11 Smallholder Options for Reclaiming and Using *Imperata cylindrica* L. (Alang-Alang) Grasslands in Indonesia

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The Alternatives to Slash and Burn (ASB) program in Indonesia aims to identify options for slowing down deforestation and promoting the rehabilitation of degraded (formerly forested) areas (van Noordwijk et al. 1997). Many previously forested areas have seen a trajectory of forest degradation similar to that shown in figure 1.1a, with a phase of low-use degraded land and a rehabilitation process. This macro process of degradation and rehabilitation may resemble the plot-level decline and restoration of productivity in a shifting cultivation cycle but is driven by more complex processes of migrating farmers, changing tenure and resource access of farmers, broader-scale landscape- or village-level control over free-ranging fires (Wibowo et al. 1997), and market-driven economic incentives. This chapter addresses technical issues associated with smallholder rehabilitation of grasslands derived from forest degradation at the ASB benchmark site in Pakuan Ratu (in the northern part of Lampung province) in Sumatra, Indonesia (see figure 13.1 later in this volume), which was chosen as representative of the vast area under *Imperata cylindrica* and related coarse grasses in Asia (approximately 35 million ha) and Indonesia (8.5 million ha) (Garrity et al. 1997). Although increasing the rate of rehabilitation of these grasslands does not necessarily slow down the rate of deforestation at the frontier, rehabilitated areas can offer an alternative attraction point for migrants.

Efforts to reclaim *Imperata* grassland areas and put them to intensive agricultural use where shifting cultivation is practiced have been debated in

Indonesia since at least the 1930s (Hagreis 1931; Danhof 1941). A common prescription was large-scale reforestation, possibly with international financial support via projects aiming to increase carbon sequestration (Drajat 1991; Tjitrosemito and Soerjani 1991). However, there is remarkably little evidence of economies of scale in reforestation (Tomich et al. 1997), and smallholder agroforestry may provide a socially, economically, and environmentally superior option.

From the history of past successful transitions of *Imperata* grasslands into densely inhabited agroforestry land use mosaics (Foresta and Michon 1997; Potter 1997), we can conclude that four conditions must be met for such reclamation to occur as a spontaneous, farmer-led process:

- A sense of security of tenure over the trees planted, if not the land itself
- Effective village-level institutions for controlling free-ranging fires
- Local farmer knowledge of agroforestry techniques and access to germplasm that can effectuate the transformation and address the often low fertility of the soils (Santoso et al. 1997)
- Physical and economic access to markets for the products of the land, leading to adequate profitability

The research results reported here focus on the third of these requirements and more specifically on technical requirements for shade-based control of *Imperata* in developing agroforestry systems.

LAND USE PATTERNS IN THE RESEARCH SITE

One of the ASB benchmark sites in Indonesia is located in Pakuan Ratu subdistrict of northern Lampung, Sumatra, at the lower reaches of the Tulang Bawang River. This area was chosen to represent the rehabilitation phase of land use change and represents a situation in which conflicts over land did not (at the time of the survey) override other concerns because the area is not (or is no longer) considered to be state forest land. Three groups of farmers (Lampungese in villages along the rivers, transmigrants moved by the government from forest reserves in southern and central Lampung, and spontaneous migrant settlers) interact with large agroindustrial estates (sugar cane [*Saccharum officinarum* L.], cassava [*Manihot esculenta* Crantz], and fast-growing timber). However, after the “Reformasi” change in Indonesian government in 1998 serious conflicts emerged between Lampungese and the state sugar cane plantation, leading to a de facto closure of roads, loss of off-farm labor opportunity, and general hardship in the transmigration villages. Forest cover was lost rapidly after logging in the early 1970s, followed by government-sponsored conversion of the land to transmigration or plantation sites. Around the transmigration villages the landscape degraded rapidly as the initial soil fertility inherited from the forest was used, and large areas became dominated by *Imperata* fallows, alternating with cassava.

