TOWARDS AN ECOLOGY-BASED STRATEGY FOR THE REFORESTATION OF *IMPERATA CYLINDRICA* GRASSLANDS IN EAST KALIMANTAN

G. Wim Tolkamp, Aldrianto Priadjati and Riskan Effendi

ABSTRACT

Unproductive *Imperata cylindrica* Beauv. grasslands cover more than 20 million hectares in Indonesia. Urgent rehabilitation is needed to prevent the worsening of this ecological and economical disaster. An ecology-based strategy to accelerate the reforestation of grassland towards a dipterocarp-dominated plantation, in which natural regeneration occurs, was developed in combination with fire control measures. The first step in the implementation of this strategy, the establishment of a pioneer plantation, started in 1996. The results so far indicate that essential prerequisites for success are the selection of both pioneer and dipterocarp species and the application of appropriate fertilisers. *Peronema canescens* is a local pioneer species which is fire tolerant and economically attractive to local people. It therefore seems to be a suitable species for the first phase of grassland reforestation in Indonesia. Hardwood cuttings of *P. canescens* were collected from 12 locations in South and East Kalimantan and propagated on a large scale. Direct planting of unrooted branch cuttings in grassland is technically feasible. The species was interplanted in 1999 with *Shorea leprosula*. This kind of plantation may serve as a buffer between existing natural forests and villages with agricultural areas and may also diminish fire risk and thus decrease the establishment of new grasslands in those areas. An introduction of these multi-species plantations (farmers' forests) is proposed. Employing this ecology-based strategy, 30 hectares of *I. cylindrica* grasslands were reforested with a mixture of species during 1998 and 1999. Land tenure issues, poor infrastructure and transportation problems affected the execution of these activities. Feasibility studies and more integrated research in a comprehensive programme (experiments performed by concessionaires, mining companies and farmers, but supervised by researchers) are suggested. Collaboration between Asian institutions and projects in Indonesia is proposed.

INTRODUCTION

Shrinking forests, expanding grasslands

In Indonesia more than 20 million hectares are covered with unproductive *Imperata cylindrica* Beauv. grasslands, generated through human influences and fires (ITTO, 1990). Natural regeneration of these grasslands into forest does not occur on a large scale in current land use practices.Large-scale reforestation activities with exotic tree species were therefore undertaken with varying results. Successful reforestation of these grasslands is effective only if it is ecologically and technically possible, economically feasible, and socially and politically realistic (Garrity, 1997). After the fierce fires in 1997/98, the area of grasslands increased dramatically, especially in Kalimantan. The need for rehabilitation is therefore very urgent and quick action is required. There is a preference for indigenous species, since these species are expected to fit better into the ecosystem than exotic species.There is thus an increased need for proper information about suitable native species, which is not yet available. Suitable species have to meet several criteria in order to be useful for the reforestation of these critical lands. Only a few local pioneer species have been tested on a small scale in Kalimantan (Otsano *et al*., 1997).

Hypothesis
The introduction of indigenous pioneer - dipterocarp - plantations offers an alternative to reforestation of *I. cylindrica* grasslands with exotic tree species plantations and slash-and burn agriculture in non-populated areas. These heterogeneous forest plantations, which contain characteristics of natural forest, may have multiple functions, i.e. buffer zones, conservation of biodiversity, water regulation, soil protection, source of timber and non-timber forest products to alleviate the poverty of local communities.

The following working hypothesis has guided the research: A pioneer – dipterocarp - plantation is increasingly more sustainable when it has a species composition more similar to that of the original local rain forest, in contrast to monocultures of exotic tree species.

Objectives and research activities
The hypothesis and the available knowledge, including the results of the first phases of the Ministry of Forestry-Tropenbos Kalimantan Programme, led in 1996 to the implementation of a study, which forms the subject of this paper (Tolkamp, 1996 a,b). The following main and secondary objectives were formulated.

***The long term objective*:**
To develop an ecology-based strategy to accelerate the succession of *I. cylindrica* grassland into a multifunctional plantation.

The short term objectives:
1. To select both pioneer and dipterocarp species for their suitability for competing with grasses;
2. To study the effect of fertilisers on succession;
3. To domesticate promising species.

The following activities were undertaken from 1996 onwards:
1. Selection of species:
- ➢ The establishment of 4 elimination experiments in 1996 and 1998 to select local pioneer species;
- ➢ In 1995 two dipterocarp species experiments were established under a canopy of residual forest and in open *I. cylindrica* grassland.

2. A study on the effect of fertilisers:
- ➢ A fertiliser experiment with 4 pioneer species to accelerate "succession" was established in *I. cylindrica* grassland in 1996.

3. Domestication of promising species:
- ➢ Collection of more than 100,000 cuttings from 12 natural populations of the fire-tolerant and economically attractive species *P. canescens* in South and East Kalimantan (1998) and seeds from two mother trees. (Tolkamp, 1998)
- ➢ Improvement of vegetative propagation techniques for *P. canescens* in order to ensure a constant supply of plant material of known origin (1998).
- ➢ The establishment in 1998 of an experiment of direct planting of unrooted and *rooted P. canescens* cuttings in *I. Cylindrica*-dominated grassland.
- ➢ The establishment in 1999 of an experiment on the influence of shading of *Shorea leprosula* by *P. canescens* with the aim of contributing to the study on water-stress physiology in this

dipterocarp species

Thirty hectares of *I. cylindrica* grasslands were reforested with a mixture of pioneer and local fruit tree species during 1998 and 1999. Land tenure issues, poor infrastructure and transport problems delayed the execution of these activities.
The fires of 1997-1998 basically destroyed all the field experiments established until then, and the species elimination experiments, in particular, had to be restarted.

