TREE SPECIES INVASIONS AND SUSTAINABLE FORESTRY IN THE EAST USAMBARAS

by Pierre Binggeli and Alan C. Hamilton

Abstract

After the introduction of non-native tree species in the Amani Botanical Gardens and in forestry, several species are now invading the natural and logged forests. The most noticeable example is the rapid spread of *Maesopsis eminii* in the submontane forest after being extensively planted in the 1960's and 1970's. Invasion of tree species into tropical forest is a most unusual phenomenon, not reported from other parts of the world.

Maesopsis becomes established in treefall gaps and its success is related to prolific seed production and widespread dispersal by hornbills, and also very fast growth rates. It is estimated that within 200 years *Maesopsis* could form up to 50 % of the canopy even in unlogged forest. We have found a number of differences in ecosystem composition and structure under *Maesopsis* forest compared to natural forest including 1) a much more open canopy, 2) impoverished understorey vegetation containing many introduced species, 3) little regeneration of primary forest tree species, 4) thin and wood-rich litter, 5) increased exposure of soil with more runoff of water on the surface during rains, 6) greatly decreased amount of organic matter in the topsoil, which is also less acidic, and 7) paucity of the chubby mycorrhizal rootlets characteristic of primary forest.

It is concluded that *Maesopsis* is a threat to the survival of some of the indigenous tree species and that it degrades catchment quality. Steps should be taken to eliminate or at least reduce the species in nature reserves, important catchment areas and in forests intended for exploitation. It is suggested that *Maesopsis* in the Kwamkoro plantations should be felled and should be replaced by native hardwood species, and a tentative silvicultural programme is put forward. We suggest that the logged forests and the rehabilitated *Maesopsis* plantations should be exploited on a sustainable basis. The silvicultural system to be implemented should simulate as much as possible natural forest dynamics. Methods of implementing environmentally sound silviculture are discussed, including felling techniques, use of machinery, and tending measures. Areas for further research are outlined.

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INTRODUCTION

Over the centuries man has had an impact on forest ecosystems on the East Usambaras, but until the last century his influence was rather limited in scope and intensity. However, over the past century human influence has dramatically increased to become very destructive. Some of man's activities have been damaging to the forests, but nevertheless have allowed the maintenance of forest cover, even though the resulting communities have been very different from their pristine states. Such activities include, in increasing order of disturbance: pole-cutting, pit-sawing and mechanized logging. Other human activities have been more destructive, leading to a complete disappearance of forest cover; these include clearance of land for farming, tea and coffee plantations and sisal estates, and clear-felling forestry. Another aspect of human impact on the forests of the East Usambaras has been the introduction of exotic tree species both for botanical and forestry purposes. At the time of their introduction, the potential threat of these to the native vegetation was not considered.

A CASE STUDY: Maesopsis eminii

After the introduction of non-native tree species to the Amani Botanical Gardens and in forestry, several species are now invading the natural and logged forests; they include *Albizia chinensis*, *Melia azedarach* and *Milletia dura*. The most noticeable example is the rapid spread of *Maesopsis eminii* in submontane forest, particularly after being extensively planted in the 1960's and 1970's in Kwamkoro Forest Reserve. *Maesopsis* is a species native to central and western Africa, and is a particularly important timber tree in Uganda. It was introduced to the East Usambaras in 1913 near the Amani

research station and during the 1960's about 400 ha were planted for forestry purposes. Because the East Usambaras forests contain a large number of endemic or near-endemic species and are therefore of great biological and conservation interest, the *Maesopsis* invasion and its potential threat to the local flora has been seen in recent years, along with extensive logging operations, as a major cause for concern. Inventory data from a recent Forest Department/FINNIDA survey show that *Maesopsis* occurs throughout the southern part of the upland plateau. Highest densities are to be found in and near the plantations at Amani and Kwamkoro, but large trees and numerous seedlings occur throughout the forest.

