (*Artocarpus integra*) etc.

In 1977, sand mining activities for construction are believed to have diverted water supplies away from agriculture. Chemical fertilizers were introduced in the same year and several farmers planted cloves (*Eugenia aromatica*). In 1979, farmers found that rubber was not profitable and replaced it with durian. In 1979 and 1980, nonagricultural developments were also progressing and these included road pavement and domestic water supply networks using PVC and plastic pipes. A re-greening (afforestation) programme was introduced in 1984. In 1990 house construction was intensified. Two urban-based businessmen obtained certification of land believed to be owned by the government during the Dutch colonial period (one was granted 25 ha land and the other 17 ha), but villagers have farmed the land for generations without a formal certificate. Local farmers then became shareholders on the lands.

In 1992 sand mining was intensified and this believed to have diverted water supplies further from lowland rice fields. In 1996 an irrigation dam was constructed on Babon River, but in only one year, the construction collapsed. Food crop based farming for corn, cassava, and peanut was also common historically.

History suggests that farmers have experimented and selected technologies they consider appropriate. They have shifted and diversified from one commodity to the other. Thus it is imperative in this study to learn from farmers about their experiences and to blend the existing knowledge with scientifically proven technology innovations.

Farming, on average, contributes to less than 50% of family income, but farmers perceive farming as important for food security and as an additional income source. Any soil erosion management to be introduced must have significant production prospects, otherwise it will be unpopular.

Local organizations

At the village level, a farm credit recipient group (KUT Group) has been established. A similar programme in the past tended to form farmer groups but the groups disappeared with the completion of the programme. The potential of a group's role for diffusion of technology between members is still difficult to assess at this stage, but at least the members seem to respond positively to our bottom-up, interdisciplinary approach. Most of the former programmes, according to the farmer group members, came with subsidized inputs or farm credit, but farmers are also hoping to have more technical guidance.

The office of the village head is considered to have an important role in farming as well as in any other development programme because every new programme should be acknowledged and registered by the village head office. A few personnel at the office, such as the Village Secretary appear to be very familiar with the farming programme and farmers' concerns.

There were a number of well-respected key persons in the village. In previous government programmes, however, they were not well identified and thus were not asked for advice. We believe that their direct involvement in the programme, including the MSEC research programme, would smooth our interaction with farmers. Family ties and a communal system was strong among villagers and this means that conservation efforts may be more successful if developed among people having communal ties.

Land tenure and urban influence

The land tenure system in Kali Garang Watershed is variable and this is reflected by the tenure system in Babon microcatchment. The lowland rice fields (0.05–0.25 ha), are cultivated either by owners or shareholders. One farmer can farm on more than one small plot. The same patterns of tenure system and farm size are also found in the upland areas (Setiani *et al.*, 1999), especially on food-crop based upland fields.

Some land owned by landlords or companies based in Semarang city is mainly planted to rambutan. However in 1998, with reform jubilation, villagers claimed land rights to cultivate the tree farm floor with annual crops such as taro (*Colocasia esculenta*) and other shade-tolerant crops. With slopes as steep as 45–75% there is a growing concern among the local government that cultivation of the land may contribute to significant amounts of sedimentation. For Babon microcatchment, the landlords seem to be cooperating with researchers and extension workers to allow management of their land as long as the tree crop yield is not reduced.

With this wide variety of social backgrounds it appears that several approaches will be needed to facilitate farmers to manage their land judiciously.

Employment

The total population of Keji village is 1,812 people and the population density is about 1,000 persons km^{-2}. The proportion of male to female is about 1:1. Most villagers consider themselves as farmers although about one-third of them work off farm (Table 6) from which several families can generate income higher than from on-farm sources (Tables 7 and 8). During the off season many villagers take off-farm employment in construction, sand mining, and trading sectors to complement the on-farm income.

Table 6. Population distribution of Keji village by sex and income sources.

Description	Number of persons
Total population	1,812
• Male	918
• Female	894
• Number of households	405
Source of income	
• Farmers (owners)	310 persons
• Farm labourers/shareholders	62 persons
• Cattle husbandry	72 persons
• Poultry	89 persons
• Off-farm	116 persons

Source: Setiani (unpublished data).

Table 7. Income sources, annual income distribution (Rupiah) and percentage of labour force earning each class of income in Keji village.

