LAND DEGRADATION

IN

JAVA, INDONESIA:

ITS EXTENT AND IMPACT

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LAND DEGRADATION IN INDONESIA: ITS EXTENT AND IMPACT

Preface

This paper is part of a series of case studies, which attempt on a pilot country basis to examine the costs of land degradation. This stage of the work involves a desk analysis of:

- Impacts of land degradation
- Costs of land degradation
- Costs of land improvement measures
- Costs of policy reform and institutional development.

In general there is reasonable, though not comprehensive, information on the impacts of land degradation and a good assessment base of the proximate and root causes. Linkages with poverty are well established and current remedial programs can be identified.

There is much less information on the impact on the ground of these actions. It is clear that the impact of land degradation is a drain on economic growth in rural areas and has an affect on national economic growth patterns. Investment in remedial action is hard to quantify, but appears an order of magnitude smaller than the scope of the problem. Actual in country joint assessment with national stakeholders will be necessary to provide specific analysis of the countries concerned.

INDONESIA

Manila
CAMBODIA
VIETNAM
Phnom Penh
Ho Chi Minh City (Saigon)
PHILIPPINES
PACIFIC OCEAN
THAILAND
MALAYSIA
Kuala Lumpur
BRUNEI
Nias
Singapore
Sumatra
Kalimantan
Sulawesi
Maluku
Irian Jaya
PAPUA NEW GUINEA
INDONESIA
Jakarta
Java
Nusa Tenggara
Flores
EAST TIMOR
Bali
Komodo & Rinca
Lombok
Darwin
0 600 km
0 400 mi
INDIAN OCEAN

LAND DEGRADATION IN INDONESIA: ITS EXTENT AND IMPACT

Executive Summary

Comprehensive studies of direct and indirect impacts of land degradation in Java in the 1980’s suggested that 750,000 – 1,000,000 ha. or 8% of all farmland was severely degraded; but more recent studies estimate a lower level of impact. In general it seems that heavy use of fertilizers and good soil water management has maintained productivity. However, the situation in other islands, not studied in detail shows ongoing degradation.

LAND DEGRADATION IN JAVA, INDONESIA

INTRODUCTION

Unlike other countries being examined in this exercise, Indonesia has been the site of many years of intensive soil science research. This research has recently been collated to examine trends in soil characteristics and productivity over the past 50 or more years. Similarly, Indonesia has been the site of several attempts to estimate the monetary costs of soil degradation, especially in terms of lost agricultural productivity. The country has an impressive record of governmental programs to prevent and mitigate soil erosion and other forms of degradation, and to promote high productivity, especially on the island of Java.

Java has a long history of settlement, and is characterized by high population densities and an intensive, highly productive agricultural system. The rice paddy system, which has been in place for many years, is located in the high potential areas of relatively fertile soils. Erosion and associated problems of nutrient depletion are minimal due to the system of flat terracing and well-maintained irrigation schemes. Since the 1920's, the lower potential uplands have been settled as a frontier zone, and they are already densely populated. Crops such as maize and cassava are produced there on sloping hillsides, and erosion and chemical degradation problems are more prevalent.

Concerns about erosion and declining productivity have been expressed since the 1860's, with warnings of erosion being seen as a great and growing danger. These fears have continued to be expressed, with severe erosion blamed on the rapidly growing population and increasingly intensive cultivation. The World Resources Institute, for example, warned in 1989 that one-third of the cultivated mountain area of Java was eroding to such an extent that one million hectares were already useless for farming, threatening the livelihoods of 12 million poor (Repetto et al. 1989). This contrasts with governmental estimates of 8% of all agricultural farmland (757,000 ha) being degraded in Java in 1987 (Lindert 2000). Similarly, estimates of the economic effects of degradation on agricultural yields in Java vary from, for example, 4% of dryland crop value (by Repetto 1989), to no net loss (by Lindert, 2000).

Java is not indicative of Indonesia as a whole, however. Java has benefited from high levels of chemical fertilizer applications, soil and water erosion control programs, abundant labor, relatively good soil, and access to markets. On the other islands, which don't necessarily have these conditions and where marginal land is increasingly being cultivated, soil degradation is severe and has significantly affected agricultural productivity.

EXTENT AND SEVERITY OF LAND DEGRADATION

Java is often divided into two zones in agronomic research and programs—the rice paddy system (*sawah)*, and the rainfed upland agricultural system (*tegalan*). Java is, in general, agriculturally old and densely populated. The use of the land has not changed much since the 1940's, except for some variation in the proportion of land under different crops. A small amount of deforestation has occurred, but the forest was replaced by uses that are not the most depleting of soil nutrients such as tree crops. The forest is protected since it is seen as essential for maintaining the hydrologic system upon which irrigation depends.