To understand the invasion pattern of a tree species various stages of its life cycle must be investigated (Fig. 1). On the East Usambaras *Maesopsis* flowers readily at an early age and all individuals produce a prolific seed crop during July-August. The stoned fleshy fruits are readily eaten and dispersed by hornbills. Seedling establishment is favoured by a double strategy. Firstly, seeds can germinate over a long period of time (up to 200 days), germination being triggered by water availability, not light. Secondly, we have found that seedlings (<1 year old) can survive in a suppressed state for several months. Because *Maesopsis* needs plenty of light to grow, it means that whenever light intensity is suddenly increased on the forest floor, it can start to grow rapidly either from the suppressed seedlings or seeds.

Forest dynamics

In order to understand the pattern of invasion of any species a clear understanding of forest dynamics is essential. All species, including trees, smaller plants and animals, show cycles of birth, growth, maturity and death. In tropical forests, these cycles are often closely related to disturbance initiated by treefalls. Treefalls create gaps, which are exploited by plant and animal species in different ways, eventually resulting in a reforming of the canopy. Tropical forests consist of a mosaic of gap, building and mature phases.

How Maesopsis invades the forests

In the natural forest *Maesopsis* becomes established in treefall gaps and its success is a consequence of prolific seed production, widespread dispersal of seeds by hornbills, absence of diseases (apart from the fungus *Meliola maesopsidis* which infests seedlings), and very fast growth rates. Only in larger gaps is there enough light for *Maesopsis* to grow. We have found that *Maesopsis* grows on bare humus soil along the logs of large treefalls. We found that 15 % of gaps in the southern submontane forest older than 15 years contained *Maesopsis*, but that 50 % of more recent gaps contained the species, indicating a rapid increase in the speed of the invasion. We estimate that within 200 years *Maesopsis* could form up to 50 % of the natural forest canopy. In recently logged forest at Kwamkoro *Maesopsis*, along with *Trema orientalis* on exposed subsoil, are the only two species regenerating freely.

Impact of Maesopsis on natural and logged forests

As compared to the natural forest some of the more obvious impacts of *Maesopsis* on the forest ecosystem composition and structure have been documented at Kwamkoro and Amani. They include:

1) a much more open canopy; few sub-canopy trees
2) floristically impoverished understorey vegetation of shrubs and herbs containing many introduced species (e.g. *Clidemia hirta, Lantana camara, Rubus rosifolius*)
3) little regeneration of primary forest trees
4) thin and wood-rich litter; (*Maesopsis* leaves decompose rapidly)
5) increased exposure of soil with more runoff of water on the surface during rain; increased soil erosion
6) greatly decreased amount of organic matter in the topsoil, which is also less acidic
7) paucity of the chubby mycorrhizal rootlets characteristic of primary forest

8) poor animal and plant diversity, including that of the soil fauna.

Most of these effects are considered environmentally deleterious. For instance, the absence of an organic-rich topsoil below *Maesopsis* canopy inhibits the regeneration of primary forest trees. With the increasing spread of *Maesopsis* in the natural forest, such a regeneration failure of primary forest trees is likely to drive some rare species towards extinction. *Maesopsis* plantations, with a thin litter, few binding rootlets near the soil surface and a single canopy, suffer from increased soil erosion.

The pattern of biological invasion observed on the East Usambaras is exceptional for a tropical forest; so far as we know, invasions of tropical forests by trees are unknown elsewhere in the world. Tropical forests are believed to be resistant to biological invasions because of their richness in species. It is noted that, in general, biological invasions are thought to be often aided by human disturbance but, in the case of the East Usambaras, *Maesopsis* invasion is occurring even where there is no such activity.

The forests of the East Usambaras and also those of the other mountains of the East African Arc may be considered as ecological islands which have been isolated from each other and the central African forests for millions of years. We believe that, like oceanic islands, their long isolation and small size have made them very susceptible to species invasions.

Proposal to eradicate Maesopsis and other invasive species

It is concluded that *Maesopsis* is a threat to the survival of rare tree species. In order to prevent genetic erosion, to preserve the biological diversity of these mountains and their catchment quality, it is suggested that an eradication programme of *Maesopsis* should be undertaken. It is proposed that the *Maesopsis* plantations at Kwamkoro should be felled and replaced by native hardwoods. In the natural forest *Maesopsis* should be controlled by ring-barking larger trees and cutting smaller ones. It might be possible to use biological control through the introduction of pests currently absent. This will have to be done carefully, using only pests specific to *Maesopsis*. Pests affecting fruit production and seed survival are potentially the most specific and promising. For eradication to be successful, it is important to control *Maesopsis* in both the plantations and the natural forest. Moody and Mack (1988) have shown that the control of large and otherwise conspicuous infestations of alien plants may be ineffective without attention being given to isolated populations. Similar eradication programmes of other invasive tree species in both lowland and submontane forests will have to be carried out.