Income source and class	Percentage of labour force earning Income
On-farm	
➢ 100,000–500,000	33.4
➢ 500,000–1,000,000	22.2
➢ 1,000,000–2,000,000	22.2
➢ 2,000,000	22.2
Off-farm	
➢ 100,000–500,000	20.0
➢ 500,000–1,000,000	00.0
➢ 1,000,000–2,000,000	40.0
➢ 2,000,000	40.0

Source: Cahyati Setiani (unpublished).
US$1.00 = Rp. 8,000

From on-farm sources only about 22% of the villagers can make >Rp.2,000,000 annual income, while off farm, around 40% of the village labour force can expect >Rp.2,000,000 annual income (Table 7). The main reasons for low on-farm income include small farm size, low inherent soil fertility, planting of low value crops, and low-input technology implementation. It seems the opportunity to make higher income is greater from the off-farm than the on-farm sector and this reflects a greater attraction for off-farm than on-farm activities. On average, 36% of family income is earned from off-farm sources (Table 8). This creates a bigger challenge for the agricultural sector to come up with more profitable technology.

Table 8. Annual income sources and expenditures of Keji households.

Income Source	Amount, Rp (%)	Expenditure Allocation	Amount, Rp (%)
Annual crops	894,120 (30)	Education	114,496 (4)
Perennial crops	476,864 (16)	Foods, clothing	1,717,440 (60)
Animal husbandry /poultry	536,472 (18)	Agricultural inputs	143,120 (5)
Off-farm	1,072,944 (36)	Social	515,232 (18)
		Miscellaneous	372,112 (13)
Total	**2,980,400 (100)**	**Total**	**2,862,400 (100)**

US$1 = Rp. 8000

Expenditure is mainly (60%) used for food and clothing while investment for agriculture and education is only 5 and 4%, respectively. Interestingly, 18% of expenditure is allocated for social events and 13% for miscellaneous secondary consumption. Thus, agricultural extension will face the challenge of how to educate farmers to reallocate their expenses.

Villagers' mobility

To complement their low income, villagers migrate either seasonally or permanently, voluntarily or through government programmes. Migration can be classified into three categories:

- **Commuting** to Ungaran and the surrounding areas for jobs with garment manufacturers and soft drink industries. This kind of employment generates around Rp.4,800,000 to Rp.9,600,000 annual income and this becomes the main employment for young female villagers. Male villagers take jobs in public transportation, and as labourers and traders as their main off-farm employment and such work can generate annual income as high as Rp. 4,800,000–Rp 18,000,000.
- **Off-season or voluntary migration** – Off-season migration to Jakarta, Semarang, and other cities as traders, or voluntary migration to major cities in Java or to the outer islands of Java as traders and labourers. Such migration is usually done by the heads of households and they visit their family every 2–6 months.
- **Transmigration** to Irian Jaya and Kalimantan. This is the last resort when there is no opportunity to obtain other on-farm or off-farm jobs.

Stakeholders in Kaligarang Watershed management

Several institutions are directly involved in Kaligarang Watershed management as shown in Table 9. This fact opens ample opportunity for MSEC to learn from the successes and failures of ongoing and completed activities. In addition, interaction with existing institutions, to be complementary and not to overlap in the programme, will be among our primary agenda. Furthermore,, empowerment of the local community to manage the land, with researchers' (and extension workers') facilitation has been and will continue to be our main approach.

Land use and vegetation

A field survey of land use conducted in April 2000 revealed 10 different land uses in the 139 ha Babon Catchment (Table 10 and Figure 5). Paddy fields stretch along the valley bottom, and various dryland crops, including rambutan (*Nephelium lappaceum*), annual food crops, bushes, nutmeg (*Myristica fragrans*) and intercropping cassava (*Manihot esculenta*) between various perennial crops

including coconut (*Cocos nucifera*), sego (*Arena pinnata*), robusta coffee (*Coffea robusta*), durian (*Durio zibethinus*), and banana (*Musa paradisiaca*) are found on the upper and the middle slopes (Figure 6). Tree density under traditional agriculture is sometimes very high (less than 3 m apart). Rambutan orchards and nutmeg farms are owned by a few landlords and the villagers cultivate lowland rice, upland food crops, and various perennial crops. In general the local farmers implement low-input (labour and supplies) agriculture. For annual upland crops, cassava is preferable to peanuts, corn etc., because of low-input requirements. As shown in Table 8, only about 5% of the family expenditure is allocated for agricultural inputs. Since the farmers' main objectives are to minimize inputs and maximize products, it appears that long-term investments such as for soil conservation is unattractive (Setiani *et al.*, 1999) unless low-cost and income-generating techniques are offered.

Table 9. Stakeholders and watershed management activities in Kaligarang Watershed.