Until recently, published analyses of soil degradation in Java were site-based and limited in time. Nevertheless, they provide an indication of the level of erosion on cultivated fields on the islands.

Van der Linden (1983) conducted detailed measurements of erosion levels on experiment plots in the Desel River watershed in central Java (Linden 1983). He found that grass-covered fields do not experience serious soil loss by surface runoff. Maize and/or cassava fields, however, are eroded at a rate of around 0.6 mm/ year, with bare soils losing soil at 8.2 mm year per ha. The total annual discharge of material estimated from the plot research from the watershed was 240 tons. This rate was less than previous measurements, perhaps because much of the highly erodable elements of the soil were already gone. He cautioned that much of the actual soil loss was due to extreme flooding events that would not be captured by the experimental plot measurements.

Diemont et a. (1991) reviewed available erosion studies and soil conservation programs on Java. He concluded that the widespread and continuous programs to reduce erosion on the hillslpes of Java through 1) slowing of deforestation rates starting in the middle of this century, and 2) widespread terracing of cultivated hillslopes and introduction of new crops and cropping systems since the 1940s. These have effectively reduced erosion levels so that surface erosion from hillslope fields is now under control (Diemont et al. 1991). The terracing and other erosion control programs were implemented by the Indonesian government and in various projects by FAO, UNDP, USAID and the Netherland's DGIS. Indeed, the National Watershed Development Program in Regreening and Reforestation channels about US$50 million annually to local governments throughout the country for watershed activities and donor countries have contributed hundreds of millions of dollars for upland agricultural projects (Huszar 1998). Their experiences on Java, however, were that although erosion declined on hillslope fields, sediment loads in rivers has remained high and often productivity has remained low. Diemont et al. (1991) maintain that morpho-erosion, such as landslides, incising rivers, roadside erosion, some irrigation drainage systems, and volcanic activity, is the main cause of high sediment loads. He suggests that low inputs, not erosion, are the source of low productivity.

Indonesia's Center for Soil and Agricultural Research recently completed a large effort to collect and harmonize historical measurements of soil nutrients, organic matter and other soil characteristics. Initial analyses of these data sets are beginning to be published (Lindert 2000). 4,562 soil profiles dating from the 1920's were collated that covered the country unevenly over time and space, but nevertheless allow examination of soil conditions in five land use categories (*sawah, tegalan*, tree crops, fallow that includes the imperata grassland, and primary forest/ waste land). These are the land use categories presented in Figure 1.

To estimate trends in soil characteristics due to human management, regression equations were conducted with numerous soil and site variables for the 1940 to 1990 period.

The major results reported by Lindert for Java include:

- Organic matter of the topsoil dropped from 1940 to 1970, and rose thereafter but has not yet reached the 1940 level. This appears to be the case for paddy and tegalan, as well as the other uses. Nitrogen probably followed the same trend.
- There was a gain of around 44% in total phosphorus over the same period, probably due to fertilizer application.
- Potassium levels may have also risen, around 28%, though the trend is less clear especially in the tegalan fields and tree crop soils. It, too, would be due to fertilizer application especially on food crops.
- The pH levels have fluctuated as Indonesia implemented liming applications and water control. Since 1970, the pH has generally risen.

Estimates of soil erosion over the same period were more difficult to generate due to the lack of direct measurements. Lindert (2000) used two approaches to examine erosion trends, one chemical and one physical. The chemical estimation is based on the assumption that erosion carries away organic matter and nutrients, so one would expect their loss with severe erosion. As the tables and figures indicate, however, this did not occur in the period since 1970 when Java was undergoing agricultural intensification associated with rapid population increases. The physical estimation of erosion is based on measurements of changes in the thickness of the topsoil layer. The manner in which topsoil depth was measured, however, varied over time. Even ignoring this, the trend was inconclusive, and apparently there was no dramatic change in topsoil depth. Lindert is unable to conclude, therefore, whether erosion has been significant.

The soil of Java, therefore, is a prime example of soil that is anthropomorphically generated. Humans have augmented the soil's endowments, especially phosphorus and potassium. The lack of clear impact of soil erosion led Lindert (2000) to conclude that future research on increasing land productivity should concentrate on other processes, such as water management, improved fertilizer application, and nutrient depletion through crop uptake.

AGRICULTURAL PRODUCTIVITY AND ECONOMIC IMPACTS OF DEGRADATION

Studies on Economic Impacts

Repetto of the World Resources Institute, Magrath and others conducted an analysis of the cost of natural resource depreciation to the Indonesian national income ("net domestic product"). The analysis has been widely cited because of its use an economic valuation approach that includes off-site costs of erosion, such as sedimentation in irrigation canals and reservoirs, and additional forms of resource depreciation such as logging (Repetto 1986; Magrath and Arens 1987; Repetto et al. 1989).

