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NO. 16

PROBLEMS AND OPPORTUNITIES

IN

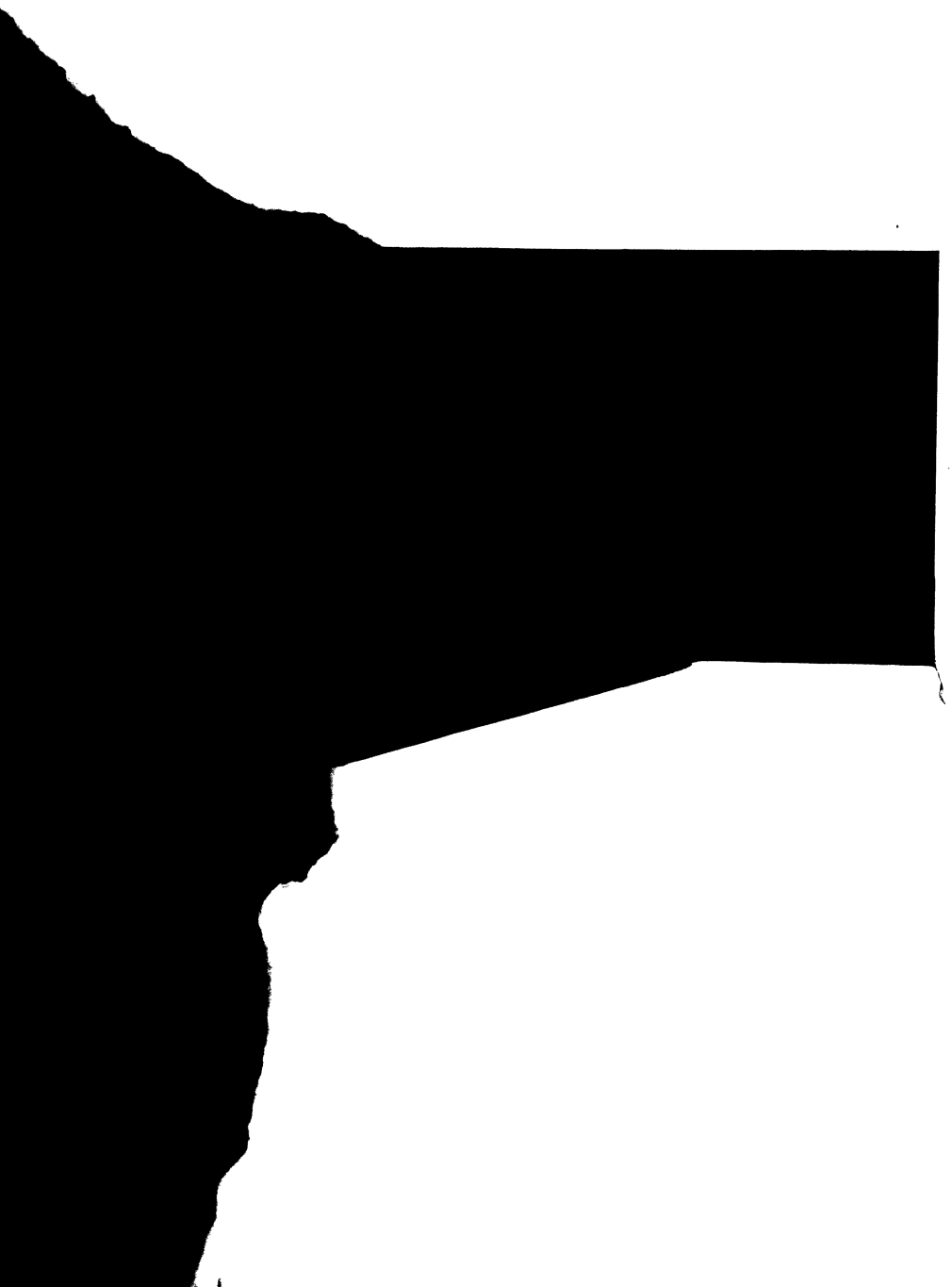
TROPICAL RAIN-FOREST MANAGEMENT

by

P.E.Neil

1981

DEPARTMENT OF FORESTRY
COMMONWEALTH FORESTRY INSTITUTE
UNIVERSITY OF OXFORD



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by
P.E.Neil

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Commonwealth Forestry Institute
Oxford University

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Peter E. Reid.

PREFACE AND SUMMARY

This thesis attempts to describe the problems and opportunities that exist in methods used to manage the complex ecosystem of the Tropical Rain Forest (T.R.F.). The emphasis is on natural regeneration (N.R.) of this forest type, although artificial regeneration methods are briefly discussed where appropriate.

The author realises that the length of the study is considerably larger than that suggested by the examiners and would like to apologise for this. However, it was felt that to do justice to this work as a compilation of aspects of T.R.F. management, it could not effectively be reduced in length. The author therefore particularly draws the examiners' attention to Parts 1 and 3 as these discuss his ideas on T.R.F. management.

Part 1 discusses the various factors that influence N.R. of T.R.F. and hence may affect the success of the silvicultural systems applied. Environmental influences are considered including the effects of water, soil, light, storms and biotic factors. This is followed by biological or intrinsic influences on N.R. and such things as population structure, abundance and growth, successional status, phenology and autotoxicity are discussed. The influence man has on N.R. can be very considerable especially with regard to use of fire and mechanical logging, although aspects related to labour, supervision, management, etc., may also severely influence the results of silvicultural systems.

Part 2 is a history of T.R.F. management and looks at the development of T.R.F. silviculture from its beginnings in India and Burma in the 1850s and its spread to Asia, Africa and S. America. Four phases of this development are discussed and the author suggests the possibility of a fifth phase that is commencing now. The history has been treated in this way as apart from Baur (1964a), the author has come across no other publication that documents and illustrates T.R.F. management. Baur's work was written almost twenty years ago and did not discuss the early beginnings of management. Much has occurred as regards the T.R.F. since the early 1960s, and it was felt that a study of the complete chronological development of T.R.F. management would illustrate those silvicultural systems implemented and be of use to present as well as future foresters as a source of reference.

Part 3 concludes the study with a discussion on the future prospects of T.R.F. of which the controversy over artificial versus natural regeneration is central. Foresters have the knowledge and means to achieve successful N.R. of T.R.F. but deforestation due to human, agricultural and economic needs continues. Conservation attitudes are discussed and T.R.F. is considered in a wider perspective. N.R. of T.R.F. has a future and although there are numerous problems the opportunities are there to achieve success.

The reference section is also of considerable length, as many articles were consulted for the study, especially

for Part 2. They have been included to enable the reader to investigate, in greater detail, aspects discussed in the text, that may be of particular interest, but unfortunately could not be included in the study. Also as is the case with Part 2, the author found no publications that provided a detailed and comprehensive coverage of T.R.F. references and it was therefore thought to be useful to include a detailed reference section in this work. To avoid having to read long lists of reference in the text which would have broken it up too much, the author has attempted to include the most relevant references to a point, and then referred the reader to the reference section for further articles.

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PART I

CHAPTER 1

INTRODUCTION

"But Eeyore," said Pooh in distress, "what can we - I mean, how shall we - do you think if we - ?"

"Yes", said Eeyore. "One of those would be just the thing. Thank you, Pooh." (Milne, 1928)

The quotation clearly conveys the predicament of the forester trying to manage the tropical rain forest (T.R.F.). This thesis aims at describing the problems and opportunities encountered in attempting to manage the highly complex T.R.F. ecosystem. The emphasis is on natural regeneration (N.R.) or what Leibundgut (1962) calls 'naturalistic' silviculture, which depends on synecological knowledge (Bakuzis, 1969).

