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JAVA'S CRITICAL UPLANDS: IS SUSTAINABLE DEVELOPMENT POSSIBLE? †

A true revolution occurred in the agricultural economies of Asia from the late 1960s onward. The spread of new farm inputs—improved seeds, fertilizers, and pesticides—led to rapid and well-documented technological change in production systems for wheat and rice. However, the producer benefits of this "Green Revolution" were confined largely to lowland areas possessing assured water supplies. The new cereal technologies have generally proven poorly suited to adverse agroclimatic environments.

Cereal yields obtained under irrigated conditions are often unattainable in the rainfed uplands. (Java's uplands contain both irrigated and rainfed land, but this paper deals mainly with the latter. The terms "rainfed uplands" and "uplands," used interchangeably, refer to rainfed, gen-

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† This paper had its origins in work that began with the author's thesis research in rural Java between 1979–81 and continued during his assignment in East Java with the Agricultural Development Council (now Winrock International) from 1983–85. Both of these activities were supported generously by the Ford Foundation. The quantitative evidence presented herein is largely secondary and relies principally upon data from Indonesia's Central Bureau of Statistics (CBS). The conclusions are no more valid than the data on which they are based, but extensive field experience in rural Java leads to the judgment that considerable confidence can be had in the trends depicted in most CBS surveys of staple crop production, costs, and rural prices. Thanks are due to many CBS staff for their gracious assistance during data collection. Winrock International provided comfortable facilities during the course of much of the analysis. William O. Jones, Scott R. Pearson, Carl H. Gotsch, and several anonymous referees offered trying, but always useful, comments on earlier drafts. However, this does not absolve the author of responsibility for errors and omissions in the final product.

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erally sloping land at elevations typically greater than 300 meters.) The following tabulation lists present and potential average rice yields in Asia in tons per hectare (IRRI, 1979):

	Present yield	Potential yield
Irrigated		
Wet season	2.6	3.6
Dry season	3.1	4.2
Rainfed	1.1	1.7

Plant breeders and agronomists at international centers such as the Centro Internacional de Agricultura Tropical (CIAT) and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) have focused on cassava, sorghum, millet, peanuts, and other minor legumes in their efforts to develop improved upland technologies. These crops are relatively tolerant of moisture stress, low soil fertility, and weeds. However, they also tend to be low-valued and less-preferred staples: direct consumption usually declines as incomes rise. They are grown largely by marginal farmers for own consumption, and quantities traded in national and world markets are usually small shares of total production (Ryan and Binswanger, 1979). Under the conditions of inelastic and slowly growing demand, most of the benefits of upward supply shifts would be appropriated by consumers through lower prices.

In the steep uplands of Asia, the conservation of soil resources may be as important as increasing food production and the welfare of poor farmers. Deforestation and the erosion of improperly managed soils are serious problems in most upland watersheds. They not only reduce the long-run productivity and sustainability of upland rainfed farming, but also have an immediate external impact on the adjacent lowlands through the siltation of rivers, reservoirs, dams, and irrigation systems. Watershed management projects now account for substantial shares of the program budgets of international assistance agencies in countries like Nepal, Thailand, Indonesia, Pakistan, and the Philippines.

This paper develops an evolutionary model of upland agriculture based on the recent experience of the densely settled island of Java, Indonesia. The thrust of the model is that the principal problems of upland agriculture—low productivity and resource depletion—will be ameliorated if demand linkages encourage the production of new upland commodities associated with reduced levels of soil erosion. Rural development efforts that result in secure markets and prices of basic staples can facilitate these linkages through changes in relative prices of specialty crops that are often well-suited to upland cultivation. A lowland Green Revolution can contribute to sustainable upland growth even if the modern staple technologies cannot be adapted readily to upland conditions. Appropriate policy interventions for accelerating positive upland evolution are determined by regional comparative advantage, farmer knowledge, and the nature of markets for inputs and outputs.

THE ISLAND OF JAVA

Located amidst the vast Indonesian archipelago, Java is one of the most densely populated areas in the developing world. With a largely rural population of almost 100 million in a land area of 132 thousand square kilometers, average farms—at about one-half hectare—are among the world's smallest. Roughly one-half of the island's arable land consists of irrigated or seasonally flooded paddies (*sawah*) on which rice is the major crop. Rice provides fully one-half of the calories in the average Indonesian's diet, and the government's efforts at rice intensification constitute a dramatic and well-documented success story in Asia's Green Revolution (for example, see Bernsten et al., 1981; Collier et al., 1982; Timmer, 1985). Until recently, however, little direct attention has been given to Java's upland farms, composed of rainfed, often hilly fields that are planted primarily to crops other than rice.

Many of Java's steep upland areas have been classified as "land which has become so degraded that it is, or soon will be, unable to sustain even subsistence agriculture" (USAID-GOI, 1983).[1] Conventional wisdom views Java's upland farmers as marginal smallholders, more or less isolated from recent economic developments of the lowlands and cities, who subsist on the meager food crops they scratch from degraded hillsides. Because of ignorance and apathy, their agricultural practices constitute "soil mining," under which few investments are made in soil conservation.

These statements are not true of upland Java as a whole. Resource degradation is indeed serious, but in many areas deep soils and abundant annual rainfall provide an agronomic potential for more productive and

[1] Indonesia's Directorate of Land Use has classified approximately 20 percent of Java's rainfed land as critical primarily on the basis of slope and elevation. "First priority" critical areas are rainfed land with a slope of 40 percent or more, regardless of prevailing forms of land use and ground cover. Eroded lands with slopes less than 40 percent are designated as "second priority," as are all rainfed lands above 500 meters in elevation and with slopes between 15 to 40 percent. The "third priority" category contains moderately sloped (15 to 40 percent) land below 500 meters and all land, regardless of slope and elevation, with specific characteristics such as danger of landslides. It is likely that official estimates of Java's critical land areas overstate the true total since these categories include both reasonably well-protected state forests and much moderately sloping or terraced farmland on which productivity declines have not occurred. See the discussion in Roche (1984a).

sustainable farm systems in many areas. The principal objective of this paper is to demonstrate how recent economic developments provide the economic incentives for realizing this potential.

Dynamics of Rainfed Land Use on Java

The large-scale clearing of Java's rainfed slopes was first reported by Dutch observers in the early 1800s but probably began somewhat earlier. The initial expansion is presumed to have been a response to population growth and the increasing costs of developing lowland paddies. From the mid-1800s, however, much steep land was opened for the cultivation of coffee by both indigenous and foreign planters. Estate cultivation expanded rapidly and many present villages were formed initially in and around estates in response to demand for plantation labor (Table 1). Severe erosion resulted where these crops were planted improperly (Palte, 1985). In the early 1900s, the growing population, perennial crop diseases, and world depression and war contributed to the denuding of forests and extensive substitution of food crops for perennials by upland farmers. It took fifteen to twenty years following Independence in 1947 for the government to allocate legal rights to land affected by these events, and the pace of smallholder terracing was slowed. Political instability caused by Islamic and anticommunist disturbances contributed to further deforestation and soil depletion during those years.

Table 1.—Reported Land Use, Java and Madura: 1883 to 1983
(1,000 hectares)

Land use	1883[a]	1913	1938	1963	1973	1978	1983
Irrigated farms	1,845	2,200	3,368	2,528	n.a.	3,511	3,501
Rainfed farms	640	1,775	3,251	3,119	n.a.	3,520	3,407
Estates	24[b]	675[c]	1,012	613	649	615	595
Home gardens	n.a.	n.a.	1,252	n.a.	n.a.	1,592	1,615
Protected forest	n.a.	n.a.	3,035	3,000[d]	2,891	2,319	2,396[e]
Non-farm	n.a.	n.a.	1,247	n.a.	n.a.	1,626	1,675

Sources: Figures for 1883, 1913, and 1938 compiled by J. Palte, 1985, *The Development of Java's Uplands in Response to Population Growth*, Gadjah Mada University Press, Yogyakarta. Figures for 1963 are from Central Bureau of Statistics, various years, *Statistical Pocketbook of Indonesia*; data for 1978 from *Land Area According to Use on Java and Madura*; data for 1983 from *1983 Agricultural Census*, Series D.

[a]Does not include Madura.

[b]1875. [c]1920. [d]1965. [e]1981.

The available statistical data make long-term comparisons difficult, but it appears likely that farmland cultivated by smallholders had peaked in area by the eve of World War II. Reserved forest area declined 20 percent between 1938 and 1983. This increment in the total rainfed area has been counterbalanced to an unknown degree by the expansion of new and rehabilitated irrigation systems on rainfed lands. At the same time, expanding village compounds, home gardens, and non-farm land uses have displaced rainfed and irrigated fields at lower elevations.

Upland farming systems were intensified over time as population grew. Intercropping of annuals and mixed agroforestry systems have been widely adopted. Most upland farmers have built at least rudimentary terraces. Cattle and small ruminants have multiplied, albeit slowly, thus providing manure that improves soil structure and fertility. Overall, these forms of intensification have probably tended to reduce rates of soil erosion. In Java's fragile uplands, however, they often came too late to reverse declines in productivity. Erosion was particularly severe in the limestone hills of the southern coast, and these areas are presently among the most degraded and poorest in Indonesia (Dames, 1955).

Recent Upland Developments

Official crop production statistics indicate that harvested areas of the major rainfed staples rose quite steadily on Java from 1950 to the mid-1960s (Chart 1). Such an increase reflected the extensification of rainfed farming due both to a deterioration of lowland irrigation systems and to the opening of steep slopes. These statistics were also indicative of more intensive land use as intercropping became more common and fallow periods were gradually shortened.[2]

Since the late 1960s, however, reported harvest areas of most of these crops have declined. The decrease has been most pronounced for root crops, cassava and sweet potatoes. The area in upland rice trended downward during this period until a sharp increase was reported in the early 1980s. Harvested areas of corn tended to fluctuate greatly between calendar years because the peak harvest month can vary from December to February depending on rainfall and the seasonality of planting. However, a downward trend in rainfed corn areas is apparent when a three-year moving average is calculated. In contrast, harvested areas of rainfed soybeans and peanuts have grown steadily since the 1950s.

