Imperata Grassland Rehabilitation using Agroforestry and Assisted Natural Regeneration

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Southeast Asian Regional Research Programme
Bogor, Indonesia
1999

Correct citation:

Friday, Kathleen S.,[1] M. Elmo Drilling,[2] and Dennis Garrity[3]. 1999. ***Imperata* grassland rehabilitation using Agroforestry and Assisted Natural Regeneration**. International Centre for Research in Agroforestry, Southeast Asian Regional Research Programme, Bogor, Indonesia.

ISBN 979-95537-0-9

Printed by:
SMT Grafika Desa Putera, Jakarta, Indonesia

This manual is a companion volume to:

***Imperata* Management for Smallholders, An Extensionist's Guide to Rational *Imperata* Management for Smallholders**. 1996. Indonesian Rubber Research Institute, Sembawa Research Station, Indonesia; Natural Resources Institute, UK; and International Centre for Research in Agroforestry. 56 p.

Both volumes may be obtained from:

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Acknowledgements

The content of this manual was drawn primarily from materials presented at the International Workshop on Agroforestry Innovations for Imperata Grassland Rehabilitation[4], held on January 23-27, 1995, in Banjarmasin, Indonesia, and from documented experience with Assisted Natural Regeneration in the Philippines.

Principal contributors to the concept and design of this manual included Hugh Bagnall-Oakley, Derek Laycock, P. John Terry, and C. Conroy (staff and advisors of Project F0028, Management of Imperata cylindrica for smallholder farming systems, DFID); and Patrick Durst (Food and Agriculture Organization [FAO] of the United Nations).

We gratefully acknowledge substantial review, suggestions, information and comments provided by Hartmut Abberger, Ernesto Cadaweng, Hubert de Foresta, Thomas Dierolf, I.V. Domingo, Patrick Durst, J.B. Friday, Ngaloken Gintings, William Granert, Chun Lai, Rodel Lasco, Dennis Orbus, John Parrotta, Paulo Pasicolan, C. Fernando Potess, Boylan Preston, James Roshetko, Wilma Sabueto, J.B. Sangalang, P. John Terry, Rodolfo Ungson, and Meine van Noordwijk. We also thank Delbert Rice for information and inspiration provided long ago.

Illustrations were prepared by Wiyono of ORSTOM/ICRAF and by illustrators at FAO and the International Institute of Rural Reconstruction publications. Text and illustrations were laid out by Tikah Atikah of ICRAF.

The writing and publication of this manual was funded jointly by the United States Agency for International Development, the USDA Forest Service, ICRAF, and FAO. Practical assistance was provided by the Asia-Pacific Agroforestry Network.

[4] Organized by the International Centre for Research in Agroforestry (ICRAF) with funding support from the United Kingdom Department for International Development (DFID), US Agency for International Development and the Australian Center for International Agricultural Research.

Table of Contents

Introduction

Imperata cylindrica grasslands are found throughout Southeast Asia. They are perpetuated by *Imperata'*s ability to resprout quickly after fire. Fire is the main reason that tree plantations fail on *Imperata* grasslands. Local people may be the cause of fire, but they are also the best partners to prevent it. They rehabilitate *Imperata* grassland rehabilitation when they own the trees and crops that will replace *Imperata*. The more valuable the new land use is to local people, the harder they will work to maintain it and prevent fire.

This manual is written to benefit people who live in an environment dominated by *Imperata* and who want to replace grasslands with agroforestry and forests. The techniques covered in this manual are most useful for medium-sized grasslands, confined to one village or community. The manual's content and format is designed for extensionists, agriculturists, foresters, development workers, and others who can assist communities and smallholders to design and implement *Imperata* rehabilitation activities.

Newly established agroforestry system

Agroforestry practices involve a close association of trees and shrubs with crops, animals, or pastures. The combination of species often uses growing space more fully than simple tree plantations, creating more shade and reducing the growth of grass. A community of small landholders can implement intensive and complex agroforestry systems over a large area, thus rehabilitating large grasslands. This manual covers how to establish agroforestry in *Imperata* grasslands, but it is not a complete textbook on agroforestry. Extensionists are encouraged to get additional information on specific agroforestry systems and crops.

Assisted Natural Regeneration

Assisted Natural Regeneration (ANR) stimu-lates the growth of natural saplings and seedlings. Regeneration is assisted by fire suppression, weed control, and attracting wildlife that spread seeds. ANR may include enrichment planting. On appropriate sites, forest cover can be re-established more quickly and cheaply with ANR than with conventional reforestation. ANR has often been implemented in partnership with local communities, making use of local knowledge and species preferences, and granting tenure of land or products. This manual contains an introductory field guide for ANR.

Readers of this manual should also have a copy of *Imperata Management for Smallholders*[5]. It provides information on cultivation and herbicides to control *Imperata* as a weed within individual farms. See Appendix A for this and other recommended references with more detailed information on specific topics.

[5] ***Imperata* Management for Smallholders, An Extensionist's Guide to Rational *Imperata* Management for Smallholders**. 1996. Indonesian Rubber Research Institute, Sembawa Research Station, Indonesia; Natural Resources Institute, UK; and International Centre for Research in Agroforestry. 56 p.

Chapter 1

Imperata and People

1.1 Why 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 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 cylindrica

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 plowed, its thick mat of rhizomes near the soil surface minimizes erosion. Reforestation is very expensive to carry out over large areas; it must be justified economically as well as environmentally.

1.2 Conditions required for grassland rehabilitation

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

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 land holder should be free to choose land use.

2. **Transportation and access to markets must be adequate**. Many *Imperata*-dominated areas are remote, and may remain in *Imperata* for that reason. Agroforestry and assisted natural regeneration will become more feasible if access is improved for implementation, protection, and marketing. Roads allow fertilizer to be brought in and produce to be taken out. What transportation is adequate depends upon where landusers live and what crops are grown.

3. **Local communities must cooperate 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 cooperate in fire prevention if they have secure tenure and access.

Development activities may be able to help put these conditions in place by building roads, creating 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 organizing cooperatives.

1.3 Working with people and Imperata

Community development should begin with local community objectives. However, national or regional governments or programs often have objectives for *Imperata* rehabilitation that are combined with watershed restoration, resettlement, or economic development. These regional objectives may complement local community objectives, or they may be in conflict with them. Conflicting objectives usually cannot be resolved by just educating the community, but require dialog and respectful negotiation.

Project managers and extension agents serve both regional programs and local communities. They can help communities to explain their needs to programs and governments.They can try to adjust outside assistance to meet the objectives of local communities as much as possible. Or, they can choose only communities that are good matches for the development activities.

1.3.1 Role of the extensionist

Extensionists are the critical link in the chain between farmers and research institutions, development organizations, and government offices. Especially in *Imperata* grassland rehabilitation, the extensionist should not just give farmers technical instructions. **An effective extensionist**...

...**listens and learns**. Often, only local people can explain the history of an *Imperata* grassland and what land claims and land uses exist.

Rehabilitation of grassland starts with vision and objectives

...**is sensitive**. Farmers have constraints and limitations, like insecure tenure or lack of resources. These constraints may keep them from carrying out recommended activities. Their reluctance may be perfectly rational. It may be the recommendations that need to be changed.

...**recognizes farmers' abilities**. Farmers are often creative experimenters. The extensionist should encourage them to establish small trials of variations on technical recommendations. Farmers with small plots can manage their land in a more complex way than large plantations. They can select and plant a mixture of multipurpose trees or specialty crops that grow in specific microsites or planting spaces. Such intensive development of the land leaves less *Imperata* as a fire hazard.

...**helps the community with its objectives**. The extensionist's work should serve community needs and objectives. In addition, short-term help

with even small or unrelated objectives will build the community support and trust needed to address long-term or regional objectives.

...**enables and empowers the community**. Within the community, the extensionist should encourage self-help groups to develop cooperation and leadership in the community. The community should be prepared to continue its activities even if the extensionist or outside funding leaves. Communities in *Imperata*-dominated areas are often remote and isolated. The extensionist can help overcome this isolation by introducing community leaders to government agencies and other sources of long-term assistance.

...**is patient and has a sense of humor!**

1.3.2 Community perspectives

Before launching any activities in *Imperata* grassland rehabilitation, outside facilitators should understand community perspectives on all ways that *Imperata* and alternative land uses affect the community. Talk to people representing all those groups potentially affected: men and women, people from various villages, people of all ethnic groups, rich and poor, young and old, long-settled residents and recent migrants, landowners and those owning no land. Often it is the least prominent people who are most dependent on forest and grassland resources.

Cover the following topics:

1. **History of the grasslands.** When did these grasslands come into being? How have they been used in the past? Have they been continuously maintained as grasslands?
2. **Use of *Imperata* and *Imperata* grasslands**. Is *Imperata* used for thatch, medicine, rituals, fodder, or other things? Are *Imperata* grasslands used for shifting agriculture, hunting grounds, pasture, or thatch production? Are there people who depend upon the *Imperata* resource for jobs? (For example, people may earn money by plowing *Imperata* fields, or by thatching roofs.)

3. **Changes in *Imperata* grassland use**. Can community elders remember these uses having changed during their lives? How has *Imperata* use been affected by changes in population, markets, technology, government pressure, or other events?

Extensionist asking questions

4. **Rules for grassland use rights**. What are the current laws, regulations, and local customs controlling use rights for these grasslands? How have these rules changed or evolved from past traditions? How might an *Imperata* grassland rehabilitation effort change these rules, for example by changing land tenure or use rights?

5. **Differences within the community**. Who uses *Imperata*? Who claims *Imperata* grasslands? Are there differences between how different groups (ethnic groups, men/women, old/young, rich/poor,

etc.) use or own it? How would changes brought about by *Imperata* grassland rehabilitation affect these groups?

6. **Local value of *Imperata***. Do local people value *Imperata* and *Imperata* grasslands? How does that value compare with the value of forest, forest plantations, other secondary vegetation, agroforestry and crops? Where do farmers prefer to plant their crops?
7. **Productivity and environmental sustainability.** Are current land use practices productive? Do they cause environmental problems? Will they continue to be productive in the long term? Do local farming practices affect primary forest, old fallows, or grasslands? Is soil erosion significant? Does the threat of fire prevent investment in valuable crops?
8. **Farmers' objectives**. What are the farmers' plans or suggestions for improvement of the *Imperata* grasslands or of their farming practices? What changes do they think would benefit their households or the community?
9. **Agroforestry or Assisted Natural Regeneration**. Can agroforestry or ANR make the improvements suggested? What kind of agroforestry or ANR practices? What species of trees, shrubs or crops do farmers want to plant?

1.3.3 Community mapping and planning

Encourage local people to engage in a participative exercise to make maps of the community and prospective land uses. This encourages sharing of information and discussing objectives. The maps become a focus around which the community begins to make decisions and plans.

Start with a map or maps describing the current situation:

Land ownership and claims. Map any large claims on forest and agricultural areas. Elicit detailed information about claims on *Imperata* grasslands.

Sketch map of current land uses
GALLERY FOREST
ROAD
ROAD
FUELWOOD COLLECTION
THATCH
GRAZING (PUBLIC)
GRAZING (PUBLIC)
GRAZING (PUBLIC)
GRAZING (PUBLIC)
GRAZING THATCH (PUBLIC)
THATCH (PUBLIC)
SWAMP

Sketch map of planned land uses
ANR
ANR
AGROPOREST
TREE CROPS
AGROPOREST
ANR TREE CROPS
AGROPOREST
ANR TREE CROPS
AGROPOREST
ANR
AGRO FOREST
ANR TREE CROPS
AGROPOREST
ANR-TREE CROPS
ANR
GRAZING
AGROPOREST
THATCH
AGROFORESTRY
GRAZING
ANR
GRAZING
GRAZING
ANR
THATCH
ANNUAL CROPS
AGROFORESTRY
ANNUAL CROPS
AGROFORESTRY
ANNUAL CROPS
ANNUAL CROPS
AGROFORESTRY
AGROPOREST
SWAMP
AGROPOREST
ANR
AGROFORESTRY
SAVAH
AGROFORESTRY
SAVAH
SWAMP
ANR
SAVAH
AGROFORESTRY

Existing vegetation types. Map the large areas of primary forest, secondary forest, agroforestry, and agriculture in the community. Pay particular attention to mapping the different kinds of *Imperata* grasslands: pure *Imperata*, *Imperata* with scattered shrubs and patches of forest, *Imperata* areas with scattered agricultural activities, sparse *Imperata* on poor soil, etc.

Land use. Show detailed information on the various uses of *Imperata* grasslands, for example, agricultural fallow, hunting, and grazing.

Special features. Include roads, streams, springs, hills, valleys, and other natural landmarks.

Mark a copy of the map to show plans for future land use:

Sites where current uses will continue: for example, forest, agroforestry, agriculture.

Sites to remain in *Imperata*, for various reasons:

- *Imperata* grasslands that the community wants to retain, for hunting, grazing, or thatch. *Imperata* might be an important source of forage for local communities' cattle and water buffalo.
- *Imperata* grasslands that are so remote, fire-prone or infertile that it is not worth trying to rehabilitate them in the near future.

Sites for conversion from *Imperata* to other land uses. Identify the planned land uses, depending on characteristics of the site and the priorities of the community:

- agriculture
- agroforestry
- assisted natural regeneration
- tree plantations
- improved forage

Improvements planned, especially buildings, roads, trails and water projects.

The community may identify only a small area of land for *Imperata* grassland rehabilitation. This may suggest that rehabilitation is not perceived to be a priority and that the community may be better served by other efforts. Perhaps more land would be desired for rehabilitation if there were better market access or more secure land tenure. Or, perhaps the community has a "wait and see" attitude, and success with a small area will motivate people to try more later.

Chapter 2

Imperata Grassland Ecology

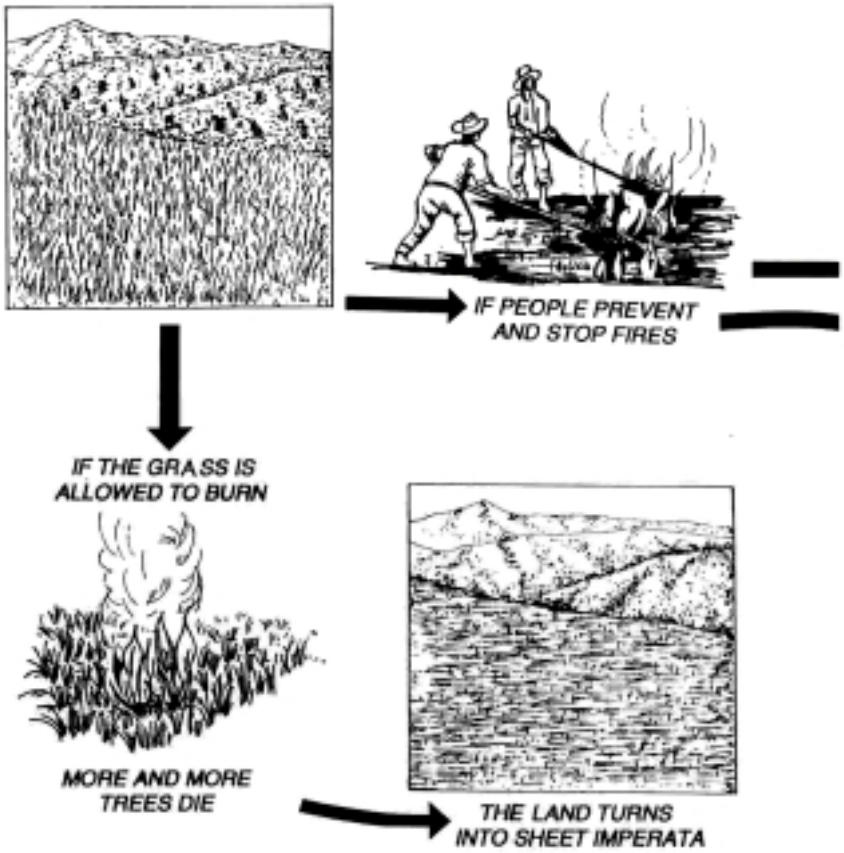
Imperata is a sun-loving perennial grass, with flammable above-ground foliage and extensive below-ground rhizomes. It propagates by seeds and lateral growth of its rhizome system.

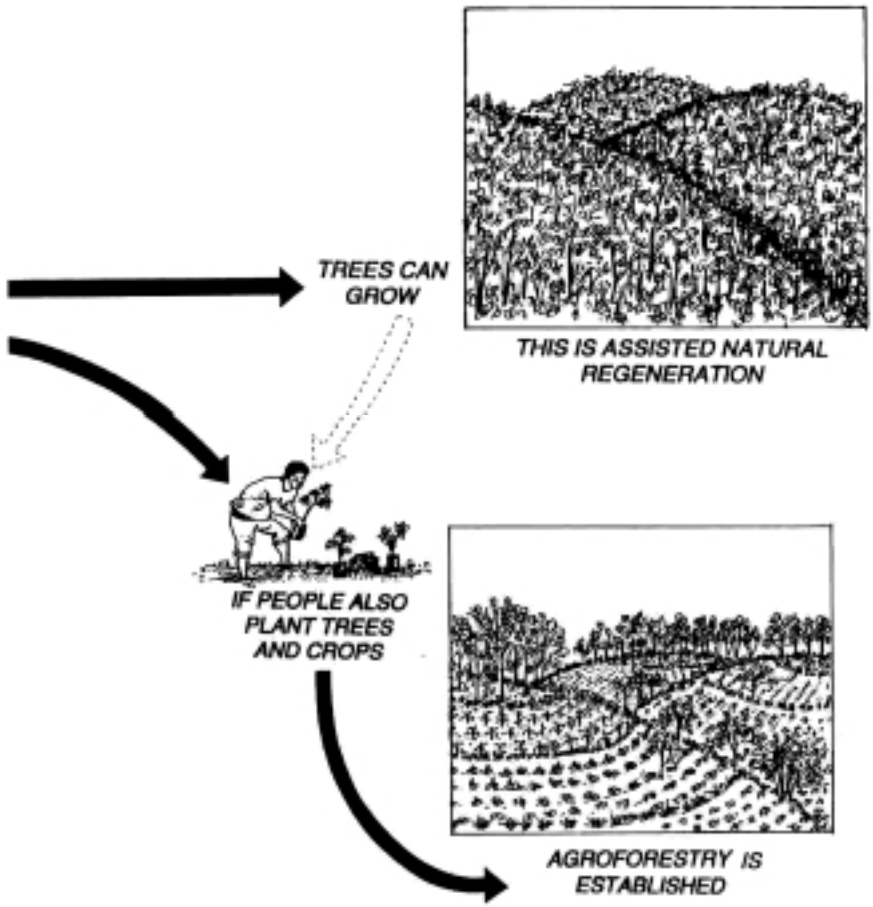
2.1 Grassland development and forest succession

Forests are the natural, original “climax” vegetation in nearly all of Southeast Asia, but *Imperata* grasslands are now widespread. When forests are disturbed by logging, shifting agriculture, or burning, *Imperata* often takes over. *Imperata*’s seeds are blown far and wide, and it is able to grow on wet or dry, fertile or infertile soils. Once established, the grass is a very flammable fuel. Even three days without rain can dry out the grass enough to carry a fire, burning both the grass and nearby forest vegetation. Fire stimulates both flowering and immediate regrowth of *Imperata*’s rhizomes. At the same time, fire damages or kills forest vegetation. If fires are frequent, *Imperata* will gradually become more dominant. It often forms monocultures except for a few scattered fire-resistant trees and shrubs, or it is part of mixed grasslands with other fire-adapted grasses. This is called a “fire climax.”

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 ("allelopathic”) substances produced in and leaking from *Imperata*'s roots and rhizomes.

The Transition from Imperata *grassland*




TREES CAN GROW
THIS IS ASSISTED NATURAL REGENERATION
IF PEOPLE ALSO PLANT TREES AND CROPS
AGROFORESTRY IS ESTABLISHED

If an *Imperata* grassland does not burn, it will naturally and gradually return to forest ("forest succession"). Slowly, pioneer trees and shrubs sprout or grow from seed, and eventually some grow above *Imperata* and outcompete it for light and water. Once *Imperata* is suppressed, additional species can grow more easily.

Assisted natural regeneration (ANR, Chapter 5) imitates this natural process. Both ANR and agroforestry speed up the conversion of grasslands by:

- protecting the whole area from fire,
- planting trees,
- suppressing *Imperata* so that it does not compete with trees for light and water, and/or
- speeding tree growth by fertilizing, liming, or adding organic material.

It is often assumed that grasslands are the final, irreversible result of deforestation and the abandonment of farmlands, and that therefore grasslands are increasing in area. While it is true that grasslands are expanding in many places, *Imperata* is only a "climax" if fire or other disturbances continue. Many grasslands have been converted into agriculture or agroforestry during this century. In some countries and provinces, the total area of *Imperata* grasslands has decreased as human populations and the demand for land have increased.

2.2 Characteristics of Imperata *grasslands*

The major characteristic of *Imperata* grasslands is the occurrence of fire. Besides that, *Imperata* may occur in a wide variety of situations. Many generalizations about *Imperata* grasslands are inaccurate, so extensionists should get correct information for each site. Nevertheless, some conditions are so common in *Imperata* grasslands that extensionists should keep them in mind.

Sloping topography. Hilly lands are more prone to the establishment and persistence of *Imperata* than flat lands because fires on sloping lands are hotter and spread more rapidly.

Soil erosion. Sloping *Imperata* lands may be prone to erosion because periodic fires expose the soil to rain. However, *Imperata* does cover the soil for most of the year and its roots hold the soil even after burning. *Imperata* is a better soil cover than no vegetation at all, and may protect the soil better than cropping systems that include plowing or other soil disturbance.

> Any agroforestry system under consideration for *Imperata* rehabilitation must protect against soil erosion. It should not be assumed that *Imperata* conversion will necessarily reduce erosion.

Climate. *Imperata* may be found in a wide range of climate types. Many grasslands grow where there are long wet seasons, provided that dry months occur often enough for fires to burn.

> Check local rainfall tables for the average monthly rainfall and the duration of both wet and dry seasons. Ask local farmers about their crop planting schedules and reasons for them.
>
> Use this information to plan fire suppression, planting schedules, and to select species.

Soil fertility. *Imperata* is not very nutrient-demanding, and is often found on infertile and acidic soils. *Imperata* land that has been burned tends to have reduced soil organic matter (OM). However, *Imperata* is also found on moderately to highly fertile soils.

> Do not assume that soils under *Imperata* are poor.
>
> Observe nearby crops for signs of nutrient stress to get an idea of soil fertility in the general area. Inquire about local fertilizer recommendations and soil test results.
>
> Sample soil pH.

Observe rocky outcrops, roadcuts, and plowed areas to get a general idea of soil depth and texture. Study soil survey results.

Use this information to select annual and perennial species and estimate needs for lime and fertilizer.

2.3 Imperata *grassland size*

Rehabilitation alternatives for *Imperata* grasslands depends upon the size of the grasslands. The larger the grassland, the more difficult it is to rehabilitate any part of it. The following tables explain the effects of grassland size.

Large grasslands: "sheet *Imperata*"

Definition & Description	*Management Implications*
Large *Imperata* grasslands spread across more than one village, municipality, or district. Fires started in distant parts of these grasslands may spread over great distances.	Fires are nearly impossible to control because of their remote starts, size, and frequency. It is difficult to educate, motivate, and coordinate all the affected communities at once. Conversion to agriculture or forestry is more practical at the edges of the grassland. Even at the edges, there is a high chance of failure.
The largest grasslands tend to occur in areas with lower soil fertility, rough topography, or in areas prone to drought.	Such areas are often unproductive sites for forestry and agroforestry.
These have often been grasslands for long periods of time, and have lost almost all the trees from the original forest. The centers of large grasslands are far from sources of seeds. They attract few birds and animals that carry seeds.	Assisted natural regeneration is practical only at the edges of forest patches.

Medium-sized grasslands: "village grasslands"

Definition & Description	*Management Implications*
Medium-sized *Imperata* grasslands are those within a village's lands.	Fire protection may be feasible through organization at the village level.
Medium-sized grasslands are often younger and have more forest vegetation. Their centers are closer to seed sources.	These areas are often suitable for assisted natural regeneration.

Small grasslands: "fields"

Definition & Description	*Management Implications*
Small *Imperata* grasslands occur within individual farms, isolated by surrounding vegetation.	Fire management is simpler when the *Imperata* field and fire risk are under the control of one farmer. *Imperata* may be treated like a weed, using techniques in the companion manual, *Imperata Management for Smallholders*.

2.4 Microsites: more than just grass

There is a great variety in *Imperata* grassland landscapes. Summarized here are features to look for and how to use them in agroforestry or assisted natural regeneration.

Springs and streams: Springs often occur in gullies, small valleys, or at the base of steep slopes. They often occupy the same relative elevation or position throughout the landscape. They may also be found by looking for the trees and shrubs that often grow near them.

Locate springs for water sources for nursery seedlings and livestock.

Observe levels of flow between rainstorms and during the dry season; a spring that dries up or a site that floods will not be useful for a nursery.

Existing fuelbreaks: The spread of a grass fire may stop at streams, rocky outcrops, roads, moist forests, and other areas with little grass or highly flammable fuel.

Begin *Imperata* rehabilitation next to existing fuelbreaks that will help protect one side of the planting from fire.

Plan a system of fuelbreaks that widen and extend existing fuelbreaks (see Section 3.3.2).

Gallery forest vegetation: Within *Imperata* grasslands, trees and shrubs may continue to grow in gullies and along streams. Even where there is no stream, trees and shrubs may grow in depressions and below springs: wherever there are moist conditions that keep the vegetation less flammable. Such forests are often called gallery forests (or gully forests).

Gallery forest in valley bottom

Begin *Imperata* rehabilitation next to existing gallery vegetation, where conditions may be relatively favorable. The vegetation and the moist soil conditions will help protect one side of the planting from fire.

Gallery forests may be a source of seeds and wildings for ANR.

Gallery vegetation is a potential source of mycorrhizae for nursery seedlings.

Gallery forests may serve as corridors for wildlife that help spread seeds.

Pioneer vegetation: Small shrubs and tree saplings are often scattered throughout *Imperata* grasslands. Observe where these are most common or occur in clusters, because they may indicate where conditions are favorable, due to fire patterns, moisture and drainage, protection from wind and sun, or other factors. Often, trees and shrubs cluster along steep slopes on one side of ridges.

Begin *Imperata* rehabilitation in areas with clusters of pioneer vegetation, where conditions may be better for planting.

Pioneer vegetation may be a source of seeds and naturally regenerated seedlings ("wildlings") of fire-resistant species for ANR.

Pioneer vegetation is a source of mycorrhizae for nursery seedlings.

Fire-resistant grass: On mountain tops there may be fire-resistant grass in monoculture stands or mixed with *Imperata*. These grass species may be indicators of drought-prone, shallow, or nutrient deficient soils. Few or no trees grow in these areas, apparently due to the low water supply. These grasslands often occupy similar topographic positions and elevations throughout a landscape.

If these areas are important, test tree and crop species on these sites before making recommendations or beginning full-scale planting.

Grazing areas: Sparse cropped grass and trampled paths zig-zagging across the slope are visible signs of grazing.

Work with livestock owners to provide for forage needs, either by setting aside adequate *Imperata* areas or providing alternate forage.

Anticipate that grazing areas will be burned to stimulate new growth of tender young grass. Control fires so they do not escape (see Sections 3.2.2 on fire regulations and 3.3.2 on fuelbreaks).

Cattle trails: Observe cattle trails from a high point and follow them through the *Imperata*.

Cattle trails may reveal good routes for graded trails from high to low positions within the area, since cattle usually follow the easiest path.

Trails may lead to waterholes that can be good sites for nurseries.

Cattle trails often lead to relatively easy gully crossings, where gully banks are not too steep. The gullies often have water and shade and are often good sites for nurseries.

Trails can serve as starting points for fuelbreak construction.

Chapter 3

Protection from Fire

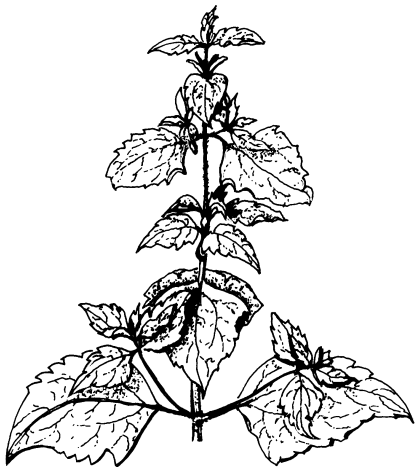
Imperata feeds fire, and fire stimulates *Imperata*! Fire protection is the most important technical challenge in *Imperata* grassland rehabilitation.