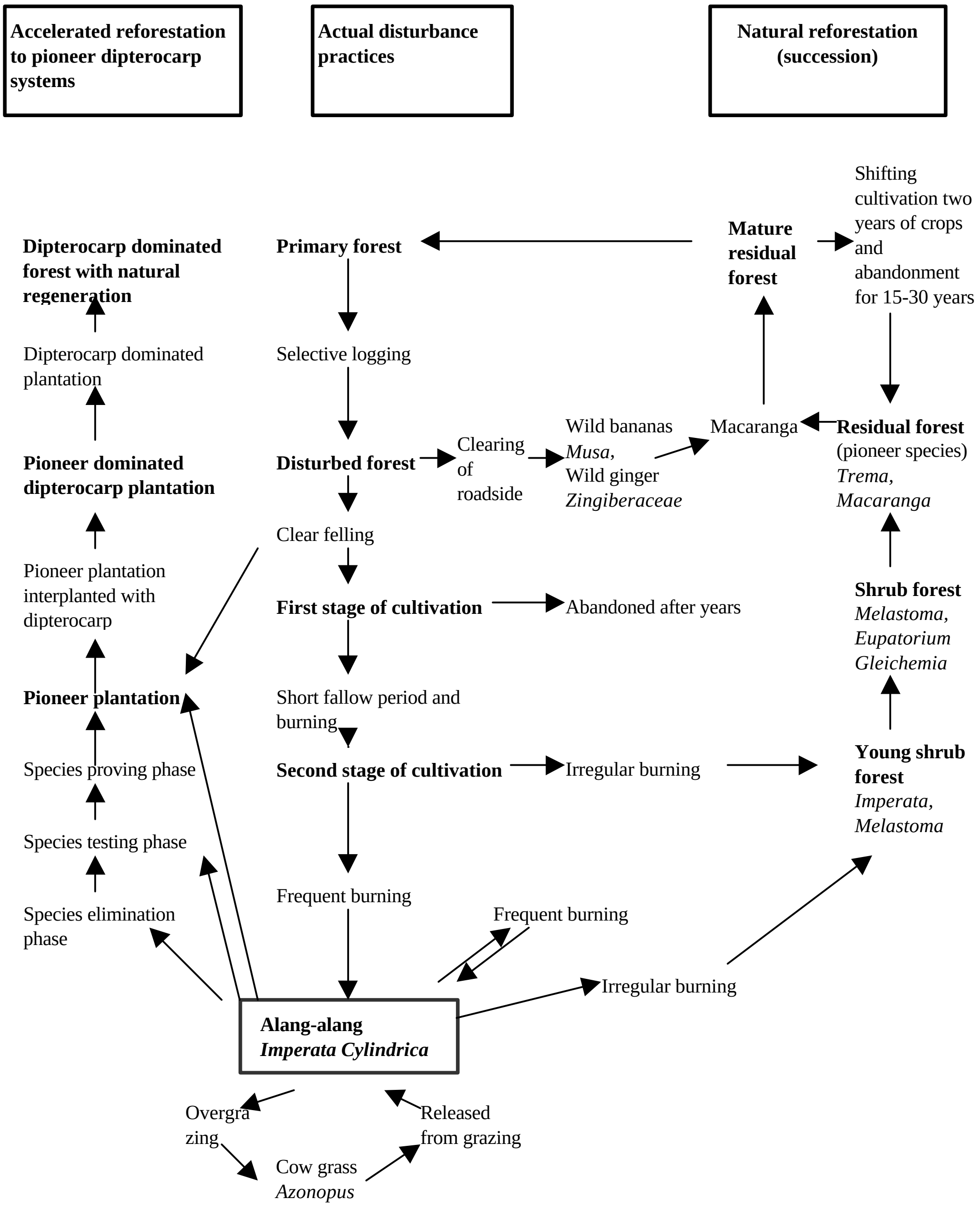


Figure 1 Natural and accelerated regeneration of *I. cylindrica* grasslands (partly adapted, MacKinnon, 1996)

BASIC CONSIDERATIONS

Imperata cylindrica grasslands

The disastrous large-scale tropical rain forest degeneration process and the opposite process of forest regeneration, the latter unfortunately only allowed to develop in relatively small areas, has been described extensively. Kathy MacKinnon et al. (1996) did this specifically in the excellent handbook "The Ecology of Kalimantan". Figure 1, partly adapted from MacKinnon, shows the processes of degradation and regeneration. Three lines represent the different processes: the central line shows the degradation of primary forest to *I. cylindrica* grasslands; the left and right lines show the processes of reforestation in opposite directions. Natural reforestation or succession is described along the right line and accelerated reforestation or ecology-based reforestation along the left line. Figure 1 serves as a guide to the arguments presented in this chapter, which serve as a rationale for this study.

Forest disturbance practices like selective logging, clear-cutting, shifting cultivation and frequent burning create *I. cylindrica* grassland. These disturbance practices are categorised in the middle column of Figure 1. When this disturbance happens regularly on large scale the process of natural regeneration or natural succession is very difficult to establish, especially in very large connected grasslands. The process of succession depends on the size of the grasslands and the presence of pioneer species (seed sources). Limited and localised land clearance may have little impact on native plants and animals, and forest regenerates more quickly in the small clearings. These small land clearances resulting from traditional shifting agriculture may lead to a change in the species composition of residual forests, favouring trees adapted to fire, cutting and other disturbances associated with shifting cultivation (MacKie *et al*., 1987).

The final stage of large-scale degeneration is *I. cylindrica* grassland. *I. cylindrica*, called "alang alang " in Indonesia, reproduces itself prolifically, both vegetatively and by seed. It has the ability to thrive on infertile soil. Its rhizomes are extremely resistant to fire; in fact, fire kills the competitive plants and thus favours the expansion of *I. cylindrica* (Brook, 1989). Because of its high growth rate and enormous biomass production, *I. cylindrica* is a strong competitor with other plants for water, light and nutrients. The allopathic effects, combined with its great ability to compete , enable *I. cylindrica* to grow in monocultures (Sambas *et al*., 1991) and hamper natural succession.

