A SUSTAINABLE UPLAND FARMING SYSTEM FOR INDONESIA

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ABSTRACT

This paper discusses the agricultural development of slopelands in Indonesia. Food production in such areas tends to be a high-input, high-risk activity. Current research is focussing on integrated farming systems based on tree crops and livestock, with only enough food production to meet local needs. Soil and water conservation are emphasized, and slopes are stabilized by bench terraces bordered by grasses and legumes, and by alley cropping with fast-growing legume trees.

INTRODUCTION

Most lowland agriculture in Indonesian is irrigated, while upland agriculture is predominantly rainfed. One of the major accomplishments in agricultural development during the last decade has been the achievement of self-sufficiency in rice, the staple food, since 1984. This success has been achieved through a massive intensification program for lowland rice, concentrated in areas with a good irrigation system, while intensification in rainfed uplands has begun only recently.

Upland areas play a very important role as watersheds in the conservation of water resources and the maintenance of a stable ecosystem. Proper management of upland areas is therefore a key issue in the successful utilization of land resources in Indonesia. The most common problems encountered in upland farming are erosion and water shortage, low soil fertility and productivity, and lack of sufficient production factors such as good seeds and credit.

An integrated farming systems approach has been developed for the sustained improvement of productivity. This is based, not on the upland production of food crops, which tends to be a high-input high-risk activity, but an integrated farming system based on perennial crops and livestock, in which food production is limited to that needed for local consumption.

BACKGROUND

Indonesia consists of four large islands and thousands of small ones. More than half of the total land area is either swampy or very steep (slope > 15%), and therefore unsuitable for agricultural development.

In Indonesia's tropical environment, where precipitation ranges from 1500 to more than 3000 mm/year, often falling within a few months of the year, traditional techniques are generally poor in conserving soil and water. As a result, productivity falls in the uplands themselves, while material washing down into the lowlands causes sedimentation and disruption of water regimes. This disruption of the ecosystem threatens investment into infrastructure, especially irrigation systems, water reservoirs and hydroelectric facilities and roads, as well as industrial and domestic water supplies and coastal estuaries important as fishing grounds. The problem is of such dimensions that unless corrective measures are taken, the productivity of agricultural areas in both uplands and lowlands is likely to be seriously impaired within a few decades.

In Java, with its very high population density, increasing areas of hilly upland are being brought under cultivation, often using inappropriate farming practices which reduce agricultural productivity.

The outer islands still have relatively sparse populations, and it has been estimated that approximately 47.1 million ha are available as new agricultural land (with slopes of 0-3%, 3-8%, and 8-15%). In addition, 15-20 million ha are potentially suitable for the cultivation of tree crops or estate crops.

Generally the fertility of upland soils in the outer islands is low. This is because these soils mostly developed under humid tropical conditions from acid sedimentary rocks. As well as being acid, the soils are deficient in phosphorus, potassium, calcium and magnesium. The organic matter content and soil CEC are generally low, and the aluminum and manganese contents are often so high that they are toxic to plants, and have a high rate of P fixation. Some soil properties of Podzolic soils in Sumatera are presented in Table 1. The main physical constraints are the low available water holding capacity, and the susceptibility of these soils to erosion.

Such soils should be considered marginal for growing food crops (annual crops) under traditional agricultural systems, but are still suitable for tree crops or estate crops and pasture development. Mixed farming, including silvipasture (a tree crop-food crop-pasture system), is a possible alternative for upland farms.

Farmers dependent on upland agriculture represent approximately 70% of the total farm population of Indonesia, and constitute the poorest strata of the rural population.

THE FARMING SYSTEMS APPROACH

A farming systems research program has been developed in order to solve the problems of upland agriculture. This is producing alternative technologies for managing uplands. These consist of a package of technology which generally contains five components: soil and water conservation and management; cropping systems (food crops, fodder); livestock; tree crops; and an economic evaluation. Inland fisheries are another important component of the farming system in some areas. The aim in both the outer islands and the upper watershed of Java is sustained agricultural development which is economically viable and environmentally sound. A combination of annual and perennial crops is very important part of this approach.