3.1 Fire protection assessment

A good fire protection program begins with an assessment that will build on the community map and land-use plan developed in Section 1.3.3. You will need to assess:

- **Risks**. How and why do most wildfires start in the community? Where do they start? Risks might include swiddens, charcoal pits, or along roads where people drop cigarettes or torches. Grazing and thatch areas that are regularly burned are also high risk sources of wildfire. Map where risks are located.
- **Climate**. Familiarize yourself with the length and severity of the dry season. Ask local people about typical years and drought or El Niɜo (ENSO) years. Ask about the frequency of short dry spells in the wet season, since *Imperata* may burn after as little as three days without rain.
- **Areas of high value**. Ask community members to rank the value of things that might burn. For example:
    1) houses
    2) mature tree crop plantations
    3) annual crops
    4) pasture grasses

  Show high-value areas on the map.



Chromolaena odorata

- **Areas of high hazard**. These are areas where a fire will spread quickly and burn hotly. The hazard depends on how much fuel there is and how flammable it is. For example, tall, old, dry *Imperata* is a high hazard fuel. In dry areas, *Chromolaena* might be a higher hazard because it can be taller. In wet areas, *Chromolaena* might be less of a hazard because it does not dry out quickly. Map hazardous areas.
- **Priorities for fire protection.** Begin by looking at high value areas. What threatens them most? Hazardous fuels within them? High-hazard *Imperata* fields next to them? A high risk of fire nearby? Identify areas that are "medium" or "high" for value, hazard, and risk.

Your fire protection program will include:

- **Prevention** to reduce fire **risk**: education and other action to keep wildfires from starting (Section 3.2).
- "**Pre-suppression**" work to reduce fuel **hazard**: making fuelbreaks or reducing fuel throughout the area (Section 3.3).
- **Suppression** - fighting fires once they start (Section 3.4).

3.2 Fire prevention

Most fires in *Imperata* are set by people. Motivating and involving people is the real solution to preventing wildfire. It is important to understand the different reasons why people set fires, and to dialog with the community about those reasons and how to handle them.

3.2.1 Sources of fire

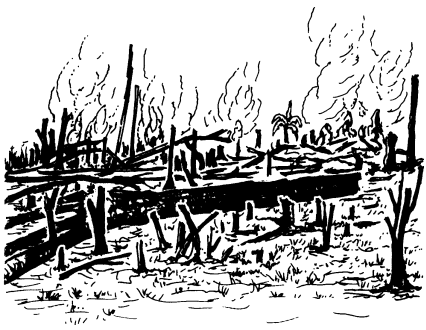
If groups within the community are opposed to a land use project, arson maybe used in opposition. In this case, the project's social aspects should be carefully reviewed, especially land and crop tenure and the fair distribution of benefits to the members of the community (Chapter 1).

Arson as protest

Grasslands maintained by fire for grazing or thatch

People also set fires to stimulate new grass shoots in grazing areas, to rejuvenate grassy areas to gather thatch, or to manage hunting grounds. Review the community plan (Section 1.3.3) see if some high-risk grasslands are a priority for rehabilitation. Where *Imperata* areas are to be maintained as grasslands, encourage the community to cooperate to establish fuelbreaks around them.

Farmers often burn their plots to clear away vegetation, to provide a source of crop nutrients from the ash, or to control pests and diseases. However, fire burns away nitrogen and organic matter that would otherwise enrich the soil. Encourage farmers to use farming systems that reduce the need for fire. Always encourage the community to develop rules and enforcement to prevent farmers' fires from becoming sources of wildfire.



Swidden fires

Cigarettes and accidents

There may also be accidents and some individuals who deliberately cause fires for fun. Education and holding people accountable to the community for fire damage will reduce the risk from accidents and arson. But there will always be some risk. Therefore, fuelbreaks and fuel reduction will always be necessary.

3.2.2 Community regulation of fire

Many traditional communities have practices and enforcement customs that have been effective for many years. They maintain a balance between agricultural needs and the forest environment. Discuss with community leaders the existing rules about fire or traditional customs that can be

revived and enforced. The goal is to keep people's controlled ("prescribed") burning from becoming a source of wildfires.

Requirements for prescribed burning of farming plots or grazing areas may include:

1. Permits from community leaders who have authority and experience with controlling fire.
2. Permits from local government offices under local or national laws.
3. Choosing a day that is not hot or windy.
4. Choosing a time of day that is not hot or windy (early morning, late afternoon).
5. Respecting "fire-free periods" when the weather or nearby forests are too dry to allow burning.
6. Notifying adjacent landowners in advance.
7. Gathering a crew of people to help.
8. Clearing a fuelbreak around the perimeter.
9. Burning from top to bottom of the slope, to slow the spread of the fire and make it easier to control.
10. Penalties for violation of the guidelines, and compensation for damage caused by escaped fires.

It is very important to enforce requirements and apply penalties in a consistent manner.

3.3 Grass pressing and other fire pre-suppression work

Greenbreaks and other fuelbreaks are strips of land prepared in advance to help keep fires from spreading past them. Fuel reduction and fuel treatments are ways to make a whole area difficult to burn by removing or compacting the fuel. Each of these techniques must be used in combination with other methods. Pressing *Imperata* is an especially useful technique for fire protection in both agroforestry and Assisted Natural Regeneration.

Pre-suppression requires labor but it is more effective and efficient than suppression. The work may be done individually or collectively by the people protect their individual or collective high-value areas such as farms and reforestation projects.

3.3.1 Fuel reduction and treatment

There are different approaches to reducing and treating fuel, each with its limitations.

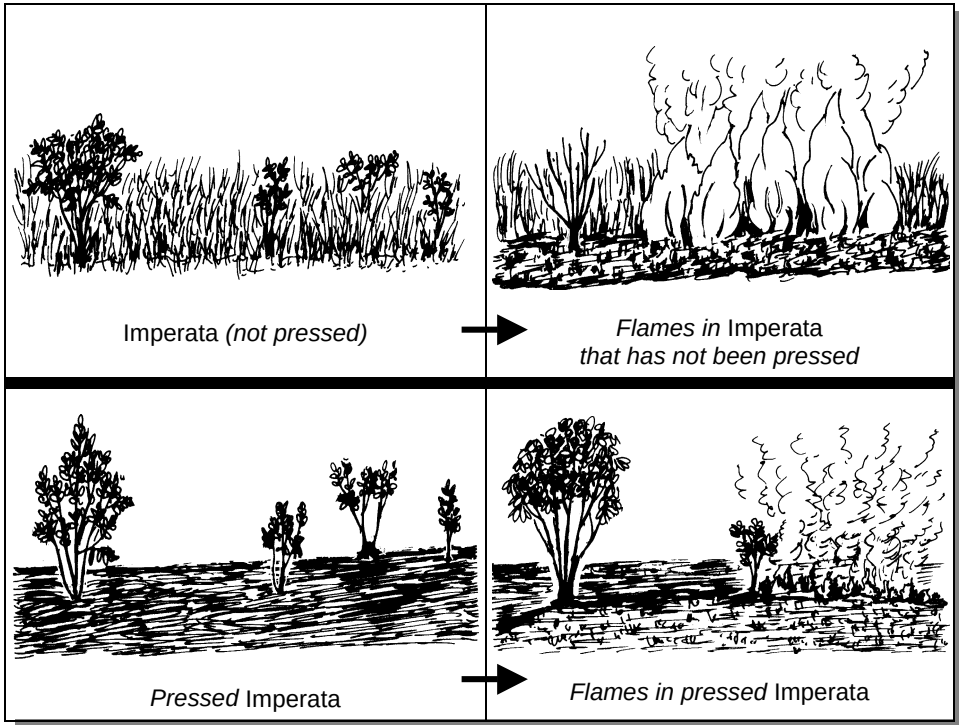
Intercropping. To protect newly planted trees and shrubs, and to make full use of the land, the grass between the trees may be cleared and the area planted to other crops that will not easily burn (Section 4.4). To keep grass out, the area must be intercropped and weeded throughout the year. Limitation: After a few years, the trees will be large enough to shade out many annual crops, but may not prevent grass from growing. This will be a dangerous period of time until the trees can completely suppress the grass, so other methods (like slashing or fuelbreaks) have to be used.

Slashing. Slashing (cutting) and removing *Imperata* effectively reduces the fire hazard. One person can slash about 200-400 m^2 in a day. Even if cut grass is left on the ground, it is less flammable since air does not circulate well in the piled grass. Flames are usually twice as high as the fuel. Cut grass is shorter than standing grass, so the flames will be shorter and easier to put out. While the regrowth is still green, it will not burn readily. Limitation: *Imperata* grows back quickly after slashing, so slashing must be repeated frequently.

Grazing. Cattle and water buffalo graze young *Imperata* and prevent it from accumulating. Limitation: Constant grazing on young *Imperata* exhausts and compacts the soil. Livestock doesn't graze old, unpalatable *Imperata*; it is left as a fire hazard.

Pressing. Pressing is also called "lodging" or "rolling." The grass is pressed low to the ground by trampling or by rolling a weight over it. Pressing bends the base of an *Imperata* culm (stem) like folding a plastic water hose. The weight of the grass helps keep it bent down. Grass in the lower layers dies. Limitation: Fire can still burn in pressed *Imperata*.

However, it burns more slowly and the flames are shorter. If the grass is pressed to a 25 cm layer, the flames will only be about 50 cm high, making them much easier to put out.



Benefits of pressing:

1. Pressed *Imperata* is much less flammable, since the air does not circulate well in the compacted grass.
2. *Imperata* regrowth after pressing is only 20-60% as fast as regrowth after slashing. Therefore, pressing does not have to be repeated as often as slashing.
3. Pressing is easier than slashing. One strong, experienced person can press about 900 m^2 in a day. Women and children can press *Imperata*.
4. Pressing helps keep *Imperata* from shading other plants.
5. People can easily move around in areas where the grass has been pressed.
6. Pressed grass mulches the soil. Dead *Imperata* on the bottom begins to decompose within a few weeks. Weeds are suppressed.

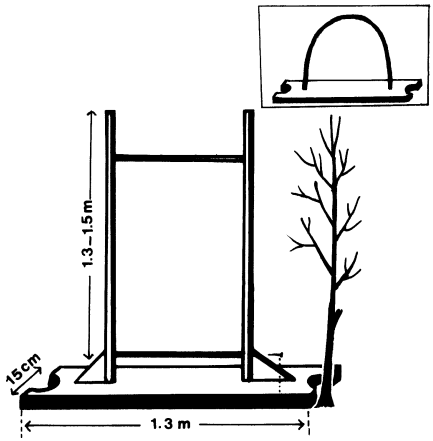
When to press:

1. Press when *Imperata* is 1 m tall. If the *Imperata* is young and shorter than 1 m, pressing is less effective; the grass will spring up again.
2. Press when the grass is wet. The water on the leaves helps them stick together so that the grass does not spring up again.
3. Press at the beginning of the dry season to reduce the fuel hazard.
4. Press at the beginning of the rainy season to keep *Imperata* from shading young tree seedlings, and to help vines grow over and suppress it.

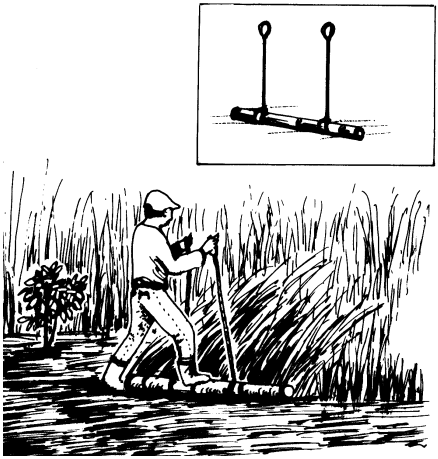
In what direction to press:

1. If grass is already naturally lodged, press it in the same direction, all the way to the ground.
2. Pressing downhill is easier and more effective than pressing uphill.
3. Press all the grass in the same direction. If the pressing “weaves” the grass like a basket, it won’t lie as flat.

Tools for pressing on irregular or steep slopes with obstacles

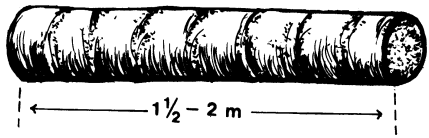


Wood plank with wooden handles. Use a wide plank of durable, lightweight wood (about 5cm x 15cm x 130cm) and securely attach wooden handles (130-150 cm long). Lift the presser along the grass shoots, press down, and step on the plank with full body weight. Use short, choppy steps. Carve half-circles at both ends of the plank to press grass close to sapling stems without damaging them.



Bamboo with rope handles. Use a piece of bamboo 15 cm in diameter and 1½-2 m long. Tie rope handles about 60 cm from both ends. Adjust the length of the rope to be held by hand or to be a yoke behind the shoulders. A wood plank can also be fitted with rope handles.

On regular slopes with few obstacles



Logs. Use a coconut log or tree trunk heavy enough to press the grass, one-and-a-half to two meters long. Use feet to push the log over the grass and step on the log with full body weight.

Oil drums. Drums should be filled with a little water for weight. Small ribs welded along the drum improve its ability to crush grass. Drums can be rolled like logs, or pulled by animals.

3.3.2 Fuelbreaks

Fuelbreaks are strips of land with a low fire hazard: they have little grass and other flammable fuel. If a fire spreads into a fuelbreak from one side, the fire's spread will slow down, giving people a chance to put it out before it spreads through the fuelbreak to the other side.

Fuelbreak width

It is hard to say how wide a fuelbreak should be. Recommendations range from 6 m to more than 30 m. Even very wide fuelbreaks may be crossed by fires, but it is difficult to maintain many wide fuelbreaks. It is important to use existing and natural fuelbreaks when possible, and to make "green" fuelbreaks (next page) multi-purpose and productive. Fuelbreaks running across the slope (on the contour) should be wider than fuelbreaks running up and down the slope (vertically), because fire can easily jump uphill.

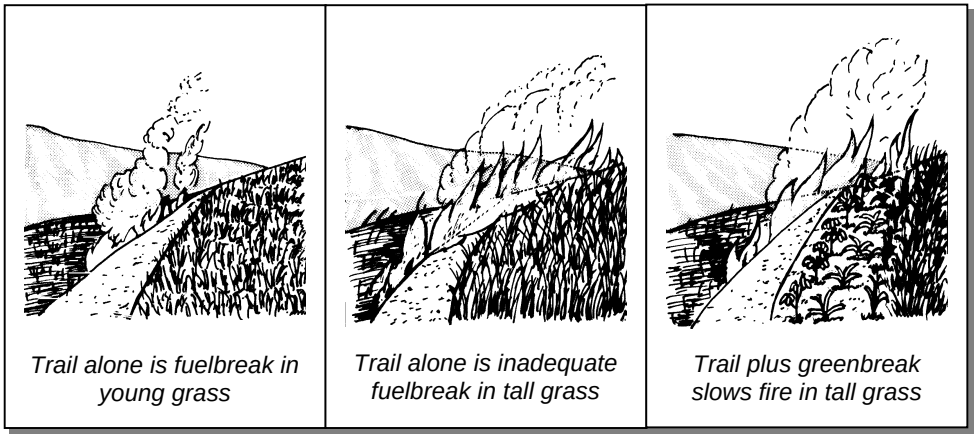
Fuelbreak types

Natural fuelbreaks include streams, rivers, rocky outcrops, and gullies. **Existing man-made fuelbreaks** include roads, trails, and rice paddies.

⇒ Use existing natural or man-made fuelbreaks and widen them where necessary.

Existing greenbreaks include forest and agricultural areas, especially moist gallery forests (Section 2.4).

⇒ Remove dead plant material and flammable plants (such as *Chromolaena*, grasses and ferns) along the edge of existing forests and shrublands, to make them more effective fuelbreaks.



Trail alone is fuelbreak in young grass

Trail alone is inadequate fuelbreak in tall grass

Trail plus greenbreak slows fire in tall grass

Grazed fuelbreaks. Grazing can be used to help maintain a fuelbreak by removing new grass as it grows.

⇒ Control grazing animals to keep them from damaging nearby trees and crops.

Live fuelbreaks or **greenbreaks**. These are wide strips where *Imperata* has been replaced with less flammable vegetation.

⇒ Choose species for greenbreaks that:

- are easy to establish
- can quickly shade or outcompete *Imperata*
- survive or re-sprout if burned
- do not drop flammable leaves
- retain succulent green foliage throughout the year

⇒ Plant trees at a close spacing (such as 1m x 1m) to achieve rapid crown closure and early suppression of the *Imperata.*

⇒ Tree species that have been used as live fuelbreaks in tropical timber plantations include *Acacia auriculiformis, A. mangium, Calliandra calothyrsus, Gmelina arborea, Leucaena leucocephala, Macadamia hildebrandii, Schima wallichii*, *Syzygium cumini*, and *Vitex pubescens*.

Multipurpose fuelbreaks. People will have more interest in establishing and maintaining multipurpose greenbreaks, even if they require more work than simple fuelbreaks.

⇒ Incorporate food or wood production in fuelbreaks where possible (see example next page).

Clean firebreaks are areas where vegetation has been completely removed by slashing or cultivation. This approach is not recommended for permanent fuelbreaks because it requires much labor, does not produce anything, and causes erosion if cultivated.

⇒ Slash or cultivate *Imperata* again before the regrowth begins to dry or turn brown (before it becomes flammable).

"Black" firebreaks are burned areas. Burning for firebreaks is not recommended, because it is unproductive, temporary (the grass grows right back), causes soil erosion, and may cause wildfires. It is dangerous unless an expert supervises the burning.

Example of a multipurpose greenbreak

Flames in the greenbreak get smaller or go out

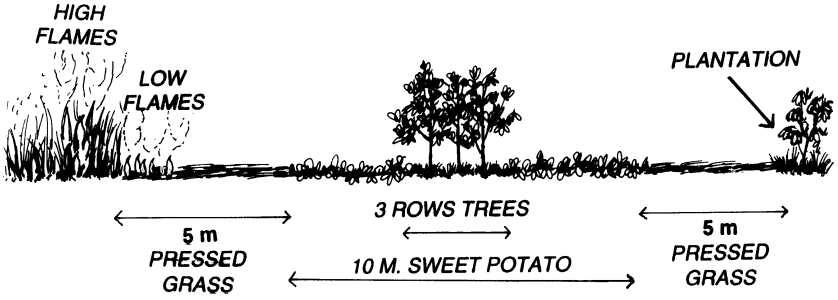


Diagram of greenbreak

Before the rainy season: brush and clear the fuelbreak 10-20 m wide. The width depends on fire risk, hazard and value of the area to be protected.

At the start of the rainy season: Plant three rows of trees and shrubs down the center of fuelbreaks at a 1x1m spacing. Plant useful species that compete well with *Imperata*, for example pigeon pea *(Cajanus cajan)*, *Gmelina arborea*, *Gliricidia sepium*, and banana.

In the rest of the cleared area, plant sweet potato or leguminous cover crops (Section 4.3).

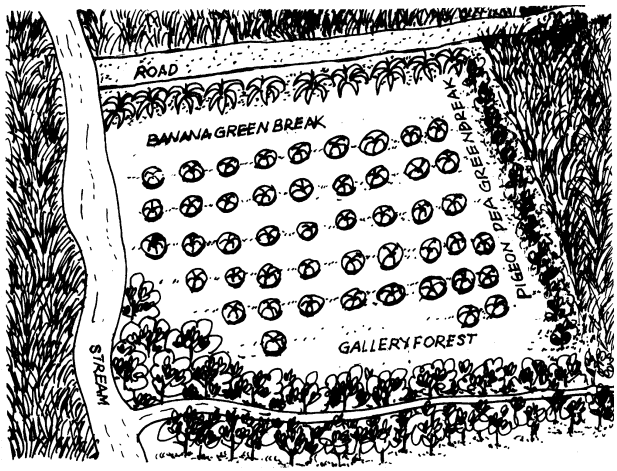
Press *Imperata* for 5 m beyond the fuelbreak on each side.

At the end of the rainy season: clear fuelbreaks again of any standing *Imperata*. Repeat grass pressing along the outside of the fuelbreak.

During the dry season: repeat grass pressing when necessary.

Fuelbreak placement

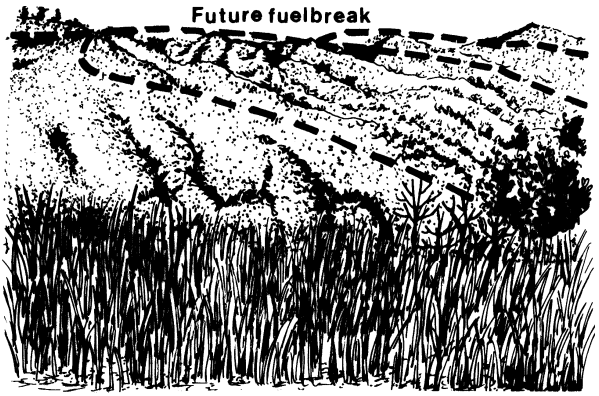
The most obvious place for a fuelbreak is around the borders of high-value areas, to protect them from adjacent grasslands. A land owner or village might place fuelbreaks around their boundaries. In addition to boundary fuelbreaks, a large plantation or ANR project should be broken up by internal fuelbreaks every 50 m, so that if a fire gets into one part of the project, it may be possible to keep it from spreading to another.



Plantation bounded by fuelbreaks

Fuelbreaks should also be placed near the boundaries of high risk areas (like grazing areas), where fires are likely to start. Instead of putting the fuelbreak on the exact boundary, it may be more practical to put the fuelbreak beside a nearby natural or manmade fuelbreak, such as a stream or road.

Spreading fires slow down and lose intensity at the tops of ridges, so fuelbreaks may be located along the ridge-top. A 10-20 m fuelbreak of young grass can be effective at the top of a ridge if it is frequently slashed.



Placement of fuelbreaks on ridges

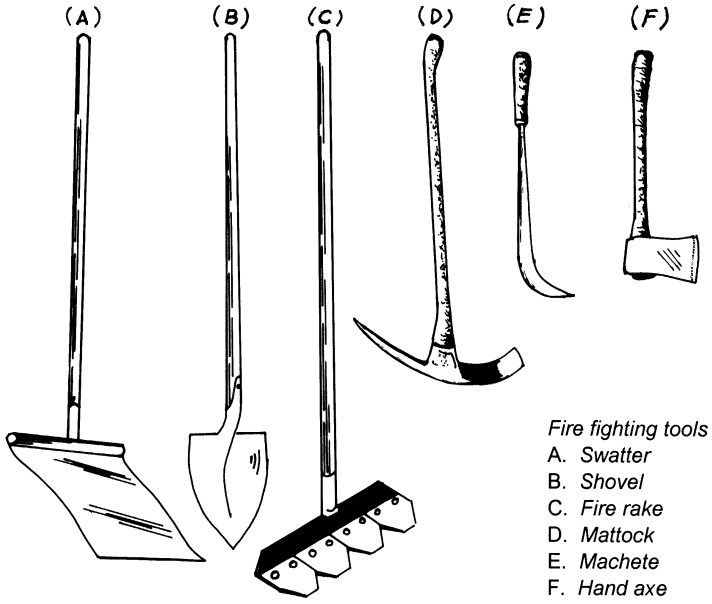
3.4 Fire suppression

Fire suppression is dangerous and difficult even with good training and equipment. The following principles are especially important in remote areas:

- Put "safety first!" If it's not safe, don't do it.
- Concentrate on fire prevention and pre-suppression. The suppression techniques in this manual are appropriate in pressed grass and near fuelbreaks, not in tall grass.
- Train a community fire brigade in fire suppression. Techniques like backfiring are not covered in this manual because they are not safe without more comprehensive training. Local government agencies may be able to provide such training; see Appendix A for fire protection manuals.

The fire brigade must determine ahead of time who will be the leader each time people gather to fight fires: the first capable person to arrive, the landowner, or the most experienced firefighter in the village. This leader must then make decisions about safety and how the group will fight the fire in a coordinated way.

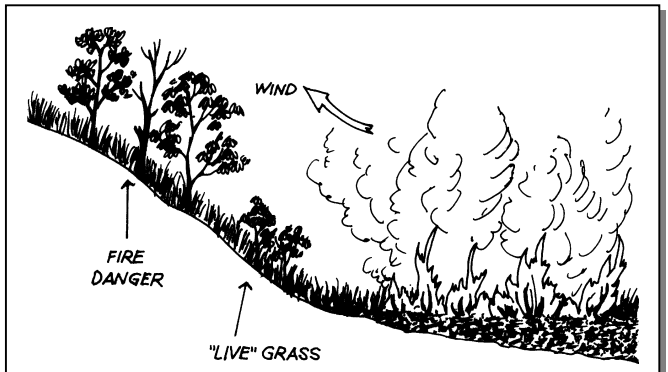
Affordable equipment for fighting grass fires in isolated areas includes farm tools to make clean fire breaks, a gong or other alarm to call for help, and swatters to put out flames. Swatters can be made from truck mud flaps, or from burlap sacks that are soaked in water. Lookout towers can be built with local materials. Firefighters should wear cotton clothes (polyester may melt on the skin) and boots if possible. Firefighters should have containers for drinking water.



Fire fighting tools
A. *Swatter*
B. *Shovel*
C. *Fire rake*
D. *Mattock*
E. *Machete*
F. *Hand axe*

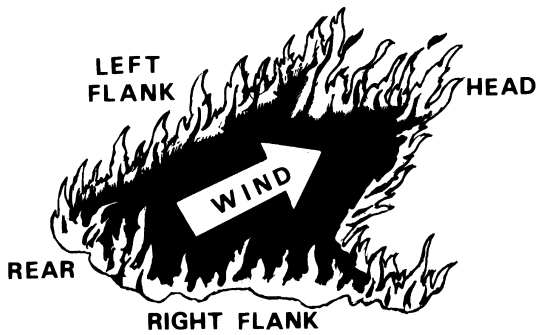
Before approaching a fire, judge how dangerous it is. Flames more than 2 m tall are not safe to fight directly. Even if the flames are low, it is not safe to fight a fire directly if it is likely to suddenly flare up. Try to predict its future behavior by considering:

- the **time of day**. Fires usually become more active as the day gets hotter.
- the **wind**. Fires spread with the wind, and become more active as wind increases.
- **nearby fuel**. The flames will be twice as tall as the fuel they are burning. A fire may spread into tall fuel and suddenly get bigger.
- **steep slopes** nearby. Fires tend to spread uphill quickly.



Low fire that is dangerous because of wind, slope, and nearby fuels

Always make sure that there is a safe “escape route” by which the firefighters can run to a safe area. Don’t go into the middle of tall grass.



Head, flanks and rear of fire

For small, controllable fires, attack the "head" (front) first, then work back down the "flanks" (sides), then the rear. If it is not safe or not practical to attack the head, concentrate on protecting high value areas on the flanks or rear.

Watch out for the head or flanks spreading back toward the firefighters.

To attack the head, flanks or rear:

First choice:
if it is safe, attack flames directly.
Attack flames directly with swatters. Work close together so that the fire does not spread in between firefighters.

Direct attack

Second choice:
Widen nearest fuelbreak. If necessary, widen the fuelbreak by pressing and possibly making a "clean firebreak" in front of it by slashing or scraping with farm tools.

Indirect attack: widen fuelbreak

3.5 Community education and enforcement

Fire education needs to reach the whole community, including children and others who may not have been involved in the community planning process. The education program should cover:

1. The community plan, fire protection assessment, and reasons why the community has decided to protect certain areas from fire.
2. Emphasis on how easy it is to prevent wildfires, compared to how difficult it is to stop a fire once it is large, or to replant after a fire.
3. Fire-related rules adopted by the community: for example, limitations on farmers' burning their fields; how rules will be enforced; penalties.
4. Agreements on cooperation for fire suppression.
5. Current fire conditions, early warnings about drought, and whether burning is allowed by law or by the community.

Kalahan Education Foundation, Philippines

An effective model of a community-based fire protection program was started in the late 1970s at the Kalahan Education Foundation in Imugan, Santa Fe, Nueva Vizcaya, Philippines. The Imugan community uses all approaches in their fire protection program. To reduce the risk to the forest reserve, farmers clear ten-meter wide strips and plant *Senna spectabilis* trees (greenbreaks) along the forest boundaries. The village's fire-brigade also suppresses fires: everyone who is able rushes to a fire to help put it out when an alarm is sounded.

Wildfires are prevented by controlling traditional agricultural fires. Farmers must apply for a permit before clearing their farm plot. After they receive the permit, farmers clear their land under strict prescribed-burning regulations written by the Foundation members. Requirements include the following:

- A two-meter wide firebreak must be cleared around the proposed burn area.
- Burning can only take place during the early morning or late afternoon when there is little or no wind.
- Before burning, farmers must notify their neighbors of the time, date, and location of the burn. Neighbors often help to assure a safe burn.