The cost of soil erosion to agriculture on Java was estimated by Repetto et al in 1989, before the studies of the extent and severity of land degradation reviewed above had been conducted. Their estimations were based on model results of potential erosion from slope, land use and other spatial (mapped) variables at a 1:1 million scale. Based on these model results, predicted soil loss on upland fields was presented by region, soil type, cropping system and crop. The resultant estimates of on-site costs due to soil erosion on upland, rainfed fields (*tegalan*) of Java ranged from 4.1 percent to 4.7 percent of production, or in economic value terms, around 0.04 percent of the value of annual agricultural output (see Tables 3 and 4). This was approximately as large as annual production increases due to irrigation, fertilizer and other improvements. For the single year of 1985, they estimated that erosion thus cost 53,956 million rupiah (approximately US$32.7 million), with a capitalized value of 539,560 rupiah (approximately US$327 million). Magrath and Arens (1987) estimated off-site sedimentation costs to be in the range of US$25 to US$90 million.

Java has also been the site of a household-level economic analysis of adoption of soil erosion control practices by Barbier (Barbier 1990, 1995; Barbier and Bishop 1995). Basically he found that the factors that influence adoption of land degradation practices include land tenure arrangements, soil characteristics, input and output prices, availability of off-farm employment, and discount rates. The relationship between erodability and profitability varies widely—many profitable perennial crops appear to have better erosion control, but high-valued crops such as vegetables cause major erosion (see Figure 4). Similarly, Huzar (1998) and Huszar and Cochrane (1990) examined soil conservation practices at the household level to identify the sustainability of SWC projects (Huszar and Cochrane 1990; Huszar 1998). They found that the sustainability of adoption of practices after the projects ended varied between households and regions, depending on income, input and output markets, and other economic and labor conditions.

Productivity Changes

At the level of Java Island, recent studies have been conducted analyzing production and productivity changes using price, production and other regional and national-level statistics.

With statistics of the Indonesia Central Bureau of Statistics, Van der Eng analyzed the evolution of aggregated production, the use of productive resources and productivity since 1880 using the growth accounting method (Eng 1996). He deducted the margins of transport, trade, storage and processing on the market price, used the rural retail price, and subtracted costs of farm-produced and purchased inputs. He did not include the costs of land degradation, but his analysis of changing land and labor productivity provide an indication of its possible effect. Because of the large difference between Java and Madura, and the other islands ("Other Islands") in terms of the agricultural and population history and farming system, he separated Java from the others in his analyses. He also separated the farm from the large-scale estate sector. His findings include:

- The growth of total production has been faster on the Other Islands compared to Java, because of the large amount of new land being put under production on the Other Islands. Nevertheless, growth in Java as been impressive, with gross value added in agriculture changing from (using 1960=100) around 45 in 1880 to 250 in 1988, and in the Other Islands from around 25 to over 300 during the same period.
- Per capita gross value added has also grown in Java and Madura, from around 4,000 rupiah in 1880 to 8,000 rupiah in 1988 (1960 rupiahs) (see Figure 2). Agricultural production per capita has, however, just matched population growth.
- 95% of the growth in Java since the 1920's can be accounted for by growing domestic demand (from population and average income growth) for crop and livestock food products.
- Although the number of people employed in agriculture continued to increase until 1990, the proportion of farmers in the population has steadily declined. The censuses underestimated the contribution of female labor force in agriculture at least until the 1970's because of counting only full-time agriculturalists; the labor share of women in rice production, for example, was more than half of the total labor input.

- Land productivity increased continuously in Java, except during the 1940's, and the rate has accelerated since 1970. Since the 1930's, this increase has been due primarily to growth in the farm sector, especially rice production.
- The ratio of irrigated land increased steadily in Java, contributing to the increase in land productivity.

Lindert (2000) estimated the effects of changes in soil nutrients on agricultural yields and the value of agricultural production by comparing site characteristics and their soil chemistry (since there was much site level data and insufficient time series data). He attempted to separate out the effects of agriculture on soil (including inputs), from the effects of soil on agriculture.

He found that for 1990, there was a high degree of variability between sites in productivity and prosperity (see maps in Figures 3a and 3b). In general, productivity per unit land was highest where population density is high, especially in Java and Bali. Unexpectedly, areas of high productivity per laborer are often the same areas as those with high land productivity.