I. cylindrica is difficult to control. Intensive mechanical site preparation is the most effective cultivation method in grassland reforestation, but is not commonly practised. The main method of control currently practised by farmers and small reforestation projects is to slash (and burn) the *I. cylindrica*. Grass pressing (i.e. lodging, rolling) is a method not used in Kalimantan for controlling I. *cylindrica*. Agricultural estates (and sometimes forestry estates) mostly practise chemical control. Farmers are also using more and more herbicides in Kalimantan. *I. cylindrica* is a light-demanding, shade-intolerant species. Biological control by suppressing the grass through shading by natural succession and by planting trees is the most obvious solution for the future.

Reforestation

Transformation of these grasslands into forest, here referred to as reforestation, is possible by natural succession or by human interference, or by a combination of both. In general, reforestation of older extended areas of I. *cylindrica* grassland is extremely difficult, because of compact and nutrient-deficient soils, hydrological instability, wide temperature variations in of the soil-rooting zone, grass competition and allelopathy and high fire susceptibility. Moreover, natural regeneration processes are hindered by annual fires and the absence of seed banks (pioneer and climax tree seed sources) and of fungal root symbionts (mycorrhizae).

The right-hand column in Figure 1 shows the sequence of the natural regeneration process if the grassland is protected against frequent fires. The progress of natural regeneration in general is slow and greatly depends, apart from fire, on the age, extent and occurrence of remnants of natural forests in the surrounding areas.

Plantation Forestry

The best known strategy for converting unproductive grassland into a more productive land use is the establishment of industrial forest plantations composed of exotic tree species. These large-scale reforestation activities have been undertaken with varying results and the sustainability of these plantations is questionable. Good soil preparation before planting is essential for the destruction of the rhizomes of *Imperata* grasses and for the establishment of plantations. Large financial investments are required for the establishment of large-scale industrial forest plantations or large-scale agricultural estates. Other transformation strategies include agroforestry and small-scale permanent agriculture.

Problems in reforestation have been studied intensively in a trial area in South Kalimantan (Otsano et al., 1997) for mainly exotic tree species. Recommended species for first rotation reforestation of grasslands must be able to colonise the site with vigorous early growth and a high survival rate. The results of experiments in South Kalimantan (Otsano *et al*., 1997) demonstrated that the fast-growing exotics are more effective in this, because - according the author - the local species are not adapted to the harsh climatic conditions and degraded soil generally characteristic of *I. cylindrica* grasslands. However, this conclusion is based on only a limited number of local species.The same author therefore recommended intensifying a species selection programme.

Accelerated regeneration, an ecology-based strategy

In the last decade, a new strategy has been under development as a reaction to the negative environmental qualities and economic feasibility of the large-scale industrial monocultures**.** This new ecology-based strategy accelerates regeneration as compared with natural regeneration or succession in grasslands, is sustainable and offers an alternative to the exotic tree species plantations. The strategy can be used in agroforestry systems, in the establishment of buffer zones around protected forests and in the reforestation of all kinds of critical land. According to Drilling (1989) and Kartawinata (1994), this strategy is known as Assisted (or Accelerated) Natural Regeneration (ANR), and has been researched in the Philippines. The strategy is a potentially rapid, efficient and cost-effective means of reforesting critical watersheds, grasslands etc. ANR is defined by Drilling as "any reforestation method that relies on natural regeneration and has weed-suppressing activities". The approach is site specific, but there are several common steps in identifying requirements at each site, in particular, in *Imperata* grasslands rehabilitation programmes:

1. Clarification of the objectives
2. Site selection
3. Protection of the area against fire
4. Identification of existing woody plants
5. Inhibition of the grass layer (intervention)
6. Facilitation of the growth of existing woody plants
7. Continued treatment of the grass layer (maintenance, out-shading grass by trees)

8. Enrichment planting of desired species
9. Silvicultural treatments of these species

The objective of this study is to find ways of accelerating the process of grassland regeneration into an ecology-based pioneer – dipterocarp-dominated - forest system. The way to reach this target is illustrated in the left-hand column of Figure 1. The first practical step is the selection of the most adapted pioneer species to out-compete the grass (species site matching). At the same time, selection of the dipterocarp species is started. The next step is the establishment of a pioneer plantation, which is followed some years later by inter-planting with dipterocarps. After one to two decades, the pioneer-dominated dipterocarp plantation is expected to change into a Dipterocarp-dominated plantation. This plantation progressively comes to resemble a natural primary forest through natural regeneration, changing tree species composition and increasing biodiversity. Sustainable management practice is an important tool for reaching this stage. During the successive steps, silvicultural treatments are improved and tested to increase productivity and/or natural regeneration. The present study concentrates on the first step of this stage: Species elimination phase – species testing phase – species proving phase – establishment of pioneer plantation.

Burley and Wood (1976) defined the “Species elimination phase” as a mass screening of a large number of possible species in small plots during a short period. The “Species testing phase” compares a reduced number of promising species in large plots for longer periods, while the “Species proving phase” confirms the superiority of the selected species under normal planting conditions.

Pioneer species selection

Technical questions arising in the reforestation of grassland are related to species choice, to the physical difficulties in planting, competition of the grass with the newly planted trees, susceptibility to fire, soil degradation (physical as well as mineral) and soil compaction. A good choice of site-specific adapted species is of crucial importance for the ecology-based strategy, for planting as well as for natural regeneration. . Many local pioneer species thrive in harsh site conditions and are fast growing, making them useful for suppressing light-loving grasses and for reforestation schemes of plantations. However, there is little written information about most of these species.