Each farmer is responsible for any damage to his or her neighbor's crops, trees, or buildings caused by wildfires escaping from his / her agricultural burns. When there is fire damage, the damages are reviewed at a village meeting and the settlement payment is set by the Foundation Board of Trustees. This payment usually takes the form of food or work, rarely cash.

The results of the Imugan wildfire prevention program have been dramatic. In the first year, the area damaged from wildfires was reduced by 90% (400 ha to 40 ha). 14,000 ha of *Miscanthus* grassland with patches of native forest is now returning to native secondary forest.

Chapter 4

Agroforestry

The choice of crops for *Imperata* grassland, like that for any other land, will depend upon:

- Local climate and soils
- Markets and subsistence needs
- Land tenure
- Available labor (people and draft animals)
- Available credit, fertilizer, planting materials, and other inputs
- Extension services

The farmer must produce those crops in a farming system that overcomes the special constraints of *Imperata* grasslands. This chapter describes agroforestry systems and methods to:

REDUCE FIRE HAZARD QUICKLY	by replacing *Imperata* with intercropped plants and continuous cropping systems.
REDUCE SOIL EROSION	when *Imperata* is removed.
INCREASE SOIL FERTILITY	to help crops grow and outcompete *Imperata.*
REDUCE FIRE HAZARD IN THE LONG TERM	by establishing permanent tree cover.
INCREASE FARM PROFITABILITY AND SUSTAINABILITY	by creating a diversified, stable farming system.

Agroforestry, and related methods and systems, for *Imperata* grassland rehabilitation

Section	METHOD / SYSTEM	Labor needs	Cash needs	Control erosion	Increase soil fertility	Reduce fire	Produce
3.3.1	Pressing	low	none			yes	
3.3.2	Greenbreaks	low-high	low-medium	depends		yes	various
4.1.2	Natural vegetative strips	low	none	yes		depends	
4.1.3 & 4.1.4	Improved vegetative strips & contour hedges	low-high	low	yes	yes		fodder
4.1.5	Rotational alleycropping	medium	low	yes	yes	yes	wood
4.2	Improved fallows	low-medium	low	depends	yes	yes	various
4.3	Leguminous cover crop	medium	low	yes	yes	depends	
4.4	Intercropped annual crops	high	low-high	*NO*	depends	yes	food, cash
4.5	Livestock	low-high	high	*NO*	depends	depends	labor, cash
4.6	Fruit, nut, and resin orchards	low-high	low-high		*NO*		food, cash
4.7	Tree plantations	low-medium	low		depends	yes	various
4.8	Multistory agroforestry	low-high	low-high	yes		yes	various

The chapter is organized so that basic methods are presented in the early sections, and more complicated systems using those methods are presented in the later sections.

Most smallholders have very limited labor and cash to invest in their annual crops. They have even less labor and cash to invest in soil conservation, fire control, and tree crops. In addition, they may have cultural preferences and beliefs that guide their choices.

Always remember:

- CHOOSE THE RIGHT SYSTEMS AND METHODS. Recommend only practices the farmer can afford; recommend practices with the greatest benefits and least costs.
- Once a system or method is chosen, DO IT RIGHT: choose quality planting material, thoroughly prepare planting sites, fertilize as necessary, and weed the crop or trees. Otherwise, *Imperata* will quickly take over.
- PREVENT FIRE and maintain fuelbreaks, or *Imperata* and the crops and trees will burn.

4.1 Soil erosion control with contour planting

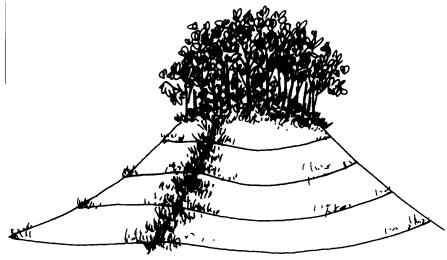
Suggest if:
- **Slope exceeds 5%**
- **Land is cultivated**

The removal of *Imperata* to convert grassland to other uses may expose the soil to erosion and do more harm than good. Vegetative barriers planted on the contour control erosion and provide organic material and nitrogen for the subsequent crops. They are very useful in *Imperata* grassland rehabilitation.

It is important to control the flow of water from above the field. If another farmer owns land upslope, encourage him or her to implement soil conservation measures. Check dams, soil traps, or diversion canals may be needed to control water coming from the plot above. If the farmer owns enough land, it is useful to plant trees at the top of the field.

4.1.1 How contours work

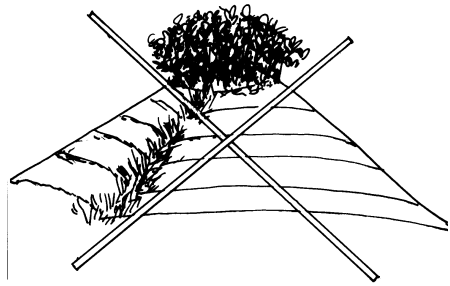
Contours are level lines across a slope at a constant elevation. Contours may curve from side to side to stay level, but they never upslope or downslope.



Contour lines on irregular slope, curving in to cross small gully

Vegetative barriers (such as grassy strips) are be located on the contour to control soil erosion. Water flowing down the slope picks up soil. When it reaches a contour barrier it slows down, the soil particles settle out, and more water enters into the soil.

Farmers must be encouraged to lay out contour lines fairly accurately. If lines are laid out by eye, they may go up and down on irregular slopes.

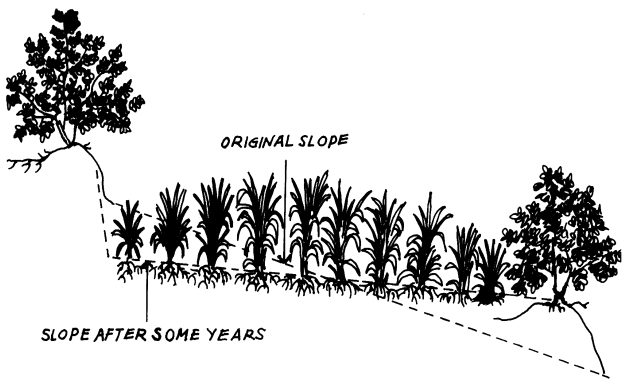


Straight lines dropping down into gullies are not contour lines

If water gathers and starts running along a sloping barrier, it may cause more erosion than if the barrier were not there.

Contour barriers can include piled crop wastes, grassy strips, and hedges. Crops are planted between the contour barriers. Plowing should also follow the contour. Even with contour barriers, land steeper than a 60% slope should not be cultivated.

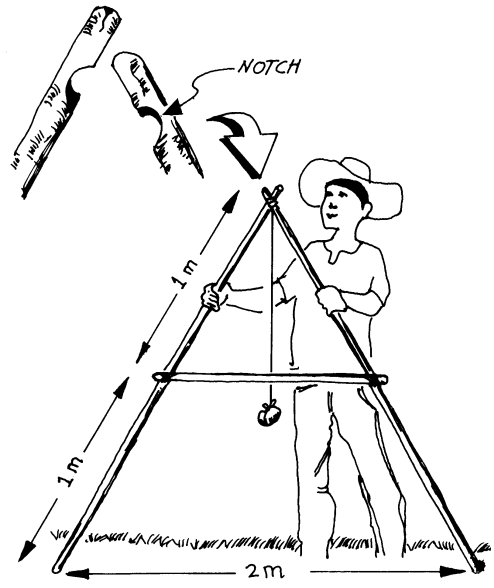
Gradually, a terrace builds up between permanent contour barriers. The terrace is flatter than the original slope, so soil erosion decreases.



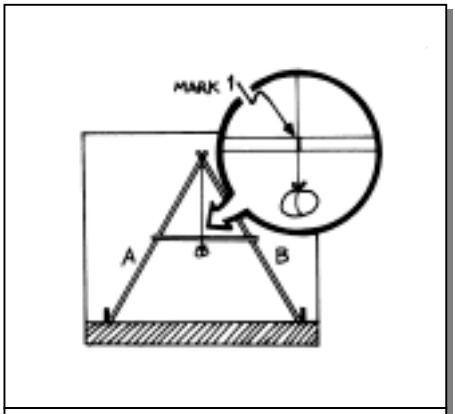
Terrace between contour hedges

Finding contour lines with an A-frame

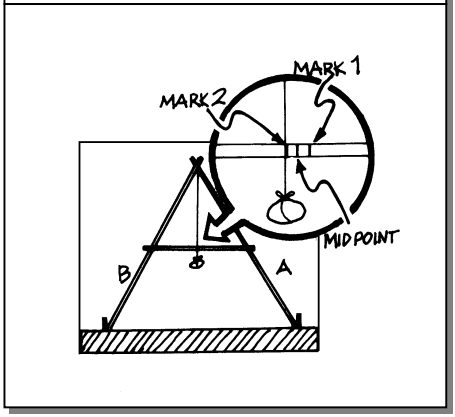
Making the A-frame. Use 3 wooden or bamboo poles about 4 cm in diameter. Join the poles securely with notches and string so that the joints do not slip. Tie a string to the top of the A-frame. Tie a rock or other weight to the other end of the string. The weight must be heavy enough that it will not be blown by the wind. The weight should hang about 20 cm below the crossbar.



Completed A-frame



Calibrating the A-frame. Place the A-frame on nearly level ground. Mark the spots where the legs (A and B) touch the ground. Mark the crossbar where the weighted string passes it ("mark 1").

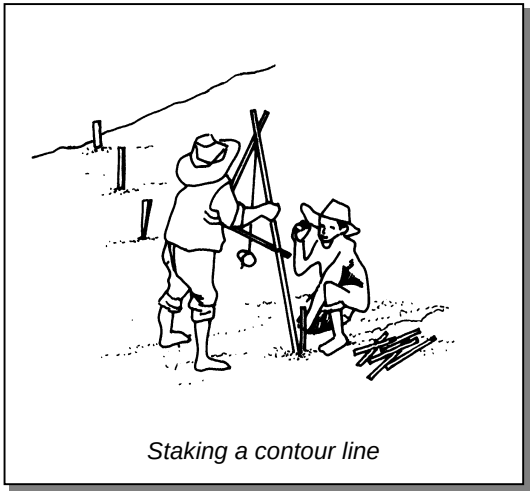


Turn the A-frame so that leg A is exactly where leg B was, and leg B is exactly where leg A was. Mark the crossbar where the string falls now ("mark 2"). If the two marks are the same, they are the midpoint. If they are different, the midpoint is halfway between them.

Check the midpoint by moving one leg until the string hangs at the midpoint. Mark the positions of legs A and B with stakes in the ground. Reverse legs A and B. If the string hangs at the midpoint again, the A-frame is level and the midpoint is accurate. Mark the midpoint clearly on the A-frame.

Marking a contour line. It is easiest for two people to work together: one to handle the A-frame, and one to mark the contour line.

1. Cut or press tall grasses and other vegetation to make it easy to move around in the field.
2. Put the first stake at the end of the highest contour line in the field.
3. Put leg "A" of the A-frame just above the stake so that it will not slip down. Adjust the location of the location of leg "B" until the weighted string hangs at the midpoint of the crossbar. The two legs are now level with each other (on the contour). Put a stake just below leg B.
4. Keep leg B at the same spot and turn the A-frame around it. Adjust leg A until the string hangs at the midpoint, and stake it.
5. Repeat steps 3 and 4 until the whole line is staked.
6. Where a small irregularity in the slope has caused a single stake to be crooked, the stake may be shifted to make the contour follow a smooth curve.



Staking a contour line

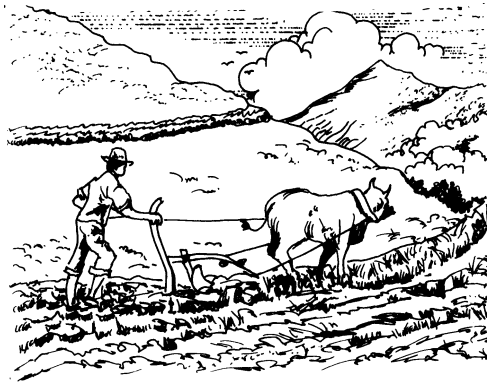
A new way to find contour lines: "The cow's back method"

Suggest if:
- **Draft animal is available**

Another method to find contours has been developed using the plow and a cow or water buffalo (carabao). This method is faster than using an A-frame, especially if the line will be plowed subsequently.

1. Lay out the first contour line in the center of the field using the A-frame.
2. Begin plowing along the contour at the location selected for the second contour line.
3. Observe the cow's head in relation to her tailbone. If the cow's head is higher than her tailbone, the cow is going uphill. Steer downhill a little.
4. If the cow's tailbone is higher than her head, the cow is going downhill. Steer uphill a little.
5. Stop after the first 50 m and test the method. Start at the same point and lay out the contour using an A-frame. If the A-frame line is within 1 vertical meter of the cow's-back line, the line is within 2% of the true contour and is acceptable. If the A-frame line is more than 1 vertical m away from the cow's-back line, start over again and adjust the technique to be more accurate.

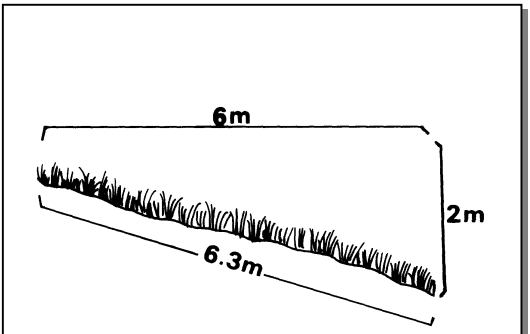
With a little practice this method can increase the speed of laying out contour lines quite strikingly compared to the A-frame.



Observation of cow's back to find contour

Distance between permanent contour barriers

Placing your vegetative barriers every 2-3 m vertical distance apart will control soil erosion very well. Contour barriers at a 2 m vertical distance will be a little over 10 m apart on a 20% slope. Farmers prefer alleyways at least 8 m wide for ease of field operations.



Example: 2m vertical spacing of contours

Even vegetative barriers spaced at 4, 8, or more vertical meters can greatly reduce soil erosion. If a farmer is doubtful about contour barriers, encourage him or her to put in just one at the center of the field, or just 3 to divide the field into quarters. The farmer can always add more later, if he finds that they work satisfactorily.

4.1.2 Natural vegetative strips

Suggest if:
- **Quick easy start is needed to control erosion**
- **Labor is limited**

When *Imperata* grasslands are cultivated for annual crops, the easiest way to control soil erosion is to leave unplowed strips of land along the contour that are 0.5 to 1.0 m wide. These natural vegetative strips (NVS) re-vegetate rapidly with native grasses and weeds. They soon form stable hedgerows with natural front-facing terraces. Installing NVS is quite simple. Once the contour lines are laid out there is no further investment in planting materials or labor. They exhibit excellent soil erosion control and require little maintenance. Establishing NVS requires only a fraction of the labor needed for conventional contour hedgerows with tree legumes (see

section 4.1.4). The fodder production of NVS is less than that of other hedgerow options, but that also means they compete less with associated crops for nutrients and water. They have proven to be popular in northern Mindanao in the Philippines, and have been adopted by hundreds of farmers in recent years.

NVS and other contour barriers occupy some field area and reduce the amount of land available for crops. Initially the yield of the total area may decrease at first because of the land taken out of production. However, the yield per area of cropped land usually increases later on due to erosion control, improved water retention, and improved soil fertility.

4.1.3 Improved vegetative strips

Suggest if:

- **Green manure or mulch is wanted**
- **Forage grasses are needed**
- **Terrace edge needs reinforcement**

Gradually, farmers may plant grasses, cover crops, shrubs, and fruit or timber trees above the strips. These will replace *Imperata.* They will filter water, trap soil, and produce fodder and mulch. Grasses commonly planted are *Pennisetum purpureum* (napier grass), *Pannicum maximum* (guinea grass), and *Vetivera zizanoides* (vetiver grass).

Some grasses, like napier, grow tall and fast in the wet season and might shade crops or compete for water and nutrients. Therefore plant only as much as will be cut and carried for forage.

Vegetative strip on contour

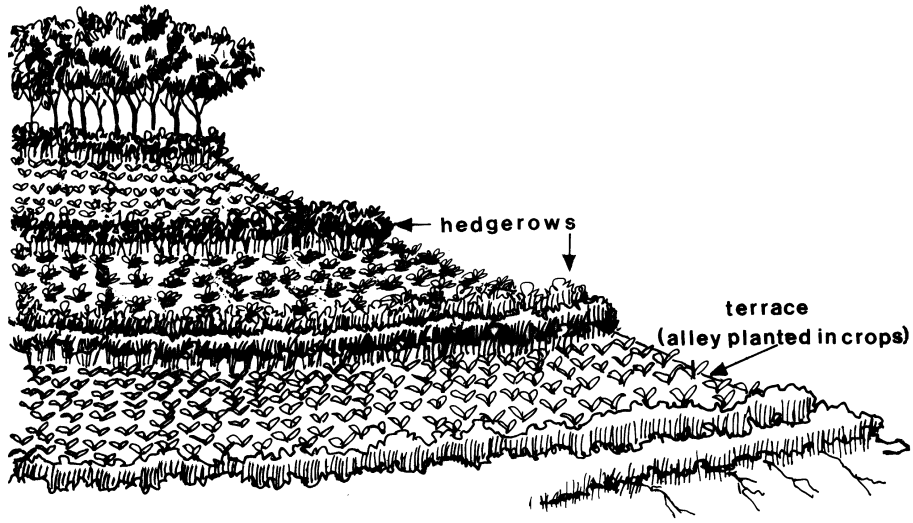
As the field is plowed on the contour, the soil that is turned downslope will accumulate above the strip and begin to form a terrace. Plant trees along the strip so their roots will anchor the edge of the terrace as it develops. Maintain grasses on the steep edge of the terrace.

4.1.4 Contour hedgerows with pruned trees

Recommended if:
- **Labor is available**
- **Fertilizer is expensive**

Not recommended if:
- **Less than 150 mm rain/month during cropping season**
- **Soil is acidic and infertile**

Hedgerows of nitrogen-fixing trees or shrubs are a special kind of vegetative strip. The trees or shrubs are trimmed to keep them from competing with nearby crops for sunlight, nutrients and water. The trimmed leaves and twigs provide nitrogen-rich mulch or fodder. The hedgerows also serve as fuelbreaks within the field.



Sloping Agricultural Land Technology (SALT) hedgerows are planted in dense double rows and trimmed frequently to produce large amounts of green manure for crops.

Intensive contour hedgerows require a great deal of labor (up to 80 days/crop/hectare). If nitrogen fertilizer is cheap and labor is expensive, hedgerows may be more costly than fertilizer as a source of nitrogen. However, the mulch from the hedgerows also may help control weeds and provides organic material. Over time, the farmer might save labor for weeding, land clearing, and cultivation.

Contour hedgerows can be implemented less intensively by carefully selecting the species, hedgerow height, and frequency of trimming. These choices will depend upon the farming system. This manual offers many choices rather than a single method.

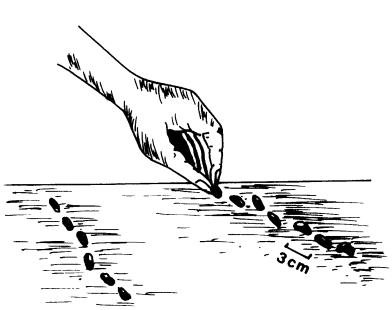
Species choice for contour hedgerows

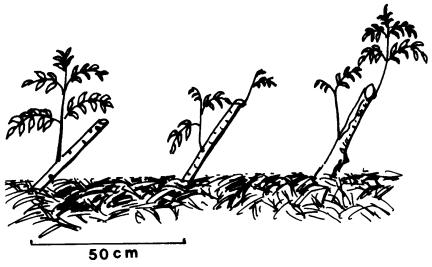
Try several different species in short hedgerows before making recommendations. Observe growth, effects on the crops, and labor requirements. Combine species that complement each other: for example, plant a row of *Flemingia* for leaves that decompose slowly and provide mulch, and a row of *Leucaena* for leaves that decompose rapidly and provide nitrogen. Mixtures of species can reduce the risk of pest attacks. Be careful not to introduce a new species that might become a weed! Try local native and naturalized species first, and avoid new species that bear many seeds.

Commonly recommended species (see also Appendix B)	Characteristics of a good species
• *Calliandra calothyrsus* • *Desmodium renzonii* • *Flemingia macrophylla* (syn. *F. congesta*) • *Gliricidia sepium* • *Leucaena diversifolia* • *L. leucocephala* • *Senna spectabilis* • Combinations of these species	• Fixes nitrogen or has leaves rich in nitrogen and phosphorus • Can be direct-seeded • Survives frequent trimming • Grows straight up (erect form) • Produces large amounts of leaves • Is adapted to local climate and soil • Has deep roots, few spreading roots • Planting material available • Produces fodder, fuelwood, etc.

Spacing within contour lines

The spacing of the trees and shrubs within contour lines depends on how much planting material is available, and how much labor is available for trimming. If trees are not closely spaced, be sure to pile crop wastes in the hedgerow to control erosion.





3 cm spacing
Double row (30-50 cm between rows)

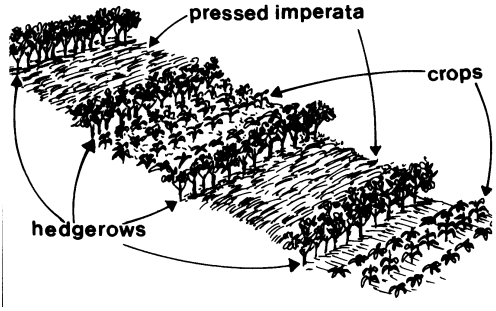
50 cm spacing
Single row

- Good erosion control
- More labor required for trimming hedges
- Direct seeding required
- More seed required
- Provides more mulch

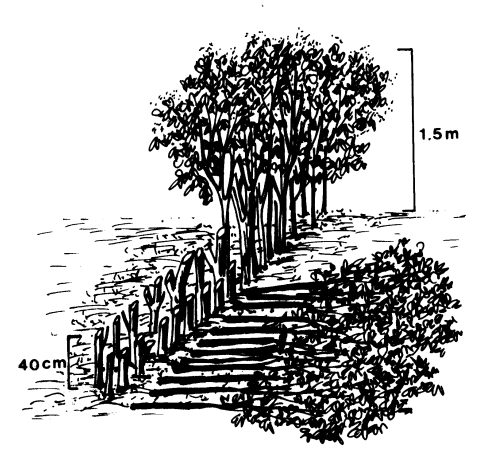
- Erosion control depends on piling of crop wastes or planting grasses in between the trees
- Less labor for trimming hedges
- Cuttings or seedlings may be used
- Less seed required
- Provides less mulch

Establishment strategy: plant hedgerows in *Imperata* grasslands.

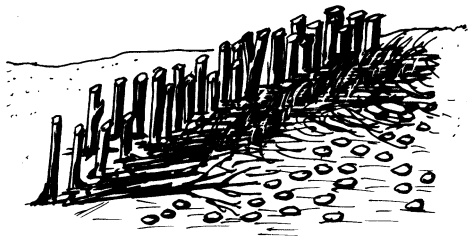
1. Protect the area from fire.
2. Mark and clear contour lines 0.5 to 1 m wide.
3. Plant trees or shrubs on the contour.
4. Press *Imperata* on alternating terraces (also called alleys or cropping areas). The *Imperata* will filter water and reduce soil erosion until hedges are established.
5. Cultivate every other terrace and plant annual crops. Permanent crops may also be planted every second or third terrace.
6. Let the hedgerows grow until they are well established (one year old or 1.5-2 m tall). Trim the hedgerows to 40 cm or knee-high.
7. Mulch the terraces with trimmings from the hedges.



Press & cultivate alternate rows



8. After the leaves and twigs have dropped from trimmed branches, pile the branches at the base of the hedgerow.
9. Cultivate the remaining terraces and plant them in annual crops also.



Pile branches

Establishment strategy: plant contour hedgerows along with crops.

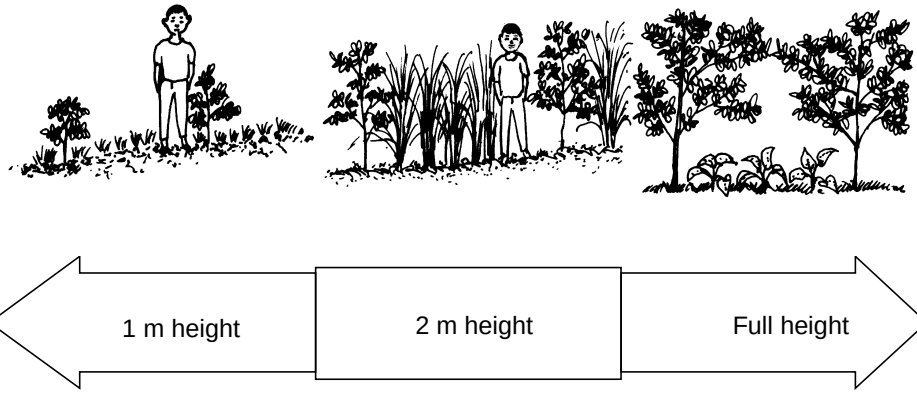
Farmers may find it simplest to cultivate the entire field and then plant hedgerows along with their crops. The disadvantage is that the field will have no erosion protection and the hedgerow seeds might wash out. Farmers looking for ways to reduce the labor of establishing hedgerows could be encouraged to start with natural vegetative strips (Section 4.1.2) and these plant trees in the hedgerows later.

When to prune the hedgerows

The hedgerows should be pruned for the first time only after they are one year old or 1.5-2 m tall. This allows their root systems to become well established.

Subsequent cuttings should take place when the crop needs more light or when the hedgerows are starting to compete with the crop for water and nutrients. Trimming the branches will cause the roots to die back, so trimming affects both shade and root competition. Trim the hedgerow before the crop starts to suffer. For example, with maize: trim the hedgerows when maize is planted, and trim a second time after the hedgerows reach 1 m height (30-45 days). A third trimming might not be necessary, once the maize is tall and the ears are maturing.

Height of hedges before trimming



- Frequent trimming (every 30-45 days)
- Young, short crops
- Sun-loving crops
- More labor required

- Allows young hedgerow to get strong
- OK for tall crops
- OK for shade-tolerant crops

- Less infrequent cutting necessary (dry season or fallow)
- OK for very shade-tolerant crops
- Less labor required

4.1.5 Rotational alleycropping: for fallow rotation systems

Suggest if:

- **Land is available for fallow**

Fields with contour hedgerows may be allowed to fallow to rebuild soil fertility. After cropping is discontinued the contour hedgerows are allowed to grow to their full height and serve as a medium-term improved fallow (Section 4.2). After two or three years, they can be cut back to allow the field to be cropped again.

Compared to ordinary contour hedgerows, this system:

- Allows trees to grow to 2 m or more in height.
- Allows the trees to be trimmed back to 10-20 cm at the beginning of cropping to reduce competition with the crop. (This is possible because trimming is less frequent).
- Generally requires less labor for trimming during the cropping period.
- Can use less dense spacing within rows, since trees would thin out during the fallow period anyway.
- Provides more weed control and soil enrichment benefits.
- Provides large quantities of mulch, fodder, or small-diameter poles and fuelwood.

Species choice for rotational alleycropping

Commonly recommended species (see also Appendix B)	Characteristics of a good species
• *Calliandra calothyrsus* • *Gliricidia sepium* • *Leucaena leucocephala* • *Sesbania sesban* • *Senna spectabilis*	• Is resistant to grass fires • Develops broad, dense canopy to shade strips between contours during the fallow period • Survives severe trimming • Fixes nitrogen or has leaves rich in nitrogen and phosphorus • Can be direct-seeded • Produces large amounts of leaves • Is adapted to local climate and soil • Has deep roots • Planting material available • Produces fodder or fuelwood

Fallowed hedgerows in Claveria, Mindanao, Philippines

Contour hedgerows are recommended in Mindanao as a method to prolong annual cropping. Even so, many farmers eventually stop pruning them and let them grow up as fallows. Farmers explain that:

- Their fields gradually become less fertile under annual cropping, even though contour hedgerows provide green manure; therefore, they must fallow their fields.
- They have other land and can afford to let some fields be fallowed.
- Pruning the hedgerows constantly requires a lot of labor.

When the fields are again opened, fertility is much increased. It also requires less labor to open these fallows for cultivation than to prepare new fields infested with *Imperata*.