Modern rice varieties were poorly adapted to rainfed upland conditions, and little serious attention was given to the varietal improvement of secondary staples until the early 1980s. New varieties of corn were released in some areas of Indonesia after 1978, but improved varieties of root

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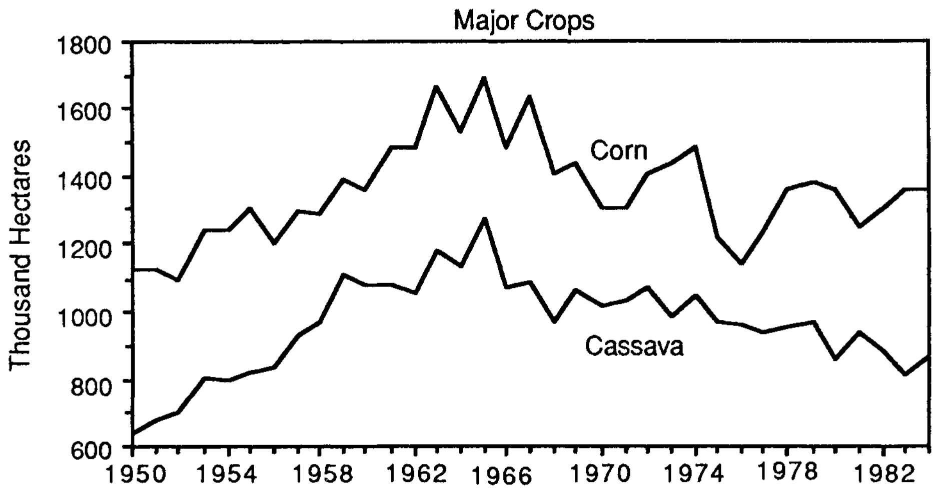
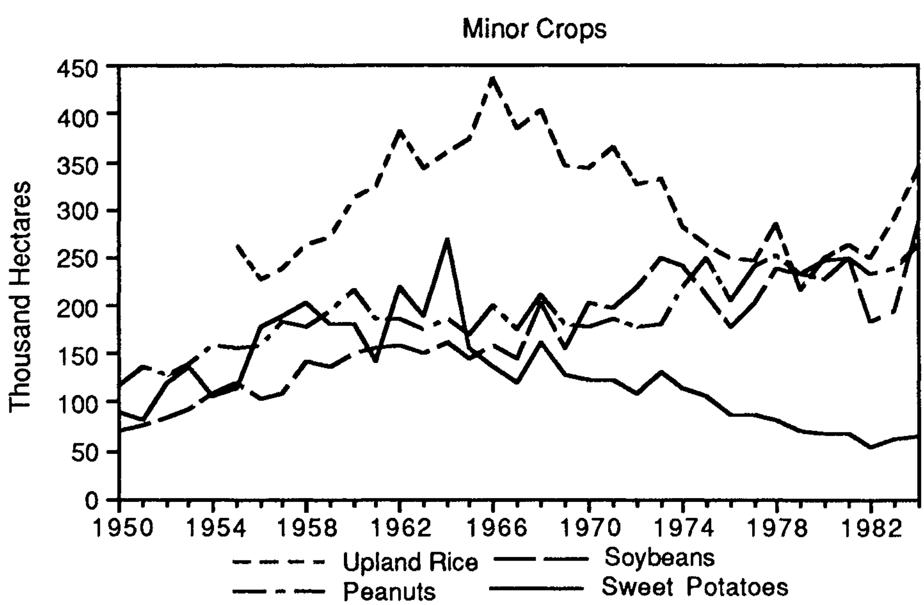
[2] It is also possible that some of the increase reflects improvements in coverage of Java's more remote areas by the CBS.

Chart 1.—Rainfed Harvest Areas of Principle Staple Crops on Java, Excluding Jakarta Province, 1950 to 1984*





Source: Central Bureau of Statistics, Jakarta.

*Corn figure is a three-year centered moving average.

crops have been introduced to only a limited extent. Nonetheless, fertilizer programs intended to support rice intensification had indirect benefits for producers and consumers of other crops. Various studies have indicated that greater use of chemical fertilizer has had a major impact on upland productivity (Table 2; also Montgomery, 1981; Roche, 1984b; and Mink, Dorosh, and Perry, 1987). Estimated yields of corn and cassava, the principal non-rice staples, rose rapidly from the early 1970s onward. These yield increases outweighed area declines, and for corn in particular, total production is believed to have risen significantly.[3]

Declining starchy staple areas have resulted from substitutions in rainfed land use that are difficult to quantify individually. Ambitious irrigation improvement programs were undertaken during the 1970s, and irrigated crops--particularly rice and sugarcane--have replaced rainfed staples in the rehabilitated lowlands. Complete time series data on these substitutions do not exist, but Java is now nearing the point of full exploitation of irrigable land. The impact of improved irrigation on areas of rainfed crops will therefore be smaller in coming years.

Of developments affecting principally rainfed uplands, least is known about government efforts to rehabilitate critical upland areas. It is likely that official figures released by Indonesia's Directorate of Land Use overestimate both the extent of truly critical lands and the areas covered effectively by regreening and reforestation programs (Roche, 1984a). However, the figures in Table 1 suggest that Java's protected and productive forest areas increased marginally between 1978 and 1983, which suggests some success in rehabilitation efforts.

Upland farmers have also increased crop areas planted to perennial cash crops, sugarcane, and vegetables during the past ten years. Since the late 1970s, a government program for extension, credit, and marketing of sugarcane has affected rainfed staple staple areas in the major cassava and corn-producing regions of East Java. Various formal and informal surveys of upland agriculture have revealed that tree crops—mainly cloves, fruits, and coffee—contribute an important and growing share of upland farmers' income and that expanded plantings of perennials have often come at the expense of areas planted to the traditional staples (Roche, 1983; Saefudin and Marisa, 1984; Manning, 1985; Manwan et al., 1985; Mink, Dorosh, and Perry, 1987). The following tabulation lists estimates of areas planted to smallholder estate crops on Java for 1963, 1973, and 1983 in thousand hectares (CBS, 1977, Vol. 3):

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[3] The cited studies support the view that production trends are reflected accurately in Indonesian crop statistics. However, the absolute levels of reported yields and areas suffer from several counteracting biases. See the discussion in Roche (1984b).

Table 2.—Agricultural Survey Estimates of Crop Yields and Chemical Fertilizer Use on Java, 1972 to 1984
(*Kilograms per hectare*)

	Irrigated rice		Upland rice[a]		Corn[b]		Cassava[c]	
	Yield	Fertilizer	Yield	Fertilizer	Yield	Fertilizer	Yield	Fertilizer
1972	2,886	129	1,239	46	1,094	45	6,967	8
1973	3,024	121	1,320	40	1,136	35	7,675	7
1974	3,018	122	1,212	46	1,163	50	8,700	9
1975	3,028	103	1,345	54	1,227	54	8,742	13
1976	3,398	127	1,364	67	1,274	58	8,799	18
1977	3,299	194	1,445	83	1,303	70	9,094	17
1978	3,400	228	1,506	82	1,398	71	9,367	22
1979	3,491	160	1,492	73	1,485	60	9,709	10
1980	3,997	277	1,594	109	1,554	109	9,859	24
1981	4,208	301	1,785	109	1,650	139	9,734	36
1982	4,544	312	1,873	122	1,702	158	9,893	35
1983	4,702	345	1,895	123	1,810	151	10,069	47
1984	4,732	346	2,111	277	1,822	106	10,483	26
Annual growth of total output, 1973–84 (percent):								
	5.6		0.4		6.8		1.7	

Source: Central Bureau of Statistics, various years, *Survey Pertanian* (Agricultural Survey), Jakarta. Composition of fertilizer use reported only after 1980 and consists of about 80 percent urea, almost 20 percent TSP, and very small quantities of potash. Production growth rates calculated with annual harvest area figures from CBS, various years, *Production of Food Crops on Java and Madura*, Jakarta.

[a]Dry, unhusked paddy.

[b]Dry, shelled.

[c]Fresh roots.

Year	Coffee	Cloves	Coconut	Sugarcane
1963	36.4	9.3	489.8	7.7
1973	40.7	30.8	373.1	26.7
1983	71.8	302.0	491.0	196.2

With the exception of sugarcane, these substitutions reflect largely the individual initiatives of farmers, since public intensification programs for their cultivation do not yet exist.

It is difficult to document aggregate production trends for fruits and vegetables because the available statistical data are incomplete and judged unreliable.[4] Official figures suggest that total production of the major vegetables changed little during the late 1970s, but sharp output gains were reported for some crops after 1982 (see Appendix Table 1).[5]

East Java's Upland Farming Systems

Studies sponsored by the Brawijaya University's Research Center, the Remote Sensing Laboratory of Gadjah Mada University, and Indonesia's Agency for Agricultural Research and Development permit detailed examination of regional innovations and recent changes in upland land use in East Java.[6] Most of these areas have been designated as critical by the Indonesian Directorate of Land Use. Brief surveys ("rapid rural appraisals") of present and historical land use patterns were conducted in twelve villages chosen to represent specific agroclimatic domains. These studies were accompanied by an integrated land survey, using remote sensing and ground survey techniques to define and map land units with similar physical characteristics like soil type, slope, and location in the landscape.[7]

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[4] With the exception of specialty areas in highland locations and near major cities, fruits and vegetables generally occupy small proportions of farmers' land, thus complicating the collection of production statistics. In addition, the CBS does not directly collect these data in the field, but instead relies on the estimates of agricultural officials at the sub-district (*kecamatan*) level, usually covering some ten to twenty villages. Unfortunately, differences in coverage during the agricultural censuses of 1973 and 1983 preclude intercensal comparisons of vegetable and fruit crop areas.

[5] Changes in production are largely due to changes in reported harvested areas as few yield trends are revealed in the data. Estimated fruit production varies considerably from year to year, again due mainly to changes in estimated areas. However, the data show a moderate trend toward increasing productivity which may indicate both higher output per tree and a greater density of trees planted per hectare.

[6] This section builds on the work of Semaoen, Fox, and Roche (1985).

[7] A complete discussion of the methods and results of the integrated land

The uplands of East Java are located primarily in the province's southern half and comprise lands of uplifted limestone or coral reef derivation and lands derived from volcanic materials (Map 1). Limestone areas tend to possess low to moderate slopes, soils that are shallow, infertile, fine-textured clays, and water supplies that are limited during the long dry season. Volcanic areas are characterized by moderate to steep topography, soils that are deep, fertile, and of medium to coarse texture, and moderate to readily available water supplies. Low-lying areas of both volcanic and limestone origin are generally irrigated, while steeper areas at elevations above 300 meters are predominantly rain-fed. The limestone and volcanic land types could be subdivided into a number of geomorphologically distinct land units, each characterized by somewhat different patterns of land use and productivity. For the purposes of this discussion, however, the rain-fed farming systems of these sub-units can be aggregated into three general forms: limestone, middle volcanic, and upper volcanic.