Transmigration programs started in 1905 in southern Lampung (Djojoprapto 1995) and—in combination with an influx of spontaneous migrants—have transformed Lampung into the most densely populated Indonesian province outside Java (174 people/km^2 in 1993), with the lowest remaining forest cover; hardly any state forest land outside national parks still had full forest cover in the late 1980s (van Noordwijk et al. 1995). Northern Lampung was the last frontier in the lowland peneplain and was used in the early 1980s to resettle spontaneous migrants from Java or Javanese born in transmigration settlements in Lampung from the fertile coffee belt in the hills, to protect the water supply to irrigation schemes (in the Way Sekampung, Way Seputih, and Tulang Bawang watersheds). These farmers were moved to Pakuan Ratu, the poorest subdistrict in Lampung and, in fact, in Sumatra as a whole (except for some of the adjacent islands), with thirty-nine of its forty-one villages classified as poor. The ASB benchmark area is largely in the Pakuan Ratu subdistrict, with Negeri Besar as the largest and oldest Lampungese settlement on the river. However, a traveler's report from 1920 had already commented on the degraded forests close to the Tulang Bawang River, linked partly to the demand for railway sleepers for the Bandar Lampung–Palembang railway construction (van Noordwijk et al. 1995).

The typical pattern in transmigration sites in the early 1980s was as follows: After clearing the forest by slash-and-burn, transmigrant farmers planted food crops in the first few years. When the fertility of the land declined by the fourth year, they shifted to off-farm activities such as daily wage labor or driving on the nearby sugar cane plantation (PG Bunga Mayang), in the remaining logging concession and forest timber company (Industrial Timber Plantation Company, or HTI), or in illegal logging operations. Only farmers who had land that could be transformed into paddy rice (*Oryza sativa* L.) could make a living from agriculture (Elmhirst 1996). The opening of cassava processing plants (PT Bumi Waras) made it worthwhile to continue farming on the acid upland soils, in what became an *Imperata*–cassava rotation, but cassava prices fluctuated, partly under the influence of European Union quotas for imports of tapioca as fodder. With declining fertility and more and more fires in the landscape, the area that was abandoned to *Imperata* increased.

By the late 1980s the sugar cane plantation started an "outgrowers" scheme, stimulating farmers to form groups (Petani Tebu Rakyat Intensifikasi) and providing credit for plowing, fertilizer, and cane planting, to be paid back through the cane harvest in the first 3 years. Although at some stage smallholder cane under this program almost equaled the area under sugar cane managed by the plantation company (and thus compensated for the overcapacity of the factory given the declining productivity of the plantation itself), relations between the plantation and farmers turned sour (Elmhirst et al. 1998) when the results for the farmers' fields were less than expected (for numerous reasons, including logistics of fertilizer delivery and transport at harvest time), and farmers could not pay back their credits. After this sugar cane phase, land was again abandoned to *Imperata* or reused for cassava, benefiting from good farmgate prices and possibly from the residual fertility of fertilizer used in the sugar cane.

The agility of the farmers' adaptations to changing income opportunities did not stop there. The transmigrant and spontaneous migrant farmers continued to struggle to transform the *Imperata* land into a productive resource, gradually clearing it manually (hoeing), plowing it by using draft animals (after a government program introduced cattle to the villages) or hired tractors, or applying herbicides, if they had the capital to do so. The farmers have tried to get tree crops started, with oil palm, fast-growing timber species (such as *Acacia mangium* Willd. and *Paraserianthes falcataria* [L.] Nielsen), and rubber as the main options. Doing so is risky because future markets for the timber are not clear, and marketing of oil palm to remote factories has been erratic because it depends on a reliable road network. Rubber became a serious option for farmers when road transport improved (especially that on the east–west axis, complementing the north–south access via the sugar cane plantation), and a new bridge provided contact with rubber-growing areas to the east of the benchmark area, around Manggala. In the ASB benchmark area, rubber planting gained importance in the villages of Panaragan, Karangsakti, and Karang Mulya, spreading from the village of Negeri Ujungkarang, where the Dinas Perkebunan (tree crop advisory service) established a nursery. Planting material is also bought from farmers in Madukoro, Negara Ratu, or Kotabumi, but village-level nurseries are now emerging. Farmers chose rubber because latex can give continuous income once the trees are tapped and can be marketed through various channels, wood of the rubber trees is valuable, and investment and maintenance costs are less than those for oil palm. Meanwhile, farmers in Batu Raja, Negara Batin, and villages further along the road to the Pakuan Ratu subdistrict office viewed oil palm as their main way out of poverty. They chose oil palm because it has a good market and can regrow after burning and drought, whereas rubber and timber trees are lost in *Imperata* fires.

Pepper and coffee have good prospects, too, and are the preferred option for the Lampungese farmers, who occupy the slightly better soils along the river (Van Noordwijk et al. 1996b). Transmigrant farmers chose this option only in the villages of Gedung Nyapah and Tulung Buyut. Coffee and black pepper have a good market, and their local price increased during the recent monetary crisis.