4.2 Improved fallows

Suggest if:

- **Fallow periods are too short or not effective**

Imperata often dominates abandoned fields as a fallow vegetation. If fire is prevented, the field may grow into shrubs and trees (Chapter 5). If fire is present, the *Imperata* fallow is a fire hazard for nearby fields and does not restore soil fertility. An improved fallow using a species other than *Imperata* should:

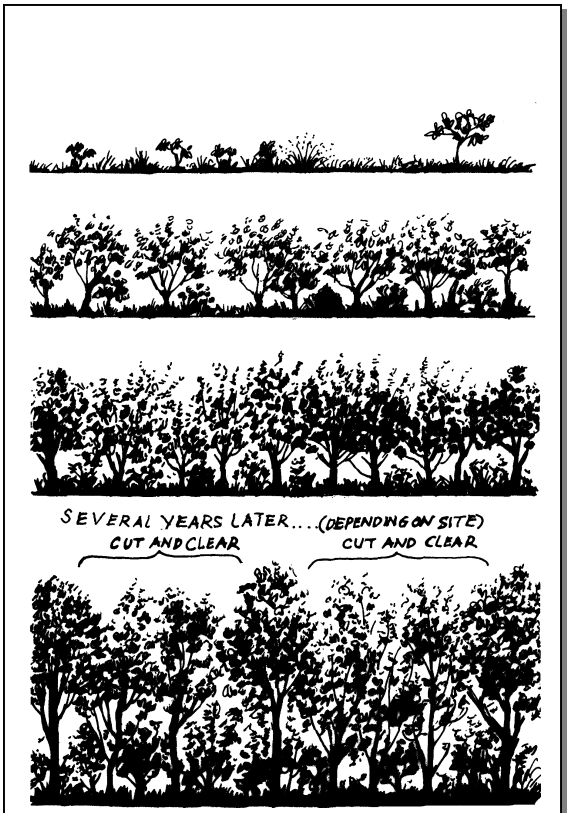
- Improve soil fertility by providing organic material and making more nitrogen and phosphorus available to the next crop. Often, this would be a nitrogen-fixing species or a species that produces a lot of foliage that decomposes rapidly.
- Protect the soil from erosion.
- Grow fast enough to outcompete weeds, including *Imperata*; cast enough shade that weeds die out before the next crop.
- Be easy to remove for the next crop.
- Possibly provide wood, forage or other products.

4.2.1 Establishing an improved fallow

It requires extra work and management for farmers to establish an improved fallow to avoid infestation of their fields by *Imperata*. This is especially true if they must work hard to convert a grassland to a fallow that will not benefit a crop until one or more years into the future. Some options are rotational alleycropping (Section 4.1.5), leguminous cover crops (Section 4.3.1), or fuelwood or timber plantations (Section 4.7).

Farmers can most easily improve the fallows that follow the crops they are already raising. They may choose combinations of the following approaches.

Maintain desirable trees and shrubs in the field. While you cultivate, plant, weed and harvest the crop, also plant trees and take care not to damage existing trees. See Section 4.8, Multistory Agroforestry, and Chapter 5, Assisted Natural Regeneration.



Mixed tree and shrub fallow

Rotational alleycropping (contour hedgerows). Allow existing contour hedgerows to grow and shade the alleyways (Section 4.1.5). If the hedgerows are far apart, or the hedgerow species is a small shrub, plant additional trees or shrubs within the row to close the canopy between hedgerows. When the fallow ends the trees are cut down and a contour hedgerow system will still be in place for soil erosion control. Crop productivity may increase compared to cropping an *Imperata* fallow.

This system is most likely to be used where farmers practice slash-and-burn cultivation in *Imperata* grasslands in situations where fires can be controlled. The tree hedgerows face risk of fire damage during the fallow period. Farmers that cultivate the soil by hand and have no access to fertilizers may find this system needs less labor in opening the land from *Imperata*. But there is considerable work required to cut the tree biomass prior to cropping. The hedgerow fallow system is less attractive to farmers with animal draft power. They are less likely to invest labor in hedgerow pruning because they normally get higher returns to their labor in land preparation.

Favor weed species other than *Imperata*. Farmers in many countries in Southeast Asia prefer fallows of *Chromolaena odorata* to *Imperata* because it enriches the soil and is easier to control after the fallow. Treatment of *Imperata* with glyphosate herbicide before the cropping period may stimulate *Chromolaena* establishment as a fallow species. *Chromolaena* tends to be favored over *Imperata* when the fallow period begins after cropping is discontinued. Both *Chromolaena* and its relative, *Austroeupatorium inufolium*, can be problem weeds. They are not palatable fodder, nor are they useful for thatch. Neither species should be introduced to an area, but they can be managed as effective fallows if they are already present.

Austroeupatorium inulifolium (syn. *Eupatorium pallescens*)

Austroeupatorium inulifolium is similar to *Chromolaena* but grows at higher elevations. The Dutch introduced it to Western Sumatra to smother *Imperata* in rubber plantations. In 1935, local farmers began to plant *A. inufolium* cuttings in *Imperata* on their farms for 3-4-year fallows. Compared to *Imperata, A. inufolium* provides much more organic material and readily available N and P to the next crop. Farmers found that with this species they were able to reduce their fallow period by half and obtain the same benefits. Farmers today sometimes scatter *A. inufolium* flowers (with seed) in their moist fields. More often, they clear their fields after the last harvest to receive windblown *A. inufolium* seed. After the fallow, they clear the *A. inufolium* and pile it between rows of vegetables. As it decomposes, they use it as mulch.

Plant tree or shrub seeds or seedlings to grow as the fallow following the crop. Commonly recommended species include *Sesbania grandiflora, Crotolaria juncea, Flemingia macrophylla, Gliricidia sepium, Vitex pubescens, Trema orientalis and Leucaena leucocephala*. Consider local native species that are known for providing mulch or that grow into secondary forest.

Economic fallows in Vietnam

These are many options to plant perennials that earn income during the fallow period. Vietnamese shifting cultivators from Song Be province sow cashew seeds at a 4m x 4m density when they plant upland rice. Seedlings are weeded but not fertilized. The cashew canopy closes after 3 or 4 years and nut production lasts until the 12th year of the fallow.

Time to plant fallow species

Example:
cashew seeds in upland rice

Example:
Leucaena *seedling in maize stubble*

at the same time as the crop | several weeks before harvest | immediately after harvest

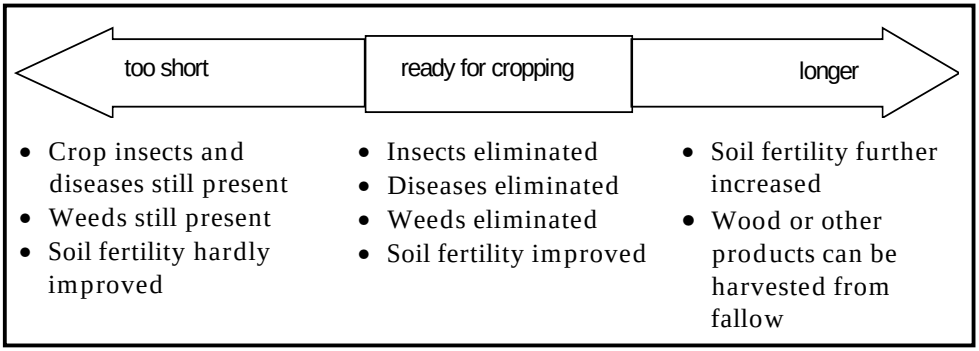
if...
- The fallow species is planted by seed
- The fallow species grows slowly at first
- The field is likely to become weedy
- The rainy season is short

if...
- Fallow seedlings are large
- The fallow species grows quickly
- The field is not weedy
- There are still a few months of rain

4.2.2 Ending the fallow

Timing. The elimination of weeds, crop insects, and diseases are critical factors in determining an appropriate fallow length. If the fallow period is likely to be short, the fallow needs to be managed carefully. Watch for dead trees and gaps where *Imperata* can grow. Replant fallow vegetation where necessary.

Fallow length



Clearing and nutrients. Farmers often burn when the fallow vegetation is bulky, but burning reduces the organic material and nitrogen returned to the soil. If wood is harvested or burned, take only the wood and leave the nutrient-rich leaves and small twigs as mulch. If wood is burned, spread the ash around. Make sure the fire does not escape.

Controlling soil erosion. Pile branches along the contour of the new field.

Successful fallow systems in the Philippines

Giant varieties of *Leucaena leucocephala* are used as an improved fallow by farmers in Occidental Mindoro, Philippines (elevation 50-600 m; four-month dry season).

Year 1:	Farmers plant *Leucaena* at the same time as they plant upland rice or maize.
Years 2-4:	*Leucaena* grows as a fallow crop, until weeds are suppressed.
Year 5:	Farmers harvest *Leucaena*, sometimes making and selling charcoal. *Leucaena* regenerates from stump sprouts and seed. Farmers trim stump sprouts when they plant rice or maize, and trim them twice again during crop growth. Farmers uproot and mulch seedlings the first time they weed the crop.
Year 6:	*Leucaena* grows into a fallow again (from stump sprouts and seed).

The *Leucaena* fallow is shorter than the local traditional bush fallow (6-8 years), with no decreases in crop yields reported by the farmers. Farmers sometimes burn the fallow to clear the *Leucaena* and remaining weeds. Soil organic matter is lower where fallows are burned.

Farmers in Naalad, Cebu, Philippines, have had a similar *Leucaena* fallow system for more than 100 years. They use the cut *Leucaena* to build low fences along the contour to catch soil and build up terraces.

Although these two examples are not in *Imperata* grasslands, *Leucaena* has been used elsewhere to suppress *Imperata*. These examples show that *Leucaena* fallows can be adopted by farmers and used for many years.

4.3 Leguminous cover crops

Leguminous cover crops (LCCs) are planted as a living mulch, to control erosion and keep weeds out. Many species are nutritious forages. When plowed under, they provide large amounts of organic material, nitrogen, and available phosphorus to the soil.

Leguminous cover crops can be used to suppress existing *Imperata* (Section 4.3.1).

They are most useful to prevent *Imperata* from growing back after it has been controlled (Section 4.3.2). Legumes are often planted as an intercrop, a relay crop, or a fallow crop.

Dead and dry leguminous vines can burn. At the beginning of the dry season, press the vines and *Imperata* to make them less flammable. Press the vines even where there is no *Imperata*. Fire and uncontrolled grazing are important constraints to the use of cover crops.

4.3.1 Establishing leguminous cover crops to suppress *Imperata*

To suppress *Imperata* before crops or trees are planted, choose an aggressive species. Use a variety with a short life (for example, *Mucuna pruriens* var. *utilis*) if another crop will be planted soon. Use a mixture including species with a longer life (for example, *Centrosema* or *Pueraria*) if cover is needed for a longer time. Use a mixture including a drought-tolerant species if there is a distinct dry season. Use good quality seed.

Leguminous cover crops to suppress *Imperata*

Recommended species (see also Appendix C)
• *Calopogonium mucunoides*
• *Centrosema pubescens*
• *Mucuna pruriens*
• *Phaseolus carcaratus*
• *Pueraria* spp.
• *Stylosanthes guyanensis*
• Mixtures of species

Characteristics of a good species
• Fixes nitrogen
• Is adapted to local soil and climate
• Establishes itself rapidly
• Tolerates allelopathic effects of *Imperata*
• Climbs over and suppresses the grass
• Provides fodder or food
• Seeds available

Strategy: seed leguminous cover crops directly into *Imperata*

Suggest if:

- **Land is not needed for 1-2 years**
- **Low-input method for suppressing *Imperata* is needed**

1. **Choose a perennial species**, such as *Pueraria phaseoloides*.
2. **Broadcast pods or seeds** in the *Imperata*. Use about 2-3 kg seeds/hectare.
3. **Press the grass and vines** at the beginning of the dry season or when the grass grows upright and becomes a fuel hazard, and at the beginning of the rainy season, when the vine begins to climb on the *Imperata*.
4. **Kill the cover crop** when the *Imperata* has been suppressed and it is time to plant annual crops. *Mucuna* and *Pueraria* can be slashed and left to dry and die. Their residue provides an excellent mulch.
5. **Plant crops** 1-2 weeks after slashing or 2-3 weeks after plowing under the residues.

Treatment of leguminous cover crops (LCC)

If animal labor is used... and If soil is infertile...	If manual labor is used... and If field is hilly...
Plow the dead LCC into the soil. *This will:* • Improve soil structure by adding organic material • Improve soil fertility by adding nitrogen	*Leave the LCC on the surface of the soil as a mulch. This will:* • Keep weeds out • Retain soil moisture • Control soil erosion

Direct seeding of leguminous cover crops in *Imperata*

***"Hapi-hapi"* in Cebu, Philippines.** Farmers in Cebu use this method in *Imperata*-infested coconut plantations to improve soil fertility and nut production. They sow 2-3 kg / ha of *Pueraria phaseoloides* seeds (or the equivalent in pods) and then burn the *Imperata* to give the *Pueraria* a quick start. They press after six months and at least once more during the first year. Within two years, the *Imperata* is controlled and the farmers plant additional crops under the coconuts.

Northern Vietnam. Farmers in upland areas rehabilitate *Imperata* grasslands by sowing rice bean (*Phaseolus carcaratus*) in previously burned fields. Two to three crops of edible beans are produced in 1-2 years with hand weeding. Yields are low but the *Imperata* is suppressed. The bean's leaves are a good fodder. Other crops are then planted, and rice bean is often used as an intercrop with trees, maize, and cassava.

Albay, Philippines. A combination of two varieties of *Crotolaria* is used for improved fallow. Seeds are broadcast in *Imperata* grasslands. After at least one year, the *Crotolaria* is slashed and plowed, and annual or permanent crops are planted.

Strategy: clear *Imperata* and plant cover crop

Suggest if:

- **Farmer wants to plant crop in 3-6 months**
- **Soil needs OM, N**

This is a more intensive strategy for a shorter time period.

1. **Clear the site and plant the cover crop**, following site preparation and fertilizer recommendations for the species.
2. **Maintain the cover crop**. Replant where necessary.
3. **Kill the cover crop** when it is time to plant annual crops.

Strategy: clear planting sites and grow leguminous cover crop over remaining *Imperata*.

Suggest if:

- **Tree crops are to be planted**
- **No other intercrop is planned**

1. **Lay out planting areas**. Mark 2 m wide strips along the contour, or 1-2 m diameter cleared circles.
2. **Prepare planting areas**. Cultivate or spray herbicide and then make furrows in the dead grass.
3. **Plant seeds of viny LCCs** in the prepared planting areas. Use locally recommended species and P fertilizers.
4. **Press**. After about 5-8 weeks, the vines reach the *Imperata* beside the planting area. Press an additional 1 m strip or circle along or around the planting area.

Press additional strip or circle

5. **Press another 1 m strip or circle** every time the vines grow over the pressed *Imperata* (every 4-6 weeks).

4.3.2 Establishing leguminous cover crops to prevent reinfestation with *Imperata*

Suggest if:

- ***Imperata* threatens to infest field again**
- **Farming system is extensive**

Leguminous cover crops are most useful as intercrops or relay crops. They shade the soil between rows and occupy the field between cropping seasons, keeping *Imperata* out.

Protect the food or cash crop from competition with the leguminous cover crop. Choose less aggressive species, or choose species with a short lifespan. Constantly train vines away from trees.

Legume crops that provide food (seeds and pods) are attractive to farmers. They are likely to provide less nitrogen to the soil because nitrogen is concentrated and removed in the seeds.

Species choice for leguminous cover crops to prevent reinfestation of *Imperata*

Characteristics of a good species

- Fixes nitrogen
- Adapted to local soil
- Adapted to local climate
- Drought resistant (for cover cropping during the dry season)
- Shade tolerant (for intercropping)
- Seeds available
- Provides food or forage
- Easy to control and remove when land is needed for other crops
  - Rapid growth and twining acceptable for relay crops
  - Slower growth, no twining for intercropping with annual crops

Recommended species (see also Appendix C)
• *Calopogonium mucunoides* • *Canavalia ensiformis* (with annuals) • *Canavalia gladiata* (with annuals) • *Centrosema pubescens* (with tree crops) • *Crotolaria* spp. (with annuals) • *Desmodium heterophylla* (with tree crops) • *Desmodium intortum* (forage) • *Dolichos lablab* (food and forage) • *Macrophyllum atropurpureum* (forage) • *Mucuna pruriens* (not for intercropping) • *Psophocarpus palustris* (with tree crops) • *Psophocarpus tetragonolobus* • *Pueraria* spp. (with tree crops) • *Stylosanthes guyanensis* (forage) • *Tephrosia candida* (with tree crops) • *Vigna unquiculata*

4.4 Annual crops and intercropping

4.4.1 Site improvement for acid infertile soils

Suggest if:

- **Soils are acidic and infertile (Oxisols, Ultisols)**

Imperata often occurs on very acid, infertile soils with not enough phosphorus (P) available for good tree growth and crop yields. On such soils, a heavy one-time application of rock phosphate (1 ton/ha) can improve the site greatly and help agriculture and agroforestry to succeed.

Soil pH should be tested and a trial should be made of this method before it is applied over a wide area. If rock phosphate is unavailable, triple super phosphate and lime can be used instead. On land that is low in available P but has a pH greater than about 5.5, a soluble P fertilizer such as triple phosphate can be used alone.

Where rock phosphate is unavailable or too costly for the farmers, it would be appropriate to seek outside assistance with credit or procurement.

This procedure is best combined with legumes and green manure as in the following example.

Rock phosphate and leguminous cover crop system in Indonesia

Crop season	Procedure	Comments
#1	• Clear *Imperata*.	
	• Broadcast 1 ton / hectare of rock phosphate	• Provides most limiting nutrient (P) • Reduces soil acidity slightly • Greatly increases growth and benefits of leguminous cover crop (see next step)
	• Plant leguminous cover crop *Mucuna pruriens* var. *cochinchinensis* (see Section 4.3.1) • Kill cover crop after 6-7 months	• Puts the P into forms more available to plants • Provides N • Provides organic material to improve soil structure • Suppresses *Imperata*
#2-7	• Plant crops, using leguminous intercrops or rotations • Fertilize with N and K if necessary	Throughout this time, rice and maize production was very good, 2-3 times higher in these fields than in fields that were not fertilized with rock phosphate (in the Indonesian study site).
#8	• Broadcast ½ ton / ha rock phosphate	
#8-11	• Plant crops and legumes • Fertilize with N and K	

Farmers may prefer to plant food crops immediately after the heavy fertilization. In that case, contour hedgerows may be planted instead of the leguminous cover crop.

Rock phosphate and contour hedgerows

Farmers grow upland rice and other crops on very infertile, acidic, hilly soils in East Pasaman, West Sumatra, Indonesia. Yields have become lower over the last 40 years as fallow periods shortened from 15 years to 5-6 years. An extension project assisted them to:

- Clear *Imperata* and plant contour hedgerows of *Flemingia macrophylla*
- Broadcast 1 ton / hectare rock phosphate
- Plant peanut and beans in the first year, with fertilizers
- Plant improved varieties of upland rice and rubber seedlings
- Use *Flemingia* trimmings as mulch and for livestock fodder as needed

High yields of annual crops were achieved. Investment in *Imperata* rehabilitation was profitable after one year, even with working capital borrowed at 20% interest rates.

4.4.2 Intercropping annual crops with trees

Suggest if:
- **Labor is available (limited acreage)**
- **Tree crops can be protected from fire**

Not recommended if:
- **Slopes are steeper than 60%**
- **Large areas are in annual crops**

Annual crops can be intercropped with trees to provide short-term income. As the annual crops are planted and weeded, *Imperata* is kept out and the area has less fire hazard. Fruit, rubber, and other tree crops are an important investment, so cultivation

practices for the annual crops should be careful not to damage or cause competition with the trees. If done correctly, the weeding and fertilizing of annual crops will benefit the tree crop. For example, fertilized chili peppers are a good intercrop for rubber trees.

The farm family may only have enough labor to handle one to two hectares of annual crops. For establishing additional tree plantings, the family may rely on cover cropping (Section 4.3), herbicides and weeding, pressing and fuelbreaks.

To reduce fire hazard, the annual crops should be:

- Less flammable than *Imperata.*
- Maintained by weeding or mulching to keep *Imperata* out.
- Followed with another crop or groundcover so that *Imperata* does not return.
- Productive and profitable enough to make it worthwhile for farmers to maintain the intercrop.

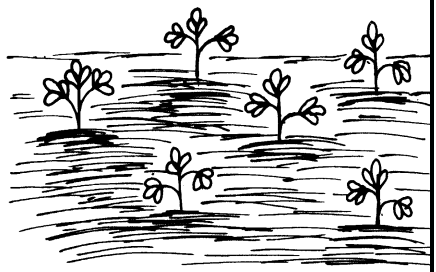
Common intercrops include upland rice, sweet potato, beans, peanut (groundnut), tomato, peppers, squash, and ginger.

To establish an annual crop as an intercrop:

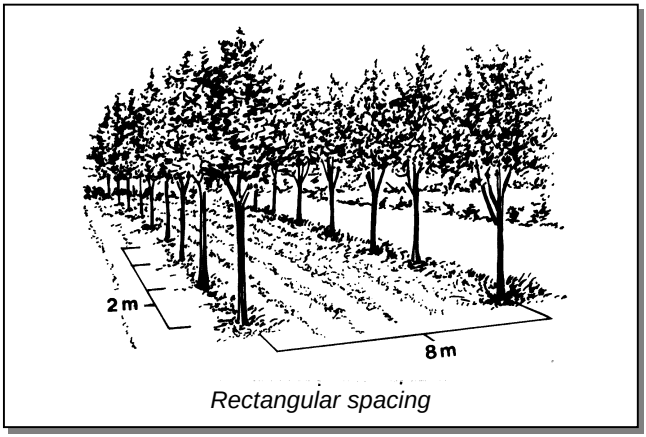
1. **Plan for erosion control**. On lands over 5% slope, plan to use some form of vegetative barrier on the contour (Section 4.1). On all lands, use mulching and cover crops (Section 4.3) wherever possible.

2. **Prepare the field**. The companion manual *Imperata Management for Smallholders* (Chapters 5 & 6; see Appendix A) provides more detail for *Imperata* control in fields, especially on the use of control herbicides and combinations of techniques.

Field preparation

If there is a low risk of fire… If labor for cultivation is limited… If money and expertise are available for herbicides…	If there is a high risk of fire… If animal labor is available… If the field is not too steep… If the soil is very compacted…
Use minimum-tillage techniques: Spray young *Imperata* with herbicide. Press it when it dies. The dead *Imperata* will serve as a mulch. 	Remove tall grass. Cultivate in the dry season: hoe or plow and harrow several times, allowing exposed rhizomes to dry and die between times. Final furrowing should be on the contour. 
Initial plant growth may be slow, but yields will be similar. Conserves soil. Field may later have more *Chromolaena* than *Imperata*.	Planting should take place as soon as the field is prepared and rains begin.

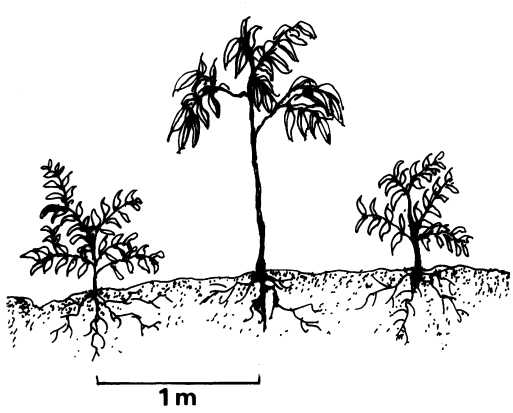
3. **Plant trees**. Lay out the rows of trees along the contour. On flat land, make rows from east to west. Use rectangular spacing to make the strips between lines wider and easier to manage for the intercrop. Mark tree planting positions with stakes so that they can be seen while the work is being done on the intercrop. Plant trees after cultivation or spraying is completed. (See Sections 4.6 and 4.7 for more information on tree crops.)



Rectangular spacing

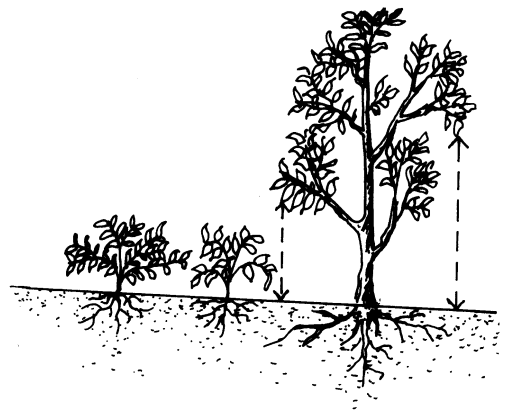
4. **Fertilize**. Many legume crops can fix their own nitrogen using root nodule bacteria (*rhizobia*). On lands that have been under pure *Imperata* for a long time, legumes may do better if inoculated with *rhizobia*. Get *rhizobium* inoculant from an agricultural extensionist, or mix soil obtained from a location where the crop has been growing vigorously with the seed before it is planted.

5. **Plant annual crops**. Do not plant annual crops closer than 1 m away from the tree base, or under the crop canopy.
6. **Control *Imperata*** during the life of the crop. Uproot, apply herbicide, or mulch.
7. **Harvest the annual crops**.



Distance between intercrop and small tree

8. **Continue to control *Imperata***. Try relay-cropping (planting a second crop before the first is harvested). Otherwise, follow the crop immediately with another crop, a leguminous cover crop (Section 4.3), or ring-weed the tree crop. Maintain a fuelbreak around the field.
9. **Be careful of trees** when cultivating the field for additional crops. Stake trees so they can be seen. Do not cultivate closer than 1 m from the stem, or under the canopy of the tree. Cultivation under the tree's canopy will damage the tree's roots.



Maintain distance between intercrop and larger trees

4.5 Livestock

4.5.1 How livestock affect *Imperata* grassland conversion

Shallow tillage and hand weeding of crops in *Imperata* grasslands are not sufficient to control *Imperata* through an entire season. The repeated plowing and harrowing needed to expose and dry *Imperata* rhizomes can be done far more easily and quickly with an ox or water buffalo and plow than with hand tools. Farmers with draft animals are much better able to:

- Till fields frequently enough to avoid the re-growth of *Imperata*.
- Intercrop annual crops with tree crops.
- Cultivate areas for tree planting and contour hedgerows.
- Pull logs or drums to press *Imperata*.
- Graze fuelbreaks.

On the other hand, farmers with draft animals may be more willing to tolerate *Imperata* as a fallow. It is also much easier to convert the land back into crops. Their animals may rely on young *Imperata* for grazing. But large animals compact the soil under *Imperata*.

In *Imperata* lands and elsewhere, livestock can serve farmers well:

- As a source of manure, converting vegetation to a higher quality source of fertilizer.
- As a source of cash income.
- As a source of draft power.

4.5.2 Using *Imperata* to support livestock

Imperata is an important forage grass simply because it is already present in large quantities in many farms and villages. Young *Imperata* grass (0-15 days) is comparable in quality to *Panicum maximum* (guinea grass). But 15 days, its quality declines quickly. *Imperata* is deficient in minerals, especially P. This is especially true when it grows on infertile soils.

Water buffalo and sheep are more hardy and better suited than other animals to utilize for *Imperata* forage. For optimum livestock productivity, supplementary feed must be provided such as: *Cajanus cajan* (pigeon pea), other legume foliage, copra, salt, and minerals.

Intensified grazing

Rotational, intensified grazing is an alternative to burning *Imperata* pastures.

1. Slash *Imperata* in a small area.
2. Confine livestock in the area.
3. Graze livestock on young *Imperata* until it is all eaten.
4. Move livestock to the next slashed area.

4.5.3 Improving *Imperata* forage

Quality and quantity of *Imperata* production can be increased with the addition of legumes (see Section 4.3):

- *Stylosanthes* spp.
- *Centrosema* spp.
- *Macrophilium atropurpureum* (siratro)

Small farmers may also replace or supplement *Imperata* forage with products of agricultural and agroforestry systems.

Tree prunings can be good forage supplements

4.5.4 Introducing livestock

Suggest if:
- **Draft labor is needed**

Good planning is necessary in any livestock introduction, to:

- Ensure that the farmers can provide sufficient feed and forage.
- Ensure that farmers are familiar with the livestock species and its management for sanitation and health.
- Develop methods (technical and social) to confine or control animals so they do not trample and eat crops.

Cut-and-carry systems confine livestock

Credit programs or programs where families receive an animal and return the first-born are often necessary to help poor families get large draft animals or good breeding animals.

4.6 Fruit, nut, and resin orchards

Suggest if:
- **Additional income or diversification is needed**

Not recommended if:
- **Land and tree tenure is insecure**

Imperata grasslands do not forgive mistakes if management in planting trees is half-hearted! However, with care grasslands can be transformed into valuable orchards.

It is most important to:

- Practice good site preparation, use quality planting material, fertilize, and weed.
- Prevent fire and maintain fuelbreaks.
- Plant annual crops to provide income until fruit trees mature.

4.6.1 Choice of crops and planting material

Many orchard species have been successfully established in *Imperata* grasslands; some are more hardy than others and are more likely to survive and be useful to small-scale farmers even if not given much care. The climate and soil preferences of these crops are shown in Appendix D. For trees that do well under shade, such as coffee and cacao, see also Section 4.8, multistory agroforestry.