He conducted two statistical tests to examine the soil-agricultural productivity relationship: one assumed that local markets are separated (approach A), and the other assumed that all districts share the same market, which would emphasize the effects of soil conditions (approach B) (reality would probably fall in between). The results (see Table 1) indicate the following:

- Water supply and proximity to large non-agricultural populations have important positive effects on productivity.
- Soil organic matter content and nitrogen appear to play a positive if weak role in effecting productivity in Java, but the other nutrients did not show up clearly. This probably reflects the large amount of chemical fertilizers being used. On the Other Islands, phosphorus and potassium showed a stronger effect on productivity.
- Other inputs (work animals, machinery and fertilizer) show positive productivity effects in the islands outside Java, but not for Java itself where their effect may be captured by more frequent harvests per year.

These results point to the impact of the application of chemical fertilizer on productivity. Their increasing use can be partly explained by their declining cost relative to production prices, due to many years of government subsidies (see Table 2). Fertilizers are effectively providing a substitute for high quality soil.

Lindert also examined changes in productivity due to changes in soil characteristics by comparing historical soil data between 1940 and 1990. He concluded that, in Java-Madura, topsoil chemical quality either dropped by 3% between 1940 and 1955, with partial recovery afterwards (seen in results of approach A, which emphasizes the effect of nitrogen and SOC), or it rose by almost 10% during the entire 50-year period (from approach B).

The topsoil chemical quality on the Outer Islands over the half century declined by around 12% or 18%, depending on the choice of approaches (A or B). The decline was most apparent after 1960. The loss was probably due to cultivation of increasingly marginal soils, continuing human-induced degradation, and use of younger (more recently cleared) land. He expects the rate of loss to slow down, now that the rate of clearance of new lands has slowed. The decline in the Outer Islands was enough to bring the country's overall national loss from 4.0% to 5.5% over that 50-year period.

Table 1 compares the changes in soil chemistry with that of overall changes in land and labor productivity. For the entire country between 1940 and 1970, both land and labor productivity were stagnant, but between 1970 and 1990, they jumped by two-thirds. Compared to those large gains, the estimated loss of 1.7 to 3.1 percent in production due to soil changes in those two decades appears small.

In Java-Madura, where the soil is inherently higher quality, the land productivity gains of 78 percent from 1970 to 1990 are even larger than for the country as a whole. The estimated effects of changes in soil quality on production, a gain of 2.8 to 4.5 percent, are small, and the effects of land degradation not apparent.

CONCLUSION

In short, Java has followed the path of land-scarce countries as expected by Hayami and Ruttan (1985) by adopting land-replacing technologies. This has been accompanied by increases in labor productivity, though not at the same rate. Major impacts of land degradation on production are not evident in the results. Land degradation even on the hillslopes of Java has not measurably reduced yields or productivity because of the 1. increasing and wide use of fertilizers, 2. increased application of labor to do SWC and other productivity enhancement practices, and 3. government terracing programs. Erosion on the Other Islands, however, has measurably reduced productivity.

Figure 1. Change in soil characteristics by land use type, Java and the Outer Islands, 1940 to 1990.
Source: Lindert 2000.