Institution	Activity
Central Java Regional Planning Board, BAPPEDA in collaboration with Gajahmada University, Yogyakarta	Developed management plan for the watershed (completed)
Afforestation and Soil Conservation Service, Dinas PKT	Regreening and conservation activities (terracing, absorption or water retardation wells, tree planting) since 1984
Regional Board of Environmental Impact Management, BAPEDALDA	Various natural resource management programmes Agroclimatic data dissemination
District-level agricultural (food crop, animal husbandry, and estate crops) services.	Promotion of agricultural management for higher productivity and income.
Assessment Institute of Agricultural Technology, Ungaran	Assessment and adaptation of site-specific agricultural technology
Ministry of Public (Civil) Works	Development of irrigation networks, domestic water supplies, roads.
P2SUKA (CSAR-CIRAD collaboration on development of Agribusiness farming system)	Watershed-scale research on agroclimate, hydrology, and agribusiness on three tributaries of Kaligarang Watershed and in Sumatra and Kalimantan.
MSEC (AARD-IBSRAM collaboration)	Conducting watershed-scale, integrated research on soil management for erosion mitigation and community welfare.

To overcome low investment and low farming efficiency problems the Provincial Agricultural Service is introducing a pilot project of the communal farming scheme on a 100 ha area. MSEC is waiting for the result of whether larger farm size, managed by the community, will make agriculture more efficient. We foresee, however, that strong and coordinated institutions are the precondition of such communal farming.

Soil fertility and nutrient management

Most farmers perceived soil fertility in the study area as low for land planted to annual food crops. However, due to their inability to purchase complete (NPK) fertilizers and/or high expectation for barnyard manure, only urea and manure are widely used. The use of manure varies depending on availability although some farmers claimed that they may have overused manure. Urea use also varies

depending on the farmers' purchasing ability. Some farmers mentioned that they use 50 kg urea 1,250 m^{-2} (400 kg ha^{-1}), a very high rate for lowland rice. Upland food crops, especially cassava, receive no external input. Cassava farming involves only soil tillage and planting using 20 cm long cuttings and the soil is never cultivated until harvest time at nine to 12 months after planting.

Table 10. Land use/vegetation of Babon Catchment.

Symbol	Land use /vegetation	Area	
		Ha	%
Sw	Lowland rice field (sawah)	34.9	25
Tg	Annual crop (cassava, peanuts)	4.0	3
Tg+Tt	Cassava intercropped between various perennial tree crops	4.4	3
Rb	Rambutan (*Nephelium lappaceum*)	66.8	48
Pl	Nutmeg (*Myristica fragrans*)	5.2	4
Bb	Bamboo (*Bambusa vulgaris*)	1.2	1
Tt	*Albizia falcata*, coconut (*Cocos nucifera*)	5.0	4
Sm	Shrubs	0.5	0
Sm + Al	Shrubs and *Imperata* grass	9.75	7
Kp+Mj	Coffee (*Coffea robusta*), Gnetum (*Gnetum gnemon*)	3.6	2
X	Cliff	3.7	3
	Total	**139.0**	**100**

