Lecture Note 5

Reclamation of *Imperata* Grassland using Agroforesty

Kurniatun Hairiah, Meine van Noordwijk and Pratiknyo Purnomosidhi

INTERNATIONAL CENTRE FOR RESEARCH IN AGROFORESTRY

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Lecture note 5

RECLAMATION OF *IMPERATA* GRASSLANDS USING AGROFORESTRY

By Kurniatun Hairiah, Meine van Noordwijk and Pratiknyo Purnomosidhi

Objectives

- To illustrate options for more productive land use of *Imperata* grasslands, building on local and generic ('scientific') knowledge, and acknowledging the multiple constraints at policy, institutional, technical and economic levels
- To discuss the technical requirements for shade-based control of *Imperata* in agroforestry systems

1. Introduction

Mankind has been creating, maintaining, and converting *Imperata cylindrica* grasslands for centuries. As human population increases, and forests disappear, many believe that these grasslands are a largely under-utilised resource. In S.E. Asia *Imperata* grasslands cover an estimated 35 million ha. A more intensive use of this area can increase their contribution to the local and national economies, and enhance their environmental services. The '*Imperata* issue', however, has many aspects and naïve simple solutions do not work.

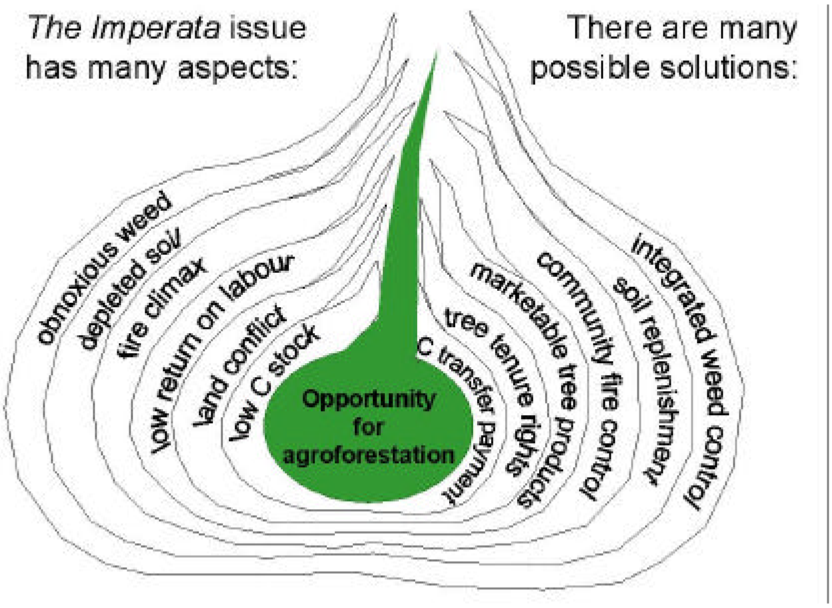


Figure 1. Understanding the 'Imperata issue' is like peeling an onion…
…every time you think you understand the constraints (left side of the onion) and identified a possible solution (right side of the onion), there's a new layer underneath
… all these layers are 'real', and should be part of a solution; together they define 'the issue'

2. Imperata grasslands and deforestation

Forests have been and continue to be opened for food crop production throughout S.E. Asia. Within a few years a substantial part of these lands can (and has) become infested with the grass *Imperata cylindrica* (‘alang-alang’, ‘cogon’, …). Farmers may then decide to move on and create new forest frontiers elsewhere, leaving the grasslands behind as under-utilised resource (Figure 2).

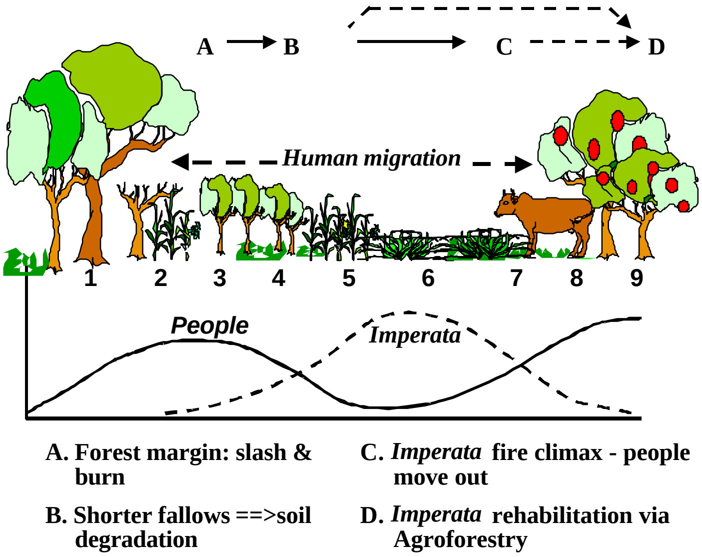


Figure 2. Schematic land use transformations from forests via *Imperata* grasslands to rehabilitated lands with various agroforestry options (Van Noordwijk, 1994); stages A & B can be characterised as ‘***more people, less forest***’, and stages C & D as ‘**more people, more trees**’.

The first issue in the context of this process of land use change is whether the initial degradation into *Imperata* can be slowed down or avoided within the context of food-crop based production systems, or only by systems with a considerable tree and/or animal component as well (ref. Lecture notes on Complex Agroforests and Indigenous Fallow Management). A second issue is how, and under which conditions, the grasslands can be reclaimed and be used more intensively.

3. How much *Imperata* area exists?

A logical first question in the ‘*Imperata* debate’, is how much area is covered. This simple question is not easy to answer, because *Imperata* may exist in quite large contiguous areas or as small patches in a vegetation mosaic with shrubs or cropped fields. Most national estimates of *Imperata* area are not based on detailed map sources but rather on quite small-scale maps (often 1:500,000 scale or smaller), due to data limitations. This leads to the exclusion of the smaller – sized *Imperata* areas, which occur at the municipal or village level, despite the fact that these are important in terms of the total area they cover. To cope with this complexity, there are four mapping scale-related categories:

- **Mega-grasslands**, often referred as ‘sheet *Imperata'* or huge *Imperata* ‘wastelands’. They are large contiguous areas of *Imperata* that would appear on small-scale maps of about 1: 1,000,000. These grasslands are large enough to span municipal or district-level boundaries. Because they are so large, the control of fire is often nearly impossible at the local level.
- **Macro-grasslands** are also large contiguous areas that encompass individual village boundaries. However, these areas are confined within a sub-district or municipality. They exhibit many of the ecological characteristics of the mega-grasslands, but may not be large enough to appear on national land-use maps.

- **Meso-grasslands** are *Imperata* areas more-or-less confined within villages. They are not large enough to be estimated except with quite large-scale maps (say 1:50,000). They are often of major local importance. Fire control is much more feasible in the meso-grasslands through regulations and monitoring at the village level.
- **Micro-grasslands** correspond to grass patches within individual fields. These patches can be managed by the individual farmer or land manager.