PREVIOUS EXPERIMENTS ON SHADE-BASED CONTROL

In 1992, an on-farm experiment was begun by the Biological Management of Soil Fertility Project to plant trees in *Imperata* grassland as a low-cost method of shading out the grass (van Noordwijk et al. 1992, 1997). Two tree species—the fire-tolerant local *Peltophorum dasyrrachis* Kurz and a common legume *Gliricidia sepium* (Jacq.) Kunth ex Walp.—were planted in *Imperata* grasslands strips 4 m apart. After 1 year, the trees reduced the vigor of the *Imperata* but not sufficiently for reclamation. In the second year, tree canopy development continued, but it was still not enough to eliminate the *Imperata*. Tree growth showed wide variability, and only in the patches where *Peltophorum* grew best was *Imperata* controlled after 2 years. In the exceptionally dry season of the El Niño year 1994, fires (a perennial concern; see Bagnall-Oakeley et al., 1997) reached the plot from an adjacent area and provided a true test of fire tolerance. All trees of both species resprouted after the fire, and the experiment continued with food crops, pruned hedgerows, and spot applications of herbicides to control *Imperata*. The experiment thus showed that shade-based control of *Imperata* grass is not easily achieved and raised questions about the intensity and duration of shade needed to do so (MacDicken et al. 1997). Further work was clearly needed.

Research Questions

Given that farmers in the ASB benchmark area had (at the time of the experiment, before the Reformasi period) reasonably secure access to land and were located near well-performing markets, and given the potential profitability of tree crops, we addressed the following specific issues:

- Which techniques are used by the farmers to convert the *Imperata* grasslands, and why?
- How can the developing agroforestry systems suppress *Imperata* regrowth and avoid the fire risks at an intermediate age (Bagnall-Oakeley et al. 1997); more specifically, how long and intense a shade is needed for adequate control (MacDicken et al. 1997).

The second research question was split into three parts: How much light can still penetrate to ground level in young rubber, oil palm, pepper–coffee, and timber production systems; for how many years can farmers still interplant food crops between the tree rows in these systems; and how does a well-established *Imperata* stand respond to shade of different intensities and duration.

MATERIAL AND METHODS

Four research activities were undertaken to address these issues: a farm household survey of reclamation methods, field measurements of light intensity at ground level in selected agroforestry systems, an experiment aimed at defining the intensity and duration of shade needed for *Imperata* control, and in-depth interviews on the management practices in four smallholder agroforestry systems in the area.

Farmer Household Survey

A survey on farmer management options for converting and using *Imperata* grassland was conducted in an area extending beyond the ASB benchmark area and including villages in the Pakuan Ratu, North Sungkai, and South Sungkai subdistricts of North Lampung district (the district has since been subdivided and the study area now belongs partly to Way Kanan district). The survey was carried out in July 1997 and again in August 1998 and focused on the details of various management strategies and the costs associated with each. Total sample size was fifty intensive household interviews.

Field Measurements of Sunlight Below Agroforestry Systems

On fifty farms, selected to cover the full spectrum of land use practices and a range of ages, light intensity and *Imperata* biomass were measured. On twenty locations per plot, relative light intensity (vis-à-vis full sunlight, measured using a photosynthetically active radiation sensor) was measured halfway between trees in the plant row and between rows. Tree diameter at 1.3 m above ground (diameter at breast height) was also measured. For oil palm plants, height was recorded instead of stem diameter. Biomass of *Imperata* grass was collected from 1-m^2 sampling areas. Results were averaged over the twenty sample points for each site for the current analysis.

Artificial Shading Experiment

An experiment to quantify the response of well-established *Imperata* stands to shade of different intensities and duration was begun at the Biological Management of Soil Fertility Research Station (van Noordwijk et al. 1996a) in November 1995, with four levels of artificial shade in a randomized block design with four replicates. The experiment was monitored to measure (at monthly intervals) the decline of standing *Imperata* biomass under different shade conditions and to measure *Imperata*'s ability to regrow from rhizomes after a ground-level cut after 0 to 7 months at each level of shading.

RESEARCH RESULTS

Farmer Household Survey

Farmers reported several techniques for clearing *Imperata* grasslands (figure 11.1) and selected one or more of the following depending on the availability of labor and cash and the crop to be planted after clearing.