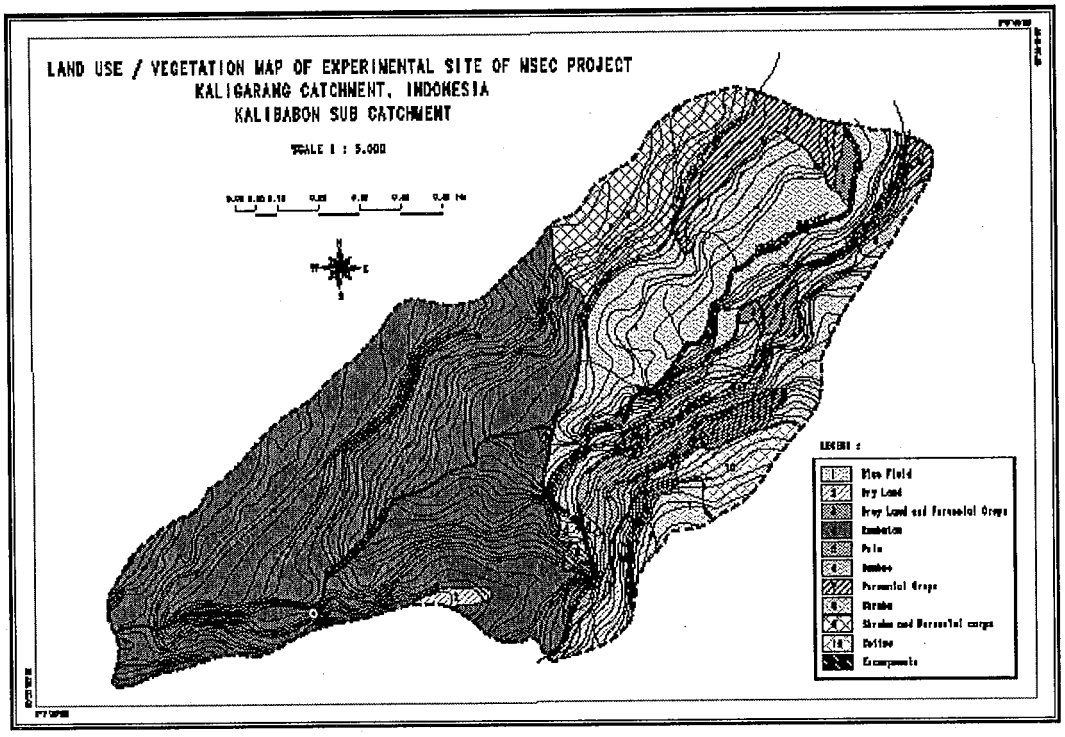


Figure 5. Land use/vegetation map of Babon Catchment.

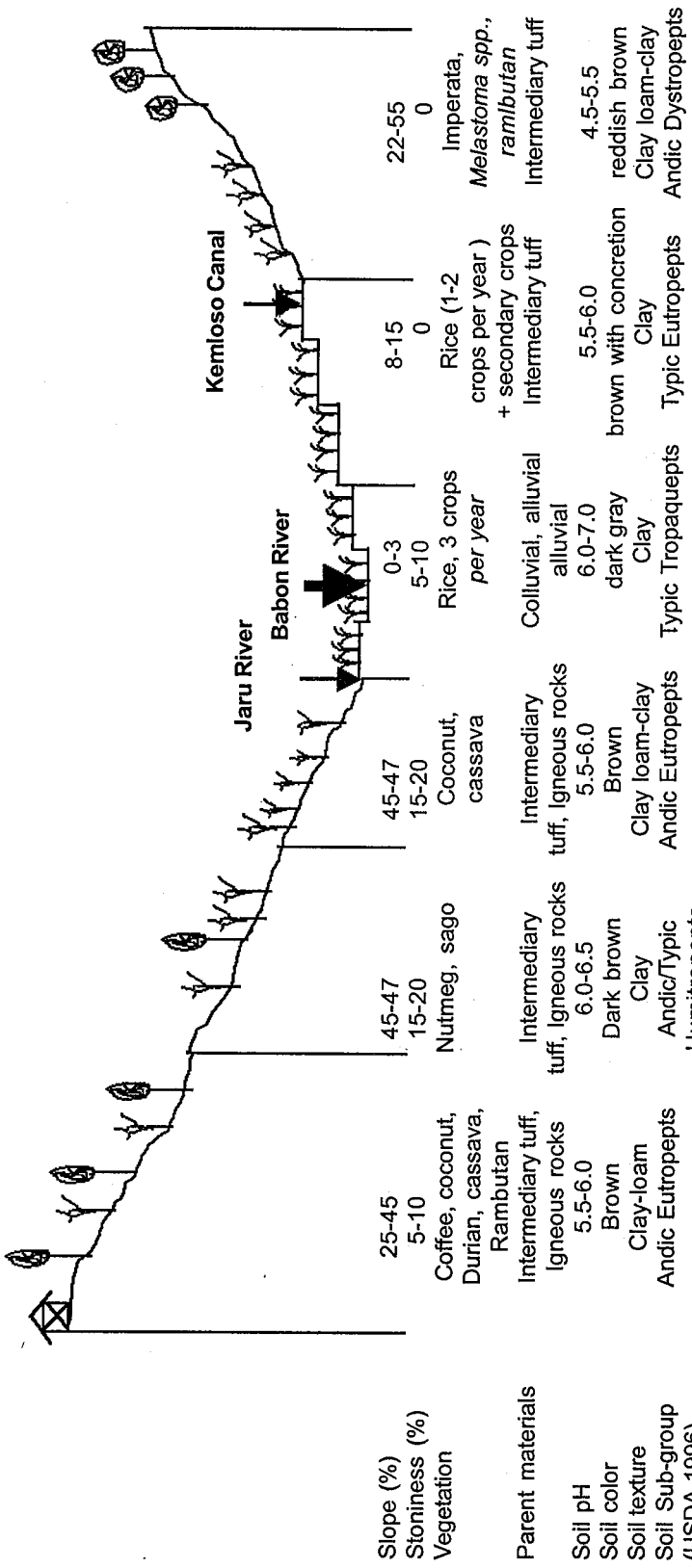


Figure 6. Southeast-Northwest transect (line A-B in Figure 2) of Babon Catchment.