The country-level estimates of *Imperata* grassland area tend to refer to analyses done at a mega scale. Macro-level areas may or may not have been detected in such exercises because the map scale was not large enough. Meso and micro grassland would definitely have been excluded.

Imperata grassland in *S.E.* Asia

Based on estimations by Garrity *et al.* (1997) the area of *Imperata* grasslands in tropical Asia is presented in Table 1. Because not all data are available for all countries, the authors developed three estimates:

- A conservative estimate
- An estimate of the expected area of sheet *Imperata*
- A larger estimate that included macro and meso level *Imperata* areas that would not have been distinguishable at the mapping scales at which most of the work was done.

The 'expected' total area of *Imperata* grassland in tropical Asia is about 35 million ha, which is about 4 % of the total land area. This estimate has its uncertainty. Conservative estimates still count up to 21 million ha. The total area of *Imperata* including mega, macro and meso grasslands over all countries could be as high as almost 54 million ha.

Table 1. Estimates of the area of *Imperata* grasslands for tropical Asia by country (Garrity *et al*. 1997)

Country	**Mega-grassland area (sheet *Imperata*)**		**Total area of mega, macro and meso grasslands**	**% area of country [a]**	**Source**
	Conservative estimate	Expected			
Southeast Asia					
Indonesia	7.5	8.5	13.5	4	Soekardi *et al.* (1993)
Philippines	4.0	5.0	6.0	17	SSC (1998)
Malaysia	0.1	0.2	0.5	<1	Shim (1993)
Vietnam	1.0	3.0	5.0	9	*
Southern China [b]	1.5	3.0	5.0	2	*
Laos	0.5	1.0	2.0	4	*
Cambodia	0.1	0.2	0.3	1	*
Thailand	1.0	2.0	4.0	4	*
Myanmar	1.0	2.0	3.0	3	*
South Asia					
Bangladesh	0.1	0.3	0.5	3	*
India	3.0	8.0	12.0	3	*
Sri Lanka	1.0	1.5	2.0	23	*
Total	20.8	34.7	53.8	4	*

[a] Expected area of mega grassland as a percentage of the total area of the country
[b] Southern China (1/5 of the country)
* Estimates by Garrity *et al*. (1997)

4. The many aspects of the '*Imperata* issue'

4a. *Imperata* as an obnoxious weed: its biology and propagation

It is believed that the increasing effort needed to keep the land free of weeds as the cropping period proceeds is often the primary reason for a patch of land to be abandoned (Nye and Greenland, 1960). In West Africa farmers abandoned their infested fields not only because of the competitiveness of the weed but also because the sharp points of emerging shoots (from rhizome) can pierce the feet of humans and livestock (Terry *et al.*, 1997).

The improvement of soil fertility may help to redress weed problems. Crops are generally less efficient competitors for soil resources than weeds, and increased total nutrient supply may especially benefit the crop.

Imperata is not only an effective competitor for water and nutrients due to its extensive but often shallow root systems, but it also has allellopathic effects on crops such as maize or cucumber, due to specific substances leached from leaves and rhizomes (Eussen, 1978). Crops are less sensitive to these substances at higher N supply. Improved soil fertility may thus help to overcome these allellopathic effects, and also the negative effects at competition.

Imperata cylindrica

Figure 3. *Imperata* cylindrica (L.) Raeuschel

Plantation crops such as coconut and oil palm are particularly susceptible to *Imperata* at the early stages of development because they do not develop a sufficiently dense canopy rapidly enough to shade out the weed. Field crops such as upland rice, maize, grain legumes, and vegetable crops are also very susceptible to competition from this weed. In root and tuber crops, such as cassava and yams, loss is not from yield reduction (direct competition), but mainly from secondary fungal infections that occur when rhizomes of *Imperata* pierce the roots and tubers.

A closer look at the biology of *Imperata* may help us in understanding its success conquering such a large area.

Imperata cylindrica is a perennial rhizomatous grass. It grows in loose to compact tufts of shoots (culms) arising from tough, branched, extensive, creeping rhizomes. A typical *Imperata* plant is shown in Figure 3 with identification of the various plant parts. It propagates sexually by seed and vegetatively by the extensive rhizome system. The plant is a prolific producer of airborne seeds: up to 3,000 per plant. This enables dispersal and colonisation over long distances. Flowering is most common in the dry season. It mostly occurs after stress, such as burning, cutting or drought.

Imperata grass normally spreads by means of underground rhizomes, which proliferate in the soil giving rise to shoots at 25 to 50 cm intervals. Rhizomes fragmented by cultivation can produce new shoots and new rhizomes very rapidly. A 15 cm rhizome fragment can produce more than 350 shoots in six weeks (Anonymous, 1996).

Imperata grasslands also persist because many other species have difficulty competing with *Imperata* for water, nutrients, and light. Some species are also affected by the toxic ("allellopathic") substances produced in and leaking from *Imperata*'s roots and rhizomes.

4b. *Imperata* grasslands as depleted lands: is it the cause of soil fertility degradation or just a symptom of it?

The spread of *Imperata* is often linked to a loss of soil fertility, leading to reduced crop vigour and more chances for the grass, which competes more effectively at lower fertility levels. This is particularly true after forest or long fallow (bush) clearance, followed by a cropping practice or duration that kills most of the tree stumps and thus slows down regeneration into bush and forest. Maintaining adequate soil nutrient status is thus one of the keys for stabilising crop productivity and preventing *Imperata* encroachment.

To some extent, *Imperata* grasslands can be seen as a 'fallow' in a rotational cropping system. A major question, however, is whether it leads to any improvement of soil fertility, or merely stops further degradation. This depends on the specific function(s) of a fallow, which could be:

- mobilising nutrients from occluded forms and/or deep soil layers into organic/ available pools in the topsoil,
- reduction of specific pests and (soil borne) diseases,
- improving soil structure and soil organic matter content,
- accumulating nutrients from elsewhere (sedimentation, atmospheric dust input, N_2 fixation).

Imperata is probably not very effective in performing any of these functions, except for capturing material flowing in from higher positions in the landscape via erosion, and possible build-up of Vesicular Arbuscular (VA) mycorrhizal inoculum. Both spore density and species richness of VA fungi have been found to be high in *Imperata* grasslands, except at the most degraded sites.

People often assume that *Imperata* is the ***cause*** and not just a ***symptom*** of degradation of cleared land. This is probably not correct. On the contrary, it is fortunate that *Imperata* can grow and thrive under the adverse conditions that exist and at least provide a cover that protects the soil from erosion (Suryatna and McIntosh, 1982).

Land degradation is mainly a consequence of a cropping pattern based on food crops such as maize, upland rice or cassava that does not supply enough organic inputs to the soil and does not provide a permanent cover of the soil surface. Cassava is probably the only crop that will grow with any vigour without fertiliser inputs after three years of consecutive cropping, although its production will be reduced to a small fraction of its potential. Consequently, there is virtually no vegetation present in the early period of the rainy season and *Imperata* seeds have an ideal place to germinate. Because crop production is very low, the farmer has no incentive to weed the fields and *Imperata* becomes firmly established before the cassava is tall enough to shade the ground.