Table 1. Characteristics of the red-yellow Podzolic soils In Sumatera, Indonesia

Soil characteristics	Location					
	Lampung		South Sumatera		West Sumatera	
	Nakau	WayAbung	Baturaja	Palembang	Sitiung	Jambi
Clay %	72	28	46	38	67	24
Organic (%)	1.00	1.36	2.64	1.45	2.34	1.74
Available P (ppm)	0.5	-	2	3.3	8.1	5.8
pH (H_2O)	4.9	4.0	4.8	4.4	4.7	4.4
Cations (meq/100g soil)						
Ca	1.9	1.2	1.4	0.5	0.7	0.7
Mg	0.4	0.4	0.6	0.3	0.3	0.4
K	0.1	0.1	0.1	0.2	0.2	0.1
A1 + H	1.0	1.4	5.2	3.0	3.3	2.3
CEC	3.5	3.2	7.5	4.0	4.6	3.5
Acid saturation (%)	31	43	70	75	72	66

Source: CSAR, Indonesia

Table 2. Effect of alley mulching applied to an Oxisol on soil physical properties and organic matter content, and on yield of food crops, in Jambi, West Sumatera

Legume tree	Bulk density (g/cm3)	Water content (%)	Organic matter (%)		Agregate stability (%)	Biomas production (mt/ha)	Yield (mt/ha)		
			C	N			Maize	Rice	Soybean
Leucaena	1.2	12.5	2.63	0.18	95.1	6.09	1.78	0.57	0.57
F. congesta	1.1	14.6	2.85	0.20	142.3	25.80	2.54	0.64	0.66
Caliandra	1.1	13.6	2.73	0.16	76.2	22.79	1.65	0.47	0.68
Control	1.3	11.3	1.31	0.07	40.5	–	1.78	0.43	0.41

Source: Suwardjo *et al.* 1987

Table 3. Effect of alley cropping system on erosion and run-off in Ungaran, Central Java

Legume tree planted in alley	Erosion (mt soil/ha)	run-off (m^3/ha)	Biomass production (mt/ha/year)
Flemingia C.	0.08	116.59	26.25
Tephrosia	11.86	672.58	13.55
Caliandra	7.04	673.60	28.61
Control	63.98	1424.43	–

Source: Umi Haryati *et al.* 1991

RESULTS OF THE FARMING SYSTEM RESEARCH

Soil Fertility Management

Nutrient Management

Of the major nutrient problems encountered in upland farming, phosphorus deficiency is the main constraint, followed by potassium deficiency. Fertilizer efficiency is low, due to the high rates of phosphorus fixation and the rapid leaching of nitrogen and potassium. The application of organic matter, in the form of composted manure and crop residues, increases the efficiency of applied chemical fertilizers.

Soil Acidity and Liming

Soil acidity is a major constraint in most upland soils, because of aluminum toxicity. Lime can be used to overcome this constraint, while tolerance to aluminum saturation varies depending on the kind of crop. Upland crop rotation systems should consider lime applications for the most acid sensitive crops.

Management of Organic Matter

One of the major problems in cultivating acid upland soils is the reduction in soil productivity as a result of the decline in soil organic matter. This decline is more rapid if all crop residues are removed or burned, as is often practiced by farmers. Soil is a *living system* which converts all fertilizers applied into available as well as non-available forms for plants. The key factor in this process is soil organic matter, which acts as a *biological buffer* to maintain a balanced supply of available nutrients for the plant roots. The addition and management of organic matter improves the growth environment of the plant and increases the benefits of fertilizer use (Tables 2, 3 and 4). Soils which are poor in organic matter lose their buffering capacity, and fertilizer efficiency de-

Table 4. Effect of mulching and tillage on the yield of food crops (on Oxisols and Ultisols), Jambi, Sumatera

Slope (%)	Treatment	Yield (mt/ha) Wet season: Corn	Wet season: Rice	Dry season: Peanut	Dry season: Corn
Oxisol					
< 8%	FO	0.55	0.68	0.35	1.37
	F1	1.36	0.80	0.82	1.58
> 8%	FO	0.93	0.53	0.86	1.00
	F1	1.15	0.85	0.97	1.05
Ultisol					
< 8%	FO	1.31	0.52	0.77	1.87
	F1	1.64	0.57	0.82	1.98
> 8%	FO	2.29	0.36	0.77	1.74
	F1	2.68	0.68	0.81	2.64

FO = Full tillage without mulching F1 = Minimum tillage + mulching *(F. congesta)*
Cropping pattern: maize + rice – peanut – maize

Source: Suwardjo *et al.* 1987

Table 5. The effect of raised bed terraces edged with grass on soil erosion in upland Central Java

Treatment	Rate of soil erosion (mt/ha/year)
Bench terrace edged with *Setaria* and *B. ruziziensis*	21.42
Bench terrace edged with *Setaria* and *C. pubescens*	34.22
Control	105.73

Source: UACP Annual Report, 1988/1989

creases.