Hardy species	Other species
• *Aleurites moluccana* (candlenut) • *Anacardium occidentale* (cashew) • *Cocos nucifera* (coconut) • *Hevea brasiliensis (*rubber) • *Mangifera indica* (mango) • *Musa* spp. (banana) • *Psidium guajava* (guava)	• *Artocarpus heterophyllus* (jackfruit) • *Canarium ovatum* (pili) • *Ceiba pentandra* (kapok) • *Citrus* spp. (citrus) • *Garcinia mangostana* (mangosteen) • *Manilkara zapota* (chico) • *Sandoricum koetjape* (santol) • *Spondias purpurea* (sineguelas) • *Syzyqium cumini* (duhat) • *Tamarindus indica* (tamarind)

Use large, healthy planting stock. When planted, trees should be already taller than the vegetation in the prepared field. Large, vigorous planting stock will be better able to compete with the grass as it grows back. Grafted, budded, and marcotted planting materials will bear fruit sooner.

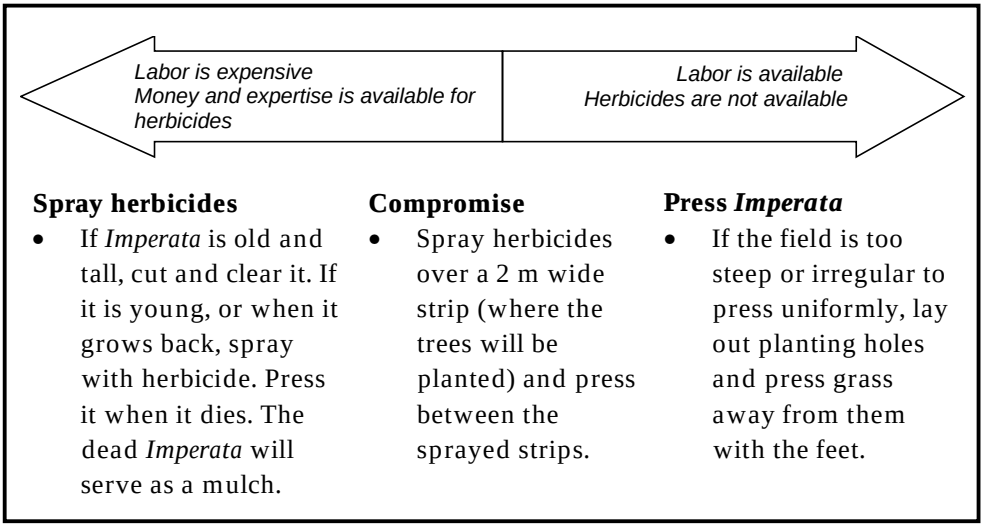
4.6.2 Site preparation

Especially in *Imperata* grasslands, good site preparation and proper establishment of a small orchard will be a better investment than poor site preparation for a larger orchard. Fast growth is necessary to outcompete the *Imperata* and at least partially suppress it to reduce the fire hazard.

Consider intercropping an annual crop. Thorough site preparation will help eliminate *Imperata* and improve tree growth, and the intercrop will provide income. See Section 4.4.2 for site preparation for intercrops.

If no annual crop will be intercropped:

1. **Prepare the field**.

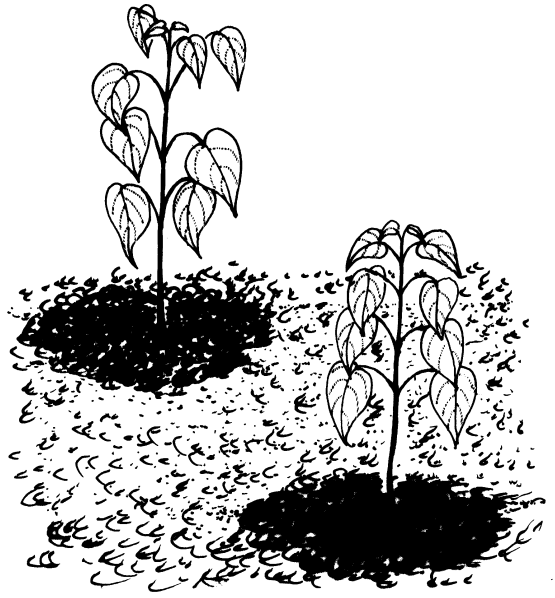


2. **Lay out planting spots**. Use spacing recommended for the crop tree species. Lay out lines along the contour.
3. **Prepare planting spots**. Plow strips at least 1 m wide. Plow at least twice, preferably during the dry season. Or, cultivate circles at least 1 m in diameter. Thorough cultivation and wider strips will result in much better initial tree growth.

4. **Establish a leguminous cover crop** (see Section 4.3). This is recommended to suppress *Imperata* regrowth following spraying or pressing. It is strongly recommended to protect soil from erosion following cultivation.
5. **Prepare holes**. Dig holes at least one week before planting. The sunlight will help decompose organic material in the hole and help kill harmful pests and diseases. Holes should be large enough to accommodate the roots of the seedling and any manure or compost to be used. Break up the subsoil at the bottom of the hole. In compacted soils, dig a larger hole. Make separate piles for topsoil and subsoil removed from the hole.

4.6.3 Planting trees

1. **Plant at the start of the rainy season**.
2. **Apply basal fertilizer** if possible. Follow recommendations for local soils, placing rock phosphate or 50-100 g of urea or complete fertilizer at the bottom of the hole. Cover the fertilizer with a small amount of topsoil before setting the seedling. If available, place one half to one kilogram of manure or compost in the hole. On acid soils, add some lime, dolomite, or gypsum.
3. **Prune any twisted roots** and place the young tree in the hole.
4. **Place topsoil** from the original hole (mixed with compost if available) around the seedling and press firmly. If more soil is needed to fill the hole, use the piled subsoil.
5. **Mulch**. Use pulled weeds, cut grass, and cover crop foliage as mulch around the trees. Mulch as much as possible without creating a fire hazard or providing a breeding ground for termites.



Mulch seedlings

4.6.4 Orchard maintenance

If the plantation is not well maintained it will have

- persistent *Imperata*
- possible fire, and
- low or no production.

To reduce fire risk and get early production, maintain the orchard as follows.

Fertilize. Use recommendations for local soils and the crop.

Ring weed. Weed as often as necessary, about 2-4 times a year depending upon the length of the rainy season. Clear grass and weeds from a circle 1 m diameter for small trees, 2 m for large trees.

Minimize competition between the leguminous cover crop and crop trees. Slash vines within circles at the base of trees, 2-4 m in diameter. Do this at the beginning of the dry season, and every 3-4 months during the wet season.

Maintain the leguminous cover crop (see Section 4.3). If the vines die or are not well established, sow additional seeds at the edge of the cleared circle around the tree, and direct vines away from the tree.

Maintain Mulch around the base of the trees.

Tend according to recommendations for the tree crop, using proper pruning techniques, and protecting the trees from insects and diseases.

4.6.5 Danger phase

The period between the time when the trees cast too much shade for intercrops and when the trees close canopy are years of high fire danger. Weeding and fertilization as recommended will help the trees grow faster and shorten this period. Weeding, herbicides, pressing, cover crops, and fuelbreaks can be used in combination to reduce fuel hazard and avoid loss of the plantation.

Some tree crops, such as pruned citrus, will never form a closed canopy to permanently suppress *Imperata*. Besides intercropping of annual crops and leguminous cover crops, another strategy is to develop a multistory agroforest to use all the growing space below and above the tree crop (Section 4.8).

4.7 Tree Plantations

Suggest if:
- **There are good local markets for wood**

Not recommended if:
- **Land or tree tenure is not secure**
- **Farmer is unable to invest in future income**

"Shade it out!" Tree plantations in *Imperata* grasslands are a race between the trees and the grass: can the trees suppress the grass before a fire burns them? The trees should be grown as quickly as possible to shorten the time until their canopies close and shade out the *Imperata*. This may require cultivation, weeding, and fertilization.

4.7.1 Choice of species

Consider first the purpose for the plantation. Many species can be successfully established as plantations in *Imperata* grasslands (see Appendix E) if given good site preparation, weeding, and fertilizer if necessary. In some cases, assisted natural regeneration might be adequate or even faster (as discussed in Chapter 5).

If the site will be used for agroforestry, one may choose nitrogen-fixing species that will fit well with the agroforestry system to follow. See Sections 4.2 (fallows) and 4.8 (multistory agroforestry and nurse trees).

If the plantation is to generate products for sale, consider the local market for wood, timber, and charcoal.

For some species, different varieties or provenances have very different growth rates, responses to fertilizer, and other characteristics.

Some species are more suited to *Imperata* grassland rehabilitation than others; they may need less care, and may suppress *Imperata* and stop being at risk for fire sooner.

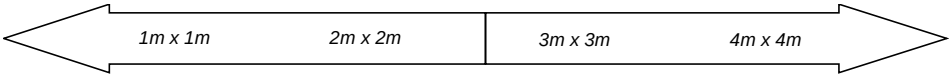
Especially successful species
Acacia mangium *A. auriculiformis* *Bambusa spp.* *Gliricidia sepium* *Gmelina arborea* *Leucaena leucocephala* *Vitex pubescens*

Desirable characteristics
Fast growing Broad, dense canopies Fire resistant: thick bark, sprouts after fire, or seeds regenerate after fire Adapted to local soil and climate

4.7.2 Plantation establishment

A plantation with close spacing will have more shade, less grass, and less fuel hazard.

Spacing



- Will suppress *Imperata* sooner
- Good for fallows, nurse crops
- More planting materials and fertilizer needed
- More work to dig holes and ring weed
- Trunks tend to grow straighter
- Less branchy
- Tree diameter growth is slower
- May need to be thinned later, or many trees may die from self-thinning competition

- Will suppress *Imperata* much later
- Good for intercropping
- Fewer planting materials and less fertilizer needed
- Less work to dig holes and ring weed
- Trunks more likely to grow crooked
- More branchy
- Tree diameter growth more rapid
- No thinning necessary

Strategy: dense planting of cuttings and stumps

Gliricidia sepium	*Vitex pubescens*
Branch cuttings outplanted at 1 x 1 m eradicated *Imperata* almost completely in 18 months at one project in Sri Lanka.	Stump cuttings of this common pioneer tree were outplanted at about 1.75 x 1.75 m. *Imperata* was eradicated in 4-5 years (Malaysia).

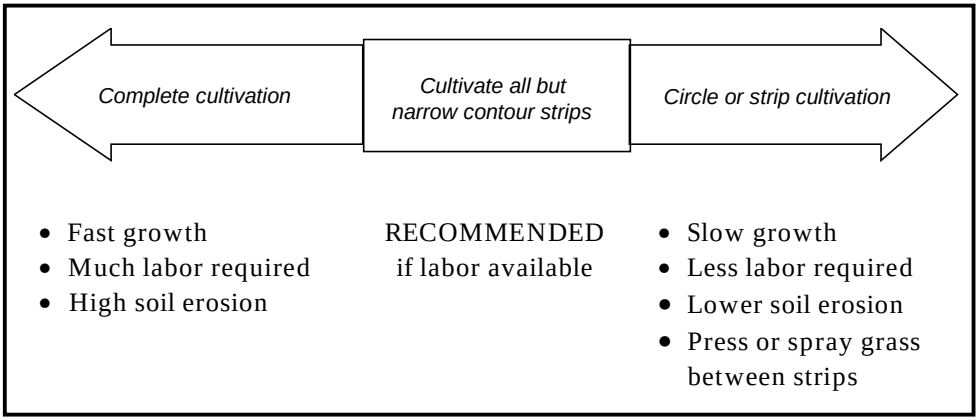
Strategy: direct seeding

There are a few examples of direct seeding approaches in *Imperata.* Direct seeding uses a lot of seed and minimum labor per seedling. Only a few very fast-growing species can succeed with so little help.

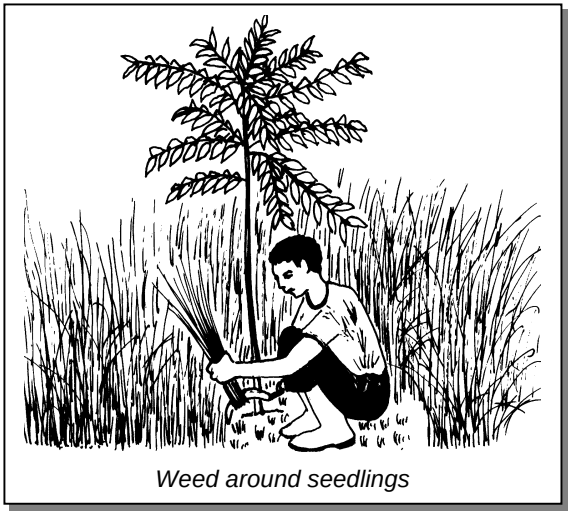
Leucaena leucocephala	*Cajanus cajan*
On a high rainfall site in Central Java, Indonesia, one project sowed 117,000 *Leucaena* seeds / hectare (17 seeds / m^2). Stocking seven years later was 10,000 trees / hectare (average 1m apart). This and other projects have found that direct seeding of *Leucaena* on plowed or burned lands can be successful, but direct seeding into grass is not.	In Central Luzon (Philippines), farmers planted *Cajanus* (pigeon pea) into small cleared spots in *Imperata*, 2-3 seeds / hill, hills spaced 1 x 1 m. The *Cajanus* was planted at the beginning of the rainy season, weeded after one month, and weeded again when necessary. *Cajanus* began to shade the grass significantly after 5-6 months. The farmers were motivated by the production of pods and fuelwood from the *Cajanus.*

Strategy: outplanting seedlings

1. **Inoculate seedlings in the nursery**. *Imperata* grasslands may be poor in soil microorganisms that help trees obtain nutrients. Add *mycorrhizae* to nursery soil: obtain *mycorrhizae* tablets from forestry extension agencies, or gather soil from where the species is already growing vigorously. For nitrogen-fixing species, add *rhizobia* to nursery soil with prepared *rhizobium* inoculant packets or obtain soil from a site where the species is growing well. Mix a small amount of this soil with the seed.
2. **Grow and harden off seedlings**. When planted, trees should already be taller than the vegetation in the prepared field. Only plant healthy, high-quality seedlings with vigorous root systems.
3. **Lay out contour lines**.
4. **Prepare the site**. Good site preparation is very important to get the seedlings growing fast so that they can suppress the *Imperata* before a fire takes place. Large scale reforestation operations have found that complete, mechanized cultivation results in much better growth than strip cultivation; however, this also causes soil erosion. Small landholders using animals to plow are able to leave narrow, unplowed natural vegetative strips along the contour to control soil erosion (Section 4.1.2).



5. **Prepare planting holes** as for orchards (Section 4.6.2), but holes may be smaller than for high-value trees, and holes may be dug at planting time.
6. **Plant and fertilize seedlings** following the same procedures as for orchards (Section 4.6.3). For nitrogen-fixing species, P fertilizer may suffice.
7. **Maintain seedlings** as for orchards (Section 4.6.4). Leguminous cover crops are not recommended because of the closer spacing and lower value of non-orchard trees.



Weed around seedlings

4.8 Multistory agroforestry

A multistory agroforestry system has at least three "stories" or "layers" of intercropped plants of different heights.

Multistory agroforestry

Each layer partially shades the layer below it. A mature, complex agroforest does not leave enough light at the ground level for *Imperata* to return.

The diversity of crops in multistory agroforestry reduces risk. If one crop fails or if prices drop for one crop, the farmer still has other crops for subsistence or cash. Because the farmer still has other intermingled crops, the agroforestry farm is not likely to be abandoned. Even if it is neglected, a mature agroforest will not revert to *Imperata* grassland.

Multistory agroforestry is commonly developed by small farmers as they:

- Plant nurse trees for shade-tolerant crops like coffee and cacao.
- Make productive use of space between and under cash crops like rubber and coconut.
- enrich fallows with species like rattan and yams.
- establish a variety of low-input, low-maintenance tree crops.

4.8.1 Crop combinations

There are many possible crop combinations that can be used in multistory agroforestry. In general, plants and crops used will include at least three heights, and will include plants that grow in direct sunlight and plants that grow in partial or full shade (see table next page).

Note that many large trees need shade when young but love sun when old. Also note that some species, like mango, cast heavy shade and few plants can grow under them. Species like *Paraserianthes falcataria* cast a lighter shade and are more suitable for multistory agroforestry.

Plants of different sizes, needing different levels of light

(See additional species in Appendixes D and E)

light needs size	sun-loving (first to be planted)	shade-tolerant when young (can be planted later)
tall (large tree)	*Albizia saman* (raintree) *Artocarpus altilis* (breadfruit) *Casuarina* spp. *Cocos nucifera* (coconut) *Gmelina arborea* *Mangifera indica* (mango) *Paraserianthes falcataria* (moluccan sau) *Pterocarpus indicus* (narra) *Swietenia macrophylla* (mahogany) *Tectona grandis* (teak)	*Durio zibethinus* (durian) *Garcinia mangostana* (mangosteen) *Nephelium lappaceum* (rambutan) Many timber trees
Medium-tall (small tree)	*Anacardium occidentale* (cashew) *Azadirachta indica* (neem) *Elaeis guineensis* (oil palm) *Persea americana* (avocado) *Psidium guajava* (guava) Many fruit trees Many fuelwood trees	*Areca catechu* (betel nut) *Annona muricata* (soursop) *Bambusa* spp. (bamboo) *Cinnamomum* spp. (cinnamon) *Lancium domesticum* (langsat, lanzones) *Myristica fragrans* (nutmeg) *Pandanus tectorius* (pandanus) *Arenga saccharifera* (sugar palm)
Medium-short (shrubs, vines, epiphytes)	*Carica papaya* (papaya) *Manihot esculenta* (cassava, tapioca) *Musa* spp. (banana)	*Coffea* spp. (coffee) *Dioscorea* spp. (yams) *Flagellaria indica* (rattan) *Musa textilis* (abaca) *Piper nigrum* (black pepper) *Theobroma cacao* (cacao) orchids
short (herbaceous)	Upland rice Many vegetables	Shade-tolerant vegetables Other shade-tolerant crops

4.8.2 Planning ahead: ecology and economics

Ecology. For any crop combination that you consider, predict how the multistory agroforestry system will grow and change over time. Each year, some plants will become less productive, and others will grow and cast additional shade. Plan the development of the multistory agroforestry system so that:

- The first plants established are adapted to full sunlight.
- The first cropping system includes *Imperata* control measures.
- Plants that can give shade are planted before plants that can tolerate shade or require shade.
- Plants that enrich the soil are planted before plants that require improved soil conditions.
- Plants that require sun are not planted where other plants will shade them before they mature.
- Medium-sized and large trees will have room to grow and will not become too crowded later. Think ahead to the width of the tree's canopy when it is mature. Consider whether the trees around it will also grow tall and wide; if they will crowd it, they should be harvested or never be planted at all.
- All growing space is used: crops fit together vertically (tall, medium, and short), horizontally (all planting spots occupied), and underground (deep-rooted and shallow-rooted plants).

Economics. Any farming system requires planning to diversify products and spread labor and income through the year. The first crops planted should provide food or income within 3-4 months (for example, sweet potato). Choose crops that give both subsistence produce and cash income. Plant trees that bear different fruits at different times of the year. A multistory agroforest will change every year for the first several years, with changes in labor requirements and products. Plan ahead.

4.8.3 Examples

Strategy: Nurse tree and shade-tolerant crops. Fast-growing nitrogen-fixing trees can be planted first to improve site conditions. This approach is often used for crops like coffee on poor sites, where nurse trees are valued for shade and soil enrichment throughout the life of the coffee crop.

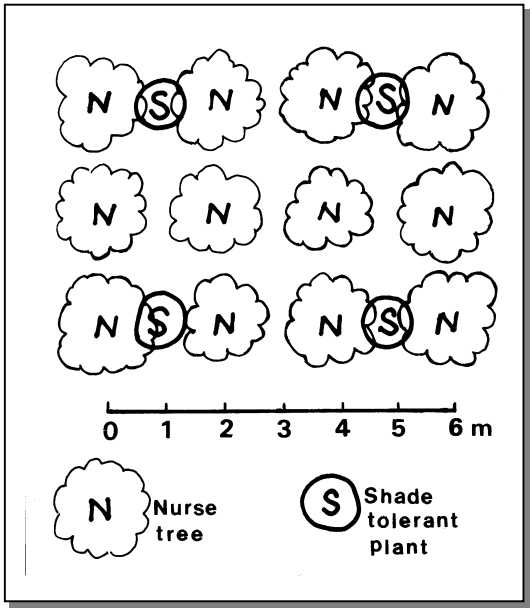
1. **Plant nurse trees** (Section 4.7). Naturally occurring trees can also provide shade; assisted natural regeneration techniques may also be used (Chapter 5).

Common species	Characteristics to look for
• *Paraserianthes falcataria*, syn. *Albizia moluccana* (moluccan sau) • *Gliricidia sepium* (madre de cacao) • *Erythrina* spp. • *Alnus* (alder) spp. • *Pterocarpus indicus* (narra) • *Acasia mangium*	• Casts light shade or can be pruned to adjust shade • Nitrogen-fixing • Produces timber, fodder, or other useful product • Sun-loving • Adapted to local climate and soils • Fast-growing

2. **Intercrop annual crops** (Section 4.4.2). Choose an intercrop each planting season that is adapted to current sun or shade conditions.

Shade-tolerant understory crops	
Ananas cosmosus (pineapple)	*Ipomea batatas* (sweet potato)
Capsicum spp. (peppers)	*Xanthosoma sagittifolium* (dryland taro)
Colocasia esculenta (sweet taro)	*Zingiber officinarum* (ginger)
Curcuma domestica (turmeric)	Mushroom cultures
Anthurium spp. (flowers)	
Brassica sp. (mustard)	

3. **Plant shade-tolerant trees**. After one year or when the nurse trees provide enough shade, plant shade-tolerant trees. Plant them 3-4 m apart from each other, or at the recommended spacing for the tree crop. Plant them 1-2 m away from the nurse trees.



4. **Fertilize, prune and weed** as for other tree crops (Section 4.6).

5. **Prune nurse trees**. When nurse trees are providing too much shade, cut branches and use the leaves as mulch.

6. **Thin trees**. Watch for adjacent trees with canopies starting to grow into each other. Also watch out for sun-loving trees that are being shaded by less valuable trees. One by one, remove weak or lower-value trees to make space for healthy or higher-value trees. Be careful not to damage other trees when cutting. The remaining trees will grow faster.

7. **Enrich with other crops**. Plant shade-tolerant crops for food and cash income.

Nurse tree system, southwestern Sumatra.

This system evolves into a permanent complex agroforest. Damar trees (*Shorea javanica*) produce a commercial resin.

Year	Plant	Grow and care for	Harvest
1	*Gliricidia sepium* (control *Imperata,* plant *Gliricidia* at 3 x 3 m)		
2	Black pepper Coffee Fruit trees Damar trees	*Gliricidia*	
3		Black pepper Coffee Fruit trees Damar trees *Gliricidia*	
4-6		Fruit trees Damar trees *Gliricidia*	Black pepper Coffee
7-8		Damar trees Fruit trees *Gliricidia*	Black pepper Coffee Fruits
9-20		Damar trees	Fruits
20+			Damar resin Fruits

Strategy: Rapid establishment of both sun-loving and shade-tolerant tree crops. Plant annual crops first. Cultivate and weed to keep *Imperata* out. Plant sun-loving plants at the same time. Plant bananas, papayas and other such plants for quick shade (and early production). Plant shade-tolerant trees and shrubs and crops in the shade of the bananas and papayas. By the time the bananas and papayas go out of production, the sun-loving crop trees will be large enough to provide shade.

Coconut-based system, Cavite, Philippines

This system can be further enriched with the addition of root crops, multi-purpose trees, black pepper, and fruit trees. Similar systems have been used to establish coconut in *Imperata* grasslands.

Year	Plant	Grow and care for	Harvest
1 (first crop, after land clearing and fertilization)	Papaya Upland rice Pineapple Coffee (under papaya) Coconut		Upland rice
1 (second crop)	Vegetables Peanuts	Papaya Pineapple Coffee Coconut	Vegetables Peanuts
2	Bananas	Pineapple Coffee Coconut	Papaya
3-4		Coconut	Papaya Pineapple Bananas Coffee
5		Coconut	Coffee Bananas
6+			Coffee Bananas Coconut

Strategy: complex agroforests. Many indigenous people care for nearly permanent tree gardens or agroforests with many species. These agroforests usually have no apparent planting pattern and may seem complicated. However, even complex agroforests can be successfully established in *Imperata* grasslands.

Rubber agroforest, South Kalimantan, Indonesia.

Farmers settled Tiwingan Baru, South Kalimantan, in 1975, in the middle of *Imperata* grasslands with very poor soils. Within a generation, farmers successfully established wide areas of agroforest using the following cropping pattern.

Year	Plant control	Grow and care for	Harvest
1	(Control *Imperata*, cultivate, fertilize) Peanut (two crops) Banana Fruit and nut trees Rubber		Peanut (two crops)
2 (first crop)	Upland rice (fertilize)	Banana Fruit and nut trees Rubber	Upland rice
2 (second crop)	Cassava* or Sweet potato	Fruit and nut trees Rubber	Sweet potato Banana
3-6		Fruit and nut trees Rubber	
7-8		Rubber	Fruit and nut trees
9+			Fruit and nut trees Rubber

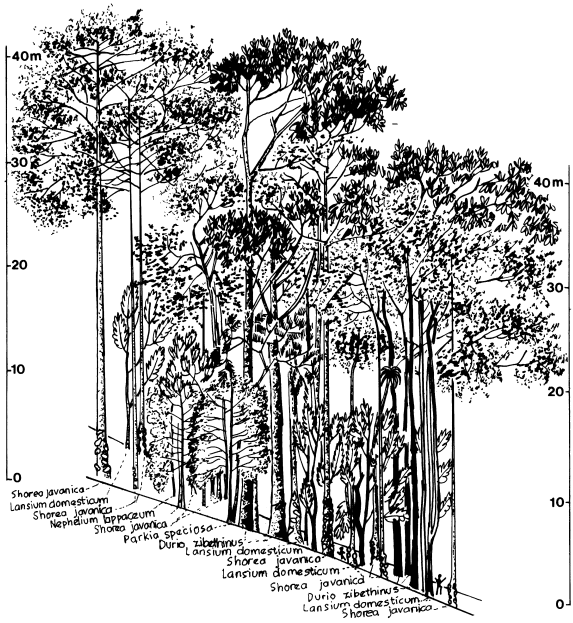
* Although farmers commonly use cassava as a rubber intercrop, the practice is not recommended because unharvested cassava is a host for white root fungus.

The most important fruit and nut trees planted were candlenut (*Aleurites moluccana*), mango (*Mangifera indica*), and durian (*Durio zibethinus*); other species included petai (*Parkia* spp.), coconut (*Cocos nucifera*), rambutan (*Nephelium lappaceum*), cloves (*Eugenia aromatica*), and kuini (*Mangifera odorata*).

Important factors in these farmers' success have been:

- Prior experience with tree crops and agroforests.
- Community cooperation in controlling swidden fires.
- Access to markets.
- Secure land tenure.

In other communities with access to markets and secure land tenure, extension assistance and community organization for fire control could likewise help rehabilitate *Imperata* grasslands.



Complex agroforest

4.9 Community-based and farmer-led approaches to sustainable upland farming

Community-based approaches to planning and managing local resources have many advantages. Farmer-led organizations at the village level accelerate the development and implementation of more sustainable farming practices. In the Philippines a “Landcare” movement has brought local communities together to tackle their agricultural problems in partnership with public sector institutions. These are voluntary, self-governing groups that share technical information, spread the adoption of new practices, enhance research, and foster farm and watershed planning processes.

Some characteristics of typical Landcare groups are:

- They form to tackle the range of sustainability issues considered important to the group.
- They tend to be based on neighborhoods or small sub-watersheds.
- The impetus for their formation comes from the community, although explicit support of government is critical.
- The momentum and ownership of the group's program is with the community.

The Claveria Landcare Association is a federation of 56 village-level chapters with 2000 members and over 40 farmer nurseries. The chapters are groups of neighboring farmers that share similar concerns about solving erosion problems and building a sustainable agriculture. Local government provides financial support for Landcare training and nursery activities. Landcare also provides a structure within which the local extension service can reach large numbers of farm families more effectively.

Chapter 5

Assisted Natural Regeneration

5.1 Introduction

5.1.1 What is Assisted Natural Regeneration?

Suggest if:
- **Pioneer trees and patches of shrub and forest are mixed with *Imperata*.**

Not recommended for:
- **Sheet *Imperata*, large grasslands**

Assisted natural regeneration (ANR) is a flexible approach to reforestation that:

1. Uses natural regeneration of forest trees ("wildlings" or natural seedlings, and sprouts).
2. "Assists" natural regeneration by preventing fire pressing *Imperata*, and helping trees grow faster in other ways. ANR is sometimes called "accelerated natural regeneration."
3. Plants additional trees when needed or wanted (enrichment planting).