The pioneer species to be selected should meet several criteria, the most important of which are a high survival rate, fast growth, a wide crown and early closure of the canopy. The role of pioneer species in successful *I. cylindrica* grasslands reforestation is that these species should serve as a nurse crop to shade out grasses, reduce vine infestations and provide shade over future crop trees that otherwise suffer if exposed to prolonged daily sunlight (Putz, 1993). The trees should be high light intensity-tolerant and easy to reproduce (by seed, cuttings etc.). The trees should also tolerate pests, diseases, fire, and low soil pH, water stress and low nutrient levels (N,P) to a certain degree. The most difficult standard criterion is that the species must be able to cope with the abundant *Imperata* rhizomes, not only in terms of allelopathy and mechanics, but also in terms of competition for water and nutrients. Finally, the species should be locally accepted and have a potential for various end users (Evans, 1984; Hadi, 1990; Soerianegara, 1980). A further step forward in selection is the domestication of a promising species.

Domestication

Leakey *et al*. (1997) defined domestication of a species in genetic terms as an accelerated and human-induced evolution. However, domestication is not only selection, as domestication integrates the four key processes of identification, production, management and adoption of the species. In the context of reforestation of grasslands, domestication of desired species has to be considered as a tool used by farmers, timber estates and projects to accelerate the reconversion of grasslands into productive areas. Discussion on the role of domestication cannot be separated from that of commercialisation. Intensive domestication for self-use or for an expanding or new market is based only on high incentives. *Peronema canescens* seems to provide these incentives and is therefore the first species to be domesticated. *P. canescens* has been found to have local and international commercial potential, it tolerates the competition of grasses, is fire tolerant and has a relatively fast youth growth. The results of the identification, selection and production of *P. canescens* as presented here is the first step in the domestication of this species.

Aim of this study
In summary, the aim of this study is to test the early growth potential of mainly unknown local species and a selection of known exotic species, and to monitor their suitability as species for further experiments, pilot plantations, buffer zones and agro-forests. The main emphasis is in finding species that are able to occupy the site and suppress the *Imperata* grass with minimum maintenance. The next chapter gives an account of the species selection experiment, the effects of fertiliser on growth performance and the domestication of promising species.

RESEARCH IMPLEMENTATION 1996 – 1999

Species Selection

Pioneer Species Selection

The two elimination experiments for the selection of 31 local species and 9 exotic species were laid out in a Randomised Incomplete Block Design each with four replications. The experimental sites were established in *I. cylindica* grassland in the rainy season in March 1996. Terrain preparation of all the experiments in the grassland involved only line slashing, which was conducted a week before planting, using a mattock to clear an area 150 cm wide. Small pits (approximately 25 cm deep) had been prepared before planting. The number of plants per species varied from 12 - 48.

The measurements taken 12 months after establishment were:
- survival rate
- height (cm) and diameter (mm) at ground level of each tree and
- health condition of each tree.

After analysing the data using a two-way ANOVA procedure the species were classified according their efficiency to compete with grasses, into four classes: promising, possible, less successful and not recommended species.

In Table 2, the species are ranked according their ability to compete with *I. cylindrica* after one year. This resulted in the classification of 3 promising species, 10 possible species, 16 less successful species and 11 not recommended species. *Peronema canescens* and *Calophyllum inophyllum* were the two most promising species in their competition with grasses in the first year. The relatively fast growth of *P. canescens* with a compact crown at the juvenile stage makes this species suitable for intensive shading, which is essential for the effectiveness of using forest plantations in suppressing *I. cylindrica*. The exotic species, such as *Acacia mangium, Eucalyptus deglupta* and *Gliricidia sepium* demonstrated a faster growth than the local species, but had a lower survival rate than the two most promising species.

Table 2 Tree species ranking, one year after establishment

Promising **Survival : > 90 %** **Height : > 115 cm**	**Possible** **75 – 89 %** **95 – 114 cm**	**Not successful** **50 – 74 %** **75 – 94 cm**	**Not recommended** **< 50 %** **< 75 cm**
Peronema canescens, *Calophyllum inophyllum* *Gliricidia sepium*	*Anthocephalus chinensis,* *Arthocarpus elastica,* *Macaranga depressa,* *Elmerillia tsiampacca,* *Teijsmanniodedron sp.* *Acacia mangium,* *Eucalyptus deglupta,* *Fleminga macrophylla,* *Cajanus cajan* *Samanea saman.*	*Arthocarpus sp.,* *Alstonia scholaris,* *Calophyllum sp.,* *Diospyros sp.,* *Duabanga moluccana,* *Eusideroxylon zwageri,* *Litsea garciae,* *Macaranga gigantea,* *Macaranga hypoleuca,* *Macaranga lowii,* *Neolisea sp.,* *Parkia javanica,* *Scarphium macropodum,* *Elmerillia ovalis,* *Leuceana diversifolia* *Leuceana leucocophala.*	*Aleuretas moluccana,* *Buchanania sessifolia,* *Kokoona sp.,* *Macaranga conifera,* *Macaranga trichocarpa,* *Monocarpia kalimantanensis,* *Neonauclea gigantea,* *Schima wallichii,* *Vernonia arborea* *Tristaniopsis sp.* *Gmelina arborea*

The fires in Kalimantan in 1997-1998 destroyed this experiment and only a few species survived or resprouted, namely, *P. canescens* (99%), *Gmelina arborea* (55%) and *Samanea saman* (45%)

Dipterocarp species selection

Two experiments with dipterocarp species were established in 1995: one under a canopy of residual forest and one on open *I. cylindrica* grassland. Eleven dipterocarp species were planted - mostly originating from wildings harvested near the Wanariset Research Station and raised in the Wanariset nursery. These 11 Dipterocarps with the serial numbers 1-11 were: *Shorea balangeran* (1), *S. leprosula* (2), *S. selanica* (3), *S. pauciflora* (4), *S. johorensis* (5), *S. seminis* (6), *S. ovalis* (7), *Drybalanops lanceolata* (8), *S. smithiana* (9), *S. parvifolia* (10), *S. laevis* (11). The residual *Macaranga* forest was treated to create a 60% canopy cover. A minimum site preparation was executed by slashing the shrubs and small trees in a 2-metre wide strip. The seedlings were planted at a spacing of 3 x 5 metres. The same method was applied in the open *I. cylindrica* grassland area. The layout of the experiment was a Randomised Complete Block Design with 16 trees per plot, replicated 4 times in the residual forest and 5 times in the open area.