SUSTAINED-YIELD AND ENVIRONMENTALLY SOUND SILVICULTURE IN KWAMKORO PLANTATIONS AND LOGGED FORESTS

Need for sustainable forestry in the East Usambaras

The new management plan calls for zonation of the forest for different purposes, including genetic conservation, catchment protection and production forestry. It is essential that production forests are managed in an environmentally sound way, to maintain or upgrade the catchment and conservation values of such forests.

The special responsibility of foresters to preserve forests and not just exploit them for short-term economic interest was acknowledged by most tropical hardwood exporting countries in the Tropical Timber Agreement adopted in 1984. One article of the agreement lists as a main objective "to encourage the development of national policies aimed at sustainable utilization and conservation of tropical forests and their genetic resources and at maintaining the ecological balance in the regions concerned" (Cross 1988).

Cropping of tropical rain forest on a sustainable basis has been attempted in several parts of the world, in Africa notably in Uganda. The intensity of logging has varied from light single tree selection to removal of most of the overstorey. Yet, worldwide, such interest in sustainable harvesting of tropical forests has been minimal, as foresters have simply been interested in harvesting trees without any

considerations for future uses and returns. Also, because expected yields are lower than those of plantations, selectively logged forests originally intended for sustained production have been abandoned in numerous countries, although their maintenance and environmental costs are lower.

A long-standing controversial aspect of sustainable forestry has been its economics. Decisions have often been based primarily on short-term economic considerations, and other possible aspects have been brushed aside as irrelevant. Putz (1987) has stressed the fact that many of the economic criticisms of sustained-yield management seem poorly founded and biased and that the economic value of tropical forest cannot reasonably be assessed with economic models designed for industrial application.

For silviculture to have an enhancing value in catchment forestry, maintenance of local microclimate and conservation of biological diversity, it has to be respectful of the environment. Furthermore, harvesting of selectively logged forests must not exceed the rate at which the forest replenishes itself. With this in mind, we suggest the following silvicultural scheme for the submontane forests set aside for exploitation. The objective is to create mixed semi-natural forests composed of local species instead of *Maesopsis* plantations and then exploit them and the logged forests on a sustainable basis.

Felling of Maesopsis plantations and their rehabilitation into hardwood forests

By felling the *Maesopsis* plantations we aim at the reconstruction of a semi-natural forest, where only native species will be used. The cornerstone strategy in tropical forest rehabilitation is the use of natural processes and natural subsidies (such as wind and animals for plant dispersal) rather than human inputs (such as planting and application of fertilizer) (Lugo 1988). Although full use of the process of succession must be made, it may be speeded up by planting primary forest species to obtain harvestable hardwoods sooner. However, some tree species with no economic value must be allowed to grow. Such species are needed because they help to provide the right environment, in terms of light availability, soil moisture and air humidity and temperature, required for successful growth of desired species. Apart from the role as nursing trees, their presence will increase species diversity, which may be important in decreasing potential epidemics.

Lugo (1988) has given a list of guidelines for rehabilitating tropical forests, which includes flexibility in the rehabilitation approach. The most adequate methods for rehabilitating the *Maesopsis* plantations will emerge from field trials, but a tentative rehabilitation plan may be suggested. Bands 10 to 20 m wide and 50 to 100 m apart should be felled along the slope contours taking care to leave some of the understorey shrubs. After log removal planting of several different hardwood species should be undertaken. Some slashing to control weeds may be needed during the first few years after planting. Whenever these bands have become well established the same treatment should be repeated at intervals to the remaining *Maesopsis* strips.

Maesopsis cut in forests designated for exploitation should be sold. Until recently this species has not been on the list of desirables for the local timber industry, but recent trials have raised interest and it is hoped that this can be further encouraged.