The N.R. of the tropical forester is quite different from that of the ecologist's N.R. (Foggie, 1960). The former's job is to bring the forest to the highest productivity for man's use, which involves the regeneration of species which are either of known present value or are likely to be usable by man. Only if other species are conducive to such regeneration or to its health, which includes the very important factor of soil conservation, will they be considered detrimental, reducing the growing space and competing for light, moisture, and nutrients with the

favoured trees, and, as such, are weeds. Therefore N.R. the T.R.F. is an attempt to convert a very complex mixture of species into a much simpler one with a high proportion of certain species (determined on their utilisable potential and not their silvicultural or ecological characteristics) and as small a proportion as possible of any others. For the purposes of this study, N.R. means avoiding planting and sowing as opposed to relying on existing seedlings and saplings or on seedlings arising from seed from individual stems of the desired species in the existing forest.

The term 'rainforest' means different things to different people. Schimper (1898, 1903) first introduced this term defining T.R.F. as "Evergreen, hygrophilous in character, at least 30 m high, but usually much taller, rich in thick-stemmed lianes and in woody as well as herbaceous epiphytes". This definition fits the concept of the T.R.F. as most writers since Schimper have used it (e.g. Richards, 1979; Whitmore, 1975), but the term has also been used in a more general sense (e.g. Baur, 1964a; NAS, 1980). It is this more general definition that is used in this study.

The T.R.F. is the most complex ecosystem on the earth (Richards, 1973a). It is by no means a mere collection of, or refuge for individual organisms, or an accidental mixture of populations. It is a dynamic system of a high order of organisation in which the morphological, physiological and ecological features of individual members are

linked together, creating forms and functions unknown outside the forest. It is a unique and rich community of plant and animal species having a number of highly specific ecological features such as high temperature and humidity, extraordinary species diversity, stratification of tree canopies, strict nutrient budget, etc.

There is much discussion about why T.R.F.'s have such rich flora (Corner, 1954; Fedorov, 1966; Margalef, 1968; Ashton, 1969; Lowe-McConnel, 1969; Richards, 1969; Janzen, 1970, 1971; Whiffin, 1978) and there is no one complete theory. Longman and Jenik (1974) summarise what they see as the salient points in the issue.

A number of paleogeographical factors, together with differences in contemporary climate, soil, and human interference indicate that the world's T.R.F's can be divided into at least three major regions: America, Africa and Indo-Malaysia including Australasia (Whitmore, 1975; Pritchett, 1979; Richards, 1979; Esteban, 1980; Spur and Barnes, 1980; N.A.S. 1980). Longman and Jenik (1974) identify four major regions listing the Indo-Malaysian and Australasian T.R.F. regions separately and further suggest that the Hawaiian islands may represent a smaller fifth zone.

In reviewing current trends, T.R.F. ecology has successively progressed through the environmental (habitat), the floristic (composition) and the structural (physiognomic) schools of approach and has entered the more recent field

of production studies (Weck, 1959; Robbins, 1969; Kira, 1969; Kira and Ogawa, 1971; Monteith, 1972, Lieth and Whittaker, 1975; Reichle et al, 1975). Despite this, many aspects of the T.R.F. remain a mystery (Janzen, 1975). As Corner(1963) says:

> It is built in surpassing beauty without any of the necessities of human endeavour; no muscle or machine, no sense organ or instrument, no thought or blue print has hoisted it up. It has grown by plant nature to a stature and complexity exceeding any pre-sentiment that can be gathered from books, and it [presents] ... one of the most baffling problems of biology.

The following chapters include some of the aspects that foresters have been working on to attain successful N.R. by silvicultural systems. These include aspects of environmental, biological or intrinsic, and human factors. A detailed history of T.R.F. management is given to illustrate the investigation and application of silvicultural systems since forestry started in the tropics. It is given in such detail as apart from work by Baur (1964a), the author knows of no other publication that describes the development of management in the tropics. A discussion on the future prospects of the T.R.F. and its management concludes this thesis.

CHAPTER 2

NATURAL REGENERATION AND ENVIRONMENTAL INFLUENCES

There are a number of environmental factors that are closely associated with the success or failure of N.R. These variables have been defined by Philip (1967) and in this chapter the variables water, soil, light, storms and biotic factors are considered. Before discussing these variables, it is worthwhile reflecting on those more general aspects that must be accounted for if silvicultural systems are to be successful: 1) the nature of the residual stand left after logging and in particular the species and vigour of the seed trees; 2) the growth, stocking and distribution of seedling and advanced sapling growth both before and after felling; 3) the damaging effect of logging on the residual seedlings, saplings and trees and of logging and extraction roading on the environment, particularly on the natural water drainage pattern and soil physical conditions; 4) damage to the residual stands by secondary fungal and insect attack following logging damage and damage by wind and bark scorch; and 5) the likelihood of weed growth, invasion by pioneer trees and increased luxuriance of climbers.

Water

Besides its influence on the occurrence of T.R.F., water, or more properly precipitation, has certain other important effects on rainforest behaviour. "Pore space

and soil moisture ... are considered by some ... to be the main factors of ecological importance" (Schulz, 1960). The importance of both soil structure and drainage in delineation of forest types in unquestionable (e.g. Lamb, 1941; Ashton, 1964; Ahn, 1961; Budowski, 1970, etc.). Rainfall is also important, possibly bringing relatively large quantities of nutrients to the ecosystem (Richards, 1973a).

T.R.F. frequently suffer from water stress and temporary dryness for short periods. This does not mean a major lack of water, but may just be one month that is relatively drier than other months. This is more important if rainfall is distinctly seasonal, as the flowering and fruiting of many species are closely correlated with the seasonal change. However, considering the forest as a whole, there are usually peaks of flowering at certain times, even in near uniform climate (Richards, 1973a; Tomlinson and Zimmerman, 1978). Flowering of Dipterocarpaceae is notorious for its infrequency and gregariousness (Poore, 1968; Whitmore, 1975). Burgess (1972) concluded from studies of gregarious flowering in Malaysia that it was connected with drought periods occurring 3-5 months before flowering. However, Ng (1977) has suggested that it is the increase in mean daily sunshine that is the flowering stimulus. Whether the increased temperatures or drier conditions associated with this increased sunlight are also factors involved in flowering is not discussed. Brunig (1971) has discussed the ecological significance of

drought in Sarawak. In other T.R.F. areas drought also appears to provide the stimulus for flowering (e.g. Nigeria - Lamb, 1941; Suriname - Schulz, 1960; Queensland - Webb, 1958 ; Jones, 1974).

Water stress may also have effects on seed germination and seedlings. Synnot (1973) states that drought caused Entandrophragma utile seedlings aged 10-14 months to be severely wilted; some failed to recover and died. Many tropical trees (e.g. Cedrela odorata, Mansonia altissima) have plentiful seedlings during the wet part of the year or after a good seed fall, but by the dry period of the year most seedlings have died. Obviously in attempting to establish such regeneration in the course of silvicultural treatment, it is essential to maintain conditions as conducive to seedling survival as possible especially during dry periods.

Excess water may also be a problem, as noted by Fox (1972), where flooding caused by impeded drainage may kill off trees and seedlings and prevent seed germination.

If the seed of desirable species matures before the wet season, it may pose serious problems for N.R. systems (cf. Rollet, 1962 - seasonal East Mekong forest). In other areas this problem does not arise due to delayed germination of seed, for example the legume Pterocarpus dalbergiodes in the Andamans (C.C.F. 1968).