Perennial crops such as rambutan (*Nephelium lappaceum*) and nutmeg (*Myristica fragrans*), are mostly under the control of landlords, and the interviewed farmers (mostly shareholders) did not explain the management of the tree crops very well. Tree monocropping is usually found on farms of large (>5 ha) landholdings. Local farmers with small (<1 ha) farm size tend to have complex agroforestry systems with a combination of perennial as well as annual crops. Fruit trees of the smallholder farms are planted from planting materials of variable quality while the city dwellers with large landholdings use grafted seedlings and plant the trees at regular plant spacing.

Soil degradation problems and management

The most commonly recognized erosion is gully erosion and landslides. Farmers are not really concerned about sheet erosion and even if it occurs, they believed that it does not cause a significant decline in soil fertility. Farmers perceive that bench terraces they had constructed almost perfectly control soil erosion and save nutrients from translocation by water. Yield decline over time, for example of cassava, is believed to result from nutrient removal with harvest.

Bench terraces (forward sloping) were constructed in the late seventies and early eighties as part of the national re-greening programme. Terrace raisers and lips are mostly devoid of erosion protecting vegetation. A typical practice in this location as well as anywhere else in Java is that farmers cut thin layers of terrace raisers during land preparation and they believe that natural vegetation grown on terrace raisers harbours many plant pests, especially rats.

Water problem and management

For the lowland rice fields, water is available for two to three rice crops per year. Only occasionally when the dry spell is extremely dry, such as in 1997, does water availability become a problem. A dam was constructed by the Ministry of Public Works on Babon stream a few years ago, but it collapsed during the first rainy season after the construction. Farmers believed that if the dam had been functional, the chance to have three rice crops per year would have been much higher. For the uplands, water availability is not considered to be a major problem by most farmers.

Re-greening activities

Re-greening is a national scale conservation programme conducted on farmers' land. Bench terracing and perennial tree planting have been promoted as the main conservation measures in the re-greening programme. Tree crops, mainly the so-called multipurpose tree species, MPTS (including *Leucaena leucocephala, Switenia mahagony,* and *Albizia falcata*) are promoted by distribution of seedlings, free of charge. The trees planted two to three years ago sometime are very closely spaced (even less than 2 x 2 m) and they compete with annual food crops which most farmers depend on for their subsistence needs.

EVALUATION OF THE ON-SITE EFFECTS OF SOIL EROSION

Erosion and land use

Presentable data currently include the relationship between rainfall and bedload from each of the Rambutan, Tegalan, and Kalisidi catchments (Figure 7). A description of the three catchments is given in Table 11. Preliminary results for 24 December 1999 to 31 April 2000, during which time the area received 2,048 mm of rainfall, indicate that the Tegalan, Rambutan, and Kalisidi catchments, respectively, produced 1,092, 179, and 7 kg bedload ha^{-1}. The three months of rainfall represents about 65% of the

total annual rainfall in the area and the sedimentation figure, especially from catchments dominated by perennial tree crops, does not seem to be very alarming. Rambutan and Kalisidi catchments have similar land use but the area of the latter is about 19 times as large as the former one. The great disparity in bedload coming from the two microcatchments is attributable to the difference in their areas.