Diversification of crops and tree crops is a major way out of this degradation cycle. These crops will cover the soil surface for a longer period. Perennials such as coffee, pepper, cloves and rubber could provide the major farm income in the long run.

Imperata plays a positive role on sloping lands in reducing soil movement and surface runoff (which carries) sediment. Contour vegetative strips of *Imperata* enhance soil conservation in the case of annual cropping on open sloping fields, although they may increase re-infestation of the cropped area by rhizomes and seeds. In climates with a pronounced dry season, however, *Imperata* grassland is prone to burning, either on purpose or by accident. Regular fires followed by heavy rain result in substantial erosion. Soil organic matter (SOM) in regularly burnt *Imperata* grassland tends to decline. Without fire reasonable SOM levels are maintained, although 'quality' of the litter and the subsequent N mineralization rates are low.

4c. Imperata as climax vegetation after fire

Imperata can survive fire, because it has many growing points on its rhizomes below a soil depth of 5 cm, and fire does not increase soil temperature above a critical level below this depth. *Imperata* can thus regrow quickly after a fire event and it tends to flower and produce seed within 2 months of being burnt. This fresh seed source will spread in the neighbourhood and help the grass to colonise new patches, on land that is still open. Many other plants and trees are not so well adapted to fire and will be killed or will recover much more slowly. From the basic biology of the plant, we can understand that it survives fires and is well placed to expand if fires occur. The grass is also a good fuel, and the dry leaves that accumulate above the soil surface, especially in long dry seasons, allow a rapid spread of fires, once they are initiated.

Most fires are set by people, either as a tool or as a weapon, and there is often a link between fire and conflicts over land tenure (compare 4e).

4d. *Imperata* control as a labour problem

Imperata control is primarily a problem of labour. It is possible to clear *Imperata* grasslands manually and plant crops or trees, but this may take up to 200 man days per ha, which is far more than it takes to open a new area of secondary forest using slash and burn methods. Ruthenberg (1976) gave estimates of 200-400 hours/ha for clearing forest and 800 – 1000 hours/ha for reclaiming grasslands. *Imperata* control measures that are too labour intensive are not practicable for farmers.

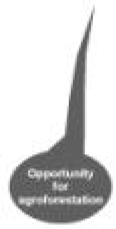
4e. Imperata grasslands as indication of conflicts over land tenure

A substantial part of the *Imperata* grasslands in S.E. Asia are found on 'state forest' lands. However there is often a big difference between a designation as 'forest' on official land use maps, and the actual land use and tree cover. A designation as 'state forest land' does not mean that there are no local claims on ownership or use rights on such lands. In the past, land classification as state land often ignored the existence or rights of local people who already cultivated that land without security of tenure. As a result, land tenure conflicts exist in almost the entire area of Indonesia and they have come to the surface in more recent years (after the 'Reformasi' period in mid-1998). Conflict areas often become unproductive grassland (*Imperata cylindrica*), very prone to fires. Smallholders in such areas have little incentive to control fires once they occur, and to stop them from spreading into areas that the government has assigned as concessions to large companies. Where the conflicts are more intense, fire is also used as weapon, including arson against large-scale plantations.

In practice the rules regulating access to state forest land do not stop people from cutting trees, destroying the vegetation, setting fire or growing food crops. However, the rules do form a constraint to farmer rehabilitation of such lands by planting trees or tree crops, as these investments require the expectation of longer-term tenure. Sufficiently strong individual land rights are essential for active tree planting by smallholders. The establishment of profitable agroforests will contribute to the wellbeing of poor farmers and to the improvement of the natural environment.

4f. Imperata grasslands have low carbon stocks

Obviously, the total C stock in soil and vegetation is much lower in an *Imperata* grassland than it is in a forest. The time-averaged C-stock (see slash-and-burn lecture note) for a cassava/*Imperata* system was about 39 Mg ha^{-1} compared to about 254 Mg ha^{-1} for a loggedover forest and 116 Mg ha^{-1} for a rubber agroforest. Substantial C sequestration can thus take place when *Imperata* grasslands are reforested, and this may help to off-set the emissions of CO_2 into the atmosphere from the use of fossil fuels, or from land cover change elsewhere.



5. Why bother to rehabilitate *Imperata* grasslands?

The most convincing reason to rehabilitate *Imperata* grassland is to make the land more **economically productive**. However, existing *Imperata* grasslands are not "wastelands." There are usually land claims and existing land uses by local people, like grazing and shifting agriculture. These uses are important to the people who depend on them, even if they don't generate much cash income. Rehabilitation of *Imperata* grasslands will be attractive to local people only if they believe that the new land use increases their production or income. Governments can support local farmers through policies and programs that reduce risks, reduce costs, and increase the profitability of agroforestry and assisted natural regeneration. Such policies and programs combine *Imperata* grassland rehabilitation with poverty alleviation.

Imperata grassland rehabilitation depends on fire control. Fire control depends upon local people. Too often, *Imperata* grassland rehabilitation projects are planned by outsiders without asking “Why?” from the perspective of the local people. If people do not agree with a project’s goals, fire will probably not be controlled and the rehabilitation will fail.

Environmental reasons alone seldom justify the conversion of grasslands. *Imperata* can be a better watershed cover than land uses that disturb the soil. If *Imperata* is not grazed or ploughed, its thick mat of rhizomes near the soil surface minimises erosion. Reforestation is very expensive to carry out over large areas; it must be justified economically as well as environmentally.

The presence of *Imperata cylindrica* in crops reduces both the crop yield and the effectiveness of use of inputs such as fertiliser. The risk of fire and consequent crop loss increases significantly. *Imperata* causes plants to become stunted and delays the start of the productive phase in perennial crops.

Example: Negative effect of *Imperata* on rubber and coconuts
Rubber:
- Annual growth reduced by more than 50 % in the first five years after transplanting.
- Start of tapping delayed by 2-4 years
- Yields are reduced during the economic lifetime of the tree
- *Imperata* rhizomes penetrate roots allowing the entry of disease-causing organisms

Coconuts:
- Inhibition of growth of roots in the topsoil
- Yellowing of leaves and poor growth
- Flowering delayed
- Number of barren inflorescences increased
- Reduction in the number of nuts per productive bunch

The control of *Imperata* has obvious benefits to the farmer, but as shown in Table 2, these benefits also have a cost. The reliance on a single control method can give other problems especially where continuous cropping is practised or where perennial tree crops such as rubber are grown.