Man's intervention by way of exploitation is having increasingly evident local effects on forest soils and their drainage. Although in forestry, complete removal of

vegetation is rare in the tropics being mainly confined to extraction routes, where complete removal has occurred the devastation has been correspondingly complete (cf. Panama-Wadsworth, 1978).

Soil

Tropical soils vary so much in texture and nutrient status that broad generalisations are difficult, but a few seem to be relevant. Because of the pattern and intensity of tropical rainfall, many of the available soil nutrients are leached out; the soils have a low level of incorporated organic matter; they tend to have poor structure, and as a result are not resilient under cultivation; and erosion by surface water presents a constant danger (Nye and Greenland, 1960; Pereira, 1973; Sanchez, 1976; Pritchett, 1979; Young, 1980). The most important aspect of the soil to N.R. is the soil surface microclimate. It is important at two crucial stages: germination and canopy opening. Survival probability is higher at germination if adequate moisture is available and temperature equable (Whitmore, 1975; Richards, 1979). This is a problem in the large seeds of the dipterocarps as they have no dormant period (or only a short one) and commence to germinate almost immediately. If the soil surface microclimate is wrong then germination will fail. The problem is compounded as with only infrequent fruiting there is a tendency to get flushes of seedlings intermittently carpeting the forest floor. The N.R. of the forest will depend to a great extent on whether enough

survive until the time the forester wants to operate (Barnard, 1954, 1956; Tong, 1971; Liew and Wang, 1973). Survival is usually reduced if germination occurs in bare exposed areas, compared with the humid forest floor.

Other problems for N.R. may occur at canopy opening. High temperatures combined with low soil moisture can be damaging causing wilting or death by scorch (Fox, 1972; Riswan, 1979; Kartawinata et al, 1981). While it may be possible to avoid fellings in the hot periods of the dry season in seasonal forests, dry spells are less predictable in less seasonal forests.

Studies by Burgess (in Whitmore, 1975) help to convey the complexity of the whole problem of N.R. Some experiments have shown that mycorrhizal fungi may be needed for germination (Fox, 1972). Ashton (1964) suggests that the different soil conditions in Brunei and their resulting variation in densities of different timber groups relative to one another, may require the adoption of different silvicultural treatments on them. A general tendency seems to be that sandy soils favour N.R. more than heavier clay soils (Lamb, 1941; Beard, 1944a; Ayliffe, 1952).

The use of more expensive machinery, capable of all weather work, is putting pressure on governments, which exercise some control over operations, to permit continuous working. Soil disturbance accentuates the competitive ability of pioneers by removing established, rooted plants and bringing seed to the surface, or allowing opportunities for fresh seed to germinate in bare soil (Schulz, 1960; Liew,

1973b). However, where such species are considered desirable, some mechanisation may be beneficial.

Light

The influence of gap size on competition and composition has been well documented (Walker, 1948; Baur, 1964a; Whitmore, 1975, 1978; Richards, 1979). Gaps are formed from death of a single tree or group of trees and may be the result of old age, wind blow, lightning, uprooting by elephants, landslides, etc., (Wyatt-Smith, 1963; Anderson, 1964, 1966; Baur, 1964b; Brunig, 1964; Fox, 1972; Longman and Jenik, 1974). The death of a single tree, or a minor windfall may not allow sufficient light to penetrate the canopy to stimulate pioneers. If light is sufficient, however, then seedlings of pioneers (trees/lianes) may become established, especially if seedlings of dominant species are lacking. Generally, the larger the gap, the more light that reaches the undergrowth and ground, and the more intense the competition. The most successful species are those that can respond rapidly to this light, though all growth may be favoured by openings (Schulz, 1960).

Light is fortunately an environmental variable that can be controlled to some extent by the silviculturist. Pioneers require almost complete light for survival and growth (and in most cases for germination also), but for the most part they are of limited economic significance. Notable exceptions, however, include Ochroma lagopus (balsa), Didymopanax morotonei (match veneer - Trinidad),

Cecropia spp. (paper pulp - Peru).

The gap opportunist species include many of the more desirable trees that ultimately form much of the T.R.F. overstorey, and for this reason this group tends to be of most interest to foresters (e.g. Meliaceae, Dipterocarpaceae and Flindersia spp.). Seeds germinate on the undisturbed forest floor, but make little further development unless they subsequently receive increased light. They go into a state approaching dormancy but retain the ability to commence active, and frequently rapid, growth if light requirements are suddenly improved. This ability to survive lengthy periods while making negligible growth, and then to respond rapidly to improved growing conditions, is a major silvical characteristic of the most desirable rainforest trees. Unfortunately, it is not confined to desirable species, but is also found in many vines such as the serious Nigerian weeds Acacia ataxacantha and Calamus spp. and the related climbing palms (Ogbe, 1968; Lowe, 1975).

The truly tolerant species are typically those of the understorey, requiring considerable shade for their early development, although some ultimately reach the overstorey (e.g. Ocotea rodiaei, Endiandra palmerstonii; Balanocarpus hemii, etc.). Growth rates of these species are usually slow.

Various investigations have been carried out examining the light aspect in N.R. (e.g. Beard, 1942; Holdridge, 1943; Schulz, 1960; Nicholson, 1960; Havel, 1971; Ampofo and

Lawson, 1972; Whitmore, 1977; Bower and Whitmore, 1980; Inoue, 1980). In studying these examples one obvious point is the complexity and variation in species and their relation to light, as well as other factors, and the various aspects a forester must consider to obtain the N.R. of the desired species.

Exploitation is the major influence on the light regime - this is what the forester can attempt to control. Where regeneration is absent, the only successful treatments to induce it have been ground weeding and a drastic opening of the canopy with complete, if temporary, soil exposure (Dawkins, 1958a; Philip, 1967). Unfortunately, when N.R. is present, there is evidence of increased felling damage to larger seedlings (Synnot, 1975). It is now considered unnecessary to carry out pre-exploitation canopy opening where adequate seedling regeneration is already present (liane cutting is done in Sabah before felling, but this is to reduce felling damage; increased light is incidental). Following exploitation climber tangles may well occur (cf. Nigeria), but such occurrences need not defeat the N.R. of the forests (cf. M.U.S. Malaysia).

Generally, the more intensive the exploitation, the fewer the possibilities for manipulation of light available to the silviculturist. Coupled with that, the more timber that is removed, or the greater the disturbance, the further back in the succession process the stand is pushed (Lamb, 1967).

Storms

The effect of gap size and therefore light can be very great in T.R.F. areas affected by storms. Typhoons, hurricanes, cyclones, etc., are of enormous violence and can devastate all in their path. Damage to forests can range from defoliation to massive windblow, both of which increase the amount of light which penetrates to the forest undergrowth. Examples of T.R.F. affected by such phenomena are found in all T.R.F. regions (e.g. Beard, 1945; Browne, 1949; Wyatt-Smith, 1954; Jones, 1956; Webb, 1958; Cousers, 1965; Nicholson, 1970; Whitmore, 1974). Storm forests are invariably even-aged and often consist of almost pure stands (Whitmore, 1975).

In terms of T.R.F. management, its history is too short to adequately account for areas prone to windblow. However, it seems fairly obvious that if periodically a portion of the forest is to fall down, an alternative rationale to sustained yield is required (cf. Johnson and Chaffey, 1973). Therefore, in areas liable to storm damage, it would seem advisable to adopt a silvicultural system that produces the highest possible aerodynamic roughness and absorptive capacity which the site condition can sustain (Brunig, 1970, 1973; Ashton and Brunig, 1975; Brunig and Heuveldop, 1976). As storms tend to simplify the T.R.F. species composition, this may be useful to the silviculturist if the less heterogeneous stand contains a larger proportion of desirable species.