The measurements taken 1, 12 and 25 months after planting covered:

- survival rate
- height (cm) and diameter (mm) at ground level of each tree and
- health condition of each tree.

The results of the two dipterocarp species trials demonstrated that there are differences in tolerance to multiple environmental stress (solar radiation, high temperature, competition and soil infertility) between the 11 two-year old dipterocarp species tested. Only ***Shorea balangeran*** seems to be more stress-tolerant than the 10 other species in *I. Cylindrica*-dominated grassland. This was clearly demonstrated some months after the last measurements during the dry season, just before the fire destroyed the experimental plots. The 10 other species showed higher survival rate in residual forest, as compared with the same species planted in grassland (Fig. 3) after 24 months. Three species, *S. balangeran, S leprosula* and *S. selanica*, grew faster in the grassland, compared with these species planted in residual forest (Fig. 2).

Figure 2.

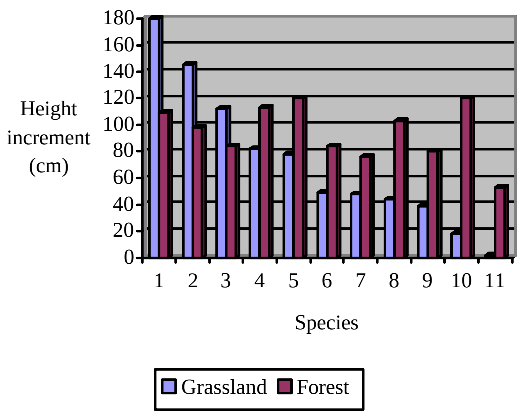
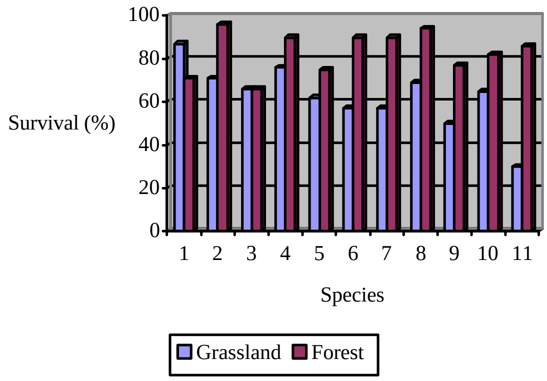


Figure 3



Figures 2 and 3 The height increment and survival (%) of 11 dipterocarp species after 24 months, planted in residual forest compared with these species planted in grassland. Numbering of species as indicated above.

Use of fertilisers

Complementary to the elimination trial, the effect of the initial application of NPK and five slow release fertilisers on the growth performance of four pioneer species were studied and measured 1, 5 and 12 months after establishment. The four species, *Acacia mangium, Anthocephalus chinensi, Macaranga pearsonii* and *Peronema canescens* were planted in 4 different experiments (Randomised Complete Block Design) all with the same fertiliser treatments. For comparison purposes, the fertiliser treatments were grouped randomly together in 6 blocks within one species.. The standard or control treatment did not receive fertilisers. The plots per treatment consisted of 4 trees with a planting distance of 1 x 2 m. A total number of 240 plants per species was tested (4 plants x 10 treatments x 6 blocks). The measurements taken 1, 5 and 12 after the establishment of the experiment were:

- survival rate
- height (cm) and diameter (mm) of each tree at 5 cm above ground level
- projection of the crown diameter of each tree after 12 months;
- the health condition of each tree using such descriptive parameters as yellow leaves, insect attack, broken branches and/or broken top
- cover of the *I. cylindrica*, which was estimated in the percentage classes 0-20, 21-40, 41-

60, 61-80 and 81-100. This variable was measured only once in the first week of March 1996, one month after the establishment of the experiment;

- in August 1997 the fertiliser experiment was destroyed by fire. The survival rate of all species was recorded 3 and 10 months after this incident. In addition, the shoot length and diameter at ground level of *P. canescens* trees were measured.

Tree growth per species (height, diameter at ground level and h/d) were analysed using the two-way ANOVA procedure for fertiliser treatments, blocks and the covariant *I. cylindrica* cover. SPSS Statistical data analysis was used for the evaluation.

The species *P. canescens* showed a very good and uniform performance and application of fertiliser did not influence its growth. However, the use of fertilisers had a positive effect on the early growth of *A.mangium*, *A. chinensis* and *M. pearsonii*. The species *A. mangium* seems to require a much higher dose of nitrogen as compared with *P. canescens*, *A. chinensis* and *M. pearsonii*. A preliminary conclusion is that the optimal dose of 4-5 grams of slow release fertiliser (Osmocote 17+9+8+4) in the planting hole is necessary for *A. chinensis* and *M. pearsonii.* The species *A. chinensis* seems to be more susceptible to draught and competition and probably requires more nutrients than *P. canescens* and *M. pearsonii.*

The 1.5 year-old plants of *P. canescens* burnt in August 1997, but resprouted vigorously after burning (99%), as opposed to *A. mangium, A. chinensis* and *M. pearsonii,* which also burnt but did not sprouted again.