Not only the direct application of organic matter, but the cultivation of fast-growing legume trees as a hedgerow or as an alley crop are effective in increasing soil organic matter. Legume trees also help control erosion (Tables 3 and 5).

Soil Conservation and Erosion Control

Acid upland soils are highly susceptible to erosion. The loss of topsoil from erosion and run-off, as well as soil compaction from mechanized land clearance, are the main causes of declining soil productivity in acid upland soils. Trials have been conducted in many parts of Indonesia to find the most appropriate methods of controlling erosion and improving soil physical properties. Research results showed that:

- Mulching with cut branches of legume trees such as *Flemengia congesta*, grown in a hedgerow or as an alley crop, in combination with minimum tillage on flat and sloping terrain, gives much better results than full tillage without mulching (Table 4).
- Contour strips using a combination of grass and legumes control erosion more effectively than strips planted in grass alone.
- Bench terraces or raised bed terraces edged with grass and protected by a mulch of cut grass or cut legume leaves and branches were effective in controlling erosion (Tables 5 and 6).
- High inputs in combination with mulching effectively reduce run-off and soil loss (Fig. 1).

Soil conservation practices of this kind – mulching with legumes, terraces with grass edges, and alley cropping or row cropping of legumes — must have first priority in any upland farming system (Fig. 2).

Cropping System

The basic idea of a cropping system based on soil conservation is that the canopy should cover the soil surface as much as possible, to reduce the force of falling raindrops and the rate of run-off and soil loss. It should also be able to produce high yields. Among the cropping systems tested, a combination of cereals and legumes (e.g. maize + soybean – maize + peanut – cow pea (mung bean)) proved to be the best. This type of system gave good yields in terms of calories, protein, cash income, and crop residues which could be used as mulch or fodder (Table 7).

However, a great deal of experience as well as experimental evidence indicates that food crop production in upland areas is a high-risk activity which needs a high level of inputs to overcome the physical constraints, including a lot of labor. Even so, production is low and unstable because of the biotic constraints (pests and diseases) and climatic factors. It is nearly impossible for subsistence farmers to overcome these constraints without assistance and subsidies from the government.

The solution seems to be an integrated farming system for upland areas, in which perennial crops are the main commodity, while the food crop component is only enough to satisfy the needs of the farm family or village community.

This type of integrated farming system, based on the maximum utilization of land resources and solar radiation, is being tested in several sites in Indonesia. It includes five components (Figs. 3 and 4).

Table 6. Effect of raised bed terraces on soybean yield and rate of erosion on Oxisols, Jambi, Sumatera

Interval between terraces	Yield (mt/ha)					Erosion (mt/ha/year)				
	T1	T2	T3	T4	Mean	T1	T2	T3	T4	Mean
3-8%										
No mulch	0.50	0.61	0.61	0.45	0.54	4.4	3.8	3.2	5.0	4.1
With mulch	0.66	0.98	1.14	0.70	0.87	3.7	2.9	2.4	3.6	3.2
8-15%										
No mulch	0.40	0.43	0.54	0.39	0.44	10.1	5.6	4.5	6.2	6.6
With mulch	0.57	1.01	1.04	0.69	0.83	4.5	3.2	3.2	3.8	3.7