Table 2. Benefits and costs of *Imperata* and *Imperata* control

***Imperata* NOT controlled**		***Imperata* controlled**	
Benefits	Costs	Benefits	Costs
Helps reduce soil erosion	Increased fire risk with associated crop loss	Reduced chance of fires and crop loss	Less erosion protection
Helps recycle soil nutrients	Competition for water and increased water stress under dry conditions	Water conservation	More intensive management required
Provides thatch for housing	Use of fertiliser by *Imperata*	Improved utilisation and benefits from fertiliser	Increased costs of inputs
Low grade animal fodder	Death of young crop plants and reduced crop yields	Increased crop yields	Labour required for implementation
	Delay in tree crop production	Earlier production in perennial crops	Other weeds may become a problem and require control

6. Conditions required for grassland rehabilitation

Imperata grassland rehabilitation can succeed only when four critical conditions are met (Figure 4). There are many examples of *Imperata* grasslands being rehabilitated without outside assistance when all four conditions were in place!

Farmers will do it once the conditions are right…

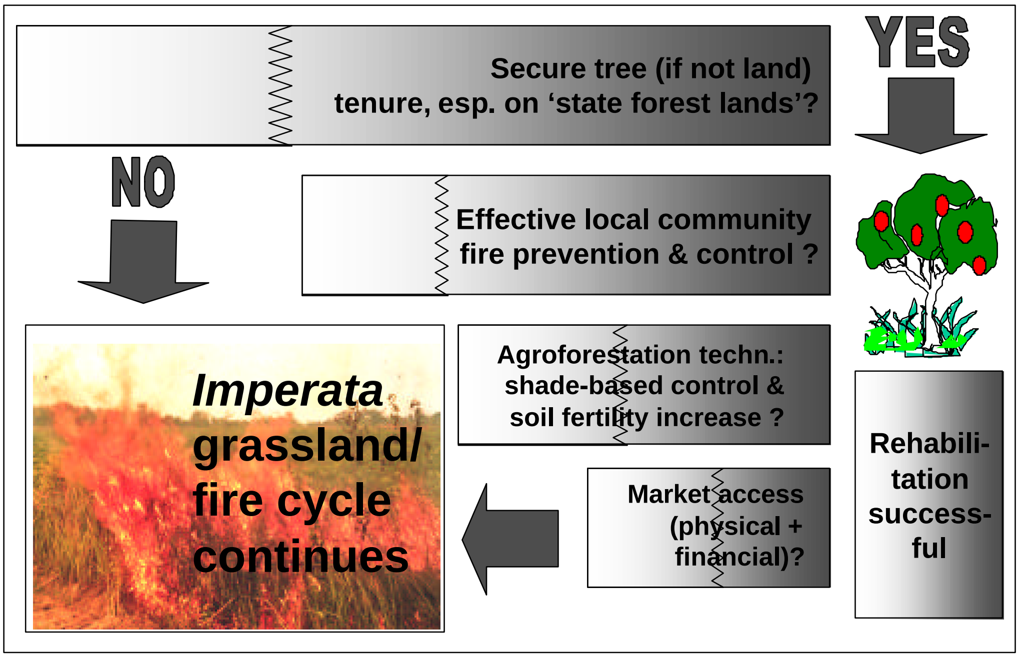


Figure 4. Farmers will take steps to rehabilitate degraded lands (including *Imperata* grasslands) if the conditions are right....

1. **People who rehabilitate *Imperata* grasslands must have clear and secure tree or land tenure**. People are directly motivated to plant and protect trees and crops, if they have clear use rights or ownership. Most *Imperata* grasslands already have local uses and local claims. Land tenure is neither clear nor secure if there is a conflict between local people who were already using the land and people trying to convert *Imperata* grasslands. Also, land use tenure is not secure if it is based on project requirements that the land user thinks are not practical or appropriate. The landholder should be free to choose land use.

2. **Local communities must co-operate in fire prevention and take the lead in fire control.** Local people are familiar with local conditions and fire risks; they are likely to be the first to know when a fire starts, and can take timely actions to extinguish fires, while they are still small. They may also have reasons to deliberately burn. They are only likely to co-operate in fire prevention if they have secure tenure and access, and would benefit from fire control.

3. **Farmers have the technical know-how and means to convert the grasslands into more profitable land use**

   Development activities may be able to help put these conditions in place by building roads, giving incentives to create markets, or providing legal tenure to local people. Extension agents may train people in fire control, or help communities improve access to markets by providing market information or organising co-operatives.

4. **Transportation and access to markets must be adequate**. Many *Imperata*-dominated areas are often remote, and remain for that very reason. Agroforestry and assisted natural regeneration will become more feasible when access is improved for implementation, protection, and marketing. Roads allow fertiliser to be brought in and products to be taken out.

7. Reclamation pathways: Existing and Potential Smallholder Practices

To control *Imperata*, it is essential to reduce the number of viable buds and prevent them from forming new aerial shoots. A continuous cropping system is often very important to prevent the establishment *Imperata* or to control it in early stages. *Imperata* is not very tolerant of shade, but will quickly germinate in the open. The main requirement of a cropping system is that it provides a closed canopy most of the time and is sufficiently dense (especially during part of the fallow period) to suppress individual *Imperata* plants (Brook, 1989).

Improving soil fertility, maximising shade, and judicious use of herbicides may be appropriate components of successful conversion of Imperata land.

7a. Use of shade as an *Imperata* control strategy

The presence of shade in increasing levels of intensity is a common function of both natural succession and most cropping systems. Usually, pioneer species are less tolerant of shade than climax species.

Based on a pot experiment Eussen (1978) found that the relative growth rates (RGR) of *Imperata* shoots and rhizomes over a period of two to six months were reduced by 50 % by a 80 % reduction in light intensity. Soerjani (1980) found that 50 % shade caused shallower mean rhizome depth than found in unshaded plants. In an control experiment, 50 % and 75 % shade lead to reductions in shoot dry weight, rhizome dry weight and total carbohydrate content of *Imperata* rhizomes (Moosavi-Nia and Dore, 1979).

Trees as shade providers for *Imperata* control
Tree crops may have advantages over herbaceous cover crops as shade providers by simultaneously providing a substantial economic product; particularly wood. In some cases, they may also be easier to manage, especially at the end of the *Imperata* suppression period when clearing and re-vegetation with other species may be done. They can provide varying levels of shade that can be managed easily through thinning, coppicing, pollarding or pruning.

Forest canopies may reduce light intensity to less than 1 % in tropical rain forests, to 50-80 % of full sunlight in leafless deciduous forests, and to 10 to 15 % in open, even-aged pine stands (Spurr and Barnes, 1980 In: MacDicken *et al.*, 1997). In the absence of fire, trees, shrubs and woody perennials often effectively colonise *Imperata* grasslands. However, as the cycle of burning and regrowth in *Imperata* lands continues, biodiversity at the macro- and micro-levels declines, reducing the potential for other species to effectively shade or outcompete the *Imperata*.

Table 3 shows the list of tree species that have been successfully used in *Imperata* grasslands in S.E. Asia. However, even if tree species can be successfully established in *Imperata* grasslands, they are not always profitable. The economic value of trees should be considered as well.