With minor modification, this typology would apply throughout Java's uplands. Upland limestone areas similar to those studied in East Java extend westward along the southern coast across Yogyakarta province and into Central Java. The remaining hills and mountains of West and Central Java are derived primarily from volcanic materials, but have been weathered more extensively due to more abundant rainfall in these provinces. The volcanic soils tend to be more acidic and somewhat lower in natural fertility than those of East Java.[8]

Limestone-based soils cover about 21 percent of East Java, but account for 35 percent of the province's heavily eroded lands (Fox and Suharsono, 1985). Soil losses have been moderate on the lowland plains of northern Java and most of the island of Madura, but severely depleted limestone uplands are concentrated at elevations generally below 500 meters along the hilly southern coast. Almost complete deforestation and erosion had made barren domes out of many of the undulating karst hills prior to the Indonesian independence. Present topsoil losses are low to moderate overall. The external costs of erosion are also low because most streams feed directly into Java's coastal areas. Indeed, many lower-lying valleys have benefited from sedimentation and contain relatively deep, productive soils.

Cropping patterns in the southern limestone uplands are based upon cassava and corn grown principally for subsistence needs. Livestock activities involving work cattle and goats are important, but their ownership is not commercially oriented. Chemical fertilizers have contributed to higher crop yields on valley soils, but productivity is extremely low on the de-

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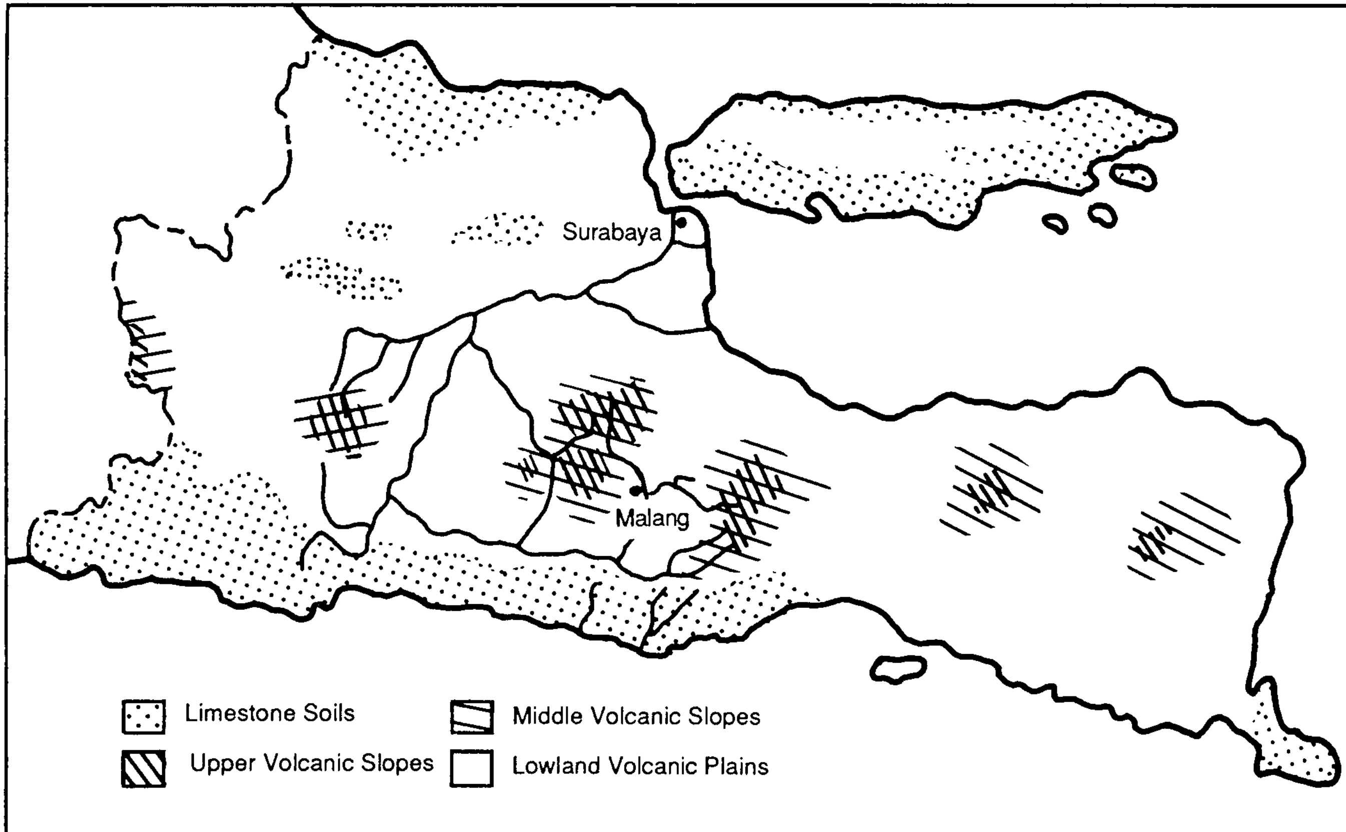
survey is presented in Fox and Suharsono (1985) and Fox (1986). More detail on the East Java village surveys is contained in Manwan et al. (1985).

[8] Dames (1955) provides the authoritative description of Java's major soil types.

Map 1.—Major Land Types in East Java



Source: Ibraham Manwan et al., 1985, *Agroecosystems Analysis of East Java's Critical Uplands*, KEPAS, Department of Agriculture, Jakarta.

pleted hillsides that cover much greater areas (Roche, 1983). Cloves have been planted extensively in a few higher areas, but overall, there have been few substitutions of commercial crops when compared to better-endowed regions of Java. Moisture availability and poor soils limit productive potential. Because of limited local economic opportunities, seasonal and permanent out-migration constitute the principal social dynamic of the villages visited. Regreening programs have succeeded in retiring some areas from annual cultivation where farm families have moved to new settlements off Java.

Farming systems along the middle volcanic slopes (400 to 1,100 meters) are characterized by medium to high productivity at present. The cropping patterns of this zone consist of field crops and diverse gardens containing both annuals and perennials. Corn, cassava, and legumes tend to dominate these gardens at lower altitudes, but perennial cash crops are becoming increasingly important at higher, steeper elevations. The use of purchased inputs varies among crops and villages, but is much higher overall than in the limestone areas. Small-scale animal husbandry—small ruminants and poultry—is a commercial activity of growing importance in many villages.

Land use is becoming highly commercialized in this zone. Farmers in several villages had substituted perennials—coffee, cloves, and apples—for food crops over the past fifteen years. In other cases, the government's rainfed sugarcane program has also reduced food crop areas, and a dairy extension and marketing program has led to considerable planting of forage crops in a group of villages near a large city. This dynamism has been facilitated greatly in recent years by the improvement of road networks and local markets. East Java's public agricultural support services are probably the best developed in Indonesia, and new inputs and informal extension are often provided by private traders and merchants.

Bench terracing has been more extensive than in the limestone zone because the land is steeper, and its higher natural productivity makes terracing worthwhile, although small areas remain unterraced, the further leveling of many existing terraces would be desirable. Farm-level problems of erosion appear to be manageable in the middle volcanic areas. The final report of an intensive, six-year study of soil conservation problems and management alternatives in one primarily middle volcanic area—East Java's Kali Konto upper watershed—stated (Netherlands, 1985):

> The main conclusion... must be that no serious watershed problems exist when a comparison is made with other upper watersheds in Indonesia... excessive run-off, the main cause of accelerated erosion, only occurs in a limited number of cases. Even there, the impact on productive capacities of fields remains limited.

The upper volcanic zone consists of moderate to steeply sloped land lying above 1,000 meters on which ground cover is primarily protected forest or short-season vegetable cropping by smallholders. Livestock are generally of minor importance. During the past decade, the highland vegetable systems have become the most commercialized and intensive in East Java, often involving extremely high rates of pesticide, fertilizer, and manure application. The upper volcanic land form covers less than 7 percent of East Java's surface, but accounts for a larger share of current erosion losses. Because of topography and planting methods, chemical and topsoil effluents may have serious external consequences, since highland streams ultimately form East Java's major river systems. However, these externalities have not yet been quantified.

High average returns to vegetable growing would make farmers reluctant to adopt more environmentally sound cultivation practices that may reduce short-term profitability. In part, this is due to the prevalence of marketing arrangements under which traders extend credit to farmers for the contract production of vegetables. A reduction in productivity could also have an adverse impact on migrant farm laborers from nearby villages who presently gain much employment on a daily or seasonal basis.

In both middle and upper volcanic areas, share tenancy and absentee land ownership have apparently become more common with the increasing importance of fruit crops, sugarcane, and vegetables. The incentives for long-term investments in soil conservation are reduced when landholdings either are operated temporarily or are so small that the major share of family income is derived from off-farm activities. The Indonesian Agricultural Census suggests that these disincentives may be significant, since more than one-quarter of Java's farmers are tenants on either part or all of the land that they operate (CBS, 1977).

ECONOMIC INCENTIVES AND UPLAND EVOLUTION

The emerging patterns of upland agriculture have arisen, in part, from changes imposed on the physical environment: irrigation and, to a lesser degree, regreening programs. The East Java studies also suggest that economic incentives have had a major influence on the private decisions of individual farmers. Prices faced by upland farmers have been affected by the interaction of income growth and staple crop supplies, and official policy decisions with respect to inputs, infrastructure, and international trade.

Developments in the Rural Economy

Aggregate statistics suggest that the structure of Java's economy has changed considerably during the past 25 years. The proportion of the labor force engaged primarily in agriculture has declined steadily from 70 to about

55 percent since 1960. The trade, processing, and service sectors have absorbed almost two-thirds of all new labor force entrants. In the 1970s, some analysts argued that these changes reflected declining opportunities in agriculture. Small farmers and the landless were presumed to be forced into ever more marginal trade and service activities by increasing inequality in land ownership and slow growth of demand for farm labor (for example, Collier, 1981). However, more recent evidence presents a brighter picture of trends from the late 1970s to the present.