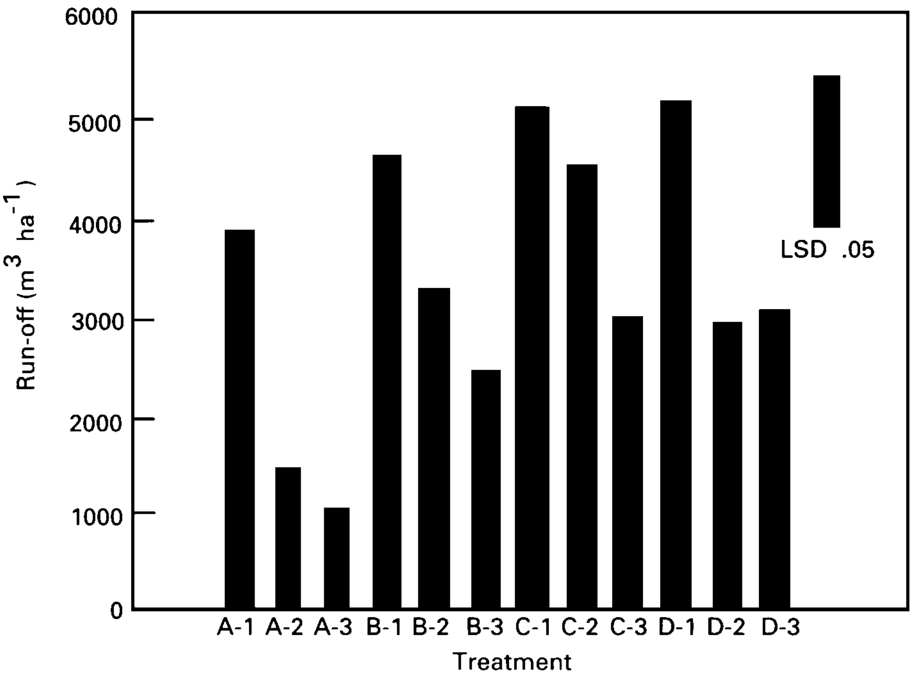
T1: Interval between terraces: 75 cm
T2: Interval between terraces: 100 cm
T3: Interval between terraces: 125 cm
T4: Interval between terraces: 150 cm

Source: Suwardjo *et al.* 1987

Table 7. Comparison of yield in terms of calories, protein and income per hectare of two cropping systems on slopeland in Jambi, Sumatera

	Yield/ha		
	Calories (mt)	Protein (kg/ha)	Income (US$)
A	10,211.0	389.6	464.4
B	13,654.8	597.8	568.3

A: Maize + rice – Maize + soybean – Mungbean
B: Maize + soybean – maize + peanut – mungbean



A-1 Alley cropping, mulching. No chemical inputs
A-2 Alley cropping, mulching. Low chemical inputs
A-3 Alley cropping, mulching. High chemical inputs

B-1 Cover, mulching. No chemical inputs
B-2 Cover, mulching. Low chemical inputs
B-3 Cover, mulching. High chemical inputs

C-1 Residues incorporated. No chemical inputs
C-2 Residues incorporated. Low chemical inputs
C-3 Residues incorporated. High chemical inputs

D-1 Residues burnt. No chemical inputs
D-2 Residues burnt. Low chemical inputs
D-3 Residues burnt. High chemical inputs

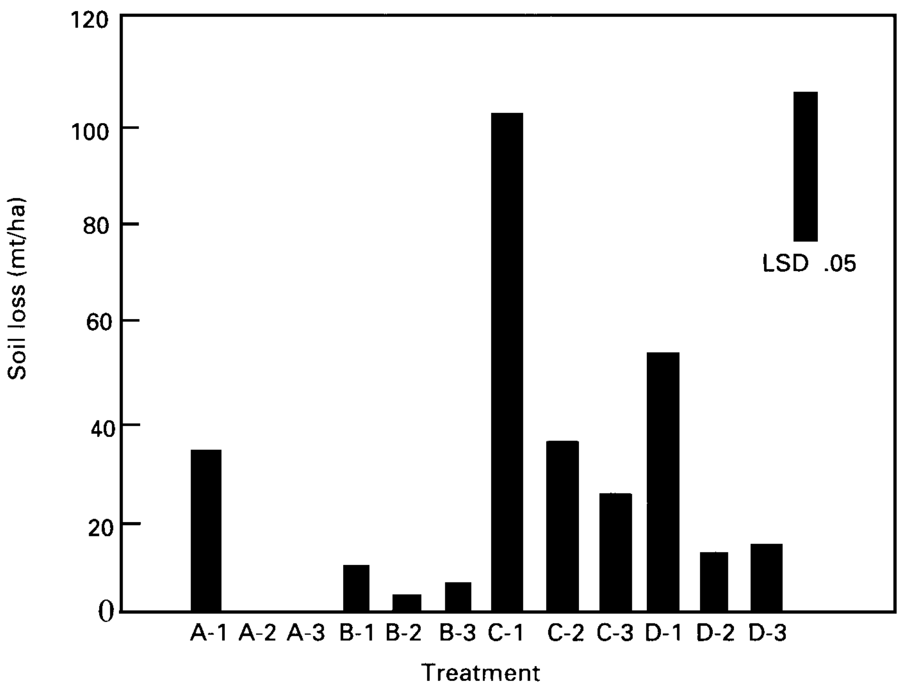


Fig. 1. Total runoff and total soil losses from different treatments on red-yellow Podzolic Soils, Jambi, Sumatera, Indonesia
Source: CSAR, Asialand Network, Indonesia Progress Report 2, 1991, IBSRAM