Table 3. Tree species reported to successfully control *Imperata cylindrica* (quoted from MacDicken *et al*., 1997, p 138)

Indonesia		Philippines
Acacia auriculiformis	*Paraserianthes falcataria*	*Albizia procera*
A. decurrens	*Peltophorum grande*	*Alnus maritima*
Albizia procera	*P. dasyrrachis*	*Anacardium occidentale*
Aleurites moluccana	*Pinus caribea*	*Bauhinia malabarica*
A. montana	*Pinus merkusii*	*Casuarina equisetifolia*
Altingia excelsa	*Psidium guajava*	*Eucalyptus camaldulensis*
Cassia multijuga	*Quercus sp.*	*E. grandis*
Casuarina equisetifolia	*Schima wallichii*	*E. saligna*
Cecropia peltata	*Sesbania sesban*	*Gliricidia sepium*
Endospermum malaccense	*Shorea leprosula*	*Gmelina arborea*
Erythrina sp	*S. ovalis*	*Leucaena leucocephala*
Fragaea fragrans	*S. platylados*	*Pinus insularis*
Hibiscus sp.	*Sindora sp.*	*Psidium guaba*
Hopea mangarawan	*Styrax benzoin*	*Vitex parviflora*
Intsia palembanica	*Swietenia macrophylla*	
Leucaena leucocephala	*Syzygium spp.*	
Morus macroura	*Toona sinensis*	
Ochroma sp.	*Vernia arborea*	
Ormosia sumatrana	*Vitex spp.*	

Malaysia	Vietnam
Dryobalanops aromatica	*Acacia auriculiformis*
Hopea kerangasensis	*A. mangium*
Pentaspodon motleyi	*Anacardium occidentale*
Shorea leprosula	*Anthocephalus chinensis*
S. macrohylla	*Indigofera teysmanii*
S.ovata	*Lagerstromeia speciosa*
Vatica nitens	*Pinus keysia*
Whiteodendron mpultonianum	*Pterocarpus spp.*
	Swietenia macrophylla

7.b. Hedgerow intercropping

Hedgerow intercropping or alley cropping is the establishment of hedgerows of fast-growing perennials interplanted with food crops. The hedgerow trees are regularly pruned during the growing season, when they give too much shade to crops. The prunings are returned to the soil as green manure. During the dry season trees are allowed to grow without pruning to cover the soil surface, to reduce evaporation and suppress weed growth.

The time required for canopy closure and weed suppression in rotational hedgerows is dependent upon species, spacing and site quality.

In practice, hedgerow intercropping often proved not to be profitable because the regular pruning needed demanded too much labour.

7.c. "Improved" fallow systems

Fallow is the period of regeneration between cropping periods and is an integral part of the shifting cultivation system. Fallow improves the soil and suppresses weeds. The determination of fallow lengths is often a function of weed competition and the amount of labour required to maintain crop yields. For example a plot may be allowed to be fallow when the labour required to keep it free of weeds exceeds the labour needed to clear a new site.

Some tree species were selected to permanently colonise sites without the need for further plantings. An example from Indonesia is *Aleurites moluccana* (candle nut, Ind. Kemiri) which has a high economic value and when planted at 4 x 4 m spacing has been successful in suppressing *Imperata* 4 years after planting in South Lampung, Sumatra, Indonesia (In: MacDicken *et al.*, 1997).

Cajanus cajan (pigeon pea) was used successfully to control *Imperata* in a reforestation project in Central Luzon in the Philippines. Two or three seeds were sown into small cleared spots at the beginning of the rainy season. Planting distance was 1 x 1 m. Weeding was done when the pigeon pea was about 30 cm (which was about one month after planting). Shading of the *Imperata* by pigeon peas was substantial within five to six months. A primary advantage of using pigeon pea was the economic value of the pods as a food crop.

There are more examples of successful trees to suppress *Imperata.*

8. Case study Shade-based control and other smallholder practices to reclaim *Imperata* (alang-alang) grasslands in N. Lampung, Sumatra, Indonesia (Purnomosidhi *et al*., in press)

Some studies were carried out in the transmigration area in N. Lampung to answer the following research questions:

a. What techniques do farmers use to clear the alang-alang land?
b. How can agroforestry systems suppress alang-alang regrowth and avoid the fire risks in the short/medium term?
c. What intensity of shade, for what length of time is required for adequate control?

8.1 Survey

The *Imperata* survey was conducted in some villages in Pakuan Ratu, N. Sungkai and S. Sungkai sub districts of Kotabumi, N. Lampung, Indonesia. The survey consisted of farmer interviews, as well as measurement of light intensity and *Imperata* biomass under difference land use practices at a range of tree ages to answer the questions a and c. The light measurements and *Imperata* population density measurements were made under *Paraserianthes* woodlots, oilpalm and rubber.

We found that basically measurements for initial clearing of Imperata fallow, farmers use two approaches:

- no-till techniques based on systemic herbicide (glyphosate), applied on young regrowth after burning existing biomass or slashing and removing it,
- soil tillage by a) hoeing (manual), or b) ploughing (using animal or tractor power), usually after the *Imperata* aboveground biomass was burnt to make work easier.

The choice of method depends on the resources and access to capital of the farmer (see Figure 5). Poorer farmers (60 - 70%) rely on hoeing with family labour, and can only clear 0.25-0.5 ha per family per year (mainly in the dry season). If labour would have to be paid for, this method would be very expensive. It is mostly used for planting food crops such as upland rice, maize or soybean. Farmers prefer a shallow soil tillage method over deep(er) ploughing, because they want to keep the dark top 15-20 cm of the soil (*"soil-meat")* intact and to avoid bringing the iron rich aggregates ("crocos") found below that depth to the surface by ploughing.

Farmers who can afford it, prefer the use of herbicide, unless they have animal draught power available. They use 2-5 litre per hectare of one of the commercially available brands of glyphosate ('Roundup', 'Spark' or 'Polaris'), often mixing more than one type. Herbicide is normally sprayed on young regrowth of *Imperata,* 2-3 weeks after slashing and/or burning the standing biomass. The effect of herbicide is visible after 2-3 weeks. Herbicide use without soil tillage is the preferred method before planting rubber, oil palm or timber trees, while food crops (monoculture or intercropped) require ploughing, according to the farmers interviewed.

Ploughing with draught animals is normally done in the dry season, when the *Imperata* rhizomes brought to the surface dry up easily, but sometimes (in 10-15 % of cases) extends into the early rainy season, when the soil is easier to work. Systemic herbicides remain effective for about 6 months, after which farmers commonly spray again. The first spraying covers the whole area, the second only the patches that remain green after two weeks; altogether at least 5 litres of herbicide is needed per hectare, costing Rp. 260 000 (1998) or Rp. 225 000 (1999). This is about 25-30 USD, which is the official minimum monthly wage in the province and even 1.5 to 1.8 times the average monthly wage in the study area. The farmers use this technique for planting cassava, rubber or oil palm without soil tillage. To reduce the amount of herbicide needed, farmers may try to slash or even burn secondary *Imperata* stands before spraying the regrowth; this may reduce herbicide use by 30-40% or 2 litres per hectare.