The techniques range from manual slashing of the grass followed by hoeing, to application of systemic herbicides followed by plowing and sometimes preceded by burning, to plowing with animal or mechanical traction, usually after burning the

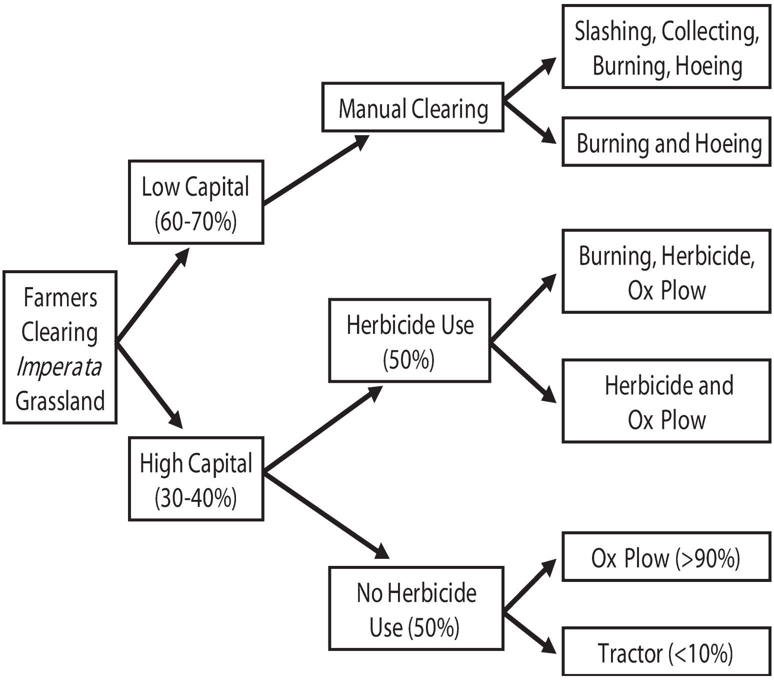

Figure 11.1 Summary of *Imperata* land clearing methods and the percentage of farmers in the survey who used the various methods.

Imperata above-ground biomass to make work easier. Before clearing by almost any method, thatch can be manually collected from *Imperata* areas and used for roofing.

Cash-poor farmers (60–70 percent of respondents) rely on hoeing with family labor and can clear only a quarter to half a hectare per family per year, in the dry season (July–October). If labor were paid, this method would be very expensive. Land cleared in this way generally was used for planting food crops such as upland rice (*Oryza sativa* L.), maize (*Zea mays* L.), or soybean (*Glycine max* [L.] Merr.). Farmers mentioned that they prefer shallow soil tillage to deeper plowing because this keeps the dark top 15 to 20 cm of soil (the “soil meat”) intact and avoids the iron-rich aggregates (locally called *crocos*) found below that depth and brought to the surface by plowing.

Farmers who can afford it prefer to use herbicides unless they have animal draft power available. Application rates ranged from 2 to 5 L/ha of one of the commercially available brands of glyphosate, often mixing more than one type. Herbicide normally was sprayed on young regrowth of *Imperata* 2 to 3 weeks after slashing or burning the standing biomass; 20 to 25 mL of herbicide is diluted in 15 L of water in a knapsack sprayer. According to the farmers, systemic herbicides remained effective for about 6 months, after which farmers commonly sprayed again, twice if the *Imperata* was not dense. The first spraying covered the entire area, and the second spraying covered only patches that remained green after 14 days; at least 5 L of herbicide was needed per hectare to achieve adequate control. Herbicide use without tillage was the preferred method of *Imperata* clearing before planting of rubber, oil palm, or timber trees; land dedicated to food crops needed plowing.

Farmers owning or having easy access to draft animals used them to convert *Imperata* grasslands. Plowing with draft animals normally is done in the dry season, when the *Imperata* rhizomes brought to the surface dry up easily, but sometimes (in 10 to 15 percent of interviewed cases) plowing extends into the early rainy season, when the soil is easier to work. Plowing in the early rains is preferred when the *Imperata* vegetation is not very dense and land is flat (on slopes manual hoeing is normal). Cattle were introduced into the area in about 1985 under a government loan scheme, benefiting transmigrants who were familiar with animal traction, rather than Lampungese farmers. Actually, farmers prefer animal drawn plows to tractors because the quality of work is good and no subsoil is brought to the surface, and they have seen what happens in tractor plowing at the sugar cane plantation. If the *Imperata* stand is dense, the early activities consist of a week of slashing, collecting, burning, and plowing per 0.25 ha or 3 to 4 days of burning and continued plowing per 0.25 ha. Normally a second tillage operation is needed once the rhizomes brought to the soil surface have dried off. Tractor-powered plows are used to clear *Imperata* land if the farmer intends to plant sugar cane or cassava; this technique became popular in the 1990s when the sugar cane factory started its outgrower scheme. In both Negara Jaya and Negara Tulang Bawang villages, a local (Lampungese) farmer has bought a tractor and started contract operations. Plowing mixes the soil to a depth of 50 cm, so most farmers perceive that soil fertility decreases because they see *crocos* appear on the top layer, to which they attribute in part the failure of the sugar cane outgrower scheme.