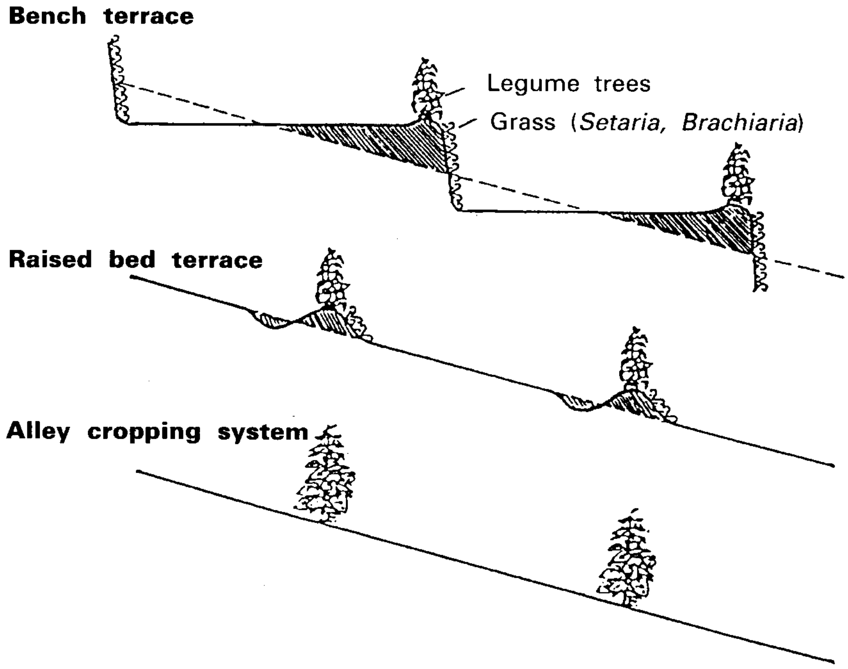


Fig. 2. Conservation methods used in upland farming, Indonesia

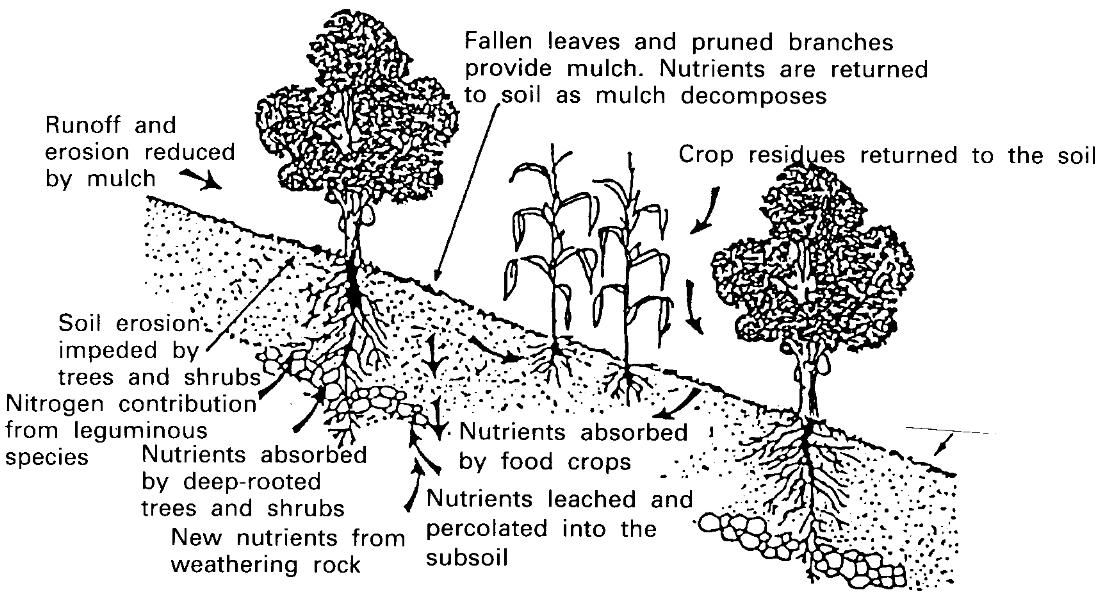


Fig. 2a. The concept of alley cropping