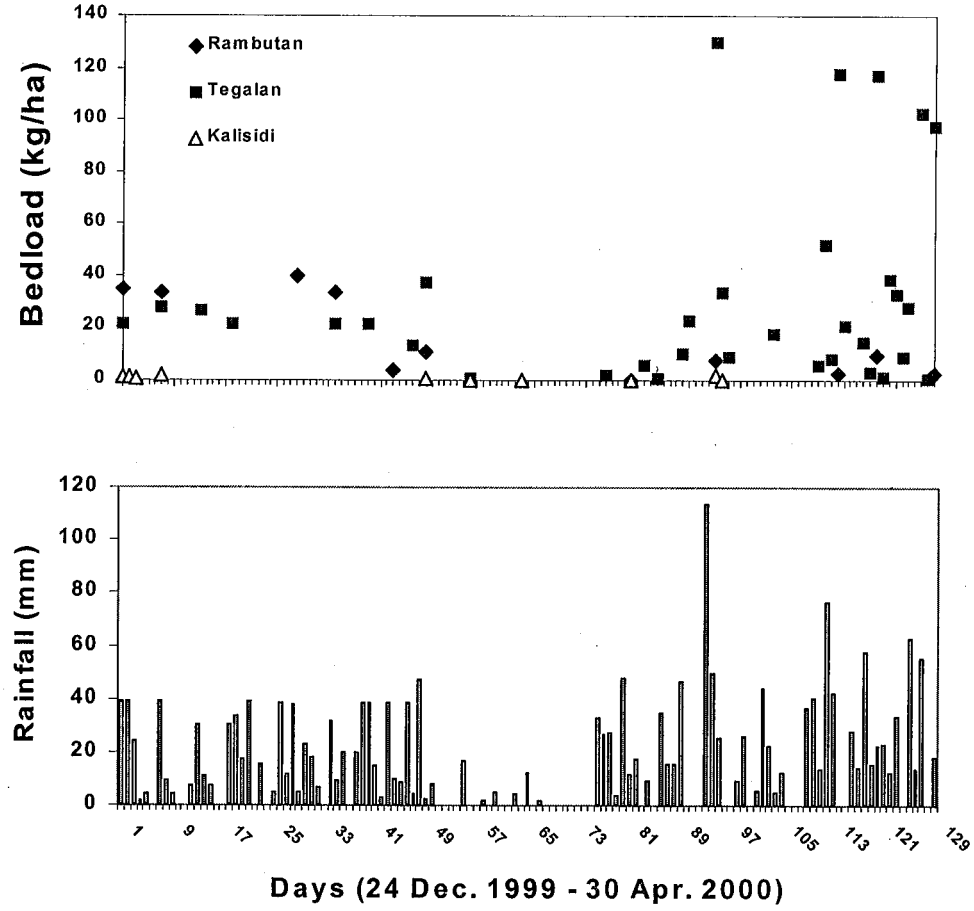


Figure 7. Rainfall and bedload from Tegalan (annual upland), Rambutan, and Kalisidi catchments

Table 11. Description of Tegalan, Rambutan, and Kalisidi catchments

Catchment	Area (ha)	Land use	Slope	
			Gradient (%)	Area (%)
Tegalan	3.2	Upland annual crop (covering about 50% area) near the sediment trap, coffee and nutmeg on the upper slopes	8–15	13
			15–25	45
			47–75	42
Rambutan	2.0	Rambutan and some bare plots	15–25	10
			25–45	40
			45-75	50
Kalisidi	38.5	Rambutan	2–8	7
			15–25	20
			25–45	30
			45–75	**43**

Sediment outflow from the lowland rice fields has not been measured yet. Preliminary inspection shows that sedimentation from lowland rice fields occurs during and shortly after ploughing, puddling, and manual weeding (which often involves puddling) operations. Simple water management techniques, i.e. plugging of water inlets and outlets of ricefields during and shortly after the puddling operations can reduce sediment levels considerably. For the rest of the year water flowing out from lowland ricefields is quite clear and contains only negligible amounts of suspended sediments. Sediments generated in the lowland rice fields will also be quantified. With low erosion and possibly low leaching rates, and relatively high nutrient inputs, irrigated rice production can be considered sustainable. Future research activities will continue the quantification of sedimentation and will assess the relative profitability of various farming system components.