Of the several ways of converting *Imperata* grassland, which were the most cost effective? Table 11.1 reports the results of the farm household survey of conversion costs. The first column presents the main input used in conversion: labor, chemicals,

Table 11.1 Costs of *Imperata* Grassland Clearing, by Clearing Method, 1998 and 1999

Primary Input Used	**Details of Clearing Method**	**Total Cost per Hectare (Rp000)**	
		1998	**1999**
Manual labor[a]	Burning–hoeing or slashing–collecting–burning–hoeing	740–960	1500–1680
Herbicide	Herbicide only	104–260	90–225
	Burning–herbicide–plowing or slashing–herbicide–plowing	464–696	590–935
Animal traction	Plowing, burning–plowing, or slashing–collecting–plowing	360–540	500–800
Tractor	Plowing	160–200	350–400

[a] Mostly unpaid family labor. Average wage rate of labor in the survey area was Rp5200 in 1998 and Rp6400 in 1999.

animal traction, and tractors. The second column provides some details of the ranges of activities involved in clearing *Imperata* grassland. The final two columns of table 11.1 present ranges of cost estimates for each general type of grassland clearing practice; cost estimates are provided for 1998 and for 1999 separately to highlight the effects of changes in relative prices that occurred over that time period on conversion costs.

In 1998, clearing *Imperata* grassland using tractor-drawn plows was cheapest (costing Rp160,000 to Rp200,000 per hectare). Using herbicides alone to clear land was a bit more expensive, costing Rp104,000 to Rp260,000. Using animal traction to clear *Imperata* grassland cost more than twice the per-hectare rate of tractors, and manually clearing was by far the most expensive.

In 1999, however, changes in fuel and other prices dramatically increased the cost of tractor use (to a range of Rp350,000 to Rp400,000 per hectare), thereby making herbicide use alone the most cost-effective way of clearing *Imperata* grasslands. The cost advantage of tractors and herbicides over manual clearing techniques and those involving animal traction remained despite price changes over the 1998 to 1999 period.

Artificial Shade Control Experiment

The shade intensity experiment showed that even if light levels are reduced to about 10 percent of full sunlight, an established *Imperata* stand will only gradually decline; a 55 percent shade for up to 8 months had little effect (figure 11.2). Hence shade alone probably could not be relied on to reduce *Imperata* grasslands.

Regrowth after removing all above-ground biomass (figure 11.3) was more affected by shading than standing biomass, but a 55 percent shade, which would be considered problematic for most food crops, had no effect on the ability of *Imperata* rhizomes to resprout. Only when an 88 percent shade was applied for more than 2 months, did the ability of rhizomes to resprout decline to a negligible level. Further analysis of the physiological backgrounds of these effects is under way.

Light Intensities Below Agroforestry Systems

These results for artificial shade were compared with results of the survey of *Imperata* occurrence and light intensity under a range of agroforestry systems (figure 11.4). A statistically significant relationship was found between light levels below the tree canopy and *Imperata* biomass. *Imperata* biomass decreased drastically when a relative light intensity of 10 to 20 percent was reached (figure 11.4). When more than 20 percent of sunlight reaches the ground, *Imperata* still has a chance in these agroforestry systems.

The various tree and plantation crops differ in the age and tree basal area they need to achieve this control target of 10 to 20 percent. Light intensity reduces more

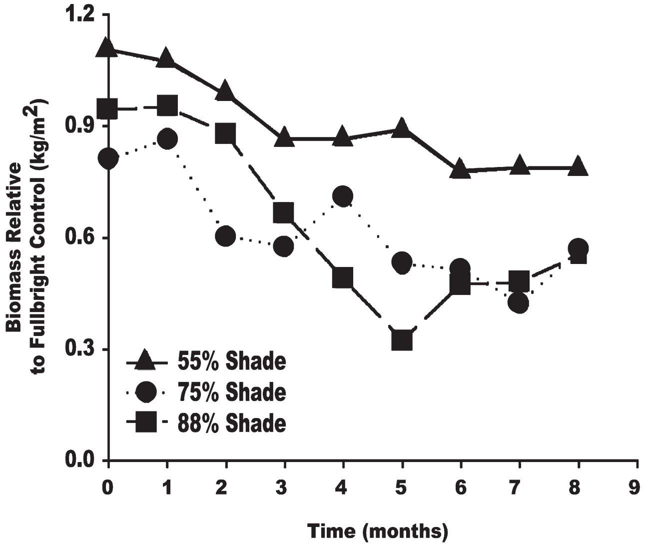

Figure 11.2 Above-ground biomass of artificially shaded *Imperata* grassland plots relative to that of unshaded control plots in the same experiment.