Source: B.T. Kang *et al.* 1986

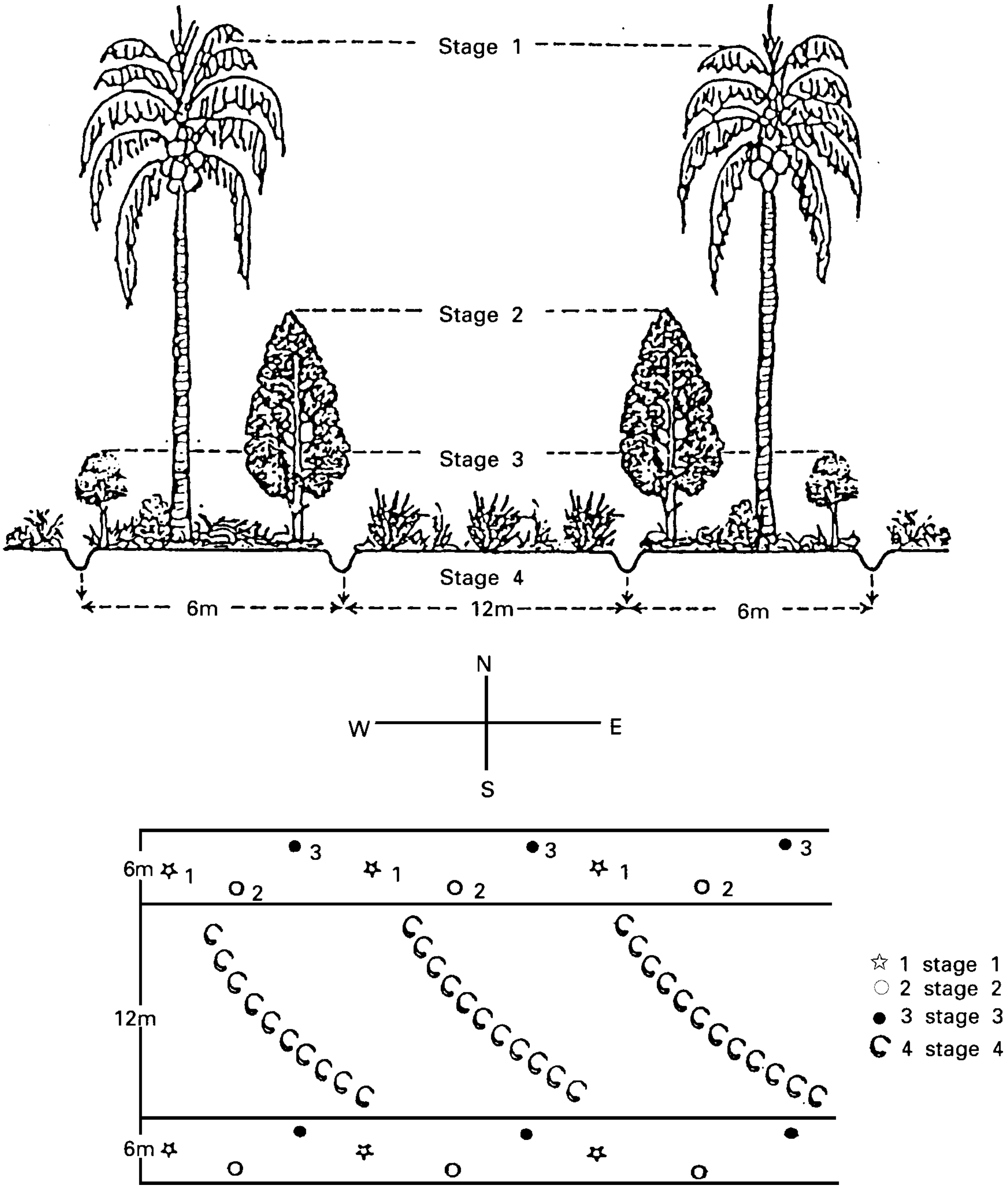


Fig. 3. Integrated conservation farming system for flat to gently sloping uplands