Domestication of *Peronema canescens* Jack. (Verbenaceae)

In 1998, the Wanariset Research Station included the domestication of *P. canescens* in its research programme. This was based on the performance of this species achievedafter the first evaluations of the pioneer species elimination experiment and the fertiliser experiment, but especially that achieved after the fierce fires of 1997-1998. Unfortunately, these fires destroyed these experiments but, as a blessing in disguise, the fires demonstrated that *P. canescens* is a fire-tolerant species with the capacity to sprout vigorously after burning.

Westphal *et al*. (1989) and Kessler *et al*. (1994) describe the general characteristics of the family Verbenaceae and in particularly *Peronema canescens* Jack. This species is a pioneer species occurring in Peninsular Malaysia, Sumatra and Borneo. It is cultivated in Indonesia, Malaysia and Thailand. The wood of *Peronema* (with the local name of sungkai) is mostly used locally for roof trusses, bridge construction and furniture. The attractive, beautiful linear figures in the wood make sungkai suitable for fancy veneer, cabinets, carvings etc. and the wood is exported to Japan. For that reason, natural populations of mature old trees are becoming extinct in Kalimantan. *Peronema* occurs in residual forest on dry and slightly moist soil at an altitude of up to 600 m. Luxuriant natural regeneration may occur in open places, such as bushlands, *I. cylindrica* grasslands, fallow or logged-over forest. Dominant natural populations of this species were present on infertile black soil hills in the ITCI concession (a large timber concession near Balikpapan) area in 1998. This indicates that the species may have the capacity to rehabilitate critical land such as grasslands and mining sites. Plants propagated spontaneously from root and branch cuttings were observed in natural populations. It was interesting to note that pigs are propagators of *Peronema* through breaking branches for nest building.

Artificial regeneration is carried out by planting branch cuttings, 2.5 cm in diameter and 25 cm long at angle directly in the field on 1 to 2 m wide strips. More common is the planting of branch cuttings directly in polybags in the nursery, transplanting them about 4 to 6 months later. Spacing in the field is commonly 3 x 2 m or 4 x 2 m. Several experiments have been conducted since 1998 and have already led to numerous useful conclusions. A short description of the experiments is given in the following paragraphs.

Collecting cuttings of 12 origins (provenances) (Tolkamp, 1998)

In June and October 1998 two field trips for the collection of cuttings and seeds from natural *P. canescens* populations were organised in South and East Kalimantan, respectively. More than 100.000 cuttings of 12 origins (provenances) were collected and propagated in the nursery. The cuttings collected along the road to Banjirmasim in South Kalimantan came from heavily burnt forest and consisted of semi-hardwood cuttings of low quality from sprouted stumps. No seed-bearing trees were observed during that period. The second survey was organised in the unburnt logged-over forest of the ITCI concession near the Meratus mountain in East Kalimantan. The rooted cuttings were planted in 1998 and 1999 in the reforestation area of *I. cylindrica* grassland.

The effect of storage duration on the rooting ability of P. canescens cuttings (Riskan & Rayan, unpublished)

Lignified *P. canescens*' branches of 1.5 cm length and with a diameter of 1.5 – 2 cm were collected. Bunches of branches for the production of 600 cuttings were stored in the shade of trees near the nursery (the minimum humidity was 60 % during daylight). 25 cuttings in 4 replicates were produced successively in polybags every ten days over a 50 day period. The rooting ability was evaluated 30 days after propagation.

The conclusions from this experiment are:

- the rooting ability of the cuttings, propagated 1, 10, 20, 30, 40 or 50 days after collection, was 94%, 91%, 94%, 98%, 98% and 97%, respectively (average = 95%).
- lignified branches of *P. canescens* can be stored for 50 days or more under tree shade before losing their rooting ability.

The effect of the origin of cuttings on the rooting ability of P. canescens (Tolkamp & Alkadafi, unpublished).

In June 1998 cuttings collected from resprouted stumps and originating from three sites in South Kalimantan were propagated in polybags and in the open soil. The survival rate and shoot length of 850 cuttings were recorded 30, 58 and 91 days after planting..

The conclusions of this experiment are:

- the optimal production period for *P. canescens* cuttings in the nursery is 4 months;
- lignified (hardwood) cuttings from branches are superior in rooting percentage and growth to partly lignified (semi-hardwood) cuttings originateing from stumps (rooting percentage respectively 76-100% and 12-36%);
- the rate of success is the same for propagation in polybags and propagation in the open soil.
- the production costs of propagated cuttings in the open soil are much lower than those of cuttings produced in polybags. However, introduction of the cutting production method in the open soil depends on the success of the establishment of bare root cuttings in the *I. cylindrica* grasslands

Direct planting of unrooted and rooted P. canescens cuttings in I. Cylindrica-dominated grasslands (Tolkamp & Taupik, unpublished)

Cuttings were planted on 11 November 1998 in small pits at a spacing of 2 x 1 metres. Manual weeding was carried out in the form of strip clearance by slashing the grass every 3 months. No fertilisers were applied before or after planting. Five treatments were tested in a randomised complete block design: (1) unrooted 100 cm cuttings; (2) unrooted 50 cm cuttings; (3) unrooted 25 cm cuttings; (4) bare root cuttings and (5) cuttings produced in polybags

The results after 4 months showed that:

- direct planting of unrooted cuttings with a length of 50 cm had the highest survival rate of 93%, but the survival rate was not significantly different from that of cuttings with a length a 100 cm (76%), cuttings of 25 cm (82%) and cuttings propagated in polybags (82%).
- bare root cuttings demonstrated a very low survival rate of 20% and this survival rate was significantly different (P = 0.00) from that of the other cutting methods.
- planting of bare root cuttings in grassland is not recommended, because of dehydration and root damage problems during transport and planting. This also means that the production programme of *P. canescens* cuttings in the open soil has been cancelled.
- establishment of *P. canescens* plantations with unrooted, lignified (hardwood) branch cuttings of 50 cm length is technically feasible and economically attractive in *I. cylindrica* grasslands. Observations on the growth are continuing.