Sustainable forestry of logged forests and rehabilitated Maesopsis plantations

For logged forests and reclaimed *Maesopsis* plantations of the East Usambaras, forestry should aim at sustained-yield tropical silviculture. In the East Usambaras, for environmental reasons, timber harvesting should be through the removal of single trees rather than extensive felling. The aim of such a system is to create small artificial gaps in the forest canopy. Later, on a regular basis, gaps should be tended to promote the regeneration and/or growth of species desired by foresters (Fig. 2).

Some details of the system

Roads and machinery

In recent years the massive building of roads and the use of heavy forestry machinery in the East Usambaras has resulted in severe soil erosion. To minimize erosion no new roads should be built, those on steep gradients should be reafforested and all vehicles should remain on existing tracks. If

mechanical extraction is regarded as unavoidable logs should be winched to the tracks from the surrounding forest.

Tree felling

The production of large gaps, which favour short-lived light-demanding species and weeds, should be avoided. When several trees are to be felled in the same area they should all be cut in such a way that their crowns fall in the same place. Pitsawing (preferably by local pitsawyers) is preferable to mechanical harvesting, leading to increase employment, lower fuel costs, and reduced ground disturbance. To enhance the economic value of the operations, harvested undesirable trees and large branches of logged timber trees should be sold as firewood. It is suggested that felling and extraction be limited to a few compartments at any one time to facilitate control.

Species to be felled

All non-native species, a certain proportion of the undesirable canopy and understorey species, and some of the mature hardwoods should be harvested. However, some of the non-commercial trees should be conserved both to provide some shelter to young shade-tolerant saplings and to maintain some diversity.

Gap formation

Gap size should be kept small to reduce the number of light-demanding species and favour the regeneration of hardwoods. Openings should be avoided during a period before the start of the heavy rains to reduce the risk of high soil erosion. In any particular area gap formation should be achieved on a regular basis, so as to avoid excessive damage to the canopy environment and resultant crown dieback and related decrease or absence of seed production. If too few saplings become established, planting will be necessary. In the first few years of gap formation regular slashing of weeds and climbers should be undertaken.

Canopy cover

Different types of forest management will affect the transformation of rainfall energy by the canopy and as a consequence the amount of soil erosion. Brandt (1988) found that during heavy storms single canopy forests (i.e. *Maesopsis* stands) increased rain drop size and that splash impact under single canopy forests was up to 6 times greater than in the open, whereas it was reduced to a minimum of 0.4 times under multiple canopies. Such increases in splash impact below single canopies will raise the rate of soil erosion, a serious matter in the East Usambaras, where the slopes are steep. Under any silvicultural system special attention should be given to reduce splash by maintaining multi-canopies stands, but more particularly allowing a large litter layer, luxuriant ground and shrubby vegetation which ultimately control soil erosion.

Research

Sustainable forestry is desirable, but much empirical experimentation and fundamental research is needed to place management techniques on a firm basis. Aspects of forest ecology needing investigation include:

1) Tree species autecology. Our knowledge of the autecology of primary forest species growing in the East Usambaras is very scanty. Studies investigating various stages of the life cycle (Fig. 1) similar to that of *Maesopsis* reported by Binggeli (1990) should be undertaken for all species which are to be harvested. They should include information on the life-span and growth rates of trees under natural conditions and the other features of a tree life cycle illustrated in Fig. 1.

2) Gap dynamics. Studies on the natural regrowth in forest gaps should be carried out, and should include: timing of gap formation linked to the timing of fruit maturity and optimal gap size and

their impact on regeneration and growth. There are indications that once a tree exceeds a certain size or age, apparently early in its life, it loses its capacity to respond to an improvement in growing conditions (Ashton 1981). The implications for silviculture is that canopy opening must occur at the right time and produce the right amount of light.

3) Nutrient cycling. It is well known that in tropical forests most of the nutrients are locked up in the living trees, but we have no indications as to what happens when a large number of trees, therefore of nutrients, are removed from the system. In the proposed silvicultural method, parts of trees will be regularly removed; will this eventually result in severe nutrient losses and much lower growth rates?

It is important to underline that all the different biological, environmental and human factors operating in a natural forest are interdependent, and consequently the areas selected as most important for research must not be tackled in isolation.