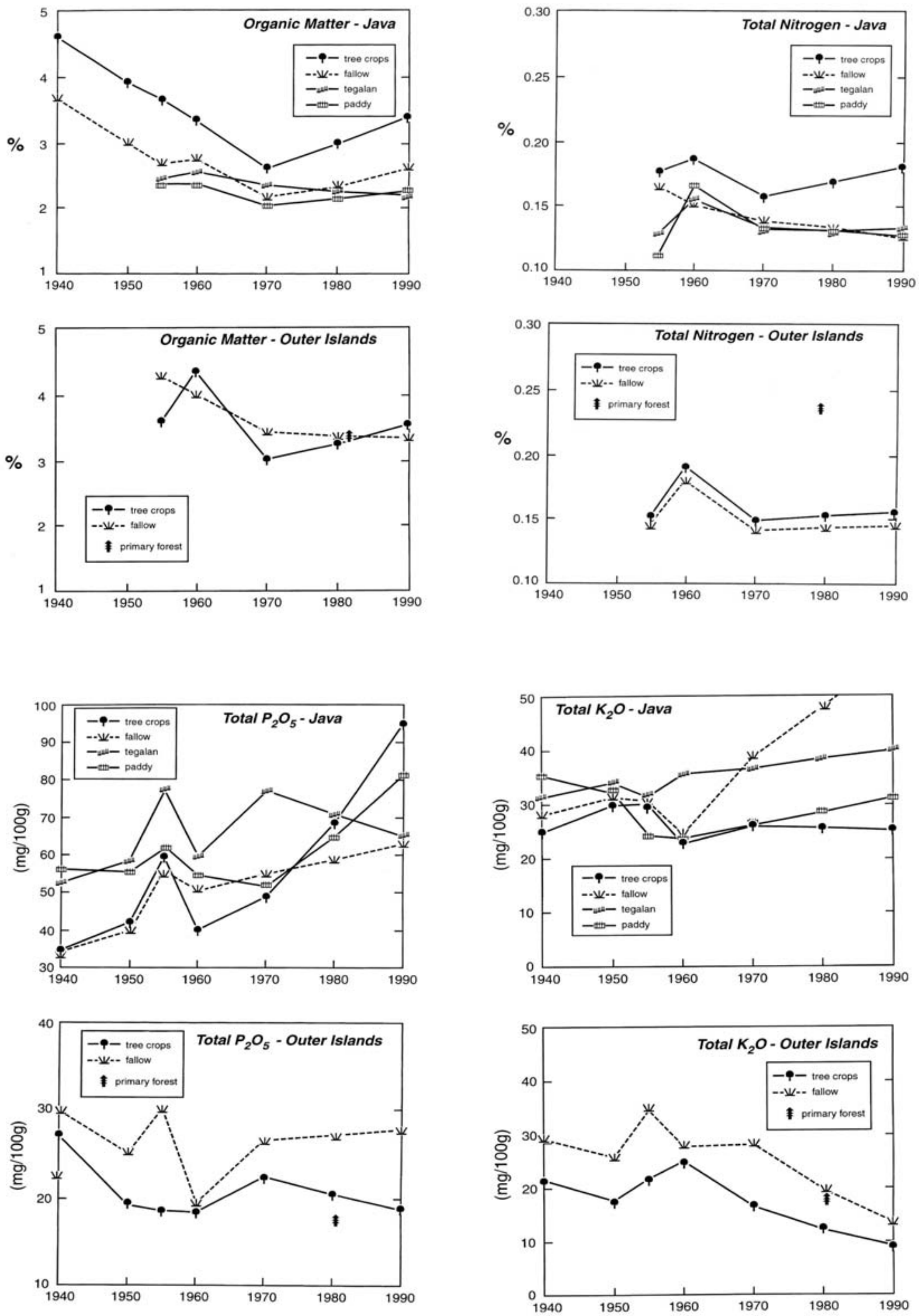


Figure 2a. Gross value of agricultural production per harvested area, 1990. Source: Lindert 2000.

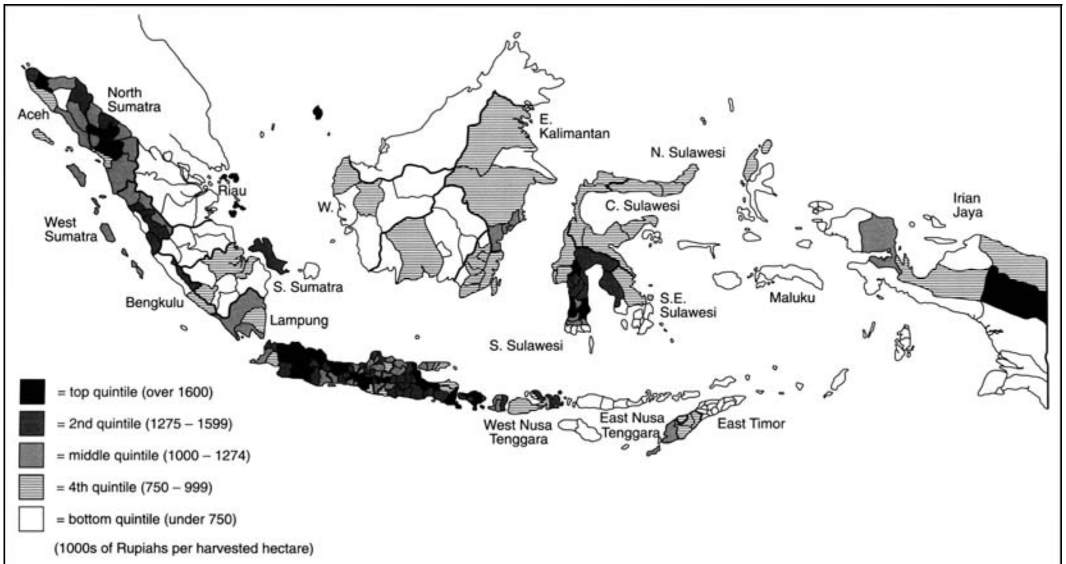


Figure 8.2
Gross value of agricultural production per harvested area, 1990

Figure 2b. Gross value of agricultural production per laborer, 1990. Source: Lindert 2000.