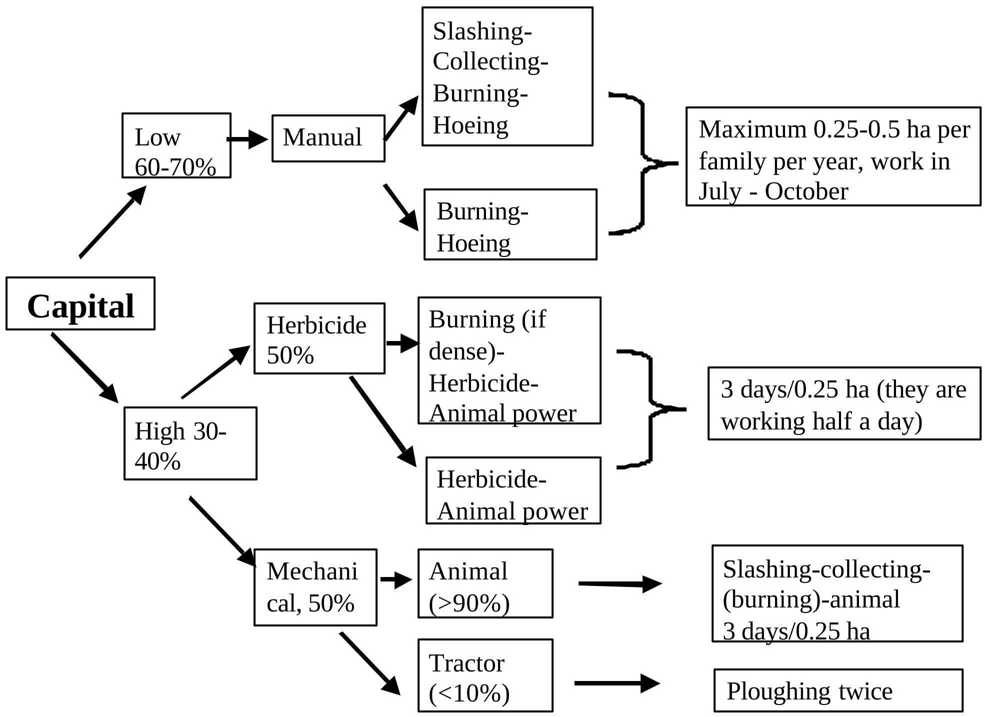


Figure 5. *Imperata* land clearance practices used by the farmers in N. Lampung.

8.2 Shading experiment

Biological reclamation methods for *Imperata* grasslands are mostly based on making use of shade. Very few quantitative data are available, however, on the intensity and duration of shade, required to effectively control the grass. Control may be defined here as the **decrease in biomass** and the **lack of regrowth** from belowground **rhizomes** after cutting the aboveground biomass. As the regrowth depends on mobilising stored carbohydrate reserves in the rhizomes, we may expect that the soluble carbohydrate content of the rhizomes can serve as an indicator of the vigour or quality of the rhizomes.

The treatments to quantify the response of a well-established *Imperata* stand to shade of different intensities and duration with various levels of artificial shade were:

1. Intensity of shade:

- 0 % shade = full sunlight
- 55 % shade = 45 % sunlight
- 75 % shade = 25 % sunlight
- 88 % shade = 12 % sunlight

2. Duration (time series)

The experiment was monitored to test the decline of standing alang-alang biomass over time and to test the ability to re-grow from rhizomes after the biomass was removed at monthly intervals.

Measurements

- Aboveground biomass in 4 x 1 m strips (every month)
- *Imperata* regrowth

Results

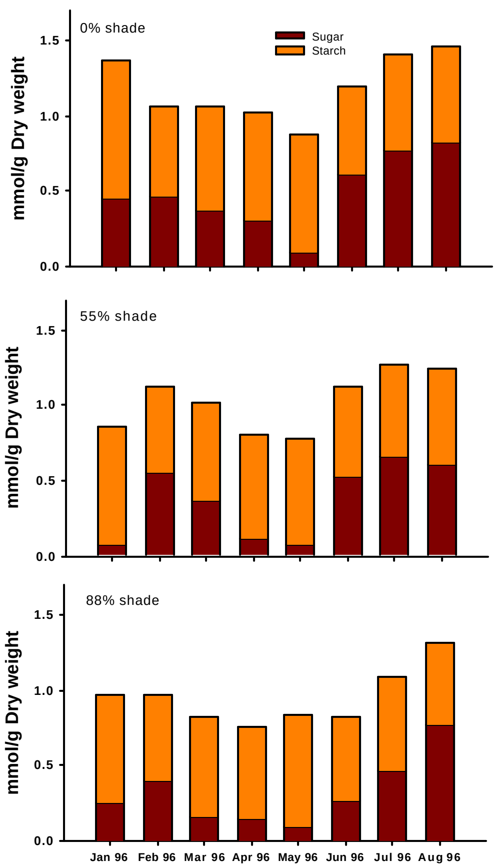


Figure 6. Effect of shading on carbohydrates concentration in *Imperata* rhizomes

As you can see in fig 6. the shade effect on carbohydrate concentration in Imperata rhizomes was very small. So, it seems that inhibition of Imperata growth by shading is not based on reduction of carbohydrates in Imperata rhizomes. More physiological research is needed to actually find out what is inhibiting the growth.

The shade-intensity experiment showed that even if light levels are reduced to about 10% of full sunlight, an established *Imperata* stand will only gradually decline, and that 50 % shade for up to 8 months had little effect (Figure 7).

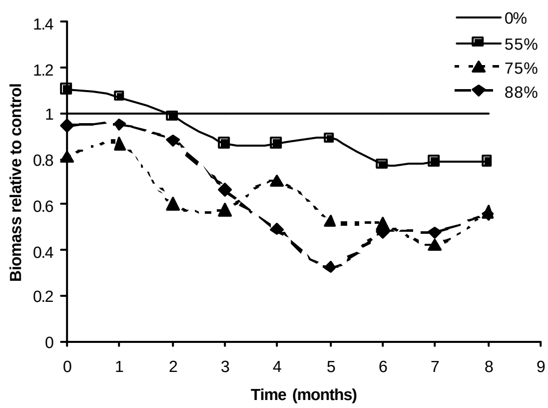


Figure 7. Aboveground biomass of *Imperata*, relative to a full-sunlight control as affected by shade intensity and duration.

Re-growth after removing all aboveground biomass was more affected by shading. A 55% shade treatment- that would be considered problematic for most food crops - had no effect on the ability of alang-alang rhizomes to re-sprout. Only when a 88% shade treatment was applied for more than two months, did the ability of rhizomes to resprout decline to a negligible amount (Figure 8).