The human factor

The success of a silvicultural system depends also on good management and administration, which means that workers must carry out treatments when and exactly how they are prescribed (Neil 1981). Proper training is required. The training of forest workers should include species identification of saplings (for which a forest tree guide should be produced), and good understanding of the causes of soil erosion and methods by which it may be prevented. Also, some emphasis should be placed on making forest workers aware that tropical rain forests are fragile environments which may be kept in an healthy state only if disturbance during felling and subsequent timber removal is kept to a minimum.

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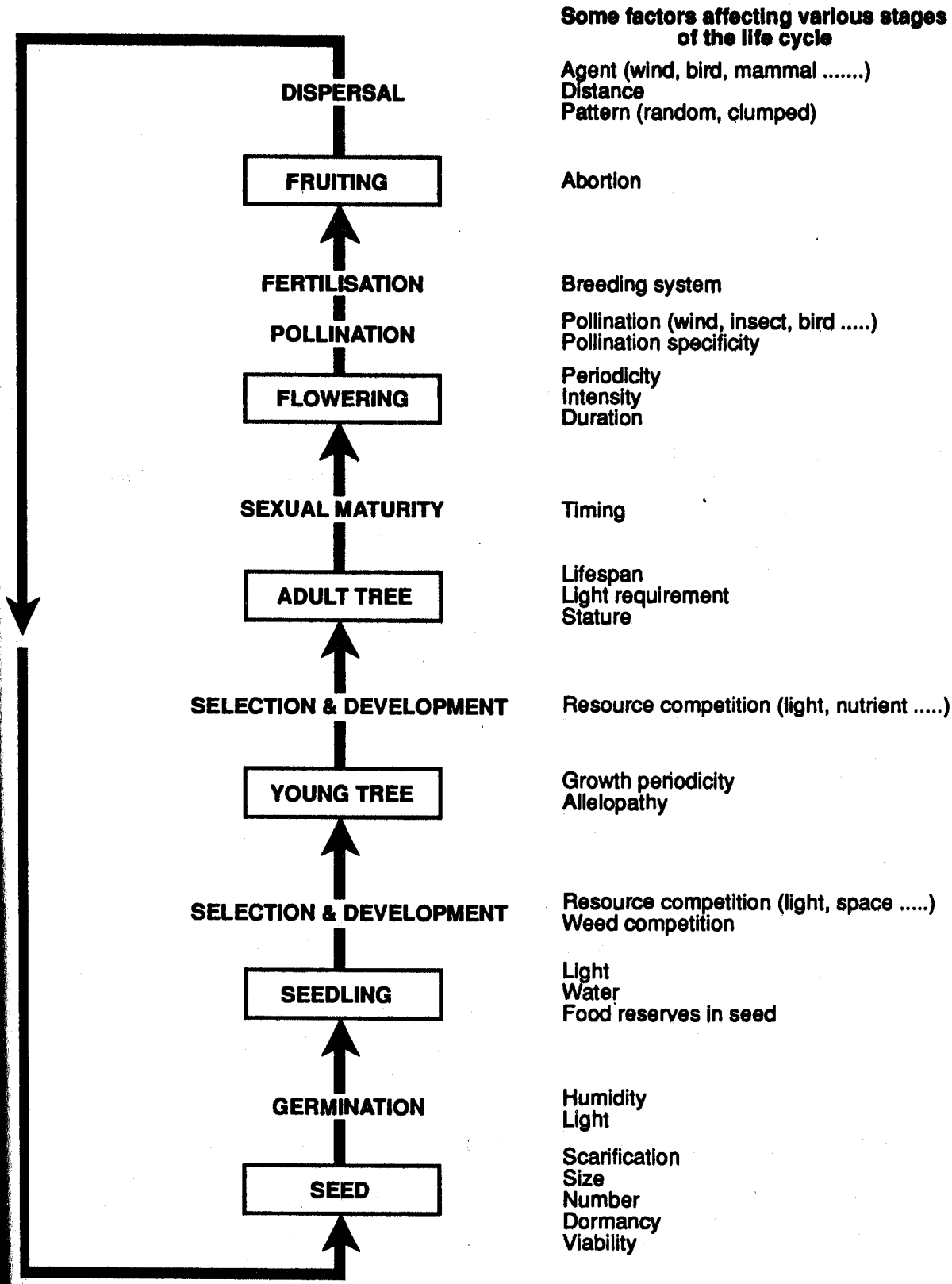

Fig. 1. Life cycle of a tree.
Note that predation, grazing, diseases and parasitism may affect each stage.