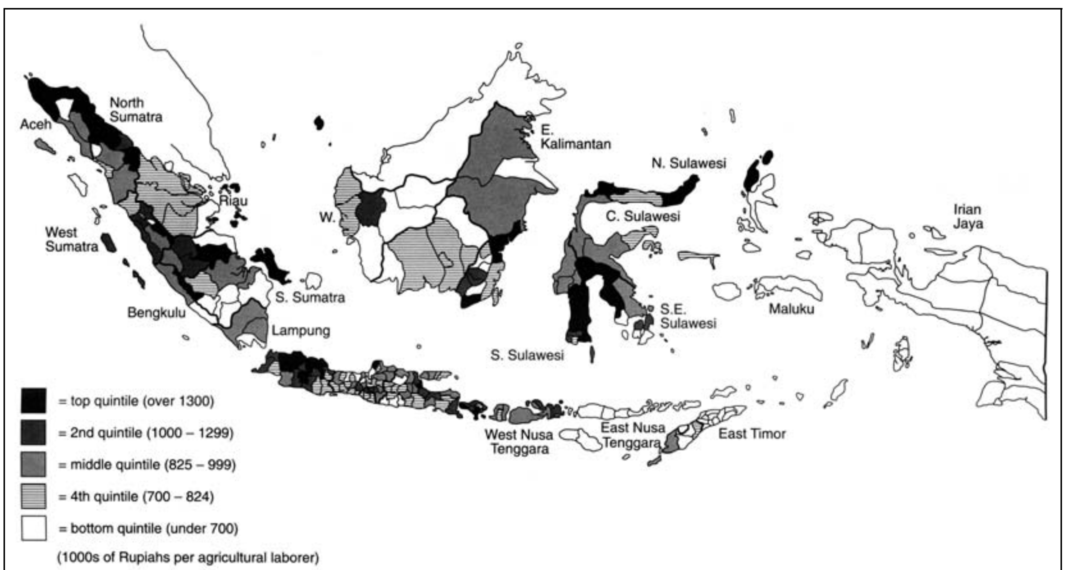
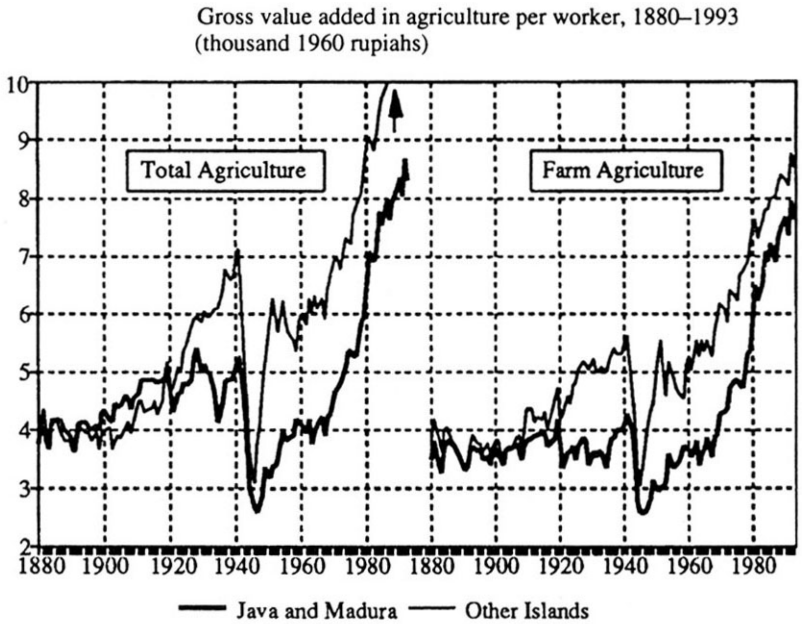
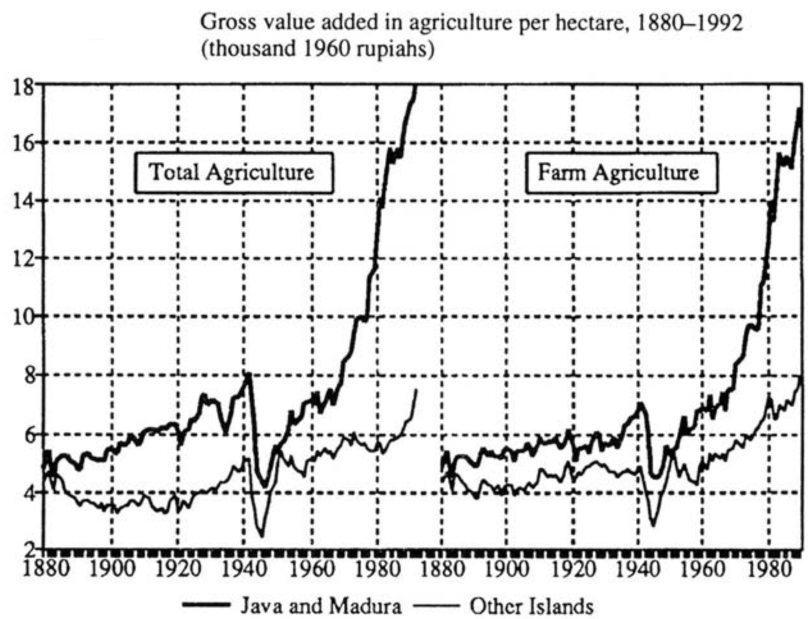


Figure 8.3
Gross value of agricultural production per laborer, 1990

Figure 3. Evolution of Agricultural Productivity in Java and Madura, and in the Other Islands.
Source: van der Eng 1996.