EVALUATION OF THE OFF-SITE EFFECTS OF SOIL EROSION

Potential off-site effects of soil erosion

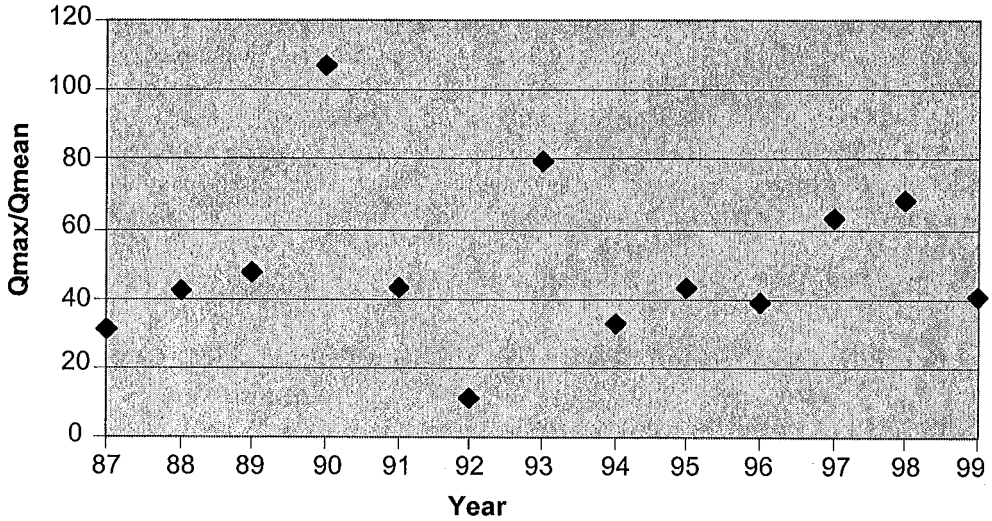
Hydrological characteristics

Flood, drought, and sedimentation were mentioned by the Provincial Irrigation Service as the main problems of Kaligarang Watershed. Interestingly, floods occur not only during the rainy season, but also during the dry season during high tides since ground surface elevation of parts of the city is lower than sea level. Other factors contributing to flooding are steep slopes, shrinking infiltrating catchment area, and high amounts and intensity of rainfall. Floods in Semarang happen every year and a historic one occurred in January 1990 when several casualties were reported and more than 30 houses were washed away. In that particular year, maximum discharge on January 26 was 107 times the mean discharge of the year (Figure 8). Yearly rainfall and Kaligarang River water discharge are given in Table 12. From the 13 years of data, the maximum discharge is mostly greater than 40 times the mean discharge of the respective year. Occasions when discharge is greater than 40 times the mean discharge occur in the wet season. Four times in the 13-year period, minimum discharge was less than 10% of the mean discharge of respective years indicating low water storage during the rainy season. The rainfall pattern certainly determines the discharge. Lack of long-term monthly and event-based rainfall and hydrological data hinders us from verifying the relationship of land use change and hydrology. Our next effort will be to acquire data from other sources such as the Institute for Land Rehabilitation and Soil Conservation (BRLKT).

Land use change has been one of the more frequently-mentioned factors affecting Kaligarang Watershed's hydrological function. Rapid housing and industrial development in the city of Semarang and on the steeplands south of Semarang city are believed to have affected flood generating discharge. In order to verify this, about 20–30 years of data will be required rather than only 13 years. Thus the main problem we encounter is data continuity and reliability. In addition, our accessibility to long-term event-based data could improve much of this analysis.

Drinking water problems

According to the Semarang Municipal Drinking Water Company, the main water source for domestic use is taken from the Kali Garang River. Problems in the water supply include both environmental and internal company problems. Environmental problems include high sediment load during and shortly after heavy storms. During the peak sediment load (no cut-off value was given), the plant operation must be stopped for 1–3 hours, during which time the load is too high to produce acceptable water quality. Water turbidity is far above 5 BTU (FAO critical value) both in wet or dry seasons (Table 13), but this could be handled through routine water cleaning processes.



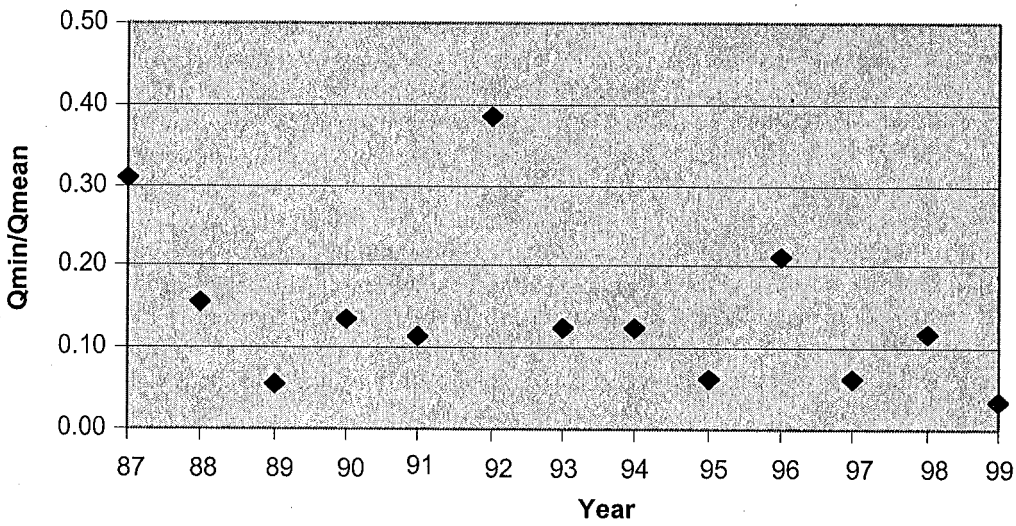


Figure 8. Maximum discharge/Mean discharge (Qmax/Qmean) of Kali Garang (Station Panjangan) from 1987 to 1999.