Biotic Factors

Gray (1974, 1975) states that relatively undisturbed mixed forests have a notably lower incidence of major pest and disease problems than do man-made situations. This is especially the case with entomological problems, although Palmer (in Fox, 1976b) discussed heavy mortality due to leaf-cutting ants in Vochysia and Goupia seedlings in Amazonia, and Synnot (1973) mentions Hypsipyla and Metoecis nigrivenella in connection with Entandrophragma utile seedling failures in Uganda. However, infestations on the scale of the Bornean Ulat bulu, an unidentified tussock moth, are rare and may even be unique in the T.R.F. situation. Larger animals are more of a problem today, especially due to the contraction of T.R.F. areas, for example elephants in Africa (Eggeling, 1947; Jones, 1956; Johnstone, 1967) and in Borneo (Fox, 1972), the tapir in Belize (Johnson and Chaffey, 1973) and deer in Borneo (Fox, 1972), etc.

Lianes, climbers, ropes, stranglers and ivies are often a serious problem in T.R.F. areas along with palms and bamboos. When small, many lianes are stimulated by cutting, whereas elimination of larger ones can be successfully carred out if left for a few years after felling (cf. "sticket" stage in M.U.S.). Refining or improvement in the sense of removing structural components believed to hinder growth or survival of N.R. is used in a number of silvicultural systems (cf. Sabah - pre-exploitation liane cutting) (Albazo and Corpuz, 1969; Liew, 1973a). Much

research has gone into methods to control climbers, palms, bamboos and weeds generally (see references).

Another biotic factor in T.R.F. affecting N.R. is fungi, e.g. mildew in logged areas (Fox, 1969).

It is not difficult to apply a uniform technique over varied conditions, but as utilisation values change, more 'undesirables' (weeds) become important. There are technological problems of a biological nature which affect the profitability of T.R.F. management. For example, unmarketable species, and relevance of wide crowns may both contribute to low yields per unit area (Dawkins, 1959; Ogbe, 1968).

CHAPTER 3

NATURAL REGENERATION AND BIOLOGICAL (INTRINSIC) INFLUENCES

This chapter reviews the biological side of the factors that may affect N.R. Five aspects are considered, namely: population structure, abundance and growth, successional status, phenology and autotoxicity.

Population Structure

The T.R.F. differs in composition from place to place. Some families and genera are pan-tropical while other taxa occur mainly or entirely in one part of the world. At the level of genera and species, only a few taxa are naturally pan-tropical (cf. Longman and Jenik, 1974). In single-dominant forests and other edaphic climaxes the floristic differences between regions are more conspicuous still

(Beard, 1944b, 1946a, 1946b; Schulz, 1960; Whitmore, 1977; Bower and Whitmore, 1980).

Spatial distribution of trees in the T.R.F. can give guidance to N.R. possibilities. Though at first sight distribution appears random, close scrutiny suggests that aggregation is common (Schulz, 1960) due to previous (or present) presence of seed bearers.

Population changes in the natural T.R.F. have only been monitored by a few long-term studies (e.g. Fox, 1972, 1976; Sarukhan, 1978; Tomboc and Bruzon, 1979; Crow, 1980, etc.). Work in Uganda by Eggeling (e.g. 1947) between 1937-41 and by his successors in the 1950s could be of great value - but only if Uganda became more accessible again. Whitmore (1981) has recently suggested work by Bormann and Likens (1979) in U.S. hardwood forests could provide valuable insights in methodology and inter-relationships for T.R.F. studies.

Richards (1973b) suggests that Africa always differs in comparison between the biota of the T.R.F. regions (cf. Brunig et al, 1978). The difference is that the majority of African T.R.F. stands have a striking disproportion between the number of mature trees of the upper storey species and that of their young stock (Mildbraed, 1930; Aubréville, 1938; Richards, 1939; Jones, 1955/6). In contrast, the stand tables of America and Indo-Malaysian T.R.F.'s show a diminshing hyperbolic (Pierlot, 1966) or (rarely) exponential (deLiocourt, 1898; Dawkins, 1958) distribution (Davis and Richards, 1933/34;

Beard, 1946a; Schulz, 1960; Baur, 1964a; Whitmore, 1974; Hartshorn, 1978; Chinte, 1980). The reason for this difference seems to be due to the effect of man on the T.R.F. (see Chapter 5). African forest is basically old secondary forest which is changing in composition particularly in respect to emergents due to previous cyclical agricultural clearance (Jones, 1956; Foggie, 1960; Schulz, 1960; Richards, 1973b). America and Indo-Malaysia were less affected by such practices.

Some approaches to silviculture are mathematical, based on the stocking and presence of a positive stand table. However, systems based on such parameters may be devalued if the seed source is lost or damage occurs to seedlings during logging.

Abundance and Growth

"The most decisive criterion for evalution of the relative importance of a number of species in a given stand is the number of individuals which, by reaching a certain size, show that they have succeeded in overcoming the principal obstacles in the struggle for existence" (Schulz, 1960). Disadvantages exist in insisting trees must reach large sizes before cropping, as although they attract premiums now, second cuts are likely to give smaller average sizes. Information on likely sizes at maturity, apparent growth rates with size, and periodicity of recruitment, may be obtained from diameter class distribution of stems in virgin forests. Tolerant species are generally found in smaller size classes, the opposite being true for

light demanders.

Species which emerge above the general canopy level forming a scattered and irregular upper layer are found in most T.R.F.s and have large basal areas and may reach heights of 60-80 m (e.g. Koompasia, Goupia, Entandrophragma, Lovoa, etc.). Two categories of emergents may be distinguished - those species with a higher percentage as emergents, and those with a lower percentage. The former are of great potential interest not only as rapid growers, but as species of persistence.

The basal area of mature stands of virgin T.R.F. ranges in different types of forest between 23-69 m^2/ha. Values of 36-46 m^2/ha are common in better quality T.R.F. (Baur, 1964b). In such stands, increment is balanced over a period of years by mortality and under such conditions individual stem growth rates vary tremendously. Despite this, a general relationship between diameter and increment rate for various species can be recognised (Jones, 1955; Schulz, 1960; Chinte, 1972). Growth curves are typically sigmoid with rapid growth through intermediate sizes (Palmer, 1974), which may produce apparent deficiencies in such stem sizes in the forest. This may also account for deficiencies in size classes in African T.R.F.

Successional Status

Succession in T.R.F. has been well documented (Nye and Greenland, 1960; Baur, 1964a; Budowski, 1965; Longman and Jenik, 1974; Whitmore, 1975, 1978; Richards, 1979; Kio, 1980),

and generally three seral stages are recognized: colonising, consolidating (mid-seral), and climax phase. Havel (1971) suggests that to become part of a stand, three phases must be successful: seed availability, germination, and seed survival. Gaps are filled by the most aggressive, rapid-growing, short-lived species classed as colonisers (e.g. Meliaceae, **Terminalia**, Heritiera, Cedrela, Agathis macrophylla (Walker, 1948), and most of the dipterocarps). These are not colonisers in the sense of pioneers, but have a presence as seedlings which survive until stimulated being normal members of the forest type. Mora in Trinidad is abundant, agressive, tolerant of shade, cheap and easy to establish, even being invasive, but it is not a pioneer (Bell, 1972).