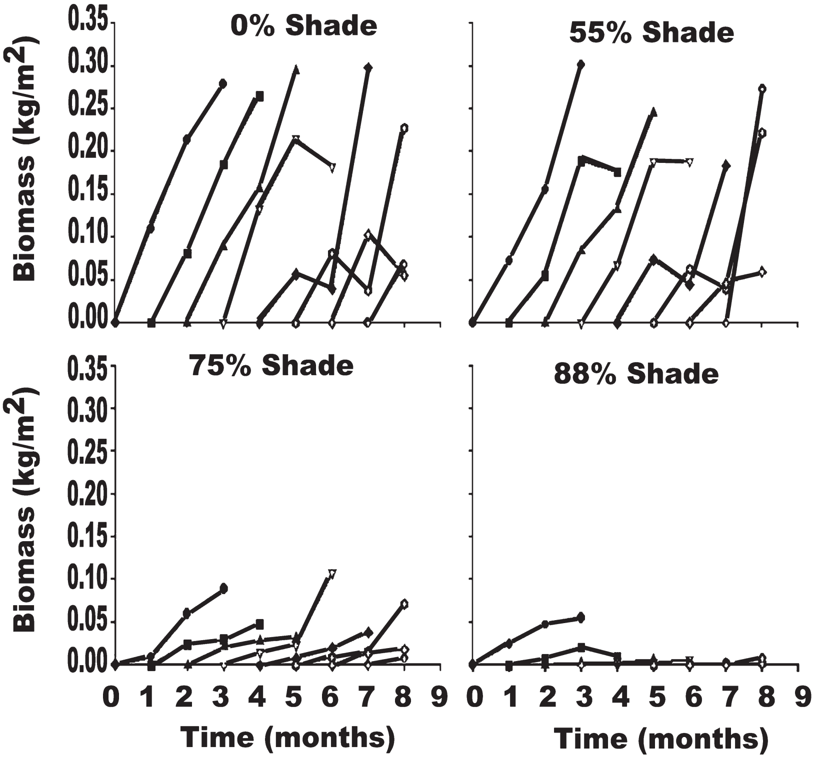

Figure 11.3 Regrowth of *Imperata* plots after a ground-level cut, made after 0–7 mo of exposure to an artificial shade of 0–88%. The symbols distinguish the number of months of artificial shade received before cutting.

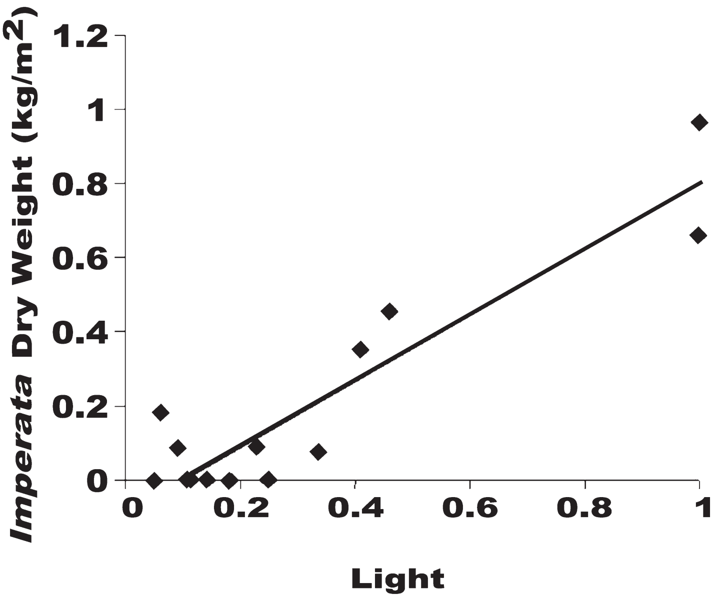

Figure 11.4 Relationship between *Imperata* biomass and relative light intensity (taking full sunlight as 1) in a survey of smallholder agroforestry systems that include coffee and pepper systems, rubber, oil palm, *Paraserianthes falcataria,* and *Acacia mangium* Willd. block planting.

quickly for a given stem basal area in rubber and *Acacia mangium* systems than in pepper agroforestry (using *Gliricidia sepium* and other trees as support and shade trees) and *Paraserianthes falcataria* (sengon) (figure 11.5).