Note: Labour productivity in farm agriculture excludes GVA from estate agriculture, but is calculated with total employment in agriculture.
Sources: Appendices 1 and 3, Other Islands 1.5 percent estimate.



Note: Land productivity in farm agriculture excludes GVA from estate agriculture and estate area.
Sources: Appendices 1 and 4, Other Islands 1.5 per cent estimate.

Table 1. Role of soil chemistry in accounting for agricultural productivity differences, Java-Madura and the outer islands, 1940 to 1990. Source: Lindert 2000.

Role of soil chemistry in accounting for agricultural productivity differences, Java-Madura and the outer islands, 1940–1990

A. A half century of agricultural growth, 1940–1990

				Percentage changes		
	1940 level	1970 level	1990 level	1940–1970	1970–1990	1940–1990
All Indonesia						
Gross value of production (billions of 1990 Rupiahs)	11,712	14,431	34,444	23.2	138.7	194.1
Harvested area (thousands of hectares)	16,521	19,105	26,990	15.6	41.3	63.4
Agricultural employment (millions)	19.94	26.37	35.75	32.2	35.6	79.3
Land productivity = Production (billions of Rupiahs) per hectare	709	755	1,276	6.5	69.0	80.0
Labor productivity = Production (thousands of Rupiahs) per person	587	547	963	−6.8	76.1	64.0
Output/hectare due to soil chemistry quality (Approach A)	105.8	101.8	100.0	−3.8	−1.7	−5.5
Output/hectare due to soil chemistry quality (Approach B)	104.2	103.2	100.0	−1.0	−3.1	−4.0
Java-Madura						
Gross value of production (billions of 1990 Rupiahs)	7,437	8,294	17,107	11.5	106.3	130.0
Harvested area (thousands of hectares)	9,169	9,971	11,553	8.7	15.9	26.0
Agricultural employment (millions)	13.21	16.07	18.48	21.7	15.0	39.9
Land productivity = Production (billions of Rupiahs) per hectare	811	832	1,481	2.5	78.0	82.5
Labor productivity = Production (thousands of Rupiahs) per person	563	516	926	−8.3	79.4	64.4
Output/hectare due to soil chemistry quality (Approach A)	101.9	97.3	100.0	−4.6	2.8	−1.9
Output/hectare due to soil chemistry quality (Approach B)	90.3	95.7	100.0	6.0	4.5	10.7
Outer islands						
Gross value of production (billions of 1990 Rupiahs)	4,275	6,137	17,337	43.6	182.5	305.6
Harvested area (thousands of hectares)	7352	9134	15437	24.2	69.0	110.0
Agricultural employment (millions)	6.73	10.30	17.27	53.0	67.7	156.6
Land productivity—Production (billions of Rupiahs) per hectare	581	672	1,123	15.6	67.1	93.2
Labor productivity—Production (thousands of Rupiahs) per person	635	596	1004	−6.2	68.5	58.1
Output/hectare due to soil chemistry quality (Approach A)	111.8	106.0	100.0	−5.2	−5.7	−10.6
Output/hectare due to soil chemistry quality (Approach B)	117.7	110.6	100.0	−6.1	−9.5	−15.0

B. Java-Madura versus the outer islands in 1990

	Java-Madura	Outer islands	% difference, Java–Outer islands
Gross value of production (billions of 1990 Rupiahs)	17,107	17,337	−1.3
Harvested area (thousands of hectares)	11,553	15,437	−25.2
Agricultural employment (millions)	18.48	17.27	7.0
Land productivity—Production (billions of Rupiahs) per hectare	1,481	1,123	31.8
Labor productivity—Production (thousands of Rupiahs) per person	926	1,004	−7.8
Output/hectare due to soil chemistry quality (Approach A)	115.2	100.0	15.2
Output/hectare due to soil chemistry quality (Approach B)	146.0	100.0	46.0

Source: The Appendices in van der Eng 1996 were used for all nonsoil aggregates.
Notes: Soil measures are based on this study's soil samples and the regression results in table 8.1. Figures for gross value of production for 1940 and 1970 are based on the assumption of a constant share of real value added in the gross value of real output.