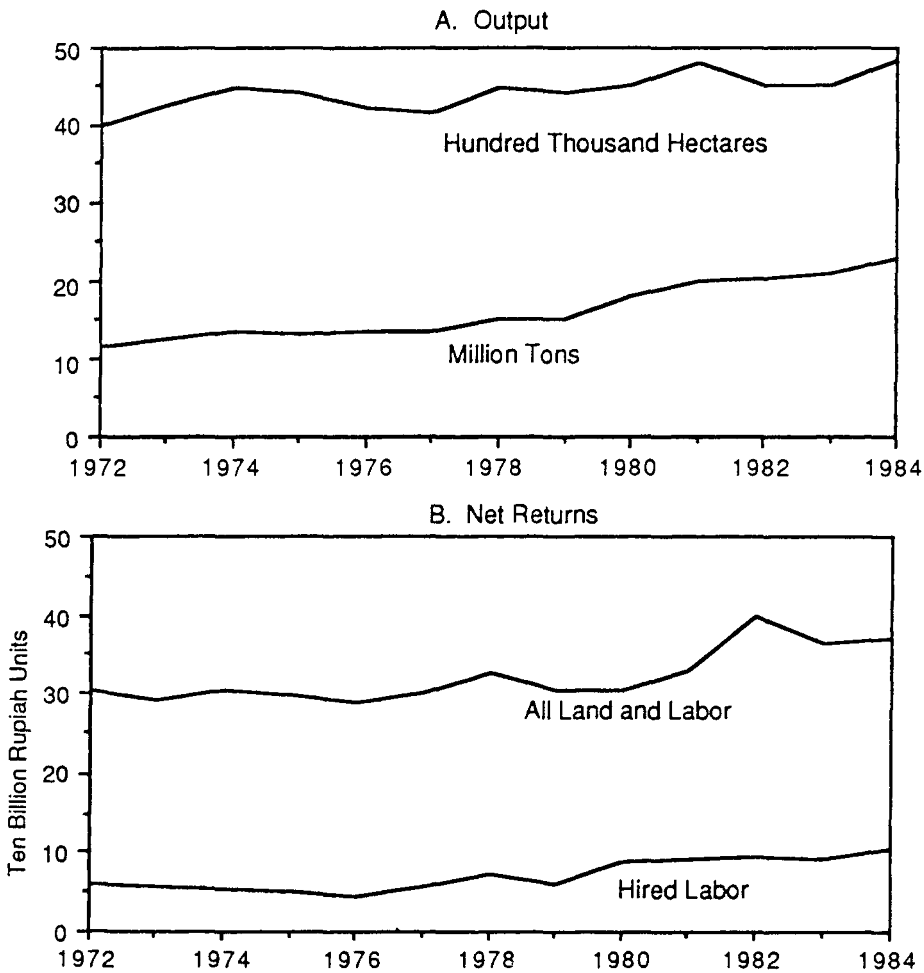
Greater security of staple food supplies and prices ranks among the principal aspects of Indonesia's development during the last fifteen years. Primarily in support of rice intensification, major investments have been made in irrigation, fertilizer production, research, extension, credit, and marketing. Agricultural price and trade policies have, overall, provided positive economic incentives to producers.[9] Agricultural development efforts have been supported by petroleum export earnings since 1973, and, more broadly, by the political and macroeconomic stability of President Soeharto's New Order government.

Rice production grew rapidly after the late 1970s as modern inputs were adopted almost universally in the irrigated lowlands. Indonesia's chronic dependence upon rice imports was, at least temporarily, arrested after 1979. Rice prices, over which the government at times had little control during the late 1960s and early 1970s, have since declined steadily in real terms.

Rice production on Java is a labor-intensive process that directly and indirectly provides employment for a major share of the rural labor force. The net impact of increased rice production on producer incomes depends upon rice yields, harvest areas, inputs, and relative prices of inputs and outputs. Estimates of the balance between these variables can be derived from Indonesia's annual Agricultural Survey, which provides a broadly representative picture of average costs and returns to the major staple crops

[9] BULOG (Indonesia's food logistics agency), the country's cooperative system, and numerous quasi-public trading firms have a significant influence on domestic marketing and prices of important food and feed commodities. Domestic prices of fertilizer and pesticides are heavily subsidized, whether compared to world prices or to domestic production costs. Input subsidies have been a major component of annual development budgets for agriculture since the early 1970s. Timmer (1985, 1986) provides comprehensive discussions of the impact of price policies for staples and inputs in Indonesia. He concludes that the social value of incremental rice output due to the fertilizer subsidy has been greater than the subsidy's social costs. Government policies also result in domestic prices of refined sugar, wheat flour, and soybeans that are far above world levels. Trade policies restrict imports of many dairy products, fruits, and vegetables. These policies are discussed more fully in a later section.

Chart 2.– Annual Irrigated Rice Production, 1972–84



Source: Central Bureau of Statistics, various years, Jakarta. Rice areas and output from *Production of Food Crops on Java and Madura*; income and wage payment estimates from *Survey Pertanian* (Agricultural Survey), deflated by CBS price index of 9 basic goods in the rural markets of Java and Madura.

over the agricultural year.[10] To estimate aggregate returns to rice production, figures on per-crop returns from the Agricultural Surveys have been multiplied by annual harvested areas and plotted in Chart 2. The growth rate of combined net returns to farm resources and hired labor averaged 2.1 percent annually between 1972–84, but increased to 3.4 percent after 1976 when rice harvest areas grew rapidly. Yields jumped sharply after 1979 as a result of good weather and an acceleration of fertilizer use (Table 2). For the period 1979–84, aggregate net returns to farm resources and hired labor grew at 4.6 percent annually.

In rural Java, an additional achievement of the past decade has been the improvement of marketing channels for farm inputs and outputs through the expansion of roads, vehicles, and public markets. It is fair to conclude that transport infrastructure is not a serious impediment to marketing at the present time, although road quality and the degree of porterage continue to affect marketing costs. Growing commercialization is characteristic of a developing agricultural economy and, on Java, the average quantities marketed by farmers have grown along with staple crop yields and production (Edmundson and Edmundson, 1982; Roche, 1984b; Timmer, 1987).

Cheaper and faster public transportation facilitated a substantial increase in population mobility during the 1970s. Greater temporary migration within rural areas and between the countryside and the cities was encouraged by developments, as yet not clearly understood, in farm and non-farm labor markets.[11] Various surveys have shown that real agricultural wage rates began rising in the late 1970s, after a period of stagnation

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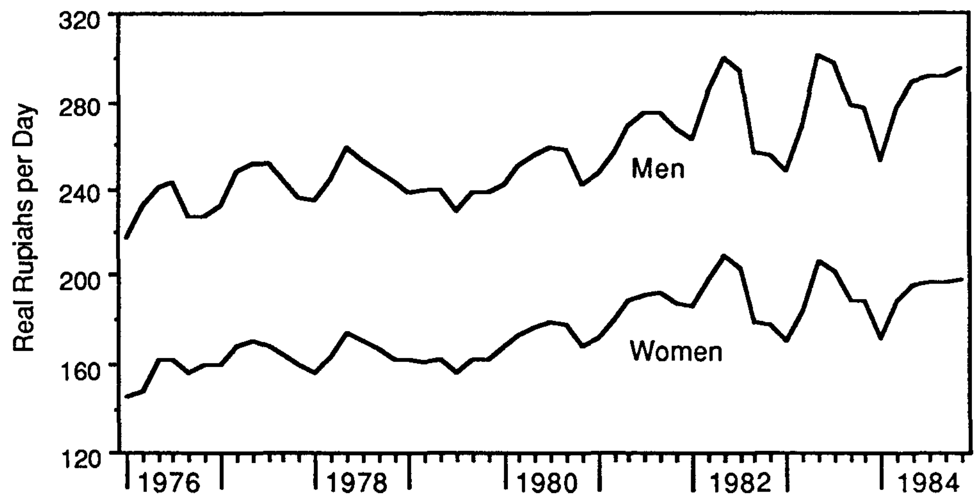
[10] The first Agricultural Survey was conducted in 1970, but the results were not considered reliable until 1972. The survey is conducted each April, when farmers are questioned about production practices during the preceding year. Given the recall problems likely with this framework, it is appropriate to interpret the results as a weighted average of costs and returns for crops planted under widely differing agroclimatic conditions. The sample size (around 10,000 per year, of which about 70 percent are from Java) is sufficiently large and the selection procedures sufficiently systematic that some confidence can be had in the results under this interpretation. The published results consist of tabulations by province, crop, and, for rice, intensification status. A limitation of the survey publications is that the tables provide information on the value, but not the physical quantities, of many inputs. Labor inputs are reported only in terms of cash and in-kind expenses for hired workers.

[11] Inconsistencies in Indonesian demographic and labor force surveys preclude detailed analysis of aggregate migration and labor market developments (Hugo, 1982). At the micro-level, intensive village studies have demonstrated the complexity of local labor markets and the wide variety of employment activities performed by rural families (for example, White, 1976; Hart, 1979). Numerous observers reported labor scarcity in rice farming during the early 1980s. There

earlier in the decade (Chart 3; also Collier et al., 1982; Kasryno, 1984; Mazumdar and Sawit, 1985; Santoso, 1986). The data in Chart 2 indicate that payments to hired labor in rice production increased very rapidly during these years as rice areas and yields grew sharply.

Chart 3.—Real Agricultural Wages on Java



Source: Figures are weighted averages of wages paid on estimates and in smallholder farming. Estate wages are from Central Bureau of Statistics, various years, *Rata-Rata Upah Perkerja Perkebunan* (Average Wages of Estate Workers), Jakarta. Farm wages derived from unpublished data collected by CBS Division of Finance and Producer Statistics, Jakarta.

Compelling evidence on rural income growth comes from a series of detailed comparative surveys conducted by Indonesia's Rural Dynamics Study (RDS) in nine predominantly irrigated villages during 1976/78 and

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are indications that small tractors have been adopted rapidly in some lowland areas in recent years (Lingard and Sri Bagyo, 1983), but by and large Java has been spared the problems of labor-displacing farm mechanization that have arisen in other Asian countries.

again in 1983. Analysts of these surveys have concluded generally that broadly based growth in family incomes and consumption occurred during this period (Saefudin and Marisa, 1984; Hartoyo and Makali, 1984; Wiradi, Manning, and Hartoyo, 1984; Manning, 1985). One analysis of the data from six villages in West Java concluded that income gains were relatively large among the landless and medium-size farmers, suggesting some narrowing of income differentials among socioeconomic groups (Table 3). Non-agricultural income sources became increasingly important, and the contribution of farm activities to total household incomes declined among many families (Saefudin and Marisa, 1984). In 1983, more than one-fifth of all economically active household members engaged in short-term and seasonal migration to work in nearby villages and cities (Colter, 1984).

Table 3.—Overall Household Income Growth in Rural Dynamics Study, West Java Villages, 1976–83
(*Percent*)

Household	Share of sample households	Average annual real income growth
Landless		
Farm laborers	10	4.7
Non-agricultural workers	5	4.8
Farmers		
Small (< 0.25ha)	40	3.1
Medium (0.25–0.5 ha)	23	5.5
Large (> 0.5 ha)	23	3.1
All households	100	3.9

Source: Rural Dynamics Study, 1976 and 1983 surveys of six villages in Cimanuk watershed area of West Java, as reported by C. Manning in World Bank, 1985, *Indonesia: Policies for Growth and Employment*, Washington, D.C.