SYNTHESIS: SMALLHOLDER AGROFORESTRY OPTIONS FOR CONVERSION OF *IMPERATA* GRASSLANDS

Because high degrees of shading were shown to reduce *Imperata* biomass and control regrowth, the next step was to identify agroforestry systems that could provide such shade and that would be attractive to smallholders. Four existing systems were evaluated in discussions with farmers.

The first system was based on fast-growing timber trees that became popular in the study area as a result of planting of *Acacia mangium* and *Paraserianthes falcataria* by the Industrial Timber Plantation Company in the early 1990s; both the technology and part of the seedlings became used outside their plantation area. Numerous farmers, stimulated by one of the village heads, started to spray the *Imperata* and plant *Paraserianthes falcataria* at a distance of 2 × 2 or 2 × 2.5 m^2 or at 2 × 4 m^2 when intended for intercropping with food crops (upland rice in year 1, cassava in years 2–4) for more than a year. Canopy closure of *Paraserianthes* is slow, so the farmers deemed weeding or plowing between rows after harvesting the food crops necessary.

In plantations that were 5 to 8 years old the light intensity at the soil surface still reached 18 to 28 percent of full sunlight, and *Imperata* remained a problem (Tjitrosemito and Soerjani 1991). Some farmers abandoned the plantation, and secondary vegetation regenerated with tree species such as *Schima wallichii* (D.C.) Korth., *Dillenia* sp., *Peltophorum dassyrachys,* shrubs such as *Chromolaena odorata* (L.) R.M. King and H. Robinson, *Melastoma* sp. or *Mimosa* sp., and grasses such as *Setaria* sp. replacing the *Imperata.* The stands remain sensitive to fire, though, and tree performance was poorer than expected. The long dry season of 1997 showed that *Paraserianthes* is suited only for the wetter sites at the bottom of slopes. *Acacia mangium* planted at a spacing of 2 × 4 m^2 (1250 trees/ha) reduced light at ground level to 10 percent of full sunlight 4 years after planting at a stem basal area of 23 m^2/ha, which is adequate for *Imperata* control.

The second system was based on rubber trees planted at a spacing of 3.3 × 6 m^2 or 4 × 5 m^2 (500 trees/ha) and took an average of 7 years before stem basal area was 10 m^2/ha and light levels at ground level were reduced below 20 percent of full sunlight. Farmers usually plant maize or cassava between the rubber tree rows in years 1 to 3. Although cassava, which belongs to the Euphorbiaceae, the same family as rubber, is considered capable of transferring soilborne diseases to rubber trees, farmers preferred it as an intercrop because of its minimal maintenance needs and its ability to provide income. After year 3, however, the transition described by Bagnall-Oakeley et al. (1997) occurred; the system provided too much shade for food crop production and too little for *Imperata* control.

The third agroforestry system evaluated was smallholder oil palm, which was only recently introduced into the benchmark site. Farmers considered oil palm a good option because it regrew after burns and appeared less affected by drought than rubber or sengon. Oil palm agronomists emphasize negative drought impacts on palm fruit production up to a year after a drought, whereas rubber tapping can resume quickly if trees survive weather or fire shocks. Farmers in the survey planted oil palm at an 8 × 9 m^2 spacing (138 plants/ha), which leaves ample area for *Imperata* growth. Farmers generally cultivated maize or rice between oil palm rows during the first few years. In some instances, smallholders with little land were allowed to grow food crops between the oil palms of richer farmers because food crops are deemed less competitive with the oil palm than *Imperata* would have been. However, as is the case for rubber, the 2- to 5-year period between the time food crop production ceased and the palm canopy effectively cut off sunlight is long enough to allow *Imperata* to become reestablished. Indeed, a stand of oil palm 10 m high still allowed about 15 percent of full sunlight to penetrate to ground level; this is sufficient sunlight for *Imperata* growth.

Lastly, pepper (*Piper nigrum* L.) and coffee agroforestry systems are found on the better soils west of the ASB benchmark area in Pakuan Ratu. Farmers start these systems by planting *Gliricidia sepium* or *Erythrina orientalis* Murray as shade and support trees at a spacing of 2 × 2 m^2. Rice, maize, or other food crops are grown for 1 or 2 years, after which coffee is planted in the middle of the 4-m^2 spaces between shade trees, and pepper vines are planted at the stem base of the shade and support trees.