Table 2. Costs due to Soil Erosion (Indonesian rupiah 1650 = US$ 1). Source: Repetto et al 1989.

Table II.12. Costs Due to Soil Erosion for Various Cropping Systems on Java

Cropping System	Crops	Estimated Proportion of Tegal (%)	Area[a] ('000 ha)	Estimated Current Net Income (Rp/ha)[b]	Weighted Production Loss (%)[c]	Annual Cost of a One Percent Productivity Decline (Rp/ha)	Single Year Cost (million Rp)	Capitalized Cost (million Rp)
West Java								
I	Cassava, Corn							
Jogyakarta								
I	Intercropped Corn & Cassava	57	112	8,220	4.7		1,011	532
II	Intercropped Corn, Cassava & Legumes	43	84	11,279	4.7		1,047	416
Total Tegal		100	196	9,531	4.7		1,026	948
East Java								
I	Intercropped Corn & Cassava Level Tegal	30	523	298,327	4.1		4,926	10,567
II	Intercropped Corn & Cassava Terraced Hillsides	30	523	58,130	4.1		2,876	6,169
III	Pure Stand Cassava Level Tegal	20	349	145,005	4.1		3,746	5,357
IV	Pure Stand Cassava Terraced Hillsides	20	349	27,806	4.1		1,816	2,597
Total Tegal		100	1,744	141,499	4.1		3,453	24,690
TOTAL TEGAL			4,747	83,649	4.3		2,686	53,956

a. Based on Central Bureau of Statistics. *See* Table II.6.
b. Net income equal to returns to land and management.
c. Based conservatively on rates for land cultivated in Cassava. Annual productivity loss for sensitive crops ranges from 6.8 to 7.8 percent.

Source: Adapted from Roche 1984, Central Bureau of Statistics, and data provided by the Agroeconomic Survey, Bogor. *See* Magrath, Arens, 1987.

Table 3. The Value of Crop Production Compared to the Cost of Erosion on Java (Indonesian rupiah 1650 = US $1). Source: Repetto et al. 1989

Table II.13. Comparison of the Value of Output of Six Major Rainfed Crops to the Cost of Erosion (million rupiah)

	West Java	Central Java	Jogyakarta	East Java	JAVA
Dry Rice	46,533	18,194	12,682	26,358	103,767
Maize	21,809	123,596	15,061	262,981	423,447
Cassava	81,041	109,148	22,410	134,962	347,561
Sweet Potatoes	22,191	12,131	542	15,331	50,195
Peanuts	44,916	56,475	18,340	74,615	194,346
Soybeans	17,807	45,398	37,664	124,171	225,040
Total	234,297	364,942	106,699	638,418	1,344,356
Cost of Single Year Erosion Loss	23,508	4,810	948	24,690	53,956
Capitalized Value of Erosion Losses	235,080	48,100	9,480	246,900	539,560
Single-year Erosion Cost as a Fraction of Value of Agricultural Output	0.10	0.01	0.01	0.04	0.04

Table 4. Growth in the Consumption of Fertilizer. Source: van der Eng 1996.

Table 2.8 Consumption of chemical fertiliser, 1910–90 (thousand tons)

	Food crops only			*All crops*		
	N	P_2O_5	K_2O	*N*	P_2O_5	K_2O
1910				15	± 1	0
1915				25	± 1	0
1920				21	2	0
1925				29	2	0
1930				31	3	1
1935				13	4	1
1940	4	2	0	24	12	3
1950				16	6	1
1955				25	9	2
1960	23	10	0	56	19	4
1965	69	21	2	98	32	9
1970	179	31	2	189	41	13
1975	305	102	4	336	112	19
1980	761	213	16	823	234	92
1985	1,134	477	68	1,496	550	176
1990	1,401	562	227	1,718	630	292

Note: For 1910–65 AS, urea, SP, DSP, TSP and potassium blends only. All quantities are converted to nutrient equivalents. The figures are three-year averages centred around the year shown to account for the carry-over of stocks.
Sources: Calculated from *Statistiek van den Handel* and succeeding foreign trade statistics; *Mededeelingen inzake Meststoffen* (Rotterdam: Internatio, 1940); P. Honig (1945) 'The Use of Fertilizers in the Netherlands Indies', *Empire Journal for Experimental Agriculture*, 13, p. 54; S. Affif and L.A. Mears (1968) 'A New Look at the Bimas Program and Rice Production', *Bulletin of Indonesian Economic Studies*, 4, No. 10, p. 40; *Kumpulan Data Pupuk* (1976–77); *Statistik Pertanian*; *Statistik Industri*; *Nota Keuangan 1991/92* (1991) p. 402; *Lampiran Pidato* (1994) p. vi–26.

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