Succession may be described in terms of shifting species balance between various groups (pioneers to primary dominants). Succession supposedly follows the 'facilitation model' (Connel and Slayter in Kio, 1979) which is typified by the 'Mosaic theory of Regeneration' (Aubréville, 1938, 1950; Daubenmire, 1969; Richards, 1979). This is where an extensive area of mixed forest may be regarded as a type of mosaic, each unit of the patchwork being a different combination of dominant species and thus, on any discrete area, different combinations will succeed one another more or less in a cyclical manner. Doubts, however, have been voiced about the over-simplification of the theory (e.g. Jones, 1955; Whitmore, 1974; Kio, 1979; Richards, 1979). The role chance plays in regeneration and, accordingly, in

the floristic composition of T.R.F. does, however, deserve serious consideration and the theory warns against uncritical applications of European phytosociological methods in the irregular patchwork of T.R.F. (Schulz, 1960).

Many species of trees may be represented as seedlings where no obvious seed bearers are close, and large numbers of small seedling lianes may survive disturbance in greater proportion than tree seedlings (Terry, 1981). Seeds of nomad (Steenis, 1956) species may be assumed to be present in T.R.F. soil continuously (Liew, 1973b). Exploitation drastically alters the behaviour of nomad species in the T.R.F. and provides many more opportunities for such species to assert themselves.

Phenology

Phenological studies are essential pre-requisites to understanding the N.R. potential. In many species some flowering occurs annually but heavy gregarious flowering and seed production are irregular (Schulz, 1960; Ng, 1966, 1977, 1978; Ng and Loh, 1974; Janzen, 1978). Gregarious flowering has numerous advantages (Whitmore, 1975) and stimuli to flowering include photoperiodism, release of water stress, cooling, accumulation of assimilates following high insolation, and water stress during opposed phases of pluvial and solar cycles (Esteban, 1980).

(See *Water* - Chapter 2.)

Autotoxicity

Succession theory implies change and so it is generally considered that pioneer stages do not regenerate

themselves, but nurse later stages. Baur (1964a) discusses toxic factors in relation to T.R.F. trees and evidence that N.R. does not always succeed in the immediate vicinity of parent trees. Troup (1952) states that Shorea robusta establishes itself best under species other than itself and Webb et al. (1967) has found similar results with Grevillea robusta. Webb et al. suggest "plantations will fail with species which do not naturally form pure stands", but do not seem to have considered rubber, oil palm, etc., which have been extremely successful in monocultures despite occurring in mixed stands naturally.

CHAPTER 4

NATURAL REGENERATION AND HUMAN INFLUENCES

This chapter deals with the various influences man has on N.R. Methods of exploitation and of forest clearance have severe effects on N.R. although, possibly most important is man's effect on T.R.F. as a whole by his decisions on how to manage, or not manage, such forests, as the case may be.

Fire

Fire is not a feature of the natural environment in T.R.F. and when it does occur many dominant, primary species are eliminated, at least temporarily. It is most often associated with man's activities (Bartlett in Whitmore, 1975; Aland, 1975), but lightning and sometimes volcanic action may also produce fire (Brunig, 1964;

Anderson, 1966; Longman and Jenik, 1974; Richards, 1979). Forest types with accumulations of peaty material and those that experience long dry spells when the ground has dried up are particularly susceptible to fire (Clarke, 1956; Schulz, 1960; Fox, 1976a).

In the transition zone between T.R.F. and savanna, fire is a much more general factor. The more pronounced periodicity of the climate and presence of grasses (e.g. Imperata) create conditions for natural spread of fire during the drier season (Richards, 1979). Terms such as 'savannisation' or 'derived savanna' are used in connection with areas repeatedly burnt, resulting in expansion of savanna into the forest zone. Riverain forests existing amidst savanna which is annually burnt provide evidence that closed forest properly supplied with water cannot be destroyed by fire.

Shifting cultivation is very widespread in T.R.F. and between 250-300 million people are thought to be subsisting by this method (Lamb, 1979; Roche, pers. comm.). Numerous publications have been produced on shifting cultivation and its effects (Chévalier, 1909, 1924; Aubréville, 1947; Shantz, 1948; Nye and Greenland, 1960; Roche, 1973; King, 1979), but today T.R.F. clearance is also resulting from ranching practices - particularly in Amazonia (UNESCO, 1972b; Goodland and Irwin, 1975; Davis, 1977; Lewis, 1979; N.A.S., 1980; Herrera et al., 1981). Fire is the main tool utilised for forest clearance.

Effects on the soil resulting from fire include

liberation of great quantities of nutrients into the soil followed by their rapid loss by leaching as nutrient uptake capacity of plants is not sufficient to absorb the great quantity so rapidly relseased. Valuable nutrients are thereby irrevocably lost (Coulter, 1950; Bazilevich and Rodin, 1966; Brinkman and Nascimento, 1973; Daniel and Kulasingham, 1974). However, if the ground is allowed to be recolonised, nutrient levels (e.g. nitrogen and carbon) may increase to near former concentrations (Duthie et al., 1936; Cunningham, 1963; Enright, 1979; Richards, 1979).

This generally means that following fire, environmental conditions very rarely favour the success of N.R. of desirable species. However, relatively abundant N.R. of Cedrela and Swietenia appeared on areas burnt in the past in Belize (Johnson and Chaffey, 1973) and in sub-tropical zones fire may favour regeneration (e.g. Tectona grandis and some tropical pines). In general though, fire is injurious to N.R. in T.R.F. and should be excluded from managed forests if possible.

Mechanical Logging

At the Logging Symposium in Krasnodar, Russia, in 1972, Professor Mayer stated, "All professors of silviculture should be killed, as silviculturists are the worst enemies of progress in mechanisation, they are the most severe obstacle for rationalisation in forest management". In contrast, Jacobs (1974 in Fox, 1976b) states, "Technical perfection in cutting and transportation equipment is,

from the biological viewpoint, disastrous. The more effective bulldozers, paper pulp machines, power saws and logging lines are, the greater the set back to natural regeneration." The whole point of N.R. is to secure a second crop following exploitation. If uncontrolled, the passage of large machines through the T.R.F. does enormous damage to prospects for N.R. Furthermore exploitation, whether selective or more comprehensive, exposes the soil to the full effects of sun, rain, wind, etc., which may cause leaching of nutrients, erosion and laterisation (McNeil, 1964, 1972). Logging damage to advance regeneration in selective exploitation may severely affect the success of the silvicultural treatment.

Despite this, logging is one of the most important means in order to realise silvicultural aims of forest management (Leibundgut, 1976). There is no silviculture without logging. The technical possibilities in logging determine the action margin of the management to a large degree (Loeffler, 1978).

Logging in T.R.F. has involved hand methods, small gauge railways, various forms of cable ways, and various forms of caterpillar tractors and bulldozers (Brown, 1950, 1955; Webb, 1950; Smythies, 1951, 1952; Martyn, 1966a; Cermak and Lloyd, 1967; Mason, 1974). Elephants were said to be difficult to feed and trees were larger than they could haul, though it has been suggested the latter may be fallacious (Whitmore and Ho, 1968). High lead logging is also used and Nicholson (1963) has noted that

it resulted in a lower loss of seedlings than tractor yarding although damage to advance growth was more severe (Meijer, 1973).

The impact of the logging operations is discussed in relation to specific countries in Part 2. However, there have been a number of general papers written, possibly the most comprehensive being ones by Synnot (1975) and Andel (1978). In 1975 a symposium was held in Indonesia on the Long-Term Effects of Logging in S.E. Asia and this discussed many of the problems involved (see references).