Although there are regional variations, the patterns of change evident in the RDS villages are consistent with the conclusions of other observers (for example, Collier et al., 1982; Edmundson and Edmundson, 1982; Santoso, 1986). Success in rice intensification is at the heart of Java's dynamism, but investments in infrastructure, public services, and manufacturing have also generated new employment (Jones, 1984; Roepstorff, 1985). These sources of growth have had major multiplier effects on trade, services, and construction in small towns and in the semi-urban regions surrounding Java's major cities. Java has not yet reached the turning point of an absolute decline in agricultural sector employment (Johnston and Kilby, 1975), but few observers would argue today that agricultural and rural transformations are not well under way.

Income Growth, Food Demand, and Food Prices

Java presents few exceptions to widely observed relationships between income growth and the composition of incremental food demand in low-income economies. Table 4 presents simple long-run estimates of income elasticities for staple and non-staple foods that have been derived from Indonesia's National Socioeconomic Survey (*SUSENAS*). In general, fruits, meats, dairy products, and vegetables are characterized by large, positive income elasticities. Consumption of sweeteners and the major legume crops—soybeans and peanuts—also tends to increase rapidly with income. In contrast, the direct consumer demand for starchy staples grows more slowly as incomes rise. For certain forms of cassava and corn, consumer demand may decline absolutely. The derived demand for cassava and corn as livestock feeds is likely to be quite income-elastic, of course, but only corn is fed in significant quantity in Indonesia at the present time.

The figures in Table 4 also indicate that rural food consumption will, if relative prices and income distribution remain the same, grow at a faster rate with income than food consumption in urban areas. Per capita consumption of highly preferred foods is lower in rural areas, but average income elasticities and the market—about 75 percent of Java's population—are considerably larger. Demand for income-elastic foods such as meat and many of the non-staple crops will increase rapidly even at the moderate rates of sustained income growth—perhaps 3–5 percent annually—that appear to have characterized rural Java during the last decade.

The balance between demand for and supply of staple and non-staple commodities can be inferred by changes in relative market prices over time. Real monthly prices of the principal staple crops are plotted in Chart 4. (The data are from East Java, but reflect trends occurring throughout the island.)[12] Ignoring normal seasonal fluctuations, the real rural price of rice was stable between 1976 and 1979, but a clear decline is evident beginning in 1980, when domestic rice production accelerated sharply (Chart 2). During

[12] Seasonal and annual trends depicted in the CBS wage and commodity price indexes are generally similar among provinces, although absolute levels often differ. A detailed examination of the coded data used to create commodity indexes reveals anomalies in a number of time series. It appears that processing problems led to errors in the average prices recorded for specific vegetables and non-rice staples during late 1982, and for specific vegetables and non-rice staples during late 1982, with a major upward bias resulting in producer price indexes for these commodity groups in all provinces. The East Java office of the Ministry of Agriculture has collected detailed information on weekly agricultural prices in major producing areas since 1980. These data have been used to adjust the CBS series from East Java. Unfortunately, no complete data are available for cross-checking purposes from the other provinces.

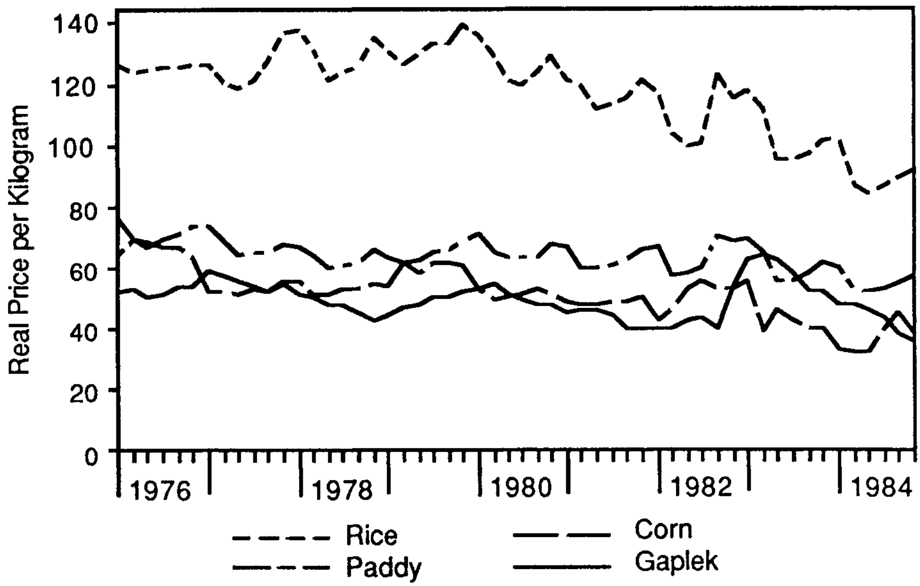
Table 4.—Food Expenditure Elasticities on Java, 1980

Commodity	Urban	R^2	Rural	R^2
Starchy staples				
White rice	0.11	.48	0.62	.84
Dry corn	−1.21	.79	−0.79	.92
Fresh cassava	−0.30	.70	0.11	.45
Dry cassava	−3.07	.84	−0.85	.52
Sweet potatoes	0.05	.03[a]	0.76	.92
Vegetable proteins				
Beancurd	0.52	.85	1.31	.92
Soy cake	0.39	.87	0.80	.96
Sweeteners				
White sugar	0.58	.96	0.88	.99
Brown sugar	0.48	.97	0.77	.98
Meats				
Chicken	2.43	.85	3.63	.88
Other meats	1.91	.91	2.93	.93
Dairy products				
Hen's eggs	1.47	.84	1.59	.97
Other eggs	1.38	.80	2.10	.91
Canned milk	1.87	.78	3.81	.91
Fruits				
Bananas	0.87	.69	1.25	.96
Pineapples	1.51	.63	1.89	.93
Papayas	0.89	.94	1.29	.92
Guavas	0.39	.48	1.47	.97
Oranges	1.49	.93	2.32	.78
Vegetables				
Cassava leaves	0.12	.44	0.05	.15[a]
Spinach	0.25	.93	0.28	.85
Eggplant	−0.17	.53	0.63	.83
Cabbage	1.18	.82	0.98	.96
White potatoes	1.59	.84	1.99	.91
Carrots	1.44	.90	1.81	.72
Cucumbers	0.99	.77	1.62	.92
Tomatoes	0.91	.93	1.82	.97
Shallots	0.47	.96	0.72	.99
Red peppers	0.72	.93	1.09	.98
Garlic	0.57	.97	0.62	.96

Source: Central Bureau of Statistics, 1980, *SUSENAS* (The National Socioeconomic Survey), Jakarta. Elasticities estimated with individual regressions of (log) weekly per capita food quantity on (log) total per capita expenditure, with observations weighted by the sample proportion of each expenditure group.

[a]Not statistically significant at the .05 level.

Chart 4.—Real Monthly Prices of Major Staples in Rural East Java, 1976-84*



Source: Price data from Central Bureau of Statistics and Department of Agriculture, various years, Jakarta, deflated by the CBS monthly consumer price index for rural East Java (1976=100).

*Rice, medium quality; paddy, IR-36 at farm level; gaplek and corn, average dry roots and seed at farm level.

these years, rice stocks of several million tons accumulated in government warehouses. Rice prices were largely market-determined at levels generally below official ceiling rates, but government purchases of paddy and rice from farmer cooperatives acted to forestall a more drastic decline in paddy prices at the farm level.

Markets for corn and dried cassava (*gaplek*), the main alternative staples, are less affected by direct government interventions, but are influenced strongly by rice prices due to substitutions in consumption that occur primarily among the rural poor (Dixon, 1984). Corn prices are also influenced by domestic and international feed demand (Timmer, 1987), while gaplek prices are affected by fluctuations in international markets for feedstuffs and starch (Nelson, 1984). Domestic prices of these and other tradable commodities rose in real terms following devaluations of the rupiah in late 1978 and early 1983. A serious drought on Java also contributed to rising prices at the time of the latter devaluation. However, these increases were temporary for the major staples. The declining price of rice during the 1980s acted to reduce the direct demand for less preferred substitutes. World prices of corn and gaplek have declined during the 1980s, thus reinforcing the impact of domestic rice prices on the demand for other staples.

Declining staple prices have varied implications for consumption because of their differing effects on producers and consumers.[13] Large increases in non-staple food consumption were measured in the RDS surveys of West Java villages in 1976 and 1983 (Hartoyo and Makali, 1984). For rural Java overall, the SUSENAS data reveal that the average budget share for starchy staples declined from almost two-fifths to less than one-quarter of total expenditure (Table 5). Non-staple consumption—including prepared foods—rose from 43 to 55 percent of the average food budget and increased moderately as a proportion of total expenditure.[14] Overall, the value of all food and tobacco consumption declined from 76 to about 65 percent of average total expenditure.

As compared to the starchy staples, prices of the more income-elastic commodities were relatively stable in real terms during the period 1976–84 (CBS, various years). As a result, the prices of many of these commodities

[13] The substitution effect of lower prices should clearly encourage greater staple consumption, but the direction of the income effect will be influenced by the degree of staple self-sufficiency in a given household. Price declines imply an increase in real income for families dependent primarily upon market purchases, but the opposite would be true in households that are net sellers. However, a majority of Java's farm families appear to purchase staples on at least a seasonal basis. The SUSENAS surveys for 1978, 1980, and 1984 indicate that almost three-quarters of average rural rice consumption is from market purchases, most of which occur during the preharvest months of January through March when the surveys are conducted.

[14] The SUSENAS data show particularly large increases have occurred in average quantities consumed of vegetables, fruits, and eggs in rural Java. Average consumption of meats, poultry, and milk has been low and stagnant. The data also indicate that average quantities of rice, fresh cassava, and gaplek have declined since 1976, while dry corn consumption has increased. For rice in particular, such a result suggests that under-reporting of consumption may have been an increasing problem in the most recent SUSENAS rounds. Timmer (1987) speculates about changes in income distribution that may be associated with these reported patterns of staple consumption.