Natural regeneration. "Pioneer" trees are the natural regeneration already growing in grasslands. These pioneers are already well established and adapted for the site. ANR also stimulates new natural regeneration from seed from nearby natural forest. In both cases, by using naturally occurring trees, ANR avoids the problem of matching species to the site. The encouragement of these species can help restore a diverse, native forest.

***Imperata* grasslands.** Preventing fire assists natural regeneration in *Imperata* grasslands, other grasslands (*Miscanthus florida*, *Themeda triandra*, *Saccharum spontaneum*, *Capillipedium parviflorum*), and secondary forest. Pressing (Section 3.3.1) is effective in *Imperata* and *Saccharum*.

Community approach. Assisted natural regeneration has been successfully implemented in village projects on communal or public lands. Full community participation is necessary to prevent fire. In the Philippines, ANR has been used in programs giving villagers legal tenure on national lands, in return for the assistance of the villagers in converting grasslands and mixed brushlands into forest. ANR techniques can also be used on individual farms, especially for fallows and agroforests.

5.1.2 Why Practice ANR?

Where the ANR approach has been implemented successfully, *Imperata* grasslands develop into secondary forest. Compared to conventional reforestation with a single tree species, the ANR approach may have social, environmental, and cost advantages. Depending upon the site, it has the potential to:

- Involve local people in developing a forest that meets their needs, to motivate them to conserve it.
- Reduce total reforestation costs, because there is less site preparation, nursery establishment, and enrichment planting.
- Fit well with farmers' cropping schedules, because ANR concentrates on maintenance instead of planting.
- Provide local employment, if there is outside funding. Most expenses are for local labor.
- Include species chosen by villagers, through enrichment planting.

Village ANR in Pakhasukjai, Chiangmai, Thailand

Akha people who migrated to this village in the mid-1970s were forced to settle in an area dominated by *Imperata,* with small scattered patches of forest and bamboo. The villagers wanted a community forest for production and for spiritual needs, so they set aside several hundred hectares of *Imperata* fallow for forest regeneration. In the forest regeneration area, they:

- Constructed a fuelbreak once a year.
- Formed fire-fighting teams.
- Cut *Imperata* for thatch.
- Did not allow farming.
- Allowed trees to be cut only with the permission of village leaders.
- Planted some areas with trees.

After eighteen years, the village forest had more than a hundred species. About half the species are typical of primary forest. The population has increased and now there is not enough land for villagers to fallow their agricultural fields. Even so, the villagers are continuing to maintain their forest. To handle the increased land pressure, they:

- Look for methods to intensify production on their remaining farmland.
- Migrate in search of work.
- Stop farming their steepest fields and assist natural forest regeneration on them.

The desire to obtain land rights and citizenship is helping to motivate these villagers to manage the forest in their village, which is within an important watershed.

- Develop a forest with many species, especially native species. This benefits wildlife habitat and reduces the risk of severe damage from pests and diseases.
- Reclaim land for long-term timber production, since it assists natural woody species that can be used as nurse trees for enrichment plantings of high-value timber tree species.
- Avoid soil erosion. ANR includes little or no cultivation. Pressed *Imperata* continues to cover and protect the soil.
- Quickly restore forest cover to watersheds. The secondary forest is likely to be multistory, including shrubs and herbaceous plants. Multistory forests control soil erosion and increase the amount of rainfall going into the ground. Restoration may take 2-7 years.

5.1.3 Constraints of ANR

Here are some problems that can prevent ANR from succeeding, together with possible solutions.

Lack of community participation.

Plan the project with local people, not for them (see Chapter 1).

Conflicting laws and regulations; insecure land and tree tenure. If communities are not legally allowed to own, enter, or manage their surrounding forests, then the community will not cooperate with fire prevention and maintenance for ANR.

Negotiate tree or land tenure as part of the project, to give people long-term interest in planting or caring for trees.

Poverty. Local people must provide for their short-term needs. Their time and possibly the ANR area is needed for food production.

Consider food and farming needs first. Negotiate pay for local people's labor if the project serves regional goals and can be subsidized.

Labor scarcity. ANR activities are labor intensive. Labor often becomes a limiting factor, since ANR is usually applied in remote grassland areas with low population densities.

Be realistic in estimating labor availability.

Inadequate extension. Because ANR activities are spread throughout the year, project staff cannot supervise all activities, and must put more responsibility in the hands of villagers.

Train local people in ANR techniques; plan adequate resources for that training.

Lack of staff support. Foresters or other project staff might not support or accept the ANR approach because it is new to them and may seem more complicated than conventional reforestation.

Experience with successful ANR implementation can help build staff confidence and support.

Planning uncertainties. Total nursery costs, maintenance activities, and production are difficult to predict because of uncertainties in the number of seedlings or wildlings needed for enrichment plantings, the time period for the natural woody species to close canopy, and the composition and volume of the secondary forest vegetation that will eventually emerge.

Conduct inventories of species present on the site (Section 5.2.2 and Appendix F). Acknowledge uncertainties in targets and budgets; plan flexibly. Monitor results and learn from experience.

Fire.

See Chapter 3 regarding fire protection.

5.2 Implementing Assisted Natural Regeneration

These steps of ANR implementation in *Imperata* grasslands are based on experience but can be adjusted depending upon the sites, resources available, and project and community objectives.

		Timing…
5.2.1	Clarify goals and objectives.	--->
5.2.2	Select appropriate sites.	--->
5.2.3	Protect the area from fire and grazing.	---------->
5.2.4	Identify and mark woody plants.	---------->
5.2.5	Suppress the grass layer.	---------->
5.2.6	Stimulate new natural regeneration.	---------->
5.2.7	Help existing woody plants grow faster.	---------->
5.2.8	Continue to suppress grass.	---------->
5.2.9	Enrich by planting sun-loving species.	---->
5.2.10	Enrich by planting shade-tolerant species.	--------->
5.2.11	Thin and prune.	---->

5.2.1 Clarify goals and objectives

Be sure that the goals and objectives of any ANR project are clear before it begins. ANR is a technology that may be used by farmers and communities on their own, but ANR may also be promoted and subsidized by a regional or

Community planning land use with a map

national program addressing watershed or timber goals. Broad goals must be negotiated and agreed upon between the community and those providing assistance from outside (see Section 1.3). Not all goals are compatible, and misunderstanding must be avoided. Here are some examples.

	Community	***Outside program***
Compatible long term goals	Get access to land for non-timber forest products, fuelwood and poles.	Produce high-value hardwoods for timber concessions.
	Get legal tenure to nearby or ancestral forest lands.	Improve watershed conditions by stopping fires and reforesting.
	Practice shifting cultivation.	Guide shifting cultivators to use *Imperata* grasslands and secondary forest land instead of primary forest land.
Conflicting long term goals	Use the land later for shifting agriculture.	Be sure that the area will be managed as forest in the future.
Compatible short term goals	Get help with road access and marketing for farm and forest products.	Provide roads to facilitate reforestation activities.
Conflicting short term goals	Earn cash income for labor on the project.	Keep project costs low by expecting villagers to invest labor in ANR in expectation of later products.

Specific objectives for ANR and land management must also be decided upon ahead of time (watershed, timber, fallow improvement). Implementation and resources needed will depend upon the objectives.

5.2.2 Select appropriate sites

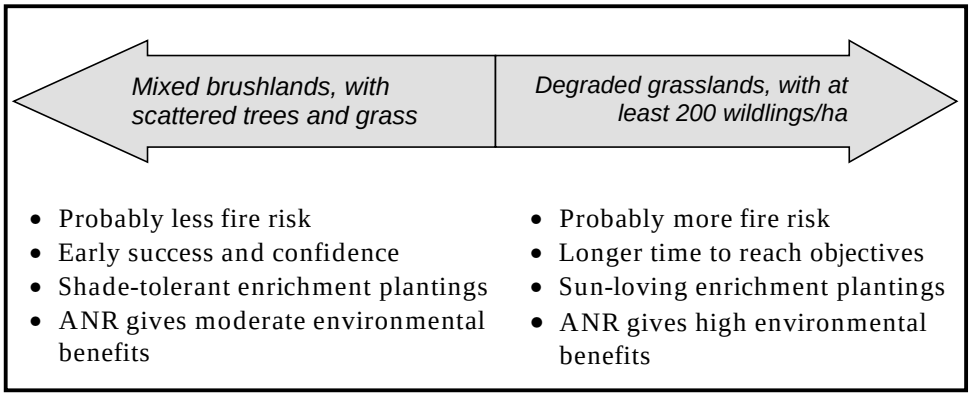
Work in communities that are interested in ANR. Work first with villages or communities that have objectives that can be achieved with ANR, and are willing to organize themselves to prevent fire. Work on lands that the village identifies (see Section 1.3.3).

Choose sites that match the objectives. Also choose objectives that match the sites!

Site	Objectives
Areas accessible to villages, where villagers have tenure or harvest rights	Produce forest and tree products for local use and sale.
Areas bordering villages or where shifting cultivation is practiced	Improve fallows. Use land for agroforestry in the future.
Steep slopes	Reduce fire threats. Reduce flow of water from area during the rainy season.
Areas subject to erosion because of regular burning of *Imperata* cover	Reduce soil erosion and siltation. Reduce flow of water from area during the rainy season.
Land under timber concession	Establish nurse trees for timber species at a low cost.
Areas in or near national parks, game refuges and nature reserves	Restore native forest species. Improve wildlife habitat.

Begin ANR work only in areas that can be protected from fire. Consider labor available to monitor and control fire, and plant and maintain firebreaks.

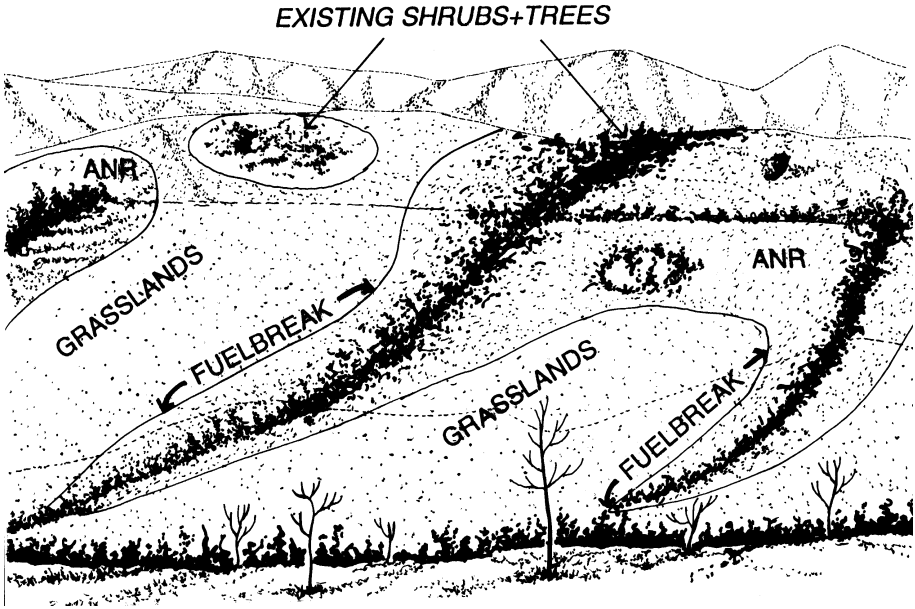
Consider the stage of plant succession of the site. If little or no natural regeneration has occurred, conventional reforestation would be as effective as ANR. If natural regeneration is advanced and most of the area has a closed canopy and trees that are over 2 m tall, use timber stand improvement techniques (including thinning, Section 5.2.11) instead of ANR. In the middle range, decide what areas to prioritize as follows.



Choose sites with enough natural regeneration already present to meet objectives. Estimate the number of existing woody plants/ha, including seedlings and saplings 15-200 cm tall. Count clumps of seedlings within one square meter as one plant. The guidelines given below are for natural regeneration relatively well spread out regardless of slope. If regeneration is uneven, use an estimate for large areas with less regeneration. To make a more careful estimate, use a tally sheet for sample plots (Appendix F).

Woody plants / ha	Timber, watershed objectives	Nature reserves, areas near forest edges, wet sites not prone to fire
Less than 200 / ha (wider than 7 x 7 m)	Use conventional reforestation or agroforestry techniques.	Use conventional reforestation or agroforestry.
200-600 / ha (7 x 7 m to 4 x 4 m)	Use conventional reforestation or agroforestry.	Use ANR with enrichment planting.
600-700 / ha (4.1 x 4.1 m to 3.8 x 3.8 m)	Use ANR with enrichment planting so that canopy closure will take place within 3-5 years.	Use ANR with enrichment planting so that canopy closure will take place within 3-5 years.
Over 700 / ha (narrower than 3.8 x 3.8 m)	Use ANR. For timber production: enrich by planting to achieve desired stocking.	Use ANR.

Choose sites close to forest patches. Gallery forests, forest edges and patches of forest have seed-bearing plants and seed-dispersing animals. This increases the number of new wildlings that can come into the ANR area. Soil conditions may also be more favorable near forest patches. Grasslands that are far from any remaining forests, and grasslands that have been burned and grazed for a long time, do not have enough natural regeneration to make ANR successful.

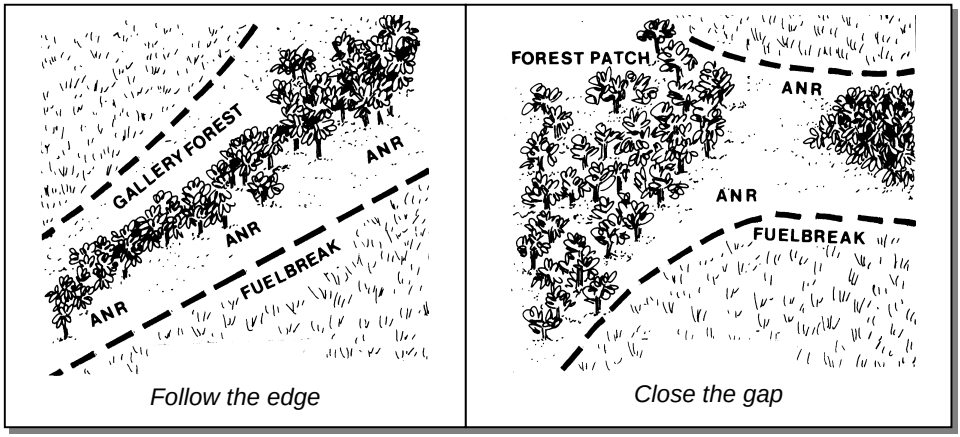


Initial areas for assisted natural regeneration

After choosing the site, get to know it well. Understand the local people, the history of the area, local species, and local soils and rainfall (Chapters 1 and 2).

5.2.3 Protect the area from fire and grazing

The most critical step in ANR is protection of woody plants from fire. Review Chapter 3 carefully. Since ANR is often implemented by communities rather than individual farmers, groups can be organized for fire control. At least a month before the dry season begins, make plans and organize firefighting crews. Review plans and roles when dry season begins. During the dry season, patrol the ANR area to locate fires.



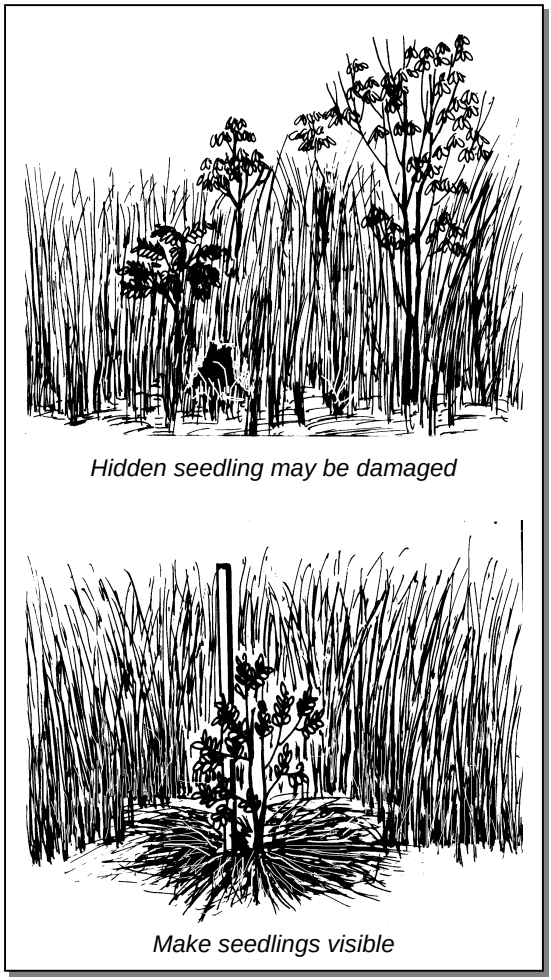
Follow the edge *Close the gap*

One strategy is to "follow the edges and close the gaps." This means to implement ANR along the edges of forests, agroforests, and other fuelbreaks. Implement ANR in the gaps between areas of forest and agroforest. These adjacent areas will serve as fuelbreaks and sources of seed.

The question of grazing in ANR areas must be addressed by the community. Animals may eat or trample woody seedlings and saplings. However, they may also help spread seeds; for example, cattle eat *Albizia saman* pods and deposit the seeds in their manure, where they germinate and grow well. Establish a one-year test comparing areas where grazing animals are kept out by a fence to areas where grazing animals are allowed to enter and spread seeds. Compare the results and adopt the better method.

5.2.4 Identify and mark woody plants

All existing woody wildlings hidden in the grass should be located and clearly marked in order to protect them during grass pressing and clearing. This can be done by two workers: the first marks the wildlings with a stake, and the second ringweeds or presses the grasses and weeds with his/her foot.



Hidden seedling may be damaged

Make seedlings visible

Mark wildlings. Use stakes only if they are available on the site. The stakes should be visible above the grass, about 1.5-3 cm in diameter and 1.5 m in height. Stakes can often be cut on the site. Do not cut any trees needed to reforest the site. Instead, make stakes from branches pruned from large trees, stems thinned from stumps of fire-hardy species, stems thinned from dense thickets, or thinnings from forests near the ANR area. When cutting stakes from clusters of stems on stumps and in thickets, cut the smaller stems, and leave the largest stems to grow. If stakes are not available, ringweeding will help make the wildlings more visible.

Ring weed. The most efficient procedure is to:

- Press grass away from the base of the wildling, using feet or a pressing board (see Section 3.3.1).
- Pull climbing vines from the trees.
- Slash or uproot ferns, climbing vines, and other weeds within ½ m of the stem. Be careful not to damage wildling stems and roots.

- Hand cultivate around the tree, removing grass rhizomes, up to a ½ m diameter if labor is available. Slashing may be done instead if it will be repeated often.

After ringweeding, the ANR site will look like this.

Be careful that ringweeding does not take away shade from wildlings that need shade, such as seedlings of climax forest tree species, especially in the dry season.

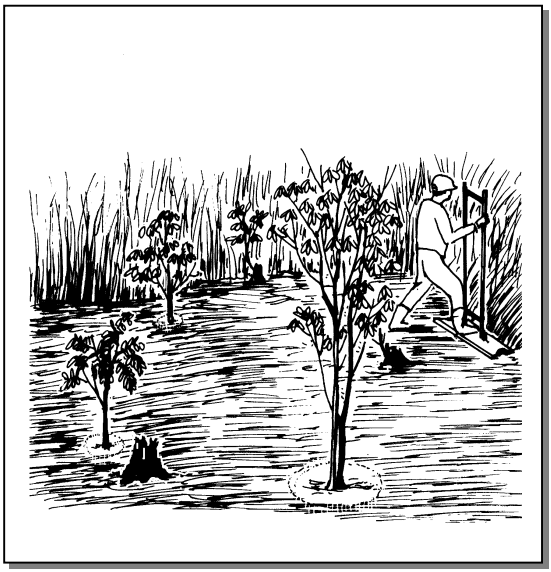
Identify and count wildlings in sample plots if this was not already done during site selection. Do this at the same time as marking and clearing. Local people may be very helpful in identifying plants, though with local names. Extensionists may also record sizes and tag seedlings for future measurement, to monitor growth and survival.

5.2.5 Suppress the grass layer throughout the site

After fire prevention and control, the most important activity in ANR is suppressing *Imperata* and other weeds. *Imperata* must be suppressed efficiently, with minimum use of cash and labor. Usually a combination of methods is used, with cheap and easy methods in open areas and more intensive methods around trees and near forest edges.

Native legumes should be protected and even released from weed competition. They make the soil more fertile and may help suppress *Imperata*. However, climbing legumes must be kept off of trees and seedlings.

Grass pressing. This is a major ANR technique; review Section 3.3.1 carefully. Its purposes in ANR are to:



- Reduce fuel hazard for fire. Press at the beginning of the dry season and whenever the grass is tall and dry.
- Control *Imperata* growth and reduce competition with trees. Press during the rainy season when leguminous cover crops and woody species emerge most rapidly.
- Make it easier and faster to move around and work in the ANR area. Press at any time of the year.
- Prepare enrichment planting areas. Press before the planting season.

Herbicides. With ANR, herbicides can be considered if labor is very limited. See the companion manual *Imperata Management for Smallholders* for practical techniques. However:

- Herbicides are expensive.
- Experience and training is required for safe handling and use.

- A shield must be used to kill only grasses and weeds and not damage woody plants.
- Dead *Imperata* is still a fuel hazard.

Not recommended:
- **Cultivation (plowing)**
- **Controlled burning**
- **Brushing (slashing)**

Widespread cultivation or plowing is generally not recommended for ANR because it exposes the land to erosion on steep slopes and destroys existing woody plants. Controlled burning is not recommended for ANR because *Imperata* regrowth is rapid, woody species are killed or damaged, and the soil is exposed to erosion. For grass suppression throughout the site, brushing is not recommended because it takes more work than pressing and stimulates more regrowth of *Imperata*.

5.2.6 Stimulate new natural regeneration

Brush grass near forests. Near forest edges and tree patches, temperature, moisture, and soil are more favorable for wildlings than in open grasslands. For the purpose of stimulating seed germination, slash or spray herbicide on all grasses and weeds within 5-20 m of the forest edge. Nearby trees and forest wildlife will provide seeds. If trees along the edge of the forest are covered with vines, pull down or slash the vines to release the trees and encourage them to seed.

Protect wildlife. Develop mechanisms within the community and educate children not to kill forest birds and bats. Birds, bats, and pigs can carry seeds into the grasslands.

Consider encouraging weeds that farmers may prefer to *Imperata*. Spraying glyphosate herbicide can cause increased germination of natural vegetation such as *Chromolaena odoratum* and *Melastoma* spp., probably because the dead grass mulches the soil.

5.2.7 Help existing woody plants grow faster

Mark new wildlings as they come in to the area, especially along forest edges.

Ring weed old and new wildlings (see Section 5.2.4).

Fertilize. The decision whether to fertilize depends upon:

- Species. Some species might not grow much faster in response to fertilizer. Before spending much money on fertilizer, test its effects on different species and different age classes in sample plots. Measure size before and after fertilization for both fertilized and unfertilized trees.
- Size of seedling. Newly planted enrichment seedlings or young wildlings will benefit more from a little fertilizer than older trees.
- Soil. Even in *Imperata* grasslands, some soils are fertile. The use of fertilizers on such soils may not improve tree survival and growth.
- Fire risk. Fertilizer might help trees close canopy sooner.
- Plantation value. Trees providing timber, or other high-value products, might be worth fertilizing.

To apply fertilizer:

- Apply fertilizer after ringweeding. Make sure it is placed in a hole and covered with soil.
- For seedlings: apply fertilizer in a spot, semi-circle, or circle about 15-20 cm from the tree.
- For nitrogen-fixing seedlings, apply about 10 g P per tree. For other seedlings, apply about 20 g N and 10 g P per tree, or about one tablespoon NPK. These are general recommendations; if recommendations from local soil tests are available, follow them instead.
- For larger trees: apply directly below the edge of the tree canopy, in a circle, semicircle, or three spots.

- Fertilizer will stimulate the growth of *Imperata* and weeds. Be sure to ring weed and hand cultivate regularly for at least 12 months after fertilization.

Thin. Where two seedlings or saplings are close enough to each other to compete for light, water, and nutrients, remove the one that is smaller, less healthy, or of a less desirable species. When a tree stump has several sprouts, remove all but the 1-3 largest.

Transplant. Make use of planting materials from thinning operations. If thinning takes place during the rainy season, transplant healthy thinned wildlings and cuttings to nearby areas with similar conditions (soil, light, moisture) where there is not enough natural regeneration. If it is near the end of the rainy season, transplant small wildlings of valuable species to a nursery. See Sections 5.2.9 and 5.2.10 for more information on enrichment planting and transplanting wildlings.

5.2.8 Continue to suppress grass

Repeat pressing and ringweeding when *Imperata* begins to compete with wildlings and trees for light and nutrients. During the rainy season, pressing and ringweeding usually need to be repeated at least once every 1½ months.

During the dry season, pressing should be done if the grass begins to grow tall, usually every 2-3 months. Be careful not to take away shade from species of wildlings that need shade.

During all activities, watch for new natural regeneration to be marked and ringweeded.

5.2.9 Enrich by planting sun-loving species

Enrichment planting can include cover crops (Section 4.3), orchard trees (Section 4.6), and plantation trees (Section 4.7), including nurse trees (Section 4.8).

Possible objectives are to:

- Fill gaps to shade out *Imperata* and convert the whole area to forest.
- Increase density so that the canopy will close sooner.
- Add trees of species valued for timber, fruit, nuts, or other products.
- Add nitrogen-fixing species as an improved fallow.

Choosing sites and strategies

Plant only as much area as can be maintained in addition to the natural regeneration that is already being ringweeded and cared for.

Strategy: follow the edges and close the gaps. Concentrate efforts where they are most likely to be successful: along the edges of existing forests and plantations, and in gaps between patches of large trees. These areas have more fire protection than open grasslands, more shade, and possibly better soil conditions. Each planting season, follow the edges of recently planted areas, and close gaps between them.

Strategy: plant nurse trees first. To plant high-value species that need shade while young, plant nurse trees first. This is similar to multistory agroforestry (Section 4.8) and tree plantations (Section 4.7).

Species choice

ANR in *Imperata* grasslands often uses the same species as in simple tree plantations in *Imperata*: species that can survive harsh conditions, grow quickly and cast heavy shade to suppress *Imperata* (Section 4.7). But the ANR approach is different from simple tree plantations because it:

- Uses a wider variety of local native species and agroforestry species.
- Has a variety of “microsites” where shrubs and trees provide shade, affect soil moisture, and form windbreaks.

Therefore, instead of choosing a single species, try to use several enrichment species matched to different spots within the ANR area.

Natural regeneration considerations. Include a few local tree species known to provide fruit or food for birds and bats that spread seed. Include local species that are common roosts (sleeping and nesting areas) for birds and bats.

In *Imperata, Acacia mangium* is a good hardy nurse tree for natural regeneration of native forest species. This is probably because *A. mangium* fixes nitrogen and provides shade. The shade is important in ANR because it suppresses *Imperata* and is favorable for shade-tolerant tree species.

Production considerations. For fertile and accessible sites, consider tree crops, multistory agroforestry species, and improved fallow species (Chapter 4). For timber and multipurpose species, choose some that will be harvested within 5-10 years (short rotation) and some high-value species that will be harvested later (medium and long rotation). Having more than one wood or timber species will absorb the loss from a low market price for one species.

Site matching. Information about common reforestation species and agroforestry species is available from foresters and agriculturalists. Information may not be available in books about local native species, but local species should be considered for local cultural, medicinal, wildlife, or other values. To figure out how to match these local species to planting spots:

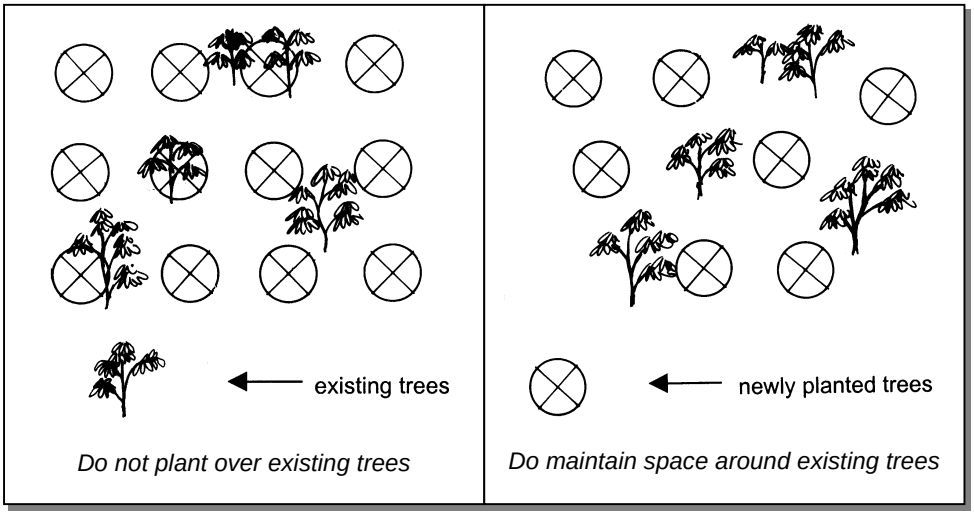
- Observe surrounding areas and notice where similar species grow well. Notice soil texture and color, soil drainage (wet, dry, variable), topographic position (slope, aspect, hilltops and ridges, streamsides, flood plains), rainfall, elevation, and shade. Consider having a soil test done for fertility.
- Talk with local people to identify potential species, their uses, and habitat requirements.