Generally, soil damage is not caused by the actual cutting of trees or their absence from a site, but arises from erosion of exposed mineral soil due to disturbance of the humus layer by machines (Hibbert, 1967; Lull and Reinhart, 1967; Brunig, 1967, 1976; Fredriksen, 1970; Hewett and Helvey, 1970; Rothwell, 1971; Megahan, 1972; Megahan and Kidd, 1972; Weert, 1974). If humus disturbance is minimised, regrowth of vegetation normally re-occupies the soil long before the stabilising influence of the former forest cover disappears. When soil distrubance does occur, similar problems occur as described in clearance of T.R.F. by fire. As much of the nutrient capital is contained in the vegetation itself, which is extremely efficient in cycling it (Golley et al., 1975; Stark and Spratt, 1977; Jordan, 1978; Jordan et al., 1980), destroying the vegetation by extraction paths and logging may deplete the nutrient capital and the combination of sun and rain is highly detrimental to the structure and absorptive

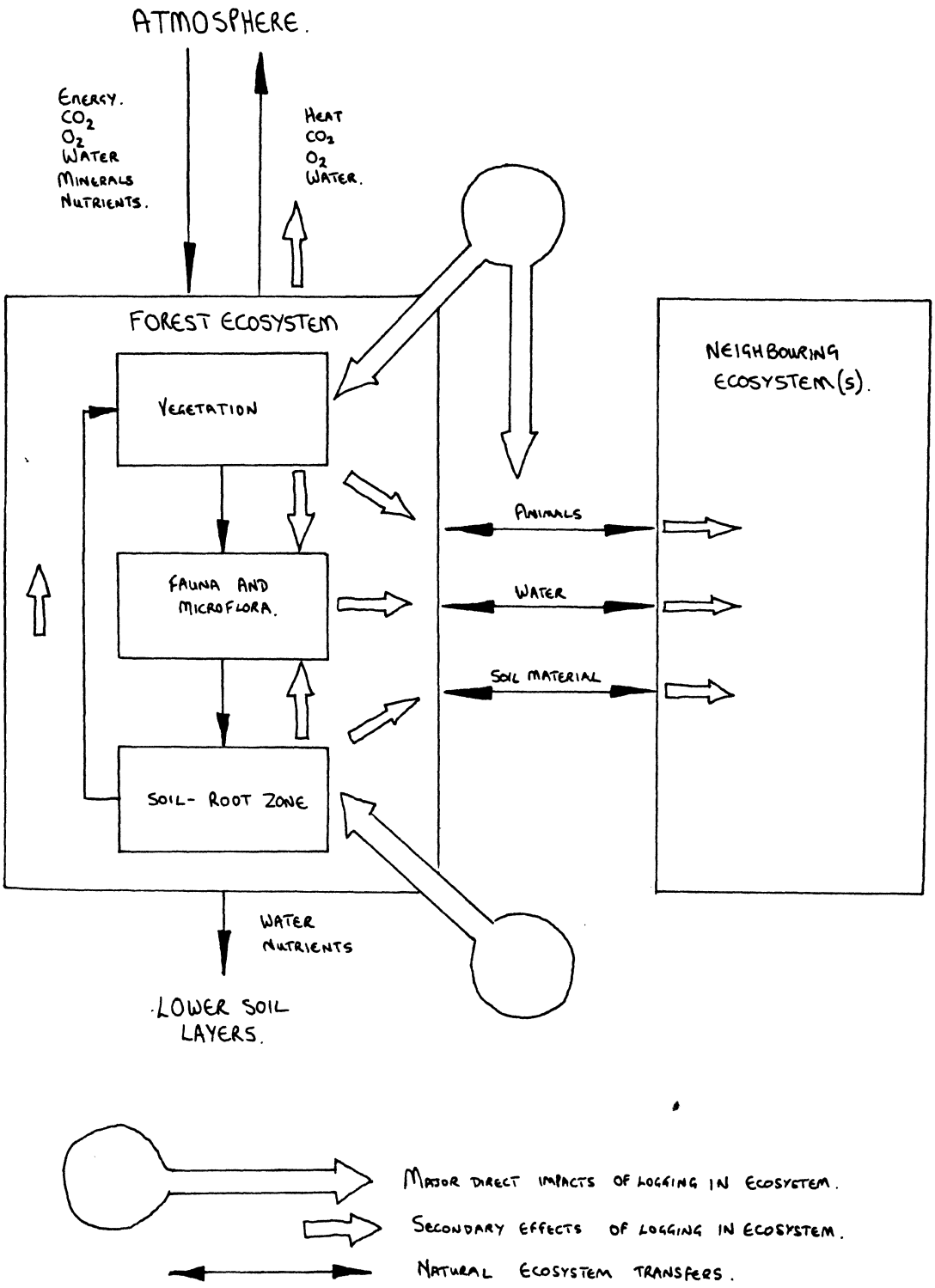
properties of the soil (Comforth, 1971; Richards, 1971; Enright, 1978).

The effects of mechanical logging operations on fauna have also been studied. Generally, it seems that logging effects depend on how specific creatures react to disturbance and change of environment from virgin to secondary forest (e.g. Scott and Selsar, 1961; Harrison, 1962; Steven, 1968; Wilson and Wilson, 1975, 1978; Hardjosentono, 1978; Jeffrey, 1978; Yong, 1978). Effects on fauna can be particularly important from the aspect of pollination and seed dispersal. Some seeds only germinate having passed through the gut of a specific organism (Wadsworth, 1954; Moore, 1957; McClure, 1966; Pijl, 1969; Janzen, 1970; Bouliere, 1973). (See Figure 1.)

Logging may be particularly destructive in selection systems and it has been criticised because of this (Dawkins, 1958a, 1959). However, aspects of resource depletion due to 'creaming' also need to be considered (Gilbert, 1980). Bell (1971b) argued 'creaming' *per se* may not be as detrimental as supposed, despite the many disadvantages of poor control, patching exploitation, defectives retention, and ease of theft. (Today, however, the effects of the opposite must also be considered with removal of the above ground biomass for wood chips. Richardson (1976) has given the topic a full discussion, though no thorough scientific study of the impact of this new technology has yet been made.)

FIGURE 1

LOCAL ENVIRONMENT – IMPACT OF LOGGING.



(After Nagle 1976)

Other arguments against selection (polycyclic) systems concern the limitations imposed on growth by inadequacy of crown size, insufficient growth rates of mature and over-mature trees left after successive exploitations, and damage to residual stand. This latter point is of particular interest in the success of N.R. systems. However, experts now suggest that although felling and logging damage is inevitable (Palmer, 1975), the intensity of damage is highest under the first selective exploitation. Subsequent fellings create less damage due to fewer and wider scattering of trees (Kio, 1978, 1980; UNESCO, 1978).

Mechanised logging has great influence over N.R. success, but stricter control over how extraction paths, roads, etc., are aligned, directional felling and pre-exploitation climber-cutting has reduced some problems (Fox, 1968c, 1972; Castillo, 1973; Fontaine, 1976; Brunig, 1975; Brunig et al., 1978; Pong, 1978; Wellburn, 1975; Jessop, 1978).