Table 5.—Average Expenditure Shares
for Food in Rural Java, 1976–84*
(*Percent*)

Category	Food expenditure 1976	Food expenditure 1980	Food expenditure 1984	Total expenditure 1976	Total expenditure 1980	Total expenditure 1984
Starchy staples						
Rice	39.3	35.6	31.6	31.1	25.7	20.6
All cereals	45.4	39.5	34.4	34.6	28.6	22.4
All cereals and cassava	50.4	42.3	36.4	38.5	30.6	23.7
Other foods						
Animal products, pulses, vegetables, and fruits	25.2	27.9	29.7	19.2	20.2	19.4
Fats, oils, spices, and beverages	13.1	14.8	15.7	10.0	10.7	10.2
Prepared foods[a]	4.2	5.9	9.6	3.2	4.3	6.2
Total non-staples	42.5	48.6	55.0	32.4	35.2	35.8
Total food and tobacco	100.0	100.0	100.0	76.3	72.3	65.1

Source: Central Bureau of Statistics, various years, *SUSENAS* (The National Socioeconomic Survey), Jakarta.

*Expenditure shares are based on per capita values of commodities consumed during the week prior to the survey, with self-produced quantities valued at local market prices. Data for 1976 were collected between January and April, whereas those for 1980 and 1984 were collected in Feburary.

[a]Includes primarily meals purchased outside the household and bottled soft drinks.

rose significantly in relation to staple prices. These price increases were particularly large for vegetables and the perennial fruit crops (see Appendix Table 2). Overall, growth of non-staple prices was greatest with respect to the farm-level prices of corn and cassava, the principal crops in traditional upland farming systems.

Longer-term trends in the relative prices of fruits and vegetables reflect primarily the balance of shifts in the island's demand and supply curves. Indonesia both imports and exports these commodities in quantities that are negligible shares of estimated domestic supply.[15] Of the non-staple goods analyzed in Appendix Table 2, import dependence is important only for

[15] Fresh products are exported primarily from producing areas in northeastern Sumatra to Singapore and Malaysia. Imported fruits and vegetables are luxury items consumed almost exclusively by wealthy urban classes. Within Indonesia, Java's imports from the other islands are consumed largely near the major cities of Jakarta and Surabaya.

soybeans and milk products. Within Indonesia, livestock are transported from other islands for slaughter near Java's major cities, but the perishability of fresh fruits and vegetables leads to high marketing margins that inhibit trade between potential importing and exporting areas.

The overall level of prices is influenced by trade policies that provide high rates of protection for domestic legumes, fruits, vegetables, and dairy products. Glassburner (1985) cites the following Effective Protection Rates (EPR) calculated for Indonesia by the World Bank (all for 1975, except soybeans and peanuts, 1981):

	EPR (percent)		EPR (percent)
Dairy products	221.4	Palm oil	−4.6
Fruits, vegetables	208.9	Gaplek, cassava starch	−10.8
Soybeans	45.6	Coconut products	−11.0
Peanuts	8.8		

Although EPR values will vary over time as prevailing prices change, the above estimates reveal the general pattern of agricultural trade policy that has long existed in Indonesia. With the principal exception of imported rice, for which domestic consumption was often subsidized during the 1970s, Indonesia's food imports are limited by tariff and quantity restrictions that raise domestic prices. In contrast, domestic prices of traditional export crops are reduced by export taxation. International trade in corn and cassava is restricted by import or export barriers depending upon domestic supplies and prices in any given year (Nelson, 1984; Timmer, 1987). In 1983, policy makers resorted to fiat in order to achieve self-sufficiency in fruits. Imports, principally of temperate varieties, were banned in an attempt to raise the level of producer prices even further.

Coffee, cloves, and coconuts are the major perennial export crops cultivated by Java's upland smallholders. Their prices are influenced to a greater degree by variability in world markets than are prices of fruits, vegetables, and livestock products which are, for the most part, not traded internationally. World and domestic prices of cloves increased sharply in relation to corn and cassava prices during the late 1970s, but have declined since the international recession of the early 1980s. In contrast, relative coffee and coconut prices declined somewhat from 1977 to 1982, but have since risen rapidly.

Upland Farm Incomes

Recent field surveys and data on rural prices suggest that the relative profitability of starchy staple production has declined in recent years as

Table 6.—Household Income from Farm Activities in Some West Java Villages (*Percent*)

Activity	Share of total farm income 1976	Share of total farm income 1983	Average annual real income growth
Irrigated rice	68	61	2.5
Other crops	7	14	14.4
Home gardens	17	14	1.6
Fishponds	2	3	9.9
Livestock	5	8	11.9
All farming	100	100	4.3

Source: Rural Dynamics Study, 1976 and 1983 surveys of six villages in Cimanuk watershed area of West Java, as reported by C. Manning in World Bank, 1985, *Indonesia: Policies for Growth and Employment*, Washington, D.C.

compared to alternative crops. Although modern rice varieties and chemical inputs have increased yields of Java's staple crops, rising farm wage rates and declining real staple prices have reduced the net impact of these technologies on farm incomes. Indeed, an analysis of data from the Agricultural Survey shows that there was no significant change in the net returns per crop to the production of cereals and cassava during the 1972-83 period. Average annual percentage changes in net returns per hectare to land, family labor, and management in real terms were as follows (see Appendix Table 3 for greater detail):

Commodity	Percent changes
Irrigated rice	−0.1
Upland rice	−0.2
Corn	2.2
Cassava	0.0
Peanuts	4.7
Soybeans	2.4

Improved irrigation and early maturing varieties have permitted more extensive rice cultivation that, in turn, has led to rapid income growth of Java's lowland agriculture. However, since harvest areas of the primarily rainfed crops generally declined during this period, it can be inferred that aggregate farm returns to these crops have declined as well. In contrast, relative prices and harvest areas of the more income-elastic legume crops have risen, implying increasing net returns both per crop and in the aggregate.

The Rural Dynamics Study surveys of West Java villages provide evidence of large increases in farm incomes from commodities other than irrigated rice (Table 6). Rice intensification programs had been established in most of the RDS villages at the time of the initial surveys in 1976. Higher rice yields had been achieved by almost all farmers at the time of the second round of surveys in 1983. However, while irrigated rice continued to be the most important source of agricultural income in 1983, its proportional contribution had declined due to rapid growth in the returns from other farm activities, especially vegetable and small-scale poultry production (Saefudin and Marisa, 1984; Manning, 1985).

Trends in the returns to specialty crops are not known, but a comparison of present profitability is possible. Costs and returns in Java's agriculture have been compiled from the available production studies and are summarized in Appendix Table 4. They represent lower and upper bounds on the levels of inputs and outputs, at 1984–85 values, reported in recent surveys, mostly of East Java, but consistent with values in other provinces. Net returns per crop, or per hectare for tree crops, 1984–85, in thousand rupiahs per hectare were:

Crop	Net income
Irrigated sugarcane	1,450–2,230
Irrigated rice	200–450
Rainfed corn	<150
Rainfed cassava	<260
Legumes	<250
Rainfed intercropped staples	150–420
Vegetables	2,070–11,200
Fruits I[a]	900–2,000
Fruits II[b]	1,000–4500
Estate crops[c]	200–850

[a]Papayas, pineapples, and oranges intercropped with annuals.
[b]Orchards of apples, grapes and mangoes.
[c]Coffee and cloves intercropped with annuals.

The data clearly show that present net incomes from vegetable and fruit cultivation often far exceed the returns to staple crops at recent relative prices. Indeed, even the lower returns to vegetables and fruits compare favorably with returns from an annual paddy-paddy-legume sequence on Java's best irrigated land. In two categories—Fruits I and Estate Crops—the figures show only the returns to perennials in rainfed agroforestry systems and do not include the income from intercropped staples. Were this income included, annual returns to these systems would be similar to average returns in irrigated cropping.

FUTURE UPLAND EVOLUTION

Rising consumer incomes and a long-term decline in the profitability of traditional staple crops will encourage several evolutionary paths for Java's upland agriculture, each is characterized by an increasing commercialization and specialization of farm practices.[16] In the middle volcanic uplands of East Java, there has been an intensification of agroforestry systems that are based increasingly upon tree crops. In a few areas, food crops have been have been replaced by grass and forage systems that support intensified livestock production. The cultivation of vegetables has also become more intensive in upper volcanic areas possessing appropriate soils and climate. In the limestone regions, in contrast, evolutionary developments have been limited by depleted soils and limited rainfall.

System Evolution and Soil Conservation

The implications of these development patterns for the sustainability of upland agriculture depend principally upon the physical and biological relationships between the agroclimatic environment, land use, and soil erosion. Soil scientists have summarized these relationships in a general mathematical expression known as the Universal Soil Loss Equation (USLE) that expresses topsoil losses as a function of rainfall pattern, soil and slope characteristics, land use, and conservation practices:

$$E = f(R, S, T, L, C),$$

where

[16] Changing patterns of profitability will also affect lowland irrigated cropping systems. Indeed, the Indonesian press has reported occasionally over the past several years that agricultural officials in certain localities have been alarmed to see farmers converting their paddy land to dry fields so that crops such as citrus and cloves can be planted! However, many lowland farmers have only limited control over the seasonal flooding of their fields, with the result that they were technically constrained to crops that tolerate standing water.

E = average annual topsoil losses (metric tons or millimeters per hectare);
R = climate (annual level and seasonal intensity of rainfall);
S = soil erodability (soil permeability, texture, organic matter content, and structure);
T = topography (gradient, length, and land form);
L = land use (plant canopy cover as compared to bare soils : $0 < L < 1$); and
C = soil conservation (terrace quality).

The functional relationship between these variables is assumed to be multiplicative. Estimates of L and C, the variables that measure the influence of man, have been derived for upland conditions on Java (Hamer, various years; Netherlands, 1985):

Land use	L value
Spices (chili pepper, ginger)	0.9
Cassava	0.8
Corn	0.7
Upland rice	0.5
Potatoes	0.4
Medium-density mixed garden	0.3
Coffee, cloves	0.2
High-density mixed garden	0.1
Dense pasture (bracharia)	0.02
Natural forest	0.001
Terrace quality	**C value**
High	0.04
Average	0.15
Poor	0.35

Empirical estimates of USLE coefficients are quite specific to the environment in which they are derived. For this reason, the above values indicate only relative orders of magnitude. However, these magnitudes reveal the considerable variation in erosion resulting under differing forms of soil cultivation and management.

In general, traditional staple crops are characterized by relatively high land use coefficients (L) because they provide limited canopy cover of the soil, particularly during the planting season when rainfall is most intense. Mature perennial crops cover the soil continuously, require little or no annual soil tillage and contribute to improved soil structure because of deep root penetration. The density of grasses, mulches, or annual crops planted between perennials will also influence overall topsoil losses. Mixed gardens of perennials and annuals can provide dense coverage and, hence, they have low measured L values. Pastures also provide dense ground cover throughout the year and estimated L values are the lowest of all forms of land cultivation. In addition, the livestock supported by forage and pasture systems will produce manure that, in turn, has a beneficial impact on soil structure and fertility. The L values estimated for vegetables and spices vary widely depending upon the extent of canopy closure provided by a specific species. Field observations suggest that highland vegetable systems are, at times, associated with serious topsoil losses on steep slopes. The run-off of chemical effluents may constitute an additional environmental concern.