Other related activities for the domestication of P. canescens

- Two types of *P. canescens* hedge orchards, namely a clonal and a ‘true to origin’ hedge orchard, were established in 1998 and in the last months of 1999. The objectives are to assure a constant supply of high quality plant material of known origin in the future for potential users (farmers, reforestation projects etc).

- *P. canescens* is a promising species suitable for a fire break in that it possesses the required properties (ITTO, 1997). A proposal was written to study the growth performance of 45 *P. canescens* clones in relation to the species’ efficiency as a fuel break. The objective of this study is to select the most suitable clone as a fuel break tree and to compare the results of the same clones, planted in a plantation and in the seed orchard. Plant material is ready in the nursery.

- Depletion of mature, natural populations through over-exploitation and fires caused seed shortages of *P. canescens*. Although artificial propagation by seed is not commonly practised and knowledge of the seed technology of this species is not available at the Wanariset, it was proposed to establish a seed orchard of the valid clones in the near future.

- An experiment on the effect of shading of *Shorea leprosula* by *P. canescens* with the aim of contributing to greater knowledge of the water stress physiology of this dipterocarp species is included in an ongoing PhD study (Priadjati).

- An agroforest plantation consisting of *Peronema canescens* (sungkai) next to *Parkia javanica* (petai) progenies, *Nephelium cuspidatum* var. *robustum* (rambutan) and *Arthocarpus integer* (cempedak) was established on *I. cylindrica* grassland in November 1998.

DISCUSSION AND CONCLUSIONS

The Tropenbos-Kalimantan Project presents an ecology-based strategy, which accelerates regeneration, is sustainable and offers a better alternative to exotic tree plantations. The strategy relies on the potentials of natural regeneration (which differs on each site site) and accelerates regeneration through planting a mix of adapted local pioneer species in an initial phase of reforestation (see Figure 1). In a later phase, climax species (Dipterocarps) are planted in between the pioneer species to approach a natural regeneration process, developing towards a more sustainable dipterocarp-dominated plantation. The strategy is already proving to be a potentially rapid, efficient and cost-effective way of establishing buffer zones around protected forests and of reforestating all kinds of critical land. The results from experiences with species selection, fertiliser application and with the domestication of desired species are promising, but the results are based on a short period and the time is not yet ripe for final recommendations.

Species selection

Increasing the diversity of species for use in grassland reforestation schemes can reduce the risk of failures, both biological and economical. Long-term functional forest use planning (single functions or multiple functions, e.g. conservation, timber, hydrology, NTF-production, agroforestry, recreation) and species site matching should produce the most suitable species. Indigenous species not yet tested may complement or outperform the limited number of exotic species currently used in grassland reforestation activities.

A limited number of local species have so far been tested in Kalimantan and the results are not yet encouraging. However, the introduction of indigenous species to exotic tree plantations should be considered as a technical transition phase and is certainly not a desirable option. Better alternatives are the systems based on natural regeneration or enrichment planting or a combination of these two reforestation methods in different variations. These alternatives may turn out to be a way of overcoming both short-term and long-term problems. This paper has affirmed that a limited number of local species can be successfully used in the establishment of a nursing pioneer plantation. Species selection at the second phase of integrating local climax tree species into the pioneer plantation and at the third phase of natural regeneration in mixed forest will certainly have its problems. However, the prospects of finding suitable indigenous species for this ecology-based strategy for the reforestation of *I. cylindrica* grasslands are very promising. The species elimination experiments of the Wanariset Station added further information to that from the South Kalimantan experiments and confirmed the need for more local species research.

The results of the species elimination experiment, based on the performance of 40 species under extreme grassland conditions, are still preliminary, but confirm that there is considerable potential for some native species under extreme conditions. Two species, *Peronema canescens* and *Calophyllum inophyllum*, were selected for further experiments in pilot plantations, fuel breaks and agroforests. *Acacia. mangium* outgrew local species, confirming the results in South Kalimantan (Otsano *et al*., 1997). However, Otsano also pointed to the fact that *P. canescens* and *C. inophyllum* were promising among the local species. This also supports the recommendation to plant at least 2500 trees of these species per hectare, based on growth, shade providing capacity and early canopy closure properties.

Application of fertiliser

For most species fertiliser application is essential as a silvicultural treatment to establish pioneer plantations for successful competition and suppression of *I. cylindrica* grass. The use of slow release fertilisers showed that the method can be recommended to stimulate early growth of the desired trees. The use of fertilisers was species' specific and had a positive effect on the early growth of *Acacia mangium*, and also on recommended indigenous species. The species *Peronema canescens* showed a very good and uniform performance in *I. cylindrica* grassland areas with low soil nutrient levels. More research is needed to clarify these aspects.

Domestication

Peronema canescens is the most appropriate species for the reforestation of grasslands. The species is easy to propagate by means of branch cuttings. Direct planting in the field of cuttings of 50 cm length is very successful. Direct planting of unrooted branch cuttings reduces the planting costs and makes reforestation of these grasslands more attractive. Another advantage is that the lignified cuttings can be stored for about 50 days without loosing their rooting ability. This makes the transport of cuttings over long distances feasible and the large-scale propagation of *P. canescens* attractive. The species has the capacity to compete with *I. cylindrica* grass and suppression of the grass can be made more effective through planting at close intervals. The species is fire-tolerant and is locally used a as commercial tree for its timber. All these characteristics merit more research in further domestication of this very useful species.