Manpower Problems

Success of N.R. is jeopardised by the lack of land tenure, inadequacy of human resource, political factors, and lack of control of over-exploitation. Unfortunately, there are numerous examples of political indifference to the role of forests and to their satisfactory regeneration. Uncontrolled and over-exploitive logging renders subsequent harvests more costly, despite providing good short-term profits. Not only future yield, but future

employment may be jeopardised when cutting in a cycle too short for regrowth to reach exploitable sizes (cf. Ghana). Multi-national companies have concessions to exploit T.R.F. areas but often Forest Departments fail to follow up companies that do not follow contract clauses about care to residual stands and advance N.R. (Schmithusen, 1976; Myers, 1978, 1979a).

The Brazilian Amazon is by all accounts in complete disorganisation with massive exploitation, encroachment and shifting cultivators following highways, etc., (Goodland and Irwin, 1975; Davis, 1977; Lewis, 1979).

Political corruption is known throughout the T.R.F. area with examples in Indonesia, Philippines, Sri Lanka, Uganda, etc., (Westoby, 1979; Mendoza, 1980; S. Sahajanathan - pers. comm.) and illegal cutting and timber smuggling are said to be rife in many. Encroachment problems are common in countries including Uganda, Indonesia and Papua, New Guinea, and effective reservation policies are desperately needed. Hughes (pers. comm.) has recently written a set of rules for the Uganda Forest Department in an attempt to improve enforcement of reserves and avoid trespass.

Men employed in N.R. work should be highly skilled in tree identification and should be able to visualise the results of present action aome 5-10 years hence. Employment of endemic forest people can be useful as they have an acute forest consciousness (Gorinsky in Grainger, 1980; Elliott, pers. comm.). People who really know

the forests do not always want steady employment or to be associated with the supervisors (Turnbull, 1961, 1965; Davis, 1977; Meggers, 1971, 1973). Urban life is often a big attraction and due to lack of total interest in the job, 'Sheffield blight' may result (Wood, pers. comm.). Examples of this situation are given in Walker (1948), Baur (1964a), Ogbe (1968), Lowe (1975), and Kio (1978).

Labourers are not alone in criticism as many supervisors and foresters do less to aid N.R. than they could. Often the case is that they feel T.R.F. N.R. involves an inferior form of silviculture than plantation establishment (Gane, 1966; Earl, 1968) - the results are less spectacular and thus not so obvious (Ogbe, 1968). Supervision of labourers by professionals is often poor in some countries (cf. Uganda) and can greatly reduce success of N.R. as many problems would not arise if management was correctly implemented. This also involves a clear definition of job and place in the managerial hierarchy which helps to avoid questioning authority, etc. The Solomons Forest Department is suffering from this problem at present.

Manpower is often insufficient or inadequately trained in various operations in tropical forestry. Projecting manpower requirements is difficult normally, but in the tropical countries problems are compounded due to lack of reliable statistics (Sommer, 1976; N.A.S., 1980) and vague forest policies. Despite this, manpower requirements and training needs have been suggested (Roche, 1975, 1979; Roche and Cooper, 1980) and will hopefully help in bringing forest services into better operational capability.

PART 2

SILVICULTURAL SYSTEMS - A HISTORY

A 'silvicultural system' may be defined as the process by which the crops constituting a forest are tended, removed, and replaced by new crops, resulting in the production of woods of a distinctive form (Troup, 1952). The silvicultural treatment of T.R.F. is a relatively new phenomenon. Dawkins (pers. comm.) has suggested three phases in T.R.F. management dating from around 1850 to the present day, i.e.,

1850-1900 Indo-Burman (Franco-Teutonic)

1900-1950 Afro-Malaysian

1950+ Pan-tropical Exploitive.

Having studied many of the references on T.R.F., the author has come to the same chronological divisions. However, the author has included a 'pre-management' phase and has identified what seems to be a fifth phase of which more will be discussed later. Figure 2 shows the mainstream of T.R.F. management development as illustrated in the following sections.

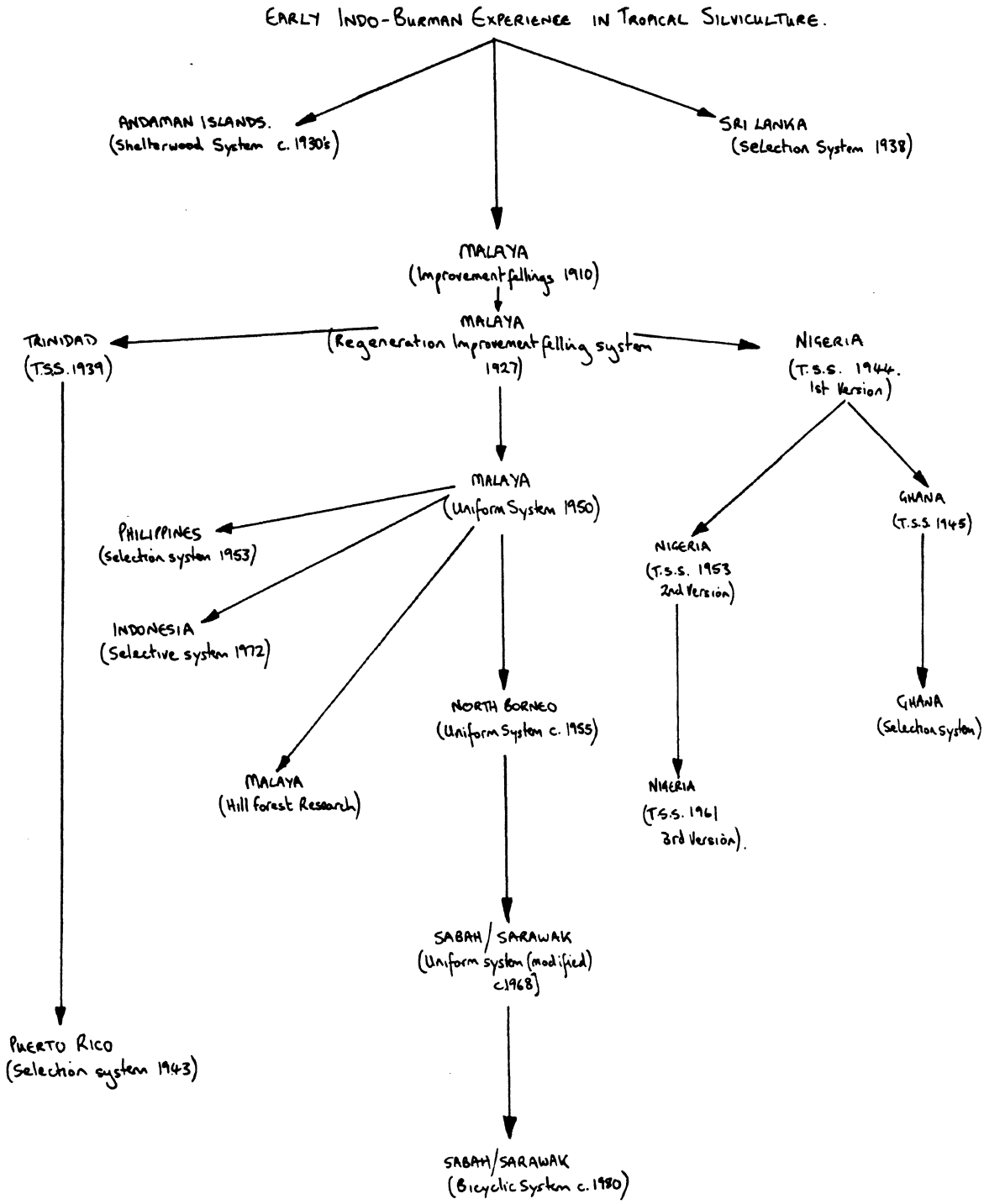
CHAPTER 1

PRE-MANAGEMENT PHASE

The T.R.F. is one of the most ancient ecosystems in the world (300 million years old). Fossil evidence indicates that it has existed continuously since the Cretaceous period (Doyle, 1978; Esteban, 1980). Both

FIGURE 2.