Plant a few target species in different sites as a test. Observe how they grow or adapt to different conditions. Select the tree species that grow the best for each site.

Implementation

Many planting techniques are the same as those for simple tree plantations (Section 4.7).

Spacing. As a rule of thumb, use a 2m x 3m spacing to close canopy within 3-5 years. For nurse trees, use 3m x 3m, or use a closer spacing and thin later. Other spacings can be used depending upon the species and objectives for the site. Maintain spacing between new trees and existing natural regeneration.



Nursery production. To estimate the amount of planting material needed, subtract the average woody plants/ha already present from the target stocking. For example, a 2m x 3m spacing is about 1670 trees/ha. If there are already 600 wildlings/ha, 1070 seedlings/ha will be needed, plus an allowance for mortality in the nursery, under transport, and in the field.

Site preparation. Cultivate planting areas 1 m in diameter.

5.2.10 Enrich by planting shade-tolerant species

Begin enrichment planting of shade-tolerant trees:

- As soon as nurse trees and existing woody species cast appropriate shade for the shade-tolerant species. Continue to weed and control *Imperata*.
- Or, wait until nurse trees and existing woody species cast heavy shade and have outcompeted *Imperata.* Thin or prune nurse trees to allow the right amount of light and shade for the shade-tolerant species. Control *Imperata* if it begins to grow again.

At the start of the rainy season, plant the high-value tree species between the nurse trees at 3 x 3 m or 4 x 4 m spacing, or at the recommended spacing requirements of each species.

Produce seedlings in the nursery, and transplant wildlings from nearby forests. When gathering wildlings, dip the roots in thick mud or a slurry of clay soil and water, and wrap them in leaves to keep them moist while being moved. Mix soil from where they were taken into the mud, slurry or nursery soil, to inoculate them with mycorrhizae and rhizobia to improve their growth. Transplant small wildlings or heavily shaded wildlings to the nursery to grow them larger and gradually accustom them to the right amount of sun.

Agroforestry species, rattans, orchids, and other non-timber forest species can also be planted (Section 4.8).

5.2.11 Thin and prune

Prune branches of nurse trees. Prune nurse trees to gradually increase light for dipterocarps and other species that need shade when young and sun when large.

Thin trees as the forest develops. As the canopy begins to close and trees compete with each other, in some cases it is worth the labor to thin trees.

If an unhealthy, branchy, crooked, or worthless tree is interfering with the growth of a healthy, straight, or valuable tree,

Cut the unhealthy, branchy, crooked, or worthless tree.

If trees are crowded, and the thinned trees can be used for firewood or other products,

Cut trees that are shorter, smaller in diameter, or less straight. The remaining trees will grow faster and produce superior seed.

When dipterocarps reach pole diameter,

Thin enough nurse trees to increase sunlight.

Do not:
- **Remove needed shade**
- **Let *Imperata* back in**
- **Damage other trees**

Be careful not to cut trees that are still needed for shade of shade-tolerant plants or seedlings. Don't cut so many trees that *Imperata* returns and becomes a fuel hazard for fire. Finally, cut trees carefully so that they don't damage other trees as they fall.

5.3 Labor and cost estimates for ANR

Appendix G shows tasks and estimated labor for a hectare of assisted natural regeneration, assuming that the site begins with 1000 woody plants/ha and no enrichment planting takes place. Labor for firebreaks establishment, pressing and ringweeding in Year One requires 49 person-days. Years Two and Three each require 31 person-days. Total labor for the three years is 111 person-days.

Cost savings of ANR in comparison to conventional reforestation can be roughly estimated by considering that a percentage of costs will be saved because of the stocking already on the site. For example, if 60% of the area already has adequate stocking and 40% of the area is planted, the costs for seedling production and outplanting will be reduced by 60%. Fire control, ringweeding and grass suppression costs would be about the same. In this example, ANR costs about 78% as much as conventional reforestation. However, that does not consider the differences in site

preparation. ANR usually uses pressing and spot cultivation for enrichment planting. Conventional reforestation might use removal of existing brush vegetation followed by complete cultivation.

ANR demonstration (general expectations)

Carefully monitor the pressing and ringweeding of the first few hectares of an ANR project, to train participants and put a demonstration area in place that will attract attention. To press and ringweed 1 ha requires 15 person-days / ha. Three hired laborers and one extensionist experienced with ANR will form a good team to demonstrate ANR on 4 ha. Allowing time for weekends, holidays, and training for interested local farmers, implementation of ANR on this demonstration area will take about one month.

5.4 Summary

Assisted natural regeneration techniques can be applied to many land uses.

Fire protection is a requirement for agroforestry, reforestation or ANR in *Imperata* grasslands. Communities motivated by land tenure or other factors can implement ANR with fire protection alone if there is sufficient natural regeneration (see the Kalahan case study, Section 3.5). ANR can therefore be a very low-input approach to reforestation within the abilities of local communities.

Pressing *Imperata* grass (Section 3.3.1) is a technique that can be used in agroforestry and tree plantations as well as ANR, to help control *Imperata* between rows and beside fuelbreaks.

Natural regeneration can be incorporated into agroforestry and conventional reforestation. Wildlings and larger shrubs and trees already present may be retained because they have timber or other values, because they provide organic material in fallows, or because they can help form fuelbreaks as they compete with *Imperata*.

Enrichment planting combined with ANR can develop a multi-species forest plantation, or can lead to a multistory agroforestry system (Section 4.8) as shade-tolerant crop species are established underneath pioneer species that are used as nurse trees.

Imperata grasslands, agricultural and agroforest crops, plantations, and native forest species each have their place in the landscape. Flexibility and open communications will help as local communities interact with the governments of larger watersheds and nations to make wise decisions about how to use land, labor, cash and other resources to achieve the greatest good for all.

Appendix A. Recommended practical references

The following references provide useful information on tree species, agroforestry systems, reforestation, community participation, and fire protection.

del Castillo, R., R. Dalmacio, R. Lasco, and N. Lawas, eds. 1994. ***Agroforestry Production and Post Production Systems: a Training Manual.*** University of the Philippines Agroforestry Program (UAP), Laguna, Philippines, and KAPWA Upliftment Foundation Inc., Davao City, Philippines. [Available from UPLB Bookstore]

del Castillo, R., R. Dalmacio, R. Lasco, and N. Lawas, eds. 1994. ***Soil and Water Conservation and Management: a Training Manual.*** University of the Philippines Agroforestry Program (UAP), Laguna, Philippines, and KAPWA Upliftment Foundation Inc., Davao City, Philippines. [Available from UPLB Bookstore]

CIFOR. 1996. ***Manual of forest fruits, seeds, and seedlings, Version 1. CIFOR CD-Rom Publication No. 1.*** Center for International Forestry Research, Bogor, Indonesia.

Coronel, R. E. 1983. ***Promising Fruits of the Philippines.*** College of Agriculture, University of the Philippines at Los Baños. College, Los Baños, Laguna, Philippines.

Davis-Case, D. 1990. ***The Community's Toolbox: The Idea, Methods, and Tools for Participatory Assessment, Monitoring and Evaluation in Community Forestry.*** Community Forestry Field Manual 2. FAO, Bangkok, Thailand.

FAO. 1996. ***Asia-Pacific Agroforestry Profiles: Second Edition.*** APAN Field Document No. 4 and RAP Publication 1996/20. Asia-Pacific Agroforestry Network, Bogor, Indonesia, and FAO, Bangkok, Thailand.

FAO and IIRR. 1995. ***Resource management for upland areas in Southeast Asia.*** FARM Field Document 2. FAO, Bangkok, Thailand, and IIRR, Cavite, Philippines. [Available from IIRR]

Freudenberger, K. S. 1994. ***Tree and Land Tenure: Rapid Appraisal Tools.*** Community Forestry Field Manual 4. FAO, Rome.

IIRR. 1992. ***Agroforestry Technology Information Kit: Second Edition.*** IIRR, Cavite, Philippines.

IIRR. 1996. ***Agriculture, Natural Resources and Environment Management Information Kit.*** IIRR, Cavite, Philippines.

IRRI and NRI. 1996. ***Imperata Management for Smallholders*****.** Indonesian Rubber Research Institute, Natural Resources Institute (United Kingdom). Indonesia. [Available from ICRAF]

Jensen, M. 1995. ***Trees Commonly Cultivated in Southeast Asia: an Illustrated Field Guide.*** RAP Publication 1995/38. FAO, Regional Office for Asia and the Pacific. Bangkok, Thailand.

Mobley, H.; J. Moore; R. Ashley; K. Burton; and H. Peeples. 1979**.** ***Planning for Initial Attack*****.** United States Department of Agriculture, Forest Service, Southeastern Area. Forestry Report SA-FR 2. Atlanta, Georgia, USA. [Available from IPIF]

PCARRD. [various dates] ***Philippines Recommends Series*****.** Philippines Council for Agriculture, Forestry and Natural Resources Research and Development. Laguna, Philippines.

PROSEA. 1992-1997. ***Plant Resources of Southeast Asia, Vol 1-11*****.** Prosea Network Office. Bogor, Indonesia.

USDA FS. [No date] ***Manual for Forest Fire Fighters.*** United States Department of Agriculture, Forest Service, Northeastern Area. Pennsylvania, USA. [Available from IPIF]

Addresses of sources:

CIFOR: Librarian, Center for International Forestry Research, Jl. CIFOR, Situ Gede, Sindangbarang, Bogor Barat 16680 Indonesia. Fax: (0251) 622-1100.

FAO/Rome: Director, Publications Division, Food and Agriculture Organization of the United Nations, Viale delle Terme di Caracalla, 00100 Rome, Italy.

FAO/Thailand: Food and Agriculture Organization of the United Nations, Regional Office for Asia and the Pacific, Maliwan Mansion, Phra Atit Road, Bangkok 10200, Thailand. Fax 66-2-2800445. Email fao-rapa@cgnet.com

ICRAF: International Centre for Research in Agroforestry, P.O. Box 161, Bogor 16001, Indonesia. Fax (62-251) 625-416. Email icraf-indonesia@cgnet.com

IIRR: International Institute of Rural Reconstruction, Y. C. James Yen Center, Biga, Silang 4118, Cavite, Philippines. Fax (63-46) 414-2420. Email iirr@cav.pworld.net.ph

IPIF: Institute of Pacific Islands Forestry, USDA FS, 1151 Punchbowl St. Rm. 323, Honolulu, Hawaii 96813 USA. Fax (1) 808-522-8236. Email ipif@gte.net

KAPWA: KAPWA Upliftment Foundation, Inc. 427 Durian St., Juna Subdivision, Matina, P.O. Box No. 81508, Davao City 8000 Philippines.

PCCARD: Philippines Council for Agriculture, Forestry and Natural Resources Research and Development, College, Los Baños, Laguna, 4030 Philippines. Fax (63) 094-50016.

PROSEA: Distribution Officer, Prosea Network Office, Herbarium Bogoriense 4th Floor, Bogor 16122 Indonesia.

UAP: University of the Philippines Agroforestry Program, 2nd Floor, UPLB-CF Administration Building, College, Los Baños, Laguna 4031 Philippines. Fax (63) 094-3206.

UPLB Bookstore: University Bookstore, SU Building, University of the Philippines at Los Baños, College, Los Baños, Laguna 4031 Philippines

Appendix B. Characteristics of contour hedgerow and rotational alleycropping species.

Name	Soil fertility enhancement	Products	Elevation (m)	Drought tolerance	pH tolerance	form
Acacia villosa (*A. glauca*)	Green manure N-fixer	Fuelwood	0-1000+	good	Acid tolerant	shrub
Ananas comosus (pineapple)	Little or none	Food	0-1500	good	acid tolerant	<1 m
Calliandra calothyrsus (*C. tetragona*)	Green manure N-fixer	Fuelwood, fodder, honey	0-2000	moderate	acid tolerant	shrub
Delonix regia (fire tree)	green manure	Fuelwood	0-2000	very good		tree
Desmodium rensonii	green manure N-fixer	Fodder	0-1000	moderate	wide range of pH values	shrub
Erythrina poeppigiana (coral tree)	green manure N-fixer	Poles, fodder	0-1900	good	Acid tolerant	tree
Flemingia macrophylla	green manure N-fixer	fodder	0-2000	moderate	wide range of pH values	shrub
Gliricidia sepium (madre de cacao)	green manure N-fixer	Posts, fuelwood, fodder, honey	0-1500	good	wide range of pH values	small tree

Name	Soil fertility enhancement	Products	Elevation (m)	Drought tolerance	pH tolerance	form
Hibiscus rosasinensis	green manure	fodder	0-1500	moderate	wide range of pH values	shrub
Leucaena diversifolia	green manure N-fixer	Light poles, fuelwood	0-2000	moderate	acid tolerant	small tree
L. leucocephala, giant varieties (ipil-ipil)	green manure N-fixer	Poles, fuel-wood, fodder	0-2000	very good	not tolerant of acid soils	tree
Pannicum maximum (guinea grass)	little or none	fodder	0-2000	good	wide range of pH values	grass
Parkia roxburghii (kupang)	green manure N-fixer	fuelwood	0-2000	good	wide range of pH values	tree
Pennisetum purpureum (napier grass)	little or none	fodder	0-2000	moderate	wide range of pH values	grass
Piliostigma malabaricum (butterfly tree)	green manure	fodder, fuelwood	0-1500	good	wide range of pH values	small tree
Senna siamea (*Cassia siamea*, Thailand shower)	green manure	fuelwood, small timber, fodder, honey	0-1500	excellent	wide range of pH values	small tree
Senna spectabilis (Cassia spectabilis, golden shower)	green manure	fuelwood	0-1500	moderate	acid tolerant	tree

Name	Soil fertility enhancement	Products	Elevation (m)	Drought tolerance	pH tolerance	form
Setaria sp.	little or none	fodder	0-2000	good	wide range of pH values	grass
Vetivera zizanoides (vetiver)	little or none	little or none	0-2000	excellent	wide range of pH values	grass

Appendix C. Characteristics of leguminous cover crop species.

Species	Growth habit	Site preferences (Numbers in parentheses indicate conditions for less favorable sites)	Competition and use as cover crop
Calopogonium caeruleum (caeruleum calopo, thua saelulium)	• Perennial • Woody vines	• tolerates soil pH as low as 4 • tolerates wide variety of soils, but prefers well-drained soils • drought tolerant	• Slow-growing for 20 months • Vigorous growth from 20 months to 5 years of age • Shade tolerant • Can smother *Imperata* • Used as intercrop in with industrial tree crops
Calopogonium mucunoides (*Stenolobium branchycarpum*, robo de iguana, falso oro, calopo, kacang asu, thua karopo)	• Perennial • seeds profusely, may regenerate annually • creeping, twining	• elevation (0) 300-1000 (2000) m • Adaptable to various soils • Tolerates soil pH 4.5-5.0 • Dry season up to 4½ months • 1200+ mm rain/year preferred	• Achieves cover within 3-6 months • Medium-low shade tolerance • Especially useful for quick cover of cleared land • Dry season forage

Species	Growth habit	Site preferences (Numbers in parentheses indicate conditions for less favorable sites)	Competition and use as cover crop
Centrosema pubescens (Centro, butterfly pea)	• perennial • trailing, twining, climbing	• elevation 0-300 (1000) m • fair tolerance of low fertility soils • Dry season up to 4½ months; more drought-tolerant than *Calopogonium* or *Puereria* • annual rainfall (1200)1500+ mm • good tolerance of waterlogging	• establishes slowly, 4-8 months • vigorous once established • Medium-high shade tolerance • Used as relay crop • Good forage, mixes well with forage grasses
Crotolaria juncea (sunn hemp, orok-orok)	• annual • erect stem 1-3 m	• elevation 0-300 m preferred • pH (4.0) 5-7.5 • Light, well-drained soils • 760+ mm rain/year preferred • can produce crops with 50 mm rainfall in 6 weeks	• Can strongly suppress *Imperata* • may inhibit maize germination • can relay plant, fallow, or interplant with tall crops
Mucuna pruriens var. *utilis* (*Stizolobium atterinium, S. niveum*, kokoa, velvet bean, Bengal bean, cowhage, koro benguk)	• annual • vines up to 6 m long	• pH 5.0-6.5 • Less tolerant of degraded and waterlogged soils than *Imperata* • drought tolerant	• large seed, fast starter • vigorous growth for 4-6 months • Good for short fallows • Not used in intercropping

Species	Growth habit	Site preferences (Numbers in parentheses indicate conditions for less favorable sites)	Competition and use as cover crop
Pueraria phaseoloides (syn. *P. javanica*) (puero, tropical kudzu, kacang riji)	• perennial • twining, climbing	• tropical lowlands • tolerates acid soils • best suited to heavy soils • good tolerance of waterlogging • annual rainfall (1200) 1500+ mm • more tolerant of drought than *Calopogonium*	• establishes slowly, 6-9 months on average; vigorous once established • medium shade tolerance • good for smothering weeds • used in fallow or with trees
Stylosanthes guianensis (stylo, thua satailo)	• perennial • bushy	• adapted to many soil types including sandy soils • fair tolerance of waterlogging • annual rainfall 1525+ mm	• Used as fallow or relay crop • Good pasture legume

Appendix D. Site preferences of perennial fruit, nut, and resin agroforestry species

These species are suited to smallholder plantings on *Imperata* grasslands.

Numbers in parentheses indicate conditions for less favorable sites.

Species	Altitude (m above sea level)	Rainfall (mm/yr)	Rainfall distribution	Soil pH	Minimum soil depth	Soil type, texture, drainage
Aleurites moluccana (candlenut, lumbang)	0-800 (1200)	1000-2500	90-200 days rain / year			Podzolic, Latosols, sandy soils & limestone soils
Anacardium occidentale (cashew)	0-800 (1500)	500-3200	Can tolerate dry season over 6 months	5-8 (4.3-8.7)	Deep; tolerates shallow	Does well on sandy soil; prefers well-drained
Areca catechu (betel nut)	0-900	1250-3000				

Species	Altitude (m above sea level)	Rainfall (mm/yr)	Rainfall distribution	Soil pH	Minimum soil depth	Soil type, texture, drainage
Artocarpus heterophyllus, syn. *A. brasiliensis, A. integra, A. integrifolia* (jackfruit, nangka)	0-1000 (1200)	Above 1500	Evenly distributed; tolerates 2-4 month dry season	5-7 (4.3-8.0)	deep	Prefers well-drained sandy or clay loam
Canarium ovatum (pili)	0-400	moist humid	Tolerates dry season; prefers evenly distributed rainfall	Slightly acidic	deep	Adaptable; prefers well-drained soils
Ceiba pentandra, syn. *C. casearia, Bombax guineese, B. orientale* (kapok)	0-600	1500-3500				
Cinnamomum burmanii (cassiavera)	(0) 600-1500	1500-2500	150-240 days rain / year			

Species	Altitude (m above sea level)	Rainfall (mm/yr)	Rainfall distribution	Soil pH	Minimum soil depth	Soil type, texture, drainage
Citrus spp. (citrus)	0-1200 (1500)	(1000) 1500-2000		5.5-6.5 (4.3-8.3)	1 m	Well-drained sandy loam with high OM
Cocos nucifera (coconut)	0-600 (900)	1200-2000 (1000-2500)	evenly distributed through year	4.3-8.3	75 cm	Prefers adequately drained, high water-holding capacity (at least 30% clay)
Coffea spp. (coffee)	0-900 (1800)	1550-1800 (1200-2500)	evenly distributed through year or short dry periods	4.5-5.5 (4.3-8.0)	1.5 m	Requires friable, loamy soil with good water holding capacity and circulation of air & moisture
Eugenia aromatica (clove)	200-600	1500-3500	90-175 days rain / year			

Species	Altitude (m above sea level)	Rainfall (mm/yr)	Rainfall distribution	Soil pH	Minimum soil depth	Soil type, texture, drainage
Garcinia mangostana (mangosteen)	0-500		Tolerates dry season; prefers rainfall well distributed through the year	Slightly acid ideal (4.3-8.0)	deep	Loam or loose clay with good drainage
Hevea braziliensis (rubber)	0-600	1500-2000	Fairly evenly distributed through the year	Acidic 4.3-8.0	1 m	Requires well-drained clay loam or sandy loam
Mangifera indica (mango)	0-600	(300) 760-2700 mm/yr	at least 5 months' dry period	5.5-7.5 (4.3-8)	deep	prefers well-drained loam soils
Manilkara zapota, syn. *Achras zapota*, *Sapota achras* (chico, sapodilla, marmalade plum, bully-tree)	0-1500 (2500)	1250-2500	Can succeed in long dry season if watered when young	4.5-7 (8.6)	deep	Prefers well-drained sandy loam

Species	Altitude (m above sea level)	Rainfall (mm/yr)	Rainfall distribution	Soil pH	Minimum soil depth	Soil type, texture, drainage
Musa spp. (banana)	0-1500 (1800)	1400-2450	At least 100 mm/month	4.5-7.5 (4.3-8.3)	deep	Prefers friable loam soil with good drainage and aeration
Myristica fragrans (nutmeg)	0-700	1500-3500	80-180 days rain / year			
Piper nigrum (black pepper)	0-500 (1000)	1500-2000 (1000-3000)	100-200 days rain / year	4.3-7.4		Loam or loose clay with good drainage
Psidium guajava (guava)	0-800	700-3700	Less than 6 months' dry season	5.5-7.5 (4.3-8.3)	deep	Prefers rich, well-drained soils high in OM
Sandoricum koetjape (santol)	0-800		Tolerates dry season; prefers evenly distributed rainfall	Slightly acidic	deep	Well drained; prefers loose friable clay loam or sandy loam with high OM

Species	Altitude (m above sea level)	Rainfall (mm/yr)	Rainfall distribution	Soil pH	Minimum soil depth	Soil type, texture, drainage
Spondias purpurea (sineguelas)	0-600 (2000)	Succeeds in wet and dry sites	Better quality fruits where dry season is long	Slightly acidic		Adaptable; prefers moist, fairly heavy loam soil
Syzyqium cumini (duhat)	0-600	1000-1500	prefers distinct dry season	Slightly acid	Deep; tolerates rocky or shallow	Prefers well-drained clay loam or sandy loam
Tamarindus indica (tamarind)	0-1500	250-2700	best if well distributed through year	Moder-ately acidic or alkaline	Tolerates rocky or shallow	Prefers well-drained sandy or clay loam with high OM

Species	Altitude (m above sea level)	Rainfall (mm/yr)	Rainfall distribution	Soil pH	Minimum soil depth	Soil type, texture, drainage
Theobroma cacao (cacao)	0-500 (1000)	1000-3000 (5000)	no more than 3 months' dry period	5-6.5 (4.3-8.7)	60-70 cm	Must be well-drained, aerated, with good moisture retention; aggregated clay or loamy sand
Vanilla fragrans (*V. planifolia*, vanilla)	0-800	2000-2500 (1500-3000)	100-178 days rain / year		Deep	Friable well-drained soils

Appendix E. Plantation tree species suitable for *Imperata* suppression.

Table 1. Plantation species reported to successfully control *Imperata*.

Note: not all species always succeed; *Imperata* often continues to grow under *Eucalyptus* and *Pinus* species and *Paraserianthes falcateria*.

Indonesia

Acacia aulacocarpa
A. auriculiformis
A. crassicarpa
A. decurrens
A. mangium
Albizia procera
Aleurites moluccana
A. montana
Altingia excelsa
Anacardium occidentale
Cassia multijuga
Casuarina equisetifolia
Cecropia peltata
Endospermum malaccense
Erythrina sp.
Fagraea fragrans
Gmelina arborea
Hibiscus spp.
Hopea mengarawan
Intstia palembanica
Leucaena leucocephala
Morus macroura
Ochroma sp.
Ormosia sumatrana
Paraserianthes falcataria (syn. *Albizia moluccana*)
Peltophorum dasyrachis (syn. *P. grande*)
Pinus caribaea
P. merkusii
Psidium guajava
Quercus sp.
Schima wallichii
Sesbania sesban
Shorea leprosula
S. ovalis
S. platyclados
Sindora sp.
Styrax benzoin
Swietenia macrophylla
Syzygium spp.
Toona sinensis
Vernia arborea
Vitex parviflora
V. pubescens

The Philippines	Vietnam	Malaysia
Albizia procera	*Acacia auriculiformis*	*Dryobalanops aromatica*
Alnus maritima	*A. mangium*	*Hopea karangasensis*
Anacardium occidentale	*Anacardium occidentale*	*Pentaspodon motleyi*
Artocarpus heterophyllus	*Anthocephalus chinensis*	*Shorea leprosula*
Bauhinia malabarica	*Indigofera teysmanii*	*S. macrophylla*
Casuarina equisetifolia	*Lagerstroemia speciosa*	*S. ovata*
Eucalyptus camaldulensis	*Pinus kesiya*	*Vatica nitens*
E. grandis	*Pterocarpus* spp.	*Whiteodendron mpultonianum*
E. saligna	*Swietenia macrophylla*	
Gliricidia sepium		
Gmelina arborea		
Leucaena leucocephala		
Pinus insularis		
Psidium guajava		
Vitex parviflora		

Table 2. Site requirements of common plantation species in *Imperata* grasslands.

Numbers in parentheses indicate conditions for less favorable sites.

Species	Elevation (m)	Soil acidity	Soil texture, type	Rainfall (mm/year)	Length of dry season
Acacia auriculiformis	0-800	pH 3.0-9.5	Infertile OK deep-shallow	(1000) 1500-2500	0-6 months
A. mangium	0-720	pH over 4.5	Tolerates thin, rocky, or alluvial soils	1000-4500	2-4 months
Calliandra calothyrsus	150-1500 (0-2000)	moderately acidic	prefers light soils, not waterlogged	(1000) 2000-4000	3-6 months
Gliricidia sepium	0-500 (1600)	tolerates acid soils	tolerates limestone, saline, or degraded soils	1500-2300	0-6 months
Gmelina arborea	0-800 (1200)	adaptable to acid soils	does not tolerate waterlogged or leached soils, dry sand	750-4500	4-6 (7) months
Leucaena leucocephala	0-1000 (1500)	pH 6-7.7	not waterlogged	(250) 600-3000	4-6 (8) months
Vitex parviflora	0-700		adaptable; prefers limestones, tolerates dry, rocky sites		0-7 months

Table 3. Sun-demanding trees that can be planted into grasslands. All are native Philippine species recommended for areas with no pronounced dry season.

Scientific Name	Family	Economic Quality	Mature height (m)	Mature diameter (m)
Dracontomelon dao	Anacardiaceae	Superb; Furniture	40	1.0
Dracontomelon edule	Anacardiaceae	Good; construction	40	1.0
Koordersiodendron pinnatum	Anacardiaceae	Superb; All purpose	25	1.2
Radermachera pinnata	Bignoniaceae	Good; all purpose; pioneer	20	0.6
Garuga floribunda	Burseraceae	Superb; All purpose	35	1.0
Afzelia rhomboidea	Caesalpiniaceae	Superb; All purpose	25	0.5
Albizia lebbekoides	Caesalpiniaceae	Light construction; pioneer	25	2.5
Intsia bijuga	Caesalpiniaceae	Superb; Furniture	50	1.5
Casuarina equisetifolia	Casuarinaceae	Good; house posts	30	1.0
Casuarina nodiflora	Casuarinaceae	Good; house construction	20	0.8
Calophyllum blancoi	Clusiaceae	Good; all purpose	25	0.6
Calophyllum inophyllum	Clusiaceae	Good; furniture	20	1.5
Terminalia catappa	Combretaceae	Good; house construction, boats	25	0.8
Terminalia foetidissima	Combretaceae	Good; house construction, boats	25	0.8
Terminalia microcarpa	Combretaceae	Light construction, wine	35	1.0
Ormosia calavensis	Fabaceae	Light construction; good mycorrhiza	15	0.6

Scientific Name	Family	Economic Quality	Mature height (m)	Mature diameter (m)
Pterocarpus indicus	Fabaceae	Superb; Furniture	40	1.2
Petersianthus quadrialatus	Lecythidaceae	Superb; All purpose	40	1.5
Melia dubia	Meliaceae	Light construction; pioneer	15	0.5
Toona sureni	Meliaceae	Good; house construction	20	0.8
Albizia procera	Mimosaceae	Superb; Furniture	25	0.7
Artocarpus sericicarpus	Moraceae	Superb; All purpose, boats	35	1.0
Myrica javanica	Myricaceae	Good; construction	20	0.8
Eucalyptus deglupta	Myrtaceae	Good; construction, pulp	70	2.4
Tristania decoticata	Myrtaceae	Superb; Heavy construction	25	1.0
Pometia pinnata	Sapindaceae	Superb; All purpose	40	0.8
Trema orientalis	Ulmaceae	Light; good shade; pioneer	35	0.5
Tectona philippinensis	Verbenaceae	Superb; Heavy construction	15	0.5
Vitex parviflora	Verbenaceae	Superb; All purpose	20	1.0
Vitex turczanihowii	Verbenaceae	Good; construction; musical instruments	30	1.0

Table 4. Shade-demanding trees to be planted a year or more after nurse trees have been planted. All are native Philippine species recommended for areas with no pronounced dry season.