The soil conservation coefficients (C) show that the quality of upland terracing also has a major impact on erosion levels. Good terraces are constructed so that terrace width and riser slopes are suited to the natural slope and contour of the landscape. Water movement must be controlled by drainage channels and proper levelling of benches. The planting of forage grasses on terrace risers can make an important contribution to structural stability. These investments provide direct benefits to farmers, but also require high labor costs.[17]

The examples below suggest the levels of annual topsoil loss which occur under different forms of land use and terracing. Following the methodology used in the Kali Konto study (Netherlands, 1985), a value is chosen for the environmental constants of climate and land form to approximate potential annual erosion from East Java's rainfed, terraced soils of the middle volcanic landform. This baseline value is then multiplied by alternative values of L and C to estimate actual topsoil losses:

[17] Excellent discussions of the techniques and economics of bench terracing in Java's uplands are provided in PRC Engineering Consultants (1980a,b) and Netherlands (1985).

Commodity and terrace quality	K(= $R * S * T$) (mt/ha/yr)	L	C	E (mt/ha/yr)	E (mm/yr)
Corn					
Poor	1,944	0.7	0.35	476	36.6
Average	1,944	0.7	0.15	204	15.7
High	1,944	0.7	0.04	54	4.2
High-density mixed garden					
Poor	1,944	0.1	0.35	68	5.2
Average	1,944	0.1	0.15	29	2.2
High	1,944	0.1	0.04	8	0.6

These crude calculations indicate that substitution of a dense agroforestry system for monoculture corn can reduce topsoil losses by a factor of seven at any level of terrace quality. On moderately sloped land with terraces of average quality, this substitution can reduce erosion to the approximate rate of natural soil formation—2.4 mm/year—that has been estimated for Java's uplands (Hamer, various years). In contrast, erosion associated with corn or cassava cultivation would remain above this equilibrium level even on terraces of high quality.

More complete data would show the influence of cultivation practices like tillage, planting density, intercropping, fertilizing, and mulching. It is clear that perennial and pasture crop systems that are of growing importance in East Java's middle volcanic areas are more protective of the topsoil than the traditional system based on staple crops. The obvious goal of upland development programs is to encourage the production of new crops characterized by both good demand prospects and topsoil maintenance. Agroforestry systems based upon perennial crops deserve emphasis in research and program design.

Sustainability objectives are also be served by facilitating farmer investments in labor-intensive terrace improvements. The incentives for investments in terraces and perennial crops are influenced strongly by land tenure patterns. Because Java's upland volcanic soils are generally quite deep, productivity declines due to erosion are a distant concern for many farmers. Even among land owners, the private costs of better terraces may often be viewed as higher than the private benefits. Subsidization of the labor costs of terracing is an important component of upland conservation programs currently underway on Java.

Variable Inputs and Program Considerations

The agricultural sector's capacity to absorb labor productively is an important concern in most densely settled agrarian economies. The figures on labor use (male and female, 5-hour days) provided in Appendix Table 4 are encouraging indicators of the potential of non-staple crops:

Crop	Labor use
Irrigated rice	250-350
Sugarcane	500-670
Rainfed rice	175-200
Rainfed corn	75-150
Rainfed cassava	160-300
Legumes	85-175
Rainfed intercropped staples	385-550
Vegetables	500-1,170
Fruits (I)	135-210
Fruits (II)	530-1,900
Estate crops	100-200

On an annual basis, measured labor inputs in fruit and vegetable production are very high even when compared to the intensive staple intercropping patterns that are common in upland Java. The direct cultivation of tree crops added from 100–210 labor days to total labor use in studies of mixed gardens containing annuals and scattered perennials. It appears likely that the labor intensity of these gardens increases with the planting density of perennials. Annual labor inputs of 1,000 days or more per hectare were commonly reported in a survey of commercial orchards in East Java.

The available data on the structure of rural employment suggest that agriculture is increasingly a part-time activity for many of Java's small farmers. Sustained growth in real rural wages and the returns to non-farm labor would tend to reduce the labor intensity of farming and encourage the production of agricultural commodities with relatively low labor requirements. However, the intensity of perennial and vegetable systems will be warranted if output prices are sufficiently high in relation to production costs.

Cash costs for seed, fertilizer, and pesticides are also high in fruit and vegetable cultivation, particularly among commercial producers of temperate highland species. Despite subsidy policies that have allowed real fertilizer and pesticide prices to decline substantially in recent years, these input costs are excessive for many small farmers if they must be borne out of pocket. Government credit programs are not yet widespread for producers of specialty crops. To some extent, markets have responded to this problem via the emergence of private credit and production contracts between farmers and traders in major producing areas. For most farmers, however, farm capital availability is a serious constraint to price responsiveness (Roche, 1983).

Limited farmer knowledge and access to technical information also slow the pace of response to market incentives. Both larger yield and market risks are incurred in the production of cash crops. Many species and varieties require specific soil and climate characteristics for good yields. Farmers know less about pest and disease problems of these unfamiliar crops, particularly of temperate zone species. Perennials are especially risky due to the long time periods often necessary to reach maturity. The same is true of raising cattle.

East Java field studies suggest that many marginal technical changes in raising food, fodder, and tree crops, and in animal husbandry systems, could be profitable for upland farmers and make a substantial overall contribution to soil conservation and improvement. Adaptive research, extension, and flexible credit services will hasten the adoption of new practices. Given the heterogeneity of Java's upland agriculture, appropriate technical and institutional inputs must be tailored to each distinct environment. This will require greater decentralization in programming than has been typical of Indonesian farm development efforts in the past.

The economics of pest management should be a priority topic in future research on specialty crops. The potential consequences of pesticide residues in water and food systems deserve investigation at the level of both farmer and consumer. Policy decisions to decrease or eliminate present pesticide subsidies would have a disproportionate impact on commercial producers of vegetables and fruits. If economic and environmental considerations dictate that pesticide use be reduced in specialty crop farming, research programs must develop alternative methods that lower production costs in greater proportion than any reductions in yields.

Prices and Efficiency

A developing country's food policy is typically based upon a mixture of goals concerning efficient income growth and improvements in income distribution, nutrition, and national food security (Timmer, Falcon, and Pearson, 1983). In the context of upland Java, specific policy objectives include efficiently increasing the incomes of relatively poor upland farmers and farm laborers and reducing the social costs of soil and forest depletion. Because these costs, present incomes, and potential productivity all vary among Java's upland areas, issues of efficiency and income distribution must also be viewed with respect to regional poverty and comparative advantage.

Manipulation of selected non-staple prices would be a cost-effective means of encouraging more profitable and sustainable upland farming to complement stronger programs for research, extension, and credit. Continuation of restrictive import policies for perennial fruits and animal husbandry products will spread agroforestry and forage systems. Price support or buffer stock schemes for tradable crops such as cloves and coffee would also have a positive impact on soil conservation.

As compared to policies that influence the prices of rice and chemical inputs, market interventions for non-staples will have much smaller repercussions in other sectors of the food system. Higher prices for income-elastic commodities raise upland incomes and employment, and constitute a progressive tax under which the burden, being proportional to consumption, falls largely upon upper income groups. Although inefficient in short-run partial equilibrium terms, these policies would have downstream benefits that could, in principle, be compared with the social costs of consumer-surplus losses and farm-level resource misallocation. Indeed, social profitability analyses of alternative forms of land use—including improved terraces—would be invaluable in the assessment of upland development strategies.

The greatest potential for efficient development exists in the volcanic hills which cover most of Java's uplands. Prospects are more problematic in the southern limestone areas where improper land use has already caused irreversible degradation. The downstream costs of erosion from limestone soils are presently low when compared to soil losses in upper volcanic areas. Concerns with regional income distribution would need to be weighted heavily in order to justify substantial investments in limestone regions. In these truly critical lands, the long-term solutions lie in out-migration—whether to new settlements off Java or to expanding non-farm sectors of the economy—and in stabilization of the environment at low levels of direct economic productivity.

CONCLUSION

The Indonesian government has chosen programs and policies for rural development that have greatly increased the availability of basic staple foods in rural areas. On Java, improvements in transportation and market infrastructure have contributed to an increasingly well-integrated economy. More efficient markets and lower real staple prices are facilitating greater specialization by comparative advantage in both upland and lowland agriculture. Rising consumer incomes are creating market incentives conducive to substitutions in upland farming systems that will, on balance, have positive implications for the future conservation of Java's fragile soils. Because of changes in incomes and relative prices, the Green Revolution in lowland rice farming has contributed to new incentives that reduce the necessity for a similar technological breakthrough in upland staple crop agriculture.

It would be premature, however, to conclude that the problems of resource depletion in Java's upland agriculture are being resolved in any permanent sense. Java's population will be an intractable source of pressure on land resources until well into the coming century. Various constraints—

land tenure, farm capital, farmer knowledge, perceived risk and uncertainty, and, in the poor limestone areas, agroclimate—limit the capacity of Java's farmers to respond rapidly to changing market signals.

The evolutionary scenario presented here is speculative and depends upon a continuation of recent trends into the future. Indonesia's immediate macroeconomic future is clouded by fiscal constraints imposed by declining oil export revenues. It will be difficult for the government to maintain past levels of development expenditure in rural areas. Rural wage and income growth, particularly in the non-farm sector, must at some point become self-sustaining for the upland transformation to continue.

How relevant is Java's experience for other developing countries? The uplands of Java are endowed with abundant annual rainfall and generally deep, fertile soils. With the exception of the island's southern limestone areas, there is considerable agronomic potential for increasing productivity. The large population provides a ready market for income-elastic commodities that are of growing importance in upland farming. Java's experience should be quite relevant to countries where conditions of agroclimatic and market potential are similar. Policy makers concerned with the development of more fragile lands can learn much from Java's southern hillsides about the long-run consequences of severe resource depletion.