The sediment load problem, however, cannot be attributed immediately to agricultural sources and may include other sources such as stream bank erosion, mass waste from road cutting operations, and erosion from housing and industrial areas. Water chemical properties (for example pH and NO_3^-) fall within the range of acceptable values (Table 13) for drinking water.

Other drinking water supply problems were attributed to internal plant problems including low plant capacity to fulfill the city requirements and leakage in the hosing systems.

Table 12. Hydrological data of Kali Garang-Panjangan, Station No. 02-047-01-01; Coordinate: 07°00'20" S; 110°23'17" E. Catchment Area: 185.2 km²

Year	Rainfall	Water yield	Water discharge		
			Q_{max}	Q_{mean}	Q_{min}
	mm	mm	$m^3\ sec^{-1}$	$m^3\ sec^{-1}$	$m^3\ sec^{-1}$
1987		1735	318	10	3.15
1988		1489	368	9	1.37
1989		1959	549	12	0.62
1990		1624	1022	10	1.30
1991		1523	387	9	1.02
1992		1514	105	9	3.50
1993		1906	916	11	1.45
1994		1383	275	8	1.05
1995		1419	365	9	0.52
1996		1787	421	11	2.28
1997		1920	729	12	0.74
1998		1368	560	8	0.96
1999		1832	451	11	0.39

Source: Adapted from Central Java Provincial Irrigation Service.

Table 13. Seasonal variation of Kaligarang River water quality and seasonal rainfall.

Year	Season	Turbidity NTU	pH	NO3 mg/l	Rainfall mm
1995	Wet	530	7.9	1	2700
	Dry	135	8.0	1	708
1996	Wet	630	8.0	1	2554
	Dry	204	7.9	2	657
1997	Wet	403	7.9	1	1200
	Dry	175	7.9	1	114
1998	Wet	379	7.6	1	2111
	Dry	308	7.6	1	905
1999	Wet	476	7.6	1	2176
	Dry	129	7.7	1	484
2000	Wet	384	8.1	1	2369
	Dry	154	8.2	1	581

Fisheries

The Municipal Fishery Service mentioned heavy metal contamination produced by industrial plants and shrimp pests and diseases along the north central Java coastal plain as the main problems to shrimp culture. Data from the Municipal Drinking Water Company (not presented) however showed Cd, and Pb concentrations of much less than 5 mg l^{-1}. The Fishery Service on the other hand added that the reduction of the shrimp culture area from 2,000 ha 10 years ago to 1,300 ha currently is attributed to the shift in the regional development direction in favour of the industrial sector from agriculture and forestry. Moreover, the current spatial planning for Semarang city allocated only 300 ha for shrimp culture, leading to a further decline of the current shrimp culture area in the near future.

From this appraisal, only two possible off-site impacts could be identified, i.e. widely fluctuating water discharge, and high sedimentation. Our current data do not permit comprehensive analysis.

Basic data such as cut-off points for flooding from Kaligarang River, longer term hydrological data, event-based river discharge, and rainfall data and land use changes remain the next data acquisition objective. Sediment load data are equally important for collection. The next major challenge after all of the required data are collected, is separation between agricultural and nonagricultural sources of off-site (downstream) impacts.

Socioeconomic evaluation of the potential impact

As explained earlier, water quantity (flood and drought) and quality (high sedimentation) problems may be partly contributed by upland farming. The separation between farm (on-site) and nonfarm (off-site) factors is rather immature at this stage, as is the socioeconomic estimate of the off-site impacts.

CONCLUSION AND RECOMMENDATIONS

- It is clear that, except for *sawah*, smallholder farmers tend to diversify their commodities to minimize risks and large landholders practise monoculture for simplicity and efficiency. In technology selection, users' characteristics should be taken into account.
- Despite a greater employment opportunity in the agricultural sector, many off-farm sectors offer higher income. In addition, investment in the agricultural sector is very low and thus interventions will have to consider simultaneously financial viability and profitability of alternative practices in addition to erosion mitigation.
- Bedload from the annual upland catchment (Tegalan) was several times higher than that of the rambutan orchard catchment, but the initial data did not suggest alarming sedimentation from these catchments. This suggests a great disparity in soil loss data gathered from plot-scale experiments and sedimentation data collected from catchment-scale experiments.
- Potential off-site impact includes floods, water shortage, and sedimentation. It seems, however, that agricultural and forestry or forest-likeland uses cause little negative impacts. Further research challenge is how to separate sediment in the river base on its sources.

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