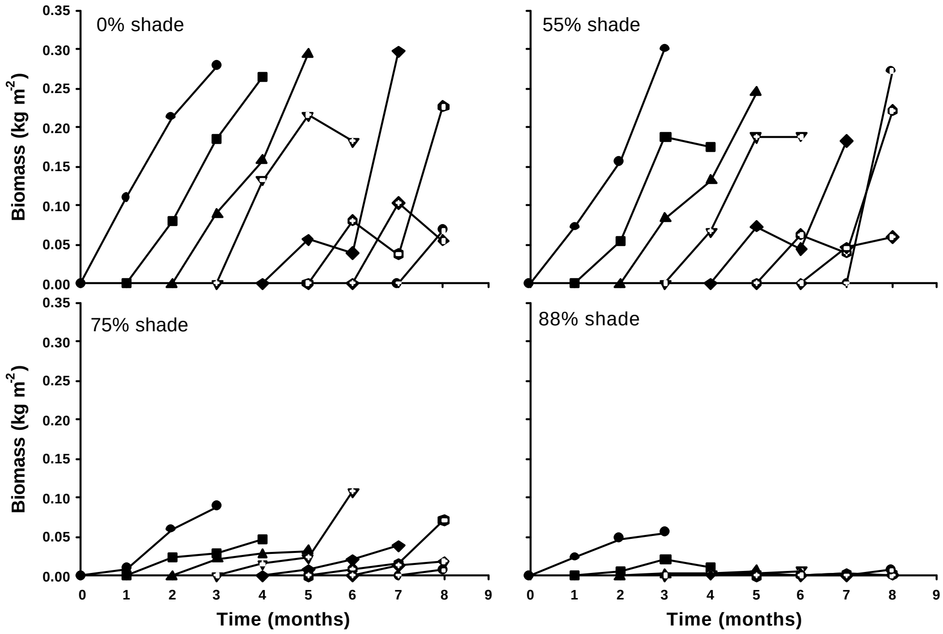


Figure 8. Regrowth potential of alang-alang after exposure to shade for different periods of time.

What intensity of shade, for what length of time is required for adequate control?

The results of artificial shade were then compared with the results of the survey of *Imperata* occurrence (and light intensity) under a range of agroforestry systems (Figure 9). A relationship was indeed found between light levels below the tree canopy and alang-alang biomass. *Imperata* biomass decreased drastically when relative light intensity of 20% was reached (Figure 9A). This suggests that farmers were probably also weeding the *Imperata* occasionally. This was because from the artificial shade experiment it was concluded that only when all the biomass is removed ($\simeq$ weeding), shade played a dominant role in reducing regrowth. When more than 20% of sunlight reaches the ground, alang-alang still has a chance in these agroforestry systems. The various tree and plantation crops differ in age, tree basal area and management. Light intensity reduces more 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* (Figure 9B). The use of canopy cover, rather than stem basal area would probably give a lower variability in the results, but stem basal area is an easier and faster parameter to measure.

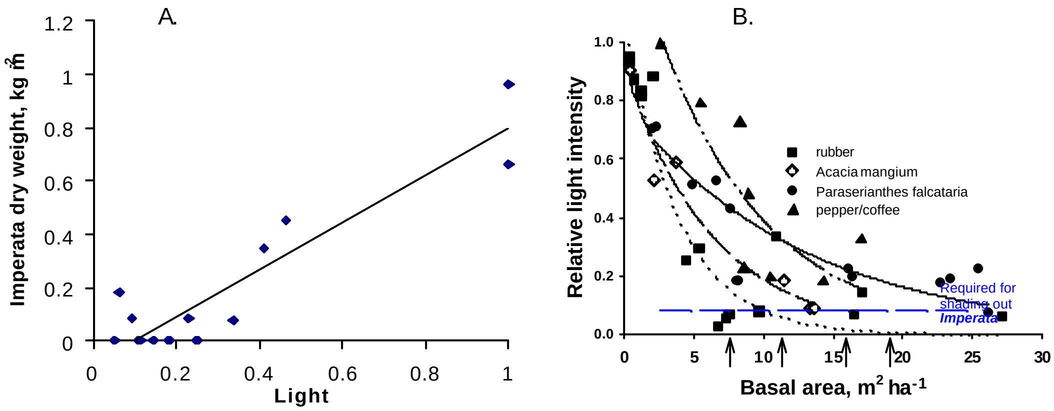


Figure 9. Relationship between alang-alang biomass and light intensity (relative to full sunlight measured with a PAR Sensor) (**A**) and light intensity with basal area on rubber (1), *Acacia mangium* (2), Paraserianthes falcataria (3), inter-cropping pepper/coffee (4) (**B**).

9. Agroforestry options

Fast growing timber trees

Systems based on fast growing timber trees became popular in this area as a spin-off (sometimes literally...) of the tree planting by the Industrial Forestry Company (HTI) in the area. A number of farmers, stimulated by one of the village heads, started to spray the *Imperata* and plant *Paraserianthes falcataria* (sengon) at a distance of 2m x 2m or 2m x 2.5 m, or at 2m x 4 m when intended for inter-cropping with food crops (upland rice in year 1, cassava in years 2 - 4) for more than 1 year. Canopy closure of type of sengon is slow, so weeding or ploughing between rows after harvesting the food crops was deemed necessary by the farmers. In plantations that were 5-8 years old the light intensity at the soil surface still reached 18-28% of full sunlight and alang-alang remained a problem (Tjitrosemito and Soerjani, 1991). Some farmers abandoned their plantations. They saw secondary vegetation regenerating with tree species such as *Schima wallichii, Dillenia sp., Peltophorum dasyrrachis*, shrubs like *Chromolaena odorata, 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 below expectations. The long dry season of 1997 showed that *Paraserianthes* is only suited for the wetter sites at the bottom of slopes. *Acacia mangium* planted at a spacing of 2 x 4 m (1250 trees ha^{-1}) reduced light at ground level to 10% of full sunlight 4 years after planting at a stem basal area of 23 cm^2 m^{-2}.

Rubber agroforestry

Rubber planted at a spacing of 3.3 m x 6 m or 4 m x 5 m (500 trees /ha) takes on average 7 years before stem basal area is 10 cm^2 m^{-2} (or m^2 ha^{-1}) and light levels at ground level are less than 20% of full sunlight. Farmers usually plant maize or cassava between the rows in year 1 - 3. Although cassava (From the same family, *Euphorbiaceae*, as rubber) is considered a risk in transferring soil-borne diseases to rubber, it is preferred by farmers as an intercrop that takes little care to maintain and can provide some income. After year 3, however, the transition described by Bagnall-Oakeley *et al*. (1997) occurs, when there is too much shade for a food crop and too little for *Imperata* control.