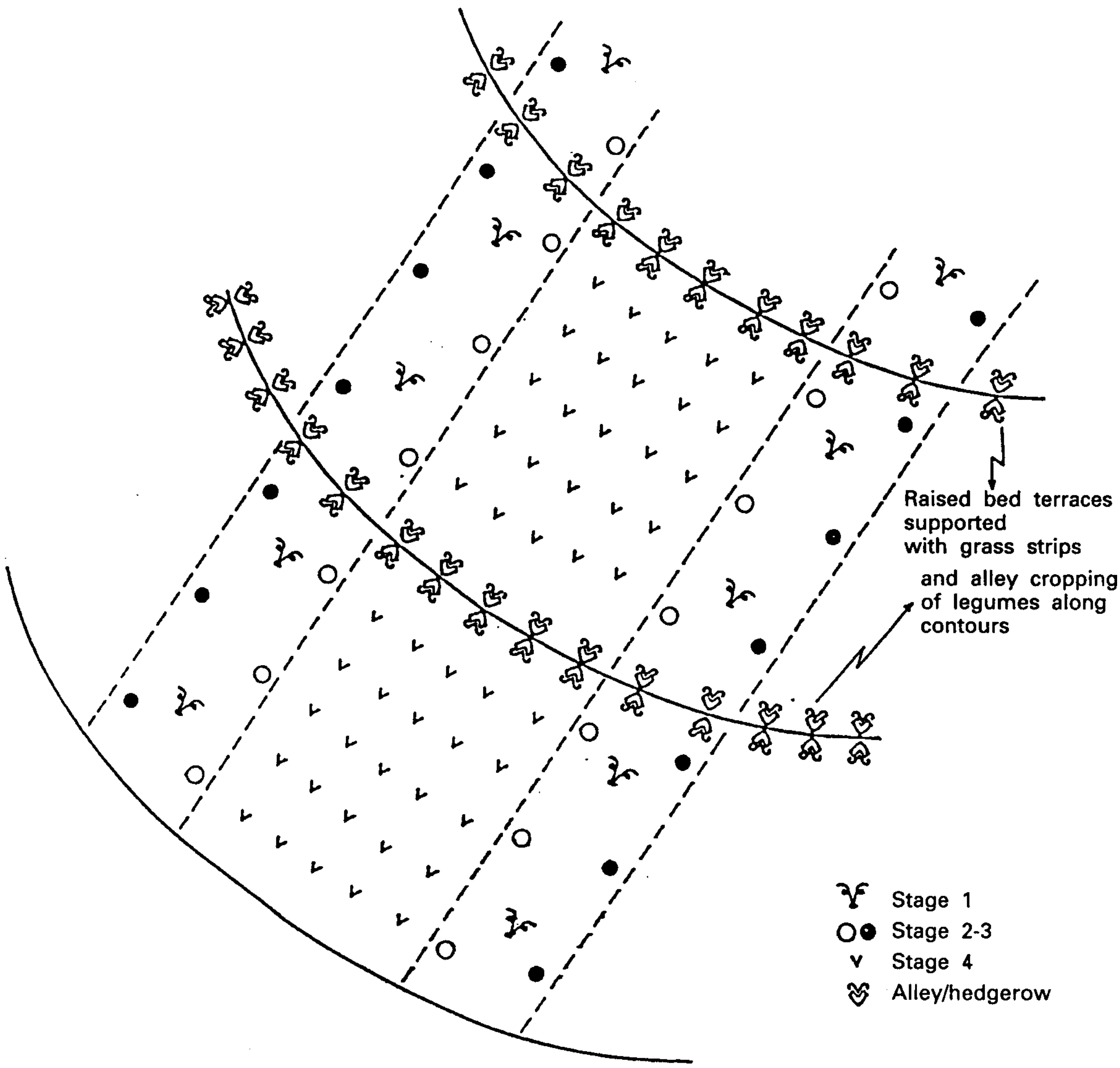


Fig. 4. Integrated farming system for slopelands

Tree Crops

Tree crops are planted in rows running east-west. Different types of tree are planted in sequence, to avoid shading and to maximize the utilization of solar radiation.