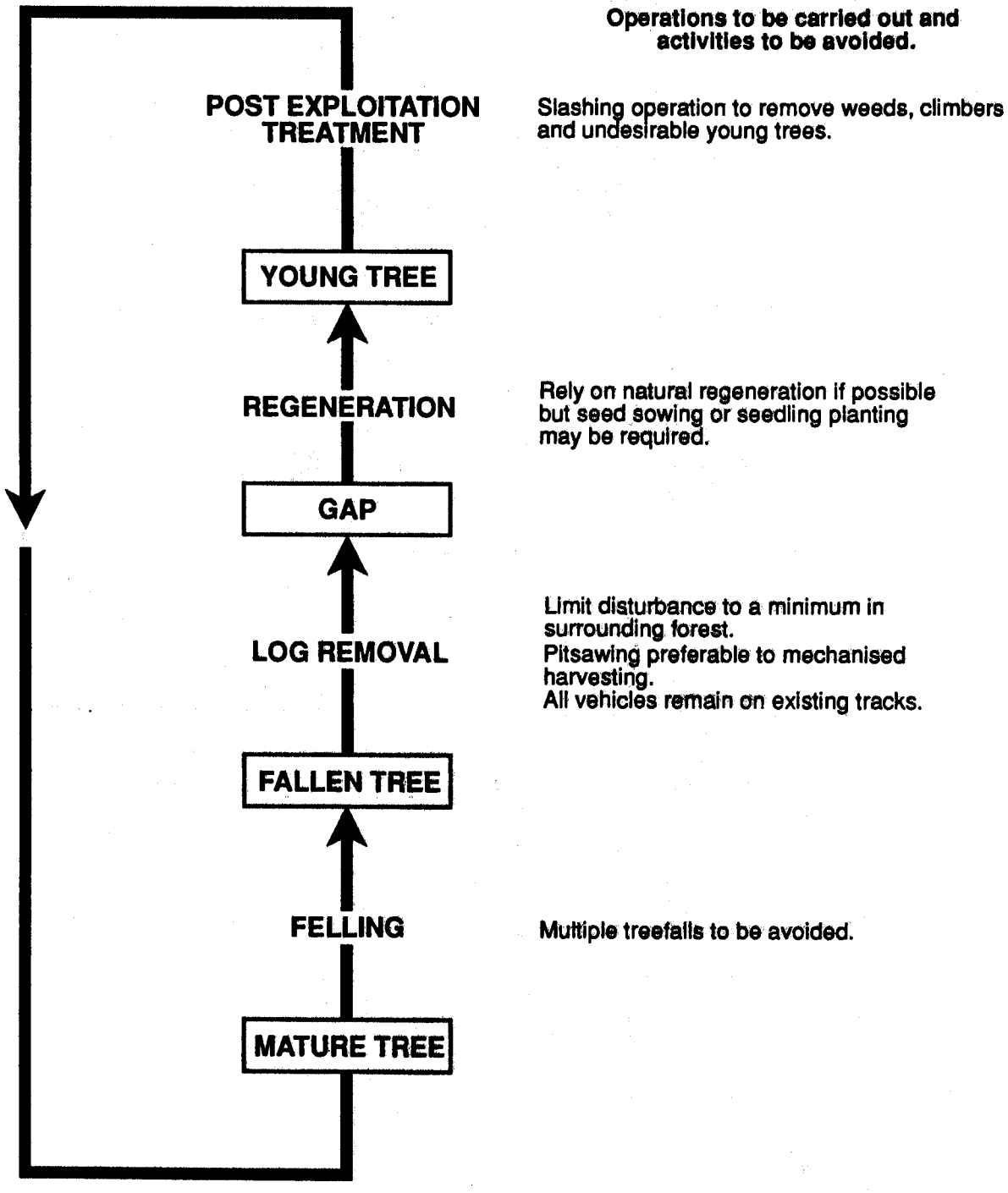

Fig. 2. Proposed silvicultural system for logged forests and converted *Maesopsis* plantation.