Oil palm plantations

Smallholder oil palm plantations are a fairly recent phenomenon in Pakuan Ratu so only a few samples could be obtained. Farmers consider oil palm as a good option, as it regrows after a burn and appears less affected by drought than rubber or sengon (oil palm agronomists, however, emphasize negative drought impacts on inflorescence production up to a year after the drought, while rubber tapping can resume quickly if the trees have survived). The farmers in the survey planted oil palm with a 8 m x 9 m spacing (138 plants ha^{-1}) leaving a lot of space for alang-alang. Generally, in the first to third year farmers plant maize or rice between rows of oil palms. In some instances, small farmers with little land are allowed to grow food crops between the oil palm of richer farmers, as food crops are deemed less competitive for the oil palm than *Imperata* would otherwise be. Just as for rubber, however, in the years after the food crops *Imperata* gets a chance to come back, before canopy closure. For an oil palm height of 1 to 5 m, light intensities at ground level averaged 50-80% , with 100% light at 4.5-5 m from the plant. A stand with an oil palm height of 10 m still allowed about 15% of full sunlight to penetrate to ground level.

Pepper/coffee agroforestry systems

These systems are found on the better soils to the West of the ASB benchmark area in Pakuan Ratu. Farmers first plant *Gliricidia sepium* and/or *Erythrina orientalis* as shade and support trees at a spacing of 2 m x 2 m. Then 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 between shade trees, and pepper vines are planted at the stem base of the trees. Fruit trees, such as *Parkia speciosa*, *Pithecellobium dulce*, *Durio zibethinus*, *Lansium domesticum* and *Ceiba pentandra* are mixed in the stand, and often as boundary markers of 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 45-50%, as the shade trees are pruned for the benefit of the pepper and coffee. In an 8-10 year old plantation (stem basal area of 10 cm^{2} m^{-2}) light intensity at ground level was 20% of full sunlight.

Summary

It is clear that technically, *Imperata* grasslands can be controlled. However before any so-called rehabilitation takes place a few questions should be answered first. Are there any land conflicts? Will anybody lose out as a result of rehabilitation? Is labour a constraint for rehabilitation? Or are there any other constraints?

If the answer is yes to any to the above questions, perhaps that issue should be resolved first before proceeding with the *Imperata* rehabilitation per se.

First steps in technically controlling *Imperata* in the agroforestation of grasslands can be achieved by either mechanical or chemical control. Farmers employ a range of techniques, depending on their resources and current cost of the technique. Food crops can be used in the first few years of most tree crops or agroforestry systems to maintain income. The gap between the last food crop interplanting and canopy closure, however, leads to a major risk of *Imperata* regrowth and fire occurrence. The optimum duration and intensity of shade, as estimated in the experiment, takes time to be reached in practice, and thus the young trees are exposed to fire risks.

In the broader picture, results from the Lampung area are encouraging for the *Imperata* grasslands elsewhere. Farmers will indeed 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.

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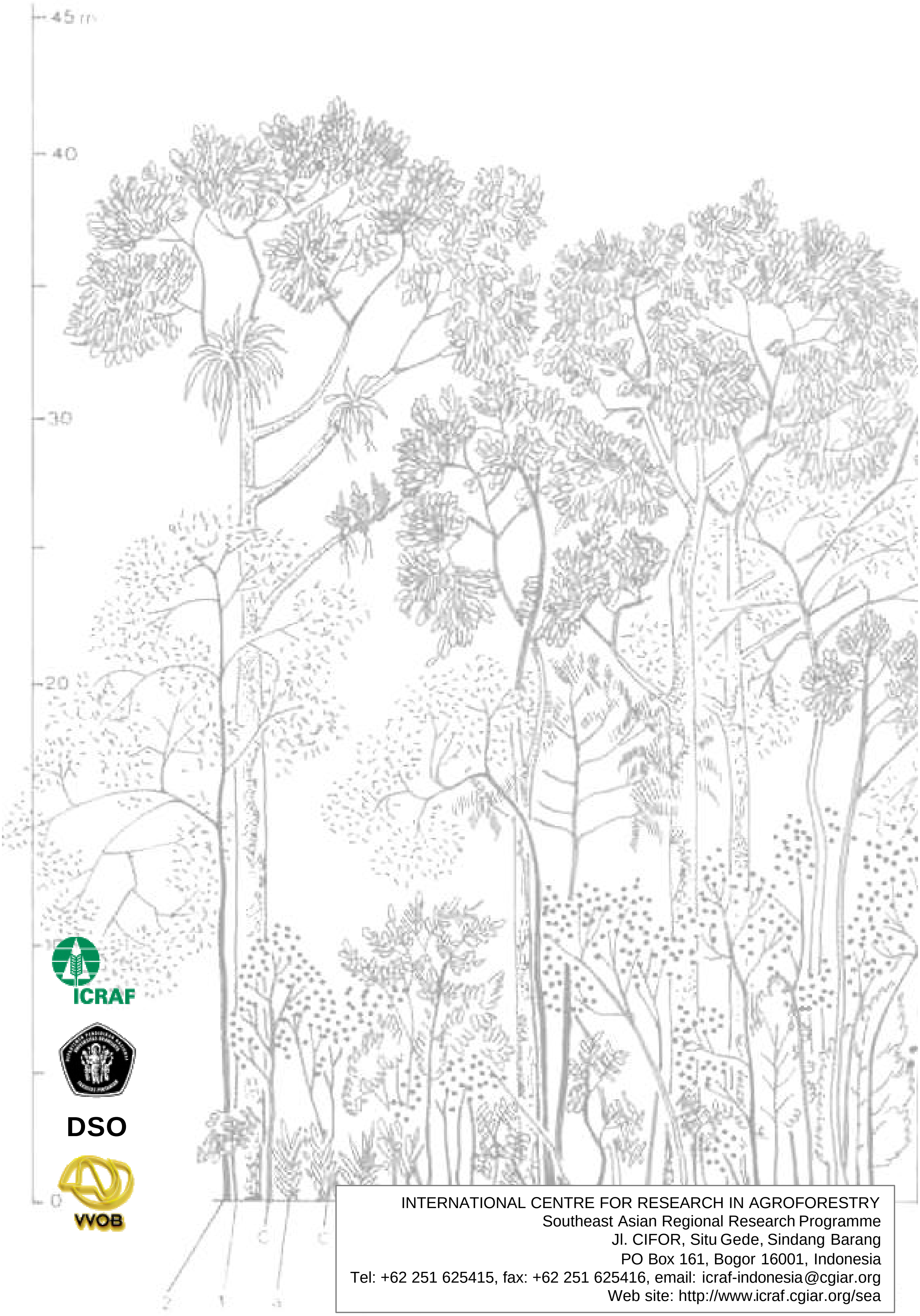

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INTERNATIONAL CENTRE FOR RESEARCH IN AGROFORESTRY
Southeast Asian Regional Research Programme
Jl. CIFOR, Situ Gede, Sindang Barang
PO Box 161, Bogor 16001, Indonesia
Tel: +62 251 625415, fax: +62 251 625416, email: icraf-indonesia@cgiar.org
Web site: http://www.icraf.cgiar.org/sea