Desirable characteristics (not all found in all species shown in this table):

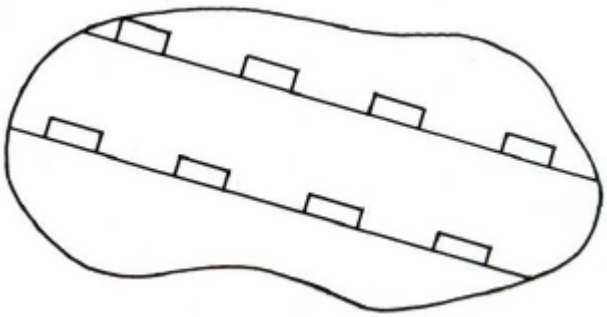
- Adjustable to a wide range of soil and light conditions
- Seeds and seedlings are easy to recognize, so germination and seedling management is easy
- Withstands transplanting to the field
- Resistant to strong winds
- Young shoots have the ability to grow through thickets or canopies of pioneer species

Scientific Name	Family	Economic Quality	Mature height (m)	Mature diameter (m)
Anisoptera thurifera	Dipterocarpaceae	Superb; All Purpose	45	2.0
Dipterocarpus warburgii	Dipterocarpaceae	Superb; All Purpose	50	1.8
Hopea acuminata	Dipterocarpaceae	Superb; Hard construction	35	0.9
Hopea foxworthyi	Dipterocarpaceae	Superb; All Purpose	35	0.6
Hopea philippinensis	Dipterocarpaceae	Good; construction	20	0.5
Hopea malibato	Dipterocarpaceae	Superb; Hard construction	35	0.5
Parashorea malaanonan	Dipterocarpaceae	Superb; All Purpose	60	2.0
Shorea almon	Dipterocarpaceae	Superb; All Purpose	70	1.6
Shorea contorta	Dipterocarpaceae	Superb; All Purpose	50	1.8
Shorea guiso	Dipterocarpaceae	Superb; All Purpose	40	1.8
Shorea malibato	Dipterocarpaceae	Superb; Hard construction	35	0.8

Scientific Name	Family	Economic Quality	Mature height (m)	Mature diameter (m)
Shorea negrosensis	Dipterocarpaceae	Superb; All Purpose	50	2.0
Shorea palosapis	Dipterocarpaceae	Superb; All Purpose	50	1.5
Shorea polysperma	Dipterocarpaceae	Superb; All Purpose	50	2.0
Diospyros philippinensis	Ebenaceae	Good; furniture	20	0.8
Castanopsis philippinensis	Fagaceae	Superb; Furniture	25	0.5
Lithocarpus pruinosa	Fagaceae	Good; construction	30	0.5
Heritiera sylvatica	Sterculiaceae	Superb; Construction, posts	20	0.8
Pterospermum obliquum	Sterculiaceae	Good; construction	25	0.7
Diplodiscus paniculatus	Tiliaceae	Good; light construction	20	0.8

Appendix F. Simple sampling for density and species of natural regeneration.

This simple method of sampling will help make decisions about whether a site has enough natural regeneration for ANR.



Layout of transects and plots

1. During the initial survey of the area, set the boundaries of the proposed ANR area.
2. Set two (2) straight parallel transect lines along the area, not too close to the boundaries or to each other.
3. Allocate four (4) 10m x 25m plots equally spaced along each line.
4. For each sample plot, record the number of seedlings of each species in the tally sheet on the next page.
5. Convert number of seedlings per plot to number of seedlings per hectare by multiplying by 40.
6. Average the results for each plot to get the average number per hectare for all plots.
7. If some adjacent plots do not pass the test for ANR but the average for the whole area passes the test (Section 5.2.2), consider whether the area should be subdivided and ANR used only where there is sufficient natural regeneration.

For good project monitoring and species and fertilizer trials, someone with a good knowledge of statistics should help plan a better sampling technique that takes into consideration (1) control plots, (2) stratification of areas with different characteristics, and (3) number of plots and plot size needed.

Tally sheet for inventory of natural regeneration.

Plot Location:

Province: _____ Municipality: _____ Name of Project/landowner: _____

Plot size: _____ m^2

Multiply number of stems by 10000/(plot size in m^2) to get total per hectare.
For a 10m x 25m plot, multiply by 10000/(10x25) = 40.

Name of Species	Tally Marks or check	Total	Total per ha.
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
TOTAL			

Appendix G. Assisted Natural Regeneration Work Plan.

Tasks, Schedule, and Average Manpower Requirements, One Hectare (Year One)

Activity	Schedule	Labor Requirements	
Year One		Derivation	Person days
1. Brushing/clearing of firebreaks 10 m wide, spaced 40 m apart within the planting block, plus firebreaks on all four sides of the perimeter. Complete grubbing out of grass; removal of cut and grubbed material from the firebreak.	Immediately prior to end of rainy season	2 internal firebreaks x 100 m long x 10 m = 2000 m2/ha Perimeter firebreaks average = 1,200 m2/ha 3,200 m2 / 200 m2/personday	16
2. Ringweeding of all naturally-growing woody-stemmed broadleaf plants (i.e. pioneers), 1 m circular. Grubbing out roots of grass in the circle. Pressing down the grass growing in areas outside the ringweeded area.	Start of rainy season	1,000 pioneers/ha / personday	10
3. Maintenance weeding/pressing down of grass in firebreaks	Once, just before end of rainy season	3,200 m2 /400 m2/personday	8
4. Maintenance ringweeding/pressing down of grass around pioneers	Every 2 months after end of rainy season (3 times)	3 times x 1,000 pioneers / 200 pioneers/personday	15
SUBTOTAL: Year One			**49**

Tasks, Schedule, and Average Manpower Requirements, One Hectare (Years Two & Three)

Activity	Schedule	Labor Requirements	
Year Two		Derivation	Person days
1. Maintenance weeding/pressing down of grass in firebreaks	Twice; one month after onset of rainy season and once just before end of rainy season	2 times x 3,200 m2 / 400 m2/personday	16
2. Maintenance ringweeding/pressing down of grass around pioneers	Every 2 months, starting 1 month after end of rainy season (3 times)	3 times x 1,000 pioneers / 200 pioneers/personday	15
SUBTOTALS: Year Two			**31**
Year Three – same as Year Two			**31**
TOTAL: 3 years			**111**

References

Please see Appendix A for recommended practical references on tree species, agroforestry systems, reforestation, community participation, fire protection, and other topics related to this manual. You may contact ICRAF for assistance in obtaining copies of these publications.

General references

Dugan, P. 1994. ***Natural Forest Regeneration and Community Management: the State of Knowledge in Asia.*** Paper presented at: "Policy Dialogue on Natural Regeneration and Community Management," East-West Center, Honolulu, Hawaii, USA, March 2-4, 1994.

Garrity, D. (ed). 1997. ***Agroforestry Innovations for Imperata Grassland Rehabilitation.*** Kluwer Academic Publisher, Boston, London. 284 p.

Menz, K., Magcale-Macandog, D., Rusastra I.W. (ed). 1998. ***Improving Smallholder Farming Systems in* Imperata *Areas of Southeast Asia: Alternatives to Shifting Cultivation.*** ACIAR Monograph No. 52. Brown Prior Anderson, Melbourne. 280 p

van Noordwijk, M. 1994. ***Agroforestry as Reclamation Pathway for* Imperata *Grassland Use by Smallholders.*** Pp. 2-10 in: Proceedings of Panel Discussion on Management of *Imperata* Control and Transfer of Technology for Smallholder Rubber Farming Systems; Baku Penelitian Sembawa, Pusat Penelitian Karet Indonesia.

van Noordwijk, M., K. Hairiah; S. Partoharjono; R. Labios, D. Garrity. 1997. ***Food-crop-based production systems as sustainable alternatives for* Imperata *grasslands?*** Agroforestry 36:55-82.

Temmes, M. 1992. ***Reforestation Operations Manual for Alang-alang grasslands.*** Enso Forest Development OY LTD and FINNIDA in cooperation with the Ministry of Forestry, Indonesia. Banjarbaru, South Kalimantan, Indonesia.

Turvey, N. 1994. ***Afforestation and rehabilitation of Imperata grasslands in Southeast Asia: Identification of priorities for research, education, training and extension.*** Australian Centre for International Agricultural Research (ACIAR) Technical Reports No. 28. Pirie Printers, Canberra, Australia.

Chapter 1: Imperata and people

Potter, L. 1997. ***The dynamics of* Imperata*: historical overview and current farmer perspectives, with special reference to South Kalimantan, Indonesia.*** Agroforestry Systems 36:31-51.

Tomich, T., J. Kuusipalo, K. Menz, and N. Byron. 1997. ***Imperata economics and policy.*** Agroforestry Systems 36:233-261.

Chapter 2: Imperata grassland ecology

Garrity, D., M. Soekardi; M. van Noordwijk; R. de la Cruz; P. Pathak; H. Gunasena, N. van So, G. Huijun and N. Majid. 1997. ***The Imperata grasslands of tropical Asia: area, distribution and typology.*** Agroforestry Systems 36:3-29.

Chapter 3: Protection from Fire

Dimayuga, M. and M. Malabanan. 1990. ***How to prevent forest fires.*** Pp. 211-221 in: Research Information Series on Ecosystems. Ecosystems Research and Development Bureau, Department of Environment and Natural Resources. College, Laguna, Philippines.

Drilling, M. Elmo. 1995. ***Grass Pressing: An Effective Technique to Inhibit Grass Growth in Small-scale Grassland Rehabilitation Projects.*** Paper presented at the International Workshop on Agroforestry Innovations to Rehabilitate Imperata Grasslands. Banjarmasin, South Kalimantan, Indonesia. 23-27 January 1995. 8 pp.

Mobley, H.; J. Moore; R. Ashley; K. Burton; and H. Peeples. 1979. ***Planning for Initial Attack.*** United States Department of Agriculture, Forest Service, Southeastern Area. Forestry Report SA-FR 2. Atlanta, Georgia, USA.[7]

[7] Including drawings used as the basis for illustrations in Section 3.4

RIBAU. 1987. ***Forest Fire Control System Guidance for the Timber Estate Unit.*** Resource Institute Bogor Agricultural University, IPB. Bogor.

Terry, P., G. Adjers, I. Akobundu, A. Anoka, M. Drilling, S. Tjitrosemito, and M. Utomo. 1997. ***Herbicides and mechanical control of* Imperata cylindrica *as a first step in grassland rehabilitation.*** Agroforestry Systems 36:151-179.

Wibowo, A., M. Suharti; A. Sagala; H. Hibani; and M. van Noordwijk. 1997. ***Fire management on* Imperata *grasslands as part of agroforestry development in Indonesia.*** Agroforestry Systems 36:203-217.

Chapter 4: Agroforestry

Cairns, M. (Unpublished). ***Profile of Alnus nepalensis-Based Swidden System: A Working Paper.*** International Centre for Research in Agroforestry, Bogor, Indonesia.

Cairns, M. 1997. ***Management of Austroeupatorium inufolium- Based Fallows by Minangkabau Farmers in Sumatra, Indonesia.*** Poster presented at: Indigenous Strategies for Intensification of Shifting Agriculture in Southeast Asia, 23-27 June 1997, Bogor, Indonesia.

Calub, A., H. Anwarhan, and W. Roder. 1995. ***Livestock in agroforestry systems.*** Paper presented at: International Workshop on Agroforestry Innovations to Rehabilitate *Imperata* Grasslands. Banjarmasin, South Kalimantan, Indonesia. 23-27 January 1995.

Fairhurst, T. 1996. ***The rehabilitation of critical land in W. Sumatra.*** Pp 629-632 in: Proc. 24th Colloquium of the International Potash Institute held at Chiang Mai, Thailand 1995. Basel, Switzerland.

de Foresta, H. and G. Michon. 1997. ***The agroforest alternative to* Imperata *grasslands: when smallholder agriculture and forestry reach sustainability.*** Agroforestry Systems 36:105-120.

Forestry/Fuelwood Research and Development Project. 1994. ***Growing multipurpose trees on small farms*** (2nd ed.). Winrock International. Bangkok, Thailand.

Garrity, D. (Unpublished). ***Conservation Tillage: a Southeast Asian Perspective.*** International Centre for Research in Agroforestry.

Garrity, D.; S. Suharti; Satyabudi P; R. Winahyu. (Unpublished). ***The Case of Tiwingan Baru: A Village Creates an Agroforest on a Critical Watershed.*** International Centre for Research in Agroforestry.

Garrity, D. 1996. ***Tree-Soil-Crop Interactions on Slopes.*** Pp. 299-318 in: Tree-Crop Interactions, eds. C.K. Ong and P. Huxley. CAB International.

ICRAF. 1996. ***Labor-minimizing techniques for establishment and maintenance of contour hedgerows: the cow's back method.*** Pp. 24-26 in Annual Report 1996, Project 4.6. International Centre for Research in Agroforestry, Bogor, Indonesia.

IIRR. 1990. ***Agroforestry Technology Information Kit*** [1st ed.]. International Institute of Rural Reconstruction, Cavite, Philippines.

IIRR. 1992. ***Agroforestry Technology Information Kit*** [2nd ed.]. International Institute of Rural Reconstruction, Cavite, Philippines.

IRRI and NRI. 1996. ***Imperata Management for Smallholders.*** Indonesian Rubber Research Institute, Natural Resources Institute (United Kingdom). Indonesia.

Lasco, R. 1997. ***The Naalad Improved Fallow System and its Implications to Global Warming.*** Poster presented at: Indigenous Strategies for Intensification of Shifting Agriculture in Southeast Asia, 23-27 June 1997, Bogor, Indonesia.

MacDicken, K. 1991. ***Impacts of Leucaena leucocephala as a fallow improvement crop in shifting cultivation on the Island of Mindoro, Philippines.*** Forest Ecology and Management, 45 (1991) 185-192.

MacDicken, K.; K. Hairiah; A. Otsamo; B. Duguma; N. Majid. 1995. ***Shade-based control of*** **Imperata cylindrica*****: Tree fallows and cover crops.*** Agroforestry Systems 36:131-149.

Margraf, J. and P. Milan. 1995. ***Ecology of Dipterocarp Forests of Leyte, Philippines.*** In: Schlte, A. (Ed.). 1995. ***Ecology of Dipterocarp Forests.*** Indonesian-German Forestry Project, Mulawarman University, Samarinda, East Kalimantan, Indonesia.

Menz, K. and P. Grist. 1997. ***Economic Opportunities for Smallholders to Combine Pulpwood Trees and Food Crops.*** Agroforestry Systems 36:221-232.

Mercado, A., D. Garrity, N. Sanchez, and L. Laput. 1997. ***Effect of Natural Vegetative Filter Strips Density on Crop Production and Soil Loss.*** Paper presented at the 1997 Federation of Crop Science Societies of the Philippines Annual Scientific Convention. Baguio City, Philippines.

Nguyen Tuan Hao, Ha Van Huy, Huynh Duc Nhan, and Nguyen Thi Thanh Thuy. 1997. ***Soil Improvement and Conservation Using Nho Nhe Bean (Phaseolus carcaratus Roxb.) in Upland Areas of Northern Vietnam: Initial Results from a Case Study.*** Paper presented at: Indigenous Strategies for Intensification of Shifting Agriculture in Southeast Asia, 23-27 June 1997, Bogor, Indonesia.

Roder, W.; S. Maniphone; B. Keoboulapha; and K. Farney. 1997. ***Fallow Improvement in Upland Rice Systems with Chromolaena odorata.*** Poster presented at: Indigenous Strategies for Intensification of Shifting Agriculture in Southeast Asia, 23-27 June 1997, Bogor, Indonesia.

Sangalang, J. 1995. ***Tree Crop-Based Systems to rehabilitate* Imperata *grasslands.*** Paper presented at: International Workshop on Agroforestry Innovations to Rehabilitate *Imperata* Grasslands, Banjarmasin, South Kalimantan, Indonesia, 23-27 January 1995.

Sangalang, J.; Cia, B.; Bandian, M.; and Pacia, R. 1994. ***Development of Sustainable Agriculture Technologies for Marginal Acidic Uplands of the Philippines.*** Paper presented at: International Seminar on Experiences in Sustainable Agriculture in Southeast Asia. Khon Kaen, Thailand. November 9-12, 1994.

Santoso, D.; S. Adiningsih; E. Mutert; T. Fairhurst; and M. van Noordwijk. 1995. ***Soil fertility management for reclamation of* Imperata *grasslands by smallholder agroforestry.*** Agroforestry Systems 36:181-202.

Sri Adiningsih, J. and Mulyadi. 1993. ***Alternative technology for rehabilitation and utilization of alang-alang land.*** Pp. 29-49 in: Syarifuddin Karama et al. (Eds*) Prosiding Seminar Lahan Alang-alang*. Pusat Penelitian Tanah dan Agroklimat, Bogor, Indonesia.

Suson, P. and D. Garrity. 1997. ***Pruned-tree Hedgerow Fallow Systems.*** Poster presented at: Indigenous Strategies for Intensification of Shifting Agriculture in Southeast Asia, 23-27 June 1997, Bogor, Indonesia.

Terry, P.; G. Adjers; I.O. Akobundo; A. Anoka; M. Drilling; S. Tjitrosemito and M. Utomo. 1997. ***Herbicides and mechanical control of* Imperata cylindrica *as a first step in grassland rehabilitation*.** Agroforestry Systems 36:151-179.

Tung, L. and D. Alcober. 1991. ***Natural Grass Strips are Preferred*.** ILEIA Newsletter, May 1991. Philippines.

Chapter 5: Assisted Natural Regeneration

Anon. 1996. ***A Philippine Response*.** In AFNews Vol. II No. 4 August 1996, Regional Secretariat for Asian Forest Network, Manila.

Dalmacio, R. (undated). ***Assisted Natural Regeneration and Accelerated Pioneer-Climax Series Strategies: Emerging Ecological Approaches to Forestation*.**

Drilling, M. 1989. ***Research priorities for reforestation in Indonesia with an emphasis on Accelerated Natural Regeneration*.** U. S. Agency for International Development. Jakarta.

Durno, J. 1996. *From* **"Imperata *Grass Forest" to community forest: The case of Pakhasukjai*.** Forest, Trees and People Newsletter No. 31(4-13).

Durno, J.; T. Deetes; and J. Rajchaprasit. 1997. ***Natural Forest Regeneration from an* Imperata *fallow: the Case of Pakhasukjai*.** Poster presented at Indigenous Strategies for Intensification of Shifting Agriculture in Southeast Asia, 23-27 June 1997, Bogor, Indonesia.

Factoran, F. 1989. ***Prioritizing Application of Assisted Natural Regeneration Method in the Development of Watershed Protection and Production forests*.** Memorandum Circular No. 17, Series of 1989. Manila, Philippines.

Intergovernmental Panel on Forests. 1996. ***Considerations for Community Participation in Forest Management*.** In AFNews Vol. II No. 4 August 1996, Regional Secretariat for Asian Forest Network, Manila, Philippines.

Jensen, C., and S. Pfeifer. 1989. ***Assisted Natural Regeneration: A New Reforestation Approach for DENR?*** An Appraisal Prepared for the Department of Environment and Natural Resources, Government of the Philippines. United States Agency for International Development, Manila. 23 pp.

Kuusipalo, J.; G. Ådjers; Y. Jafarsidik; A. Otsamo; K. Tuomela; R. Vuokko. 1995. ***Restoration of Natural Vegetation in Degraded*** **Imperata** ***Cylindrica Grassland: Understory Development in Forest Plantations.*** Journal of Vegetation Science 6:205-210.

Lansigan, F. (undated). ***Statistical Considerations for Data Acquisition in Assisted Natural Regeneration.*** Pp. 32-38 in: DENR (undated). Part I, Theoretical basis for ANR. Department of Environment and Natural Resources. Quezon City, Philippines.

Margraf, J. and P. Milan. 1995**.** ***Ecology of Dipterocarp Forests of Leyte, Philippines.*** In: Schlte, A. (Ed.). 1995. ***Ecology of Dipterocarp Forests.*** Indonesian-German Forestry Project, Mulawarman University, Samarinda, East Kalimantan, Indonesia.[7]

Parrotta, J. 1993. ***Secondary Forest Regeneration on Degraded Tropical Lands: The Role of Plantations as "Foster Ecosystems."*** Pp. 63-73 In: ***Restoration of Tropical Forest Ecosystems.*** Eds. H. Lieth and M. Lohmann. Kluwer Academic Publishers, Netherlands.

Pasicolan, P. (Unpublished). ***An Analysis of the Bioecological Interaction between Grazing Animals and*** **Samanea saman** ***Trees in Degraded Grassland Areas: A Variant of Assisted Natural Regeneration.*** Isabela State University, Isabela, Philippines.

PCARRD. 1982. ***The Philippines recommends for reforestation.*** Philippine Council for Agriculture and Resources Research. Los Baños, Laguna, Philippines.

Sajise, P. (undated). ***Assisted Natural Regeneration Guidelines.*** Pp. 25-28 in: DENR (undated). Part I, Theoretical basis for ANR. Department of Environment and Natural Resources. Quezon City, Philippines.

[7] Including drawings used as the basis for illustrations in Section 5.2.4

Soedjito, H., and P. Dugan. 1992. ***Natural Resources Management Project (NRMP): an Environmental Assessment of Forestry, Agriculture and Research Activities.*** Government of Indonesia - U.S. Agency for International Development, Jakarta, Indonesia.

Appendix B: Characteristics of contour hedgerow and rotational alleycropping species

Forestry/Fuelwood Research and Development Project. 1994**.** ***Growing multipurpose trees on small farms*** (2nd ed.). Winrock International. Bangkok, Thailand. 320 pp.

IIRR. 1990. ***Agroforestry Technology Information Kit*** [1st ed.]. International Institute of Rural Reconstruction, Cavite, Philippines.

IIRR. 1992. ***Agroforestry Technology Information Kit*** [2nd ed.]. International Institute of Rural Reconstruction, Cavite, Philippines.

Appendix C: Characteristics of leguminous cover crop species

del Castillo, R., R. Dalmacio, R. Lasco, and N. Lawas, eds. 1994. ***Agroforestry Production and Post Production Systems: a Training Manual.*** University of the Philippines Agroforestry Program, Laguna, Philippines, and Kapwa Upliftment Foundation Inc., Davao City, Philippines.

Horne, P. 1997. ***Farmer-developed forage management strategies for stabilisation of shifting cultivation systems.*** Paper presented at: Indigenous Strategies for Intensification of Shifting Agriculture in Southeast Asia, 23-27 June 1997, Bogor, Indonesia.

IIRR. 1992. ***Agroforestry Technology Information Kit*** [2nd ed.]. International Institute of Rural Reconstruction, Cavite, Philippines.

IRRI and NRI. 1996. ***Imperata Management for Smallholders.*** Indonesian Rubber Research Institute, Natural Resources Institute (United Kingdom). Indonesia.

MacDicken, K.; K. Hairiah; A. Otsamo; B. Duguma; N. Majid. 1995. ***Shade-based control of* Imperata cylindrica*: Tree fallows and cover crops*.** Agroforestry Systems 36:131-149.

PROSEA. 1992. ***Plant Resources of Southeast Asia. Vol. 4: Forages***. Plant Resources of South-East Asia Network Office. Bogor, Indonesia.

USDA Soil Conservation Service. 1994. ***'Tropic Sun'*** sunn hemp. Program Aid Number 1555. USA.

Yost, R. and D. Evans. 1988. ***Green Manure and Legume Covers in the Tropics.*** Research Series 055. College of Tropical Agriculture and Human Resources, University of Hawaii, Honolulu, Hawaii, USA.

Appendix D:
Site preferences of perennial fruit, nut, and resin agroforestry species

Del Castillo, R., R. Dalmacio, R. Lasco, and N. Lawas, eds. 1994. ***Agroforestry Production and Post Production Systems: a Training Manual*.** University of the Philippines Agroforestry Program, Laguna, Philippines, and Kapwa Upliftment Foundation Inc., Davao City, Philippines.

Coronel, R. 1983. ***Promising Fruits of the Philippines*.** College of Agriculture, University of the Philippines at Los Banos.

Dali, J. and A. Gintings. 1993. ***Cara penanaman kemiri*.** Informasi teknis No. 38. Pusat Penelihan da Pengembangan Hutan. Bogor, Indonesia.

Forestry/Fuelwood Research and Development Project. 1994. ***Growing multipurpose trees on small farms*** (2nd ed.). Winrock International. Bangkok, Thailand.

Hensleigh, T. and B. Holaway, eds. 1988. ***Agroforestry Species for the Philippines*.** US Peace Corps, Washington, DC, USA.

IIRR. 1992. ***Agroforestry Technology Information Kit*** [2nd ed.]. International Institute of Rural Reconstruction, Cavite, Philippines.

PCARRD. 1992. ***The Philippines Recommends for Reforestation.*** Philippines Council for Agriculture and Resources Research. Laguna, Philippines.

Rosihan, R. and P. Wahid. 1990. ***Potensi dan sifat-sifat sumber daya iklim di sekitar Danau Singkarak untuk Pengembangan Tanaman Industri dan Perkebunan.*** Prosiding Singkarak untuk Pengembangan Tanaman Industri dan Perkebunan. Prosiding Kamunikasi Ilmiah Pengembangan Tanaman Industri dan Perkebunan pada Lahan Kristis Sekitar Danau singkarak - Sumatera Barat, Solok, 5-6 Sept. 1990.

Appendix E:
Plantation tree species suitable for Imperata suppression

Florece, L.; and J. Duma. (undated). ***Ecological Requirements of Forest Tree Species for ANR.*** In: DENR (undated). Part I, Theoretical basis for ANR. Department of Environment and Natural Resources. Quezon City, Philippines.

MacDicken, K.; K. Hairiah; A. Otsamo; B. Duguma; N. Majid. 1995. ***Shade-based control of*** **Imperata cylindrica*: Tree fallows and cover crops*.** Agroforestry Systems 36:131-149.

Margraf, J. and P. Milan. 1995. ***Ecology of Dipterocarp Forests of Leyte, Philippines.*** 21 pp. In: Schlte, A. (Ed.). 1995. ***Ecology of Dipterocarp Forests.*** Indonesian-German Forestry Project, Mulawarman University, Samarinda, East Kalimantan, Indonesia.

Oldeman, L. 1975. ***An agroclimate map of Java and Madura.*** Contributions of the Central Research Institute for Agriculture. Bogor, Indonesia 17:1-22.

Purdoc. 1982. ***Indonesian Forestry Abstracts*: *Dutch literature until about 1960*.** Centre for Agricultural Publishing and Documentation. Wageningen, Netherlands.

Temmes, M. 1992. ***Reforestation Operations Manual for Alang-alang grasslands.*** Enso Forest Development OY LTD and FINNIDA in cooperation with the Ministry of Forestry, Indonesia. Banjarbaru, South Kalimantan, Indonesia.

van So, N. 1995. **Imperata *grasslands in Vietnam: Typology and control.*** Paper presented at: International Workshop on Agroforestry Innovations to Rehabilitate Imperata Grasslands. Banjarmasin, South Kalimantan, Indonesia. 23-27 January 1995.

Appendix F:
Simple sampling for density and species of natural regeneration.

Lansigan, F. (Undated). Exercise No. 2B: ***Sampling for Regenerant Density Measurement and Layout.*** P. 15 in: DENR (undated) Part II, Field Exercises for ANR. Department of Environment and Natural Resources. Quezon City, Philippines.

Appendix G: Assisted Natural Regeneration labor requirements

Dalmacio, M. (undated) ***Assisted Natural Regeneration: A Strategy for Cheap, Fast, and Effective Regeneration of Denuded Forest Lands.***