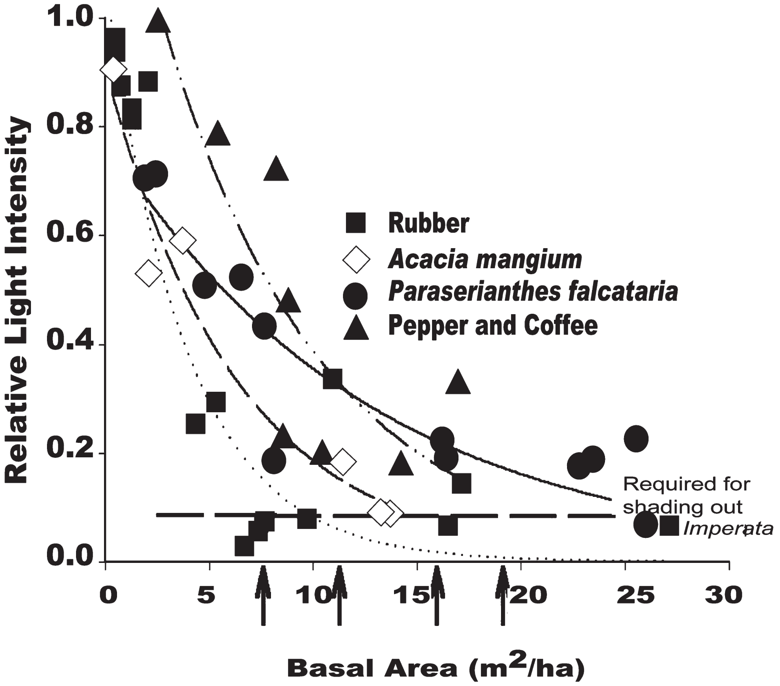

Figure 11.5 Relationship between tree basal area and relative light intensity (taking full sunlight as 1) in a survey of smallholder agroforestry systems that include coffee and pepper systems, rubber, *Paraserianthes falcataria,* and *Acacia mangium* Willd. block planting; the line at a relative light intensity of 0.15 indicates the target for full control (compare figure 11.4).

Fruit trees such as *Parkia speciosa* Hassk, *Pithecellobium dulce* (Roxb.) Bentham, *Durio zibethinus* Murray, *Lansium domesticum* Corr., and *Ceiba pentandra* (L.) Gaertn. are mixed between the stands, often especially as boundary markers for the field. When these plantations are 4 years old (stem basal area 5 cm^2/m^2), light intensity at ground level may still be 45 to 50 percent because the shade trees are pruned for the benefit of the pepper and coffee. In an 8- to 10-year-old plantation (stem basal area of 10 cm^2/m^2) light intensity at ground level was 20 percent of full sunlight, again sufficient for *Imperata* growth.

DISCUSSION AND CONCLUSION

Imperata cylindrica (alang-alang) grasslands occupy large areas of Southeast Asia and are viewed both as a consequence of failed rural development strategies and as an opportunity for expanding agricultural production in areas with diminished forest resources. However, reducing *Imperata* grassland area and controlling regrowth will not be easy and may be beyond the reach of cash-poor smallholders who need immediate returns to labor.

The first steps in controlling *Imperata* in the agroforestation of grasslands can be achieved by either mechanical or chemical control, and farmers use a range of techniques, depending on their resources and current prices. Food crops are used in the first few years of most tree crop or agroforestry systems to maintain income and provide a low-cost (from the tree crop perspective) *Imperata* control option. However, the gap between the last food crop interplanting and canopy closure leads to a major risk of *Imperata* regrowth and fire occurrence. Targets for shade duration and intensity as estimated in the experiment cannot be easily reached in practice. Farmers in the study area have been experimenting with a range of tree crops and agroforestry systems, but results during the El Niño drought of 1997 discouraged the use of trees such as *Paraserianthes falcataria*. A wider range of tree options is needed, and information on site-by-species matching can avoid (or reduce) disappointment.

In the broader picture, results for the ASB benchmark area are encouraging for the *Imperata* grasslands elsewhere, on state forest land. Farmers will explore and exploit a range of options once they have security of tenure and can develop village level rules and controls for the use of fire. For society to reap the benefits of additional carbon storage on these former grasslands, no specific subsidies are needed once tenure policies are right, although farmers welcome technical support in finding locally suited trees. In the benchmark area, the International Center for Research in Agroforestry and its partners are now engaged in this type of on-farm experimentation.

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