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Appendix Table 1.—Production of Principal Vegetables and Fruits, Total Indonesia and Java, 1976 to 1984–85
(1,000 metric tons)

	Potatoes		Cabbages		Red peppers		Onions		Tomatoes	
Year	Total	Java	Total	Java	Total	Java	Total	Java	Total	Java
1976	127	129	250	207	267	130	185	127	64	31
1977	248	203	265	176	215	123	171	102	115	31
1978	233	175	346	249	216	128	201	130	117	68
1979	204	148	330	245	220	113	219	160	98	44
1980	230	169	323	222	208	124	218	138	101	40
1981	217	135	349	224	217	115	176	95	109	46
1982	180	99	388	182	191	86	201	82	109	41
1983	217	175	412	259	292	208	378	184	173	23
1984	372	292	584	478	314	192	209	194	138	62

	Cucumbers		Carrots		Eggplant		String beans		Shallots	
Year	Total	Java	Total	Java	Total	Java	Total	Java	Total	Java
1976	139	86	20	8	110	57	26	13	50	29
1977	152	69	15	9	109	54	27	14	54	34
1978	170	76	46	43	120	54	31	17	80	52
1979	168	84	37	31	131	57	39	19	71	48
1980	175	87	43	38	140	54	48	22	76	53
1981	152	85	55	50	135	56	50	23	79	51
1982	169	72	41	45	112	49	56	24	76	41
1983	219	98	34	47	198	69	74	32	89	41
1984	220	116	54	45	139	68	83	43	108	77

Year	Bananas Total	Bananas Java	Citrus Total	Citrus Java	Papayas Total	Papayas Java	Mangoes Total	Mangoes Java	Pineapples Total	Pineapples Java
1976	2,262	666	143	70	223	125	426	140	113	16
1977	1,752	922	210	82	244	135	344	186	154	16
1978	1,378	808	220	76	220	133	164	88	151	12
1979	1,622	925	188	49	264	170	333	242	259	84
1980	1,977	963	311	90	315	202	325	211	181	27
1981	2,058	1,218	466	143	323	206	309	164	214	71
1982	2,036	1,131	342	111	289	127	423	256	306	152
1983	2,320	1,075	540	115	353	135	473	298	494	150
1984	1,992	1,153	539	103	269	136	442	223	475	214
1985	n.a.	1,066	n.a.	145	n.a.	142	n.a.	242	n.a.	138

Source: Central Bureau of Statistics, Jakarta. Figures for Java are from *Production of Vegetable Crops on Java and Madura* and *Production of Fruits on Java and Madura*, various years. Estimated Indonesian totals taken from *Food Balance Sheets for Indonesia*, various years, which use off-Java production estimates made by the Department of Agriculture. Because these sources differ, the totals for Java are occasionally larger than those for Indonesia.

Appendix Table 2.—Changes in Legume and Non-Staple Prices Relative to Farm-Level Prices of Rice, Cassava, and Corn in East Java, 1976 to 1984
(*Average annual percent change with respect to staple price*)

	Rice		Cassava		Corn	
Crop	Coeff.	R^2	Coeff.	R^2	Coeff.	R^2
Legumes						
Peanuts	2.5	.58[a]	2.7	.19	5.7	.69[a]
Soybeans	2.2	.50[a]	2.4	.21	5.4	.81[a]
Vegetables						
Potatoes	−0.5	.02	−0.3	.01	2.7	.35[a]
Cabbages	11.0	.85[a]	11.2	.84[a]	14.2	.86[a]
Red peppers	5.1	.70[a]	5.3	.58[a]	8.3	.92[a]
Tomatoes	8.8	.41[a]	9.0	.31	12.0	.51[a]
Green beans	4.9	.60[a]	5.1	.36[a]	8.1	.67[a]
Long beans	2.5	.38[a]	2.7	.15	5.7	.61[a]
Carrots	−2.3	.20	−2.1	.53[a]	0.9	.05
Cucumbers	0.7	.02	0.8	.01	3.8	.32
Spinach	−3.4	.84[a]	−3.3	.26	−0.2	.00
Eggplant	−1.4	.07	−1.3	.02	1.7	.06
Fruits						
Bananas	5.0	.93[a]	5.2	.58[a]	8.2	.86[a]
Papayas	3.0	.85[a]	3.1	.31	6.2	.76[a]
Pineapple	−7.5	.67[a]	−7.3	.76[a]	−4.3	.45[a]
Oranges	7.5	.61[a]	7.7	.68[a]	10.7	.75[a]
Mangoes	11.9	.84[a]	12.0	.73[a]	15.1	.86[a]
Guavas	0.2	.01	0.4	.01	3.4	.60[a]
Apples	1.8	.50[a]	1.9	.12	5.0	.79[a]
Avocadoes	0.9	.05	1.1	.06	4.1	.74[a]
Sapodilla plums	11.5	.86[a]	11.7	.71[a]	14.7	.84[a]
Meat and dairy						
Beef	1.8	.14	1.9	.14	4.9	.58[a]
Chicken	0.8	.06	0.9	.04	4.0	.57[a]
Hen's eggs	−0.6	.13	−0.4	.01	2.6	.46[a]
Milk powder	0.2	.01	0.3	.00	3.4	.49[a]
Canned milk	−0.7	.31	−0.6	.01	2.4	.48[a]
Estate crops						
Coffee	−2.1	.10	−2.0	.05	1.0	.02
Cloves	1.2	.01	1.4	.02	4.4	.12
Coconuts	2.4	.08	2.5	.05	5.6	.26

Source: Price data for apples, pineapples, and avocadoes are from the Directorate General of Food Crops, Surabaya, for the retail level in the district capital markets of East Java. Clove prices are from the Directorate General of Estates in Surabaya. Prices used for meat and dairy products are from the Central Bureau of Statistics for the retail level in the rural markets of East Java. All other figures are based upon farm-level price data from the CBS. Average annual percentage changes are coefficients derived from semi-log regressions.

[a]Equation statistically significant at the .05 level.

Appendix Table 3.—Trends in the Real Profitability of Staple Crops on Java, 1972–83/84*
(Average annual percent change)

Crop	Yield	Price	Total value	Labor costs[a]	Other costs[b]	Total costs	Profit[c]
Irrigated rice	4.5	−3.4	1.1	4.7	1.8	3.7	−0.1
R^2	.94[d]	.84[d]	.29[d]	.57[d]	.26[d]	.57[d]	.00
Upland rice	4.3	−3.7	0.6	3.7	−0.3	2.4	−0.2
R^2	.94[d]	.73[d]	.08	.38[d]	.01	.35[d]	.01
Corn	4.7	−2.6	2.0	2.2	1.0	1.6	2.2
R^2	.99[d]	.46[d]	.33[d]	.15	.08	.15	.21
Cassava	2.8	−2.5	0.3	0.7	3.0	1.5	0.0
R^2	.83[d]	.22	.00	.01	.18	.04	.00
Peanuts	2.5	1.4	3.9	1.1	3.5	2.5	4.7
R^2	.77[d]	.08	.37[d]	.02	.42[d]	.19	.28[d]
Soybeans	1.8	0.5	2.3	2.6	1.0	1.8	2.4
R^2	.70[d]	.05	.45[d]	.21	.10	.18	.27[d]

Sources: Central Bureau of Statistics, various years, *Survey Pertanian* (Agricultural Survey), Jakarta. Prices, costs, and output values deflated by the CBS price index of 9 basic consumer goods in the rural markets of Java and Madura (1971= 100).

*Estimated with semi-log regressions. All trends for 1972–83 except rice, 1972–84.

[a]Real wages paid to hired labor (per hectare), with cash values imputed for crop shares paid at time of harvest. Does not include value of farmer's own labor.

[b]Real cash or imputed costs per hectare for seed, fertilizer, pesticides, oxen plowing, implements, taxes, and irrigation and other fees. Does not include actual or imputed costs of land.

[c]Real net returns per hectare to land, family labor, and management (i.e., total real value of output less total real cash costs).

[d]Equation statistically significant at the .05 level.

Appendix Table 4.—Estimates of Costs and Returns to Staple and Non-Staple Crop Production*
(*1,000 thousand rupiahs per hectare*)

Crop	Growing season (months)	Labor use[a] (days)	Seed costs	Fertilizer use[b] Chemical (kg)	Fertilizer use[b] Organic (tons)	Pesticide costs	Productivity (tons)	Gross return	Net income[c]
Irrigated paddy	4	250–350	9	200–400	0.5–2.0	low	3.5–6.0	525–900	200–450
Irrigated sugarcane	16	500–670	175	850	n.a.	none	90–114	2,050–3,150	1,450–2,230
Rainfed paddy[d]	4	175–200	8	100–200	1.4–3.5	low	1.0–2.5	150–375	<200
Rainfed corn[e]	3–4	75–150	4	75–250	0–0.2	none or low	0.9–1.5	120–210	<150
Rainfed cassava[e]	8–11	160–300	0	0–450	0–5.5	none	7–25	210–750	<260
Legumes[f]	3–4	85–175	30–40	0–100	0	2–5	0.3–1.2	165–550	<250
Rainfed inter-cropped staples[g]	n.a.	385–550	20–60	125–250	1.4–3.5	none or low	n.a.	475–710	150–420
Vegetables[h]	3–5	500–1,170	80–625	800–1,800	2–6	35–420	5–36	2,750–12,900	2,070–11,200
Fruits I[i]	perennial	135–210	n.a.	750–1,500	5–16	high	7–40	1,800–6,000	900–2,000
Fruits II[j]	perennial	530–1,900	n.a.	800–2,200	5–25	high	8–40+	6,300–16,000	1,000–4,500
Estate crops[k]	perennial	100–200	low	100–710	0–16	none or low	0.1–0.8	300–1,000	200–850

Source: Data compiled from farmer interviews in twelve East Java villages during 1984–85, and from various production surveys conducted by other authors during the 1980s. Detailed list of sources available upon request.

*Figures indicate reported ranges of costs and returns from monoculture stands except where noted below. Joint costs in intercropped stands have been allocated in proportion to each crop's contribution to the total value of output. n.a. = not applicable or data not available.

[a]Male and female labor combined; working day of about five hours.

[b]Chemical fertilizers include urea, TSP, ammonium sulphate, NPK, and KCL.

[c]Approximate return to land and management per crop or, for perennials, per year. 1984–85 prices used. Cash costs and the value of family labor at local wage rates deducted from gross output value. 1985 exchange rate was about Rp (rupiahs) 1,100 = US$1.

[d]Often intercropped with annuals.

[e]Primarily monoculture.

[f]Include soybeans and peanuts, primarily monoculture, both irrigated and rainfed.

[g]Include rainfed paddy, corn, cassava, and legumes planted over an 8–11 month growing season.

[h]Primarily rainfed monoculture and intercropped stands of varieties which include garlic, red peppers, carrots, potatoes, cabbage, tomatoes, red onions, shallots, and radishes.

[i]Papayas, pineapples, and oranges intercropped with annuals.

[j]Orchards of apples, grapes, and mangoes.

[k]Coffee and cloves intercropped with annuals.