1st stage : Coconut, oilpalm, durian, petai.
2nd stage : Clove, cinnamon, nutmeg, jackfruit.
3rd stage : Banana, orange, pineapple, root crops, medicinal herbs, spices.

Food and Forage Crops

Food and forage crops are planted during the 4th stage. By this time, some of the soil physical constraints have been alleviated, while there is good erosion control. The management of food crops includes proper crop rotation and the utilization of crop residues.

Livestock

This component is very important in an integrated farming system. Raising livestock helps maintain soil productivity by recycling organic matter, while the grass planted on the edges of terraces for fodder helps control erosion. Livestock also represent capital investment, and an additional source of income and draft power for the farmer.

Management of Organic Matter

Organic matter plays a very important role in sustaining soil productivity. Hence the crop residues, animal wastes, cut biomass of hedgerow crops and cover crops should be managed properly, to increase soil productivity.

Fisheries

Fisheries are included if the soil and topography make it possible to construct a pond to catch run-off in the rainy season. This pond also serves as a water source for irrigation and other purposes.

SOCIO-ECONOMIC ANALYSIS

Food Crops

Food crops are a key component in the upland farming system, to provide a secure food supply for the farm family. Economic analysis indicated that the adoption of a high level of inputs (fertilizers, lime etc.) depends on the cost-benefit ratio and market opportunities. However, in general a medium level of inputs, including fertilizers, is necessary.

The adoption of alley cropping by upland farmers is gradually increasing. This has a high production of biomass for use as fodder or for mulching, which in turn increases soil productivity. The twigs and branches can also be used as fuel.

Terracing

With regard to terracing, in general bench terraces are preferable to raised bed terraces. There is less erosion and fertilizer loss with bench terraces, and they are more convenient to build and manage. Economic analysis indicated that terracing increases net benefits by more than five times, compared to the control treatment (Table 8).

Tree Crops

The selection of tree crops depends on the land potential, farmer preferences, and marketing prospects for the product. Both coconut and banana offer good potential at present.

Credit

Subsidies and credit are needed at the early stages, especially for conservation practices such as the establishment of terraces and hedgerows and for purchased production factors such as seed and fertilizer.

CONCLUSION

The intensifive agricultural production which was so successful in Indonesia's irrigated lowlands, making it possible for the country to achieve self-sufficiency in rice, does not give comparable results in upland areas. Erosion resulting from poor soil management has lowered the productivity of upland areas, and threatens the lowlands with sedimentation and other damage to irrigation and road systems. The Indonesian government is now promoting integrated farming based on perennial crops and livestock, in which food production is limited to that needed for local consumption. Upland slopes used for agriculture are stabilized by terraces held by grasses and legumes, which not only

Table 8. Economic analysis of the third year of the integrated farming system in Blitar, East Java

	Farmers' current practices	Integrated farming system (annuals, perennials and livestock)	
		Bench terraces	Raised bed terraces
1. Gross income (US$/ha/year)	269.2	1021.9	792.0
2. Total costs (US$/ha/year)	161.1	274.2	217.5
3. Net income (US$/ha/year)	108.1	747.7	575.5

control erosion but also provide fodder for cattle and small ruminants. Fast-growing legume trees planted in hedgerows or as an alley crop are also a useful source of fodder, and provide soil nutrients and protection from erosion, especially if the cut branches and leaves are used as a green mulch. Government support is needed during the early years when terraces are being built and trees planted, but eventually an integrated upland farming system of this kind gives a profit five times higher than conventional upland farming. The complete system gives the farm family food security and an eventual cash income, using minimal purchased inputs and conserving soil and water resources.

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DISCUSSION

In the discussion after the paper presentation, a Korean soil scientist, Dr. C.W. Hong, who has worked for several years in Ghana, pointed out that in tropical upland farming there is often a big gap between what is agronomically desirable and what the farmer can in practice carry out with his available resources. While the farming methods currently being used by African farmers are often damaging to the environment, for the farmer to change these required funding which he does not have. Terracing is one example of this: farmers without outside support are not able to cover the cost. He suggested that if farmers are to develop from subsistence agriculture with low yields to more productive methods, they need both cash crops and access to markets where they can sell them. He emphasized that agriculture takes place in the context of a global economy. The poor farmer cannot cover the cost of sustainable agriculture which protects the environment, and rich countries are not yet willing to cover the cost of the necessary changes.