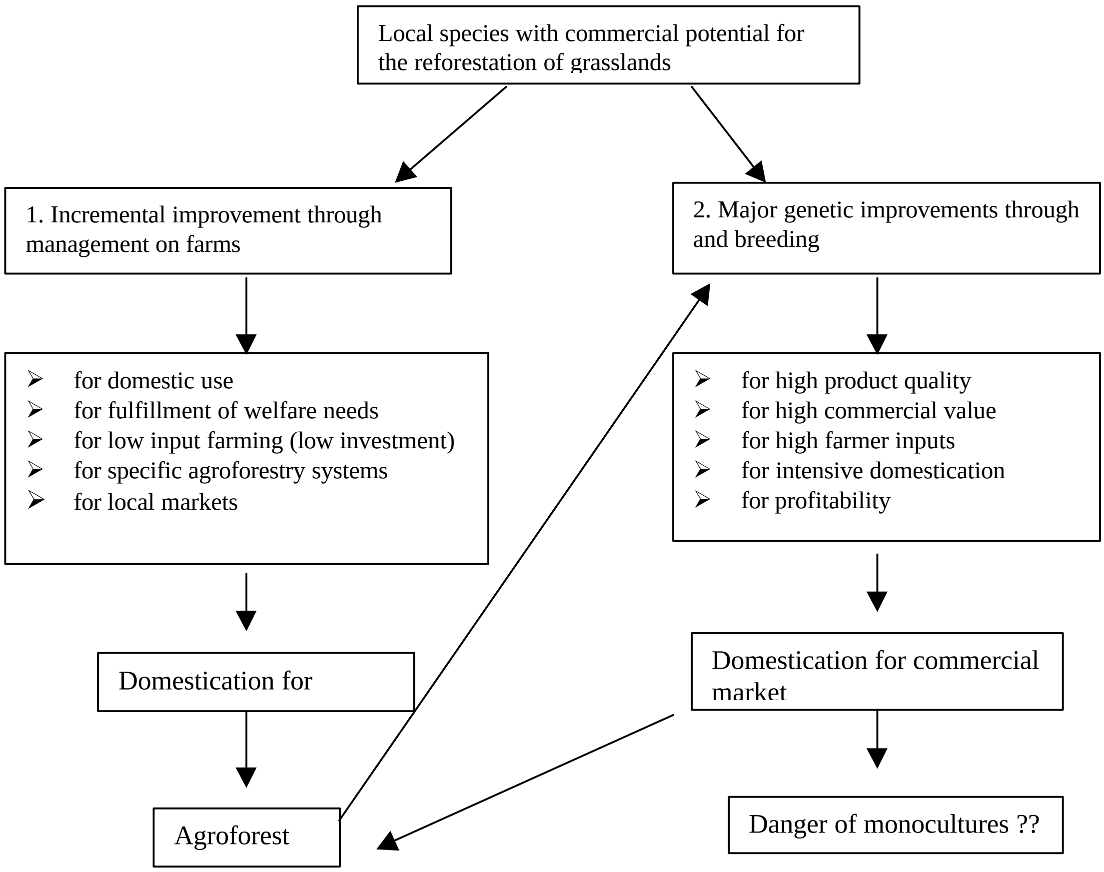


Figure 4 Two strategies in the domestication and commercialisation of a species and its products (modified from Leakey *et al*., 1997)

Two strategies for the domestication of selected species will be followed in further Wanariset research:

- incremental improvement through management on farm; and
- major leaps in tree improvement by genetic selection and breeding.

Figure 4, modified from Leakey et al., 1997, represents these two strategies diagrammatically. The first strategy is farmer-oriented, while the second is market-oriented. The two strategies are not mutually exclusive; collected *P. canescens* cuttings of different origins and many mother trees are used in both strategies. The selected cultivars or clones from genetic improvement programmes can be grown on farms as well as on large plantations (Figure 4). Monocultures are not established. The project will inform concessionaires, reforestation projects and farmers of the great economic and environmental potential of mixtures of pioneer and climax species for converting grasslands. For that reason, feasibility studies directed at solving individual problems and integrated research in an extended programme are recommended. It should be a common effort of all the stakeholders, i.e. of concessionaires, reforestation projects, farmers and researchers. It is also suggested that this research should be integrated into national regional and international research programmes, such as the programmes of Tropenbos International, CIFOR, ICRAF, BIO-REFOR.

RECOMMENDATIONS

The significance of the study is the introduction of an ecology-based strategy – which is a site specific, accelerated natural regeneration method - as a practical tool for the rehabilitation of degraded areas, in particular, the reforestation of *Imperata cylindrica* grasslands in Indonesia. The Wanariset Research Station, located in a mosaic like landscape, is pre-eminently suitable for conducting research in conservation, tropical forest ecology, species-site matching, and reforestation of *I. cylindrica* grasslands, agroforestry and social forestry.

In this context, it is recommended that:

- implementation be started of the ecology-based strategy for the rehabilitation of critical land with farmers in the Wanariset area.
- research on this ecology based strategy in the Wanariset Research Forest should continue and be intensified
- native tree resources for appropriate grassland reforestation should be explored and studied
- The domestication of tree species for on-farm-use and for the commercial market should continue and be intensified. The domestication of *Peronema canescens and Calophyllum inophyllum*, in particular, should proceed.
- A feasibility study be implemented to investigate the possibilities of direct sowing to reforest grasslands in combination with different silvicultural treatments. Controlled fires for land preparation should form part of this study.
- Plantations consisting of mixtures of *Peronema canescens*, dipterocarps and fruit trees should be created to serve as buffers for existing primary forests, plantations, estate crops, agricultural fields and villages, thus reducing the risk of encroachment and the penetration of fires and grasses.
- The direct sowing of a mixture of selected species (such as *Trema* sp.). be tested at places where seed (from the seed bank) is exhausted. Sowing should take place after controlled burning at the beginning of the rainy season.
- establish close collaboration between Indonesian, Asian and international organisations.

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