DEVELOPMENT OF TROPICAL RAIN FOREST MANAGEMENT.



N.B. UGANDA is not included as it generally followed its own course of development based on observations initially by Eggeling.

Based on BAUR (1964a) - updated

geological and biogeographical data point to the existence of pluvial periods when evergreen forest extended far beyond its present units - even to Britain which was then presumably tropical (Corner, 1954; UNESCO, 1959; Richards, 1979).

The forest seems always to have been part of man's environment. Evidence from paleaontology (e.g. Leakey, 1964) shows that the evolution of Homo sapiens took place somewhere near the margins of the tropical and sub-tropical forests. Later, man turned to the closed forest either temporarily as a hunter or food gatherer, or he was forced by inter-tribal conflicts to live there permanently. Initially he made no attempt at cultivation and even today a few tribes still live this way (e.g. Acta of the Philippines, Kuba of Sumatra, Ituri of Congo, Cinta-Larga in Amazonia) (Turnbull, 1961; Whitmore, 1975; Davis, 1977). Primitive man identified himself with the environment through the beliefs of animism (Ashby, 1978; Neil, 1978, 1980a) and had no more effect on the forest ecosystem than other animals (Turnbull, 1961, 1965; Meggers, 1971, 1973; Fosberg, 1973; Davis, 1977; S. Jones, pers. comm.).

Slowly, however, man began to alter the vegetation of the T.R.F., mainly by forest clearance, usually to carry out some kind of agriculture. Fire was a potent weapon (Longman and Jenik, 1974; Bartlett in Whitmore, 1975; Lewis, 1979). This has been going on for at least 3000 years in Africa, 7000 years in South and Central America, and possibly for 9000 years or more in India and New Guinea

(Golson, 1968, in Davidson, 1976a; Elliott, 1977, pers. comm.; Flenley, 1979). On alluvial plains settled societies evolved mostly based on permanent fields often established on former swamp and seasonal-swamp forest land. Elsewhere, the art of shifting cultivation (chena, huma, ladang, kaingrin, tamrai, shag) was developed (Nye and Greenland, 1960; King, 1968, 1979; Roche, 1973, 1977; Whitmore, 1975; Richards, 1979; Grainger, 1980).

The influence of a relatively large population of agricultural people in tropical West Africa has been felt even in the most remote and inaccessible areas (Chévalier, 1909, 1924; Aubréville, 1947, 1949; Shantz, 1948; Richards, 1973). In America and Asia, civilisations developed, but on a more localised scale and more so in the monsoon forests than T.R.F.s. (Schulz, 1960; Longman and Jenik, 1974; Whitmore, 1975). Consequently, the structure of African T.R.F. differs from those of the other regions as discussed earlier.

CHAPTER 2

INDO-BURMAN PHASE 1850-1900

No European foresters became involved in the management of T.R.F.s until the 1850s. The early methods were first applied to dry deciduous and moist deciduous forests (Champion, 1936a), well outside the range of T.R.F. in the sense of this thesis. However, these first efforts to bring the natural tropical forest under conditions of

scientific management were the basis for future management developments in the T.R.F.

Following a report by Dr. McClelland, Superintendent of Forests, Pegu, shortly after the annexation of Burma by Britain in 1852, the Governor General of India, Lord Dalhousie, laid down the outline of a permanent policy for forest conservation. Primarily this entailed the teak forests being retained and managed by the State. The outcome was the appointment of Dr. Dietrich Brandis in January 1856 (Blandford, 1958). Brandis was the first technically trained officer to be employed, not only in Burma, but in the British Empire. He was a German and the product of the European quasi-military disciplined system of forest education, hence the basis for Dawkins' 'Franco-Teutonic' phase.

Brandis was in charge of forestry in Burma from 1856-1862 and drew up the first working plan for Burmese forests. Exploitation was controlled by his 'Yield Regulation by Number of Trees' method, which was based on growth ring counts, observation of trees of known age, and estimation of stock based on linear valuation surveys (Brasnett, 1953; Sagreiya, 1956; Blandford, 1958).

Brandis was instrumental in the establishment of the Forest School at Dehra Dun in 1863 - the first indigenous torpical forestry school. Lecturers included Schlich and Fernandez, the latter writing the first tropical forest textbook (1888). The work was very theoretical and largely based on European lines. Indeed Fernandez writes,

"As to systems of regeneration and treatment we can at present do little more than borrow from our 'confrères' in Europe". The complete respect and care of the soil and biome was of paramount importance and all aspects were conservational. Indeed, 'Jardinage', a French word which literally means gardening, was one method described. Silviculture dominated management in what Dawkins (pers. comm.) calls the 'softly, softly' approach. The methods were well suited to India and Burma due to their history of forestry (e.g. forest grazing of stock, royal ownership of game, and snow and avalanche problems) and forest consciousness, which was similar to that of Europe.

Although there was a predilection for N.R. during the same period, the system known as 'taungya' was becoming known to European foresters (Blandford, 1924, 1958; Troup, 1952; Taylor, 1962; King, 1968). From Burma the method was taken to Chittagong in India in 1890, and to Bengal in 1896 (Raghavan, 1960). The method was introduced to South Africa as early as 1887 (Hailey, 1957).

CHAPTER 3

AFRO-MALAYSIAN PHASE 1900-1950

At the turn of the century, attempts at managing tropical forest were extending to other parts of the world from the Indo-Burman area. This was the start of true T.R.F. management in areas such as Malaysia and Africa, as well as Australia and the Caribbean, but management in

the Indo-Burman area continued on its own traditional lines.

The conservation attitude of the Indo-Burman foresters remained paramount in the early years of the 20th century. The 'softly, softly' methods were continued but with a more practical approach due to the publication of a new Manual (Anon, 1906), which described the best of early Indo-Burman experience on improvement and selection methods. During this period the regeneration of Sal (Shorea robusta) was probably most important particularly in the 'moist high-level alluvial forest' in the United Provinces, where the sal was of specially fine quality (Champion, 1933, 1936a; Smythies, 1939, 1940; Davis, 1944). Work on this species offered an excellent illustration of the kind of difficulties that arise and the way in which technique must be closely adjusted to the biology of the tree (Troup, 1952).

Most tropical forests were opened up on a polycyclic system often called 'selection' but more accurately 'girth-limit'. The girth was fixed high to ensure against overcutting and in theory, at least, left the forests in a state sufficiently valuable to be exploited again when their silviculture should be better known (Dawkins, 1961). The trees just below girth-limit were generally healthy looking and if not fast growing then, again theoretically, accelerated by the felling itself, with or without further liberation. Despite the 1906 Manual describing the operation of selection systems and commenting, "It is impossible to go far wrong in a method of such extreme simplicity", there was a marked swing away from uneven-aged towards

even-aged systems (Krishnaswamy, 1952; Ghani, 1954; Kadambi, 1954). Bourne (1935) suggested that where the choice is open, the irregular forest is the better proposition from practically every point of view. However, Champion (1936b) disagreed with this as did Champion and Trevor (1938) and emphasised the problems of uneven-aged systems with examples of failure. The selection or girth-limit system was recognised as being dysgenic (Champion, 1936b). Also, with India's generally understocked forests, frequent lack of successful regeneration technique, and low percentage of the more valuable species, greater real progress could be made with conversion methods to regular rather than irregular forests. In these regular forests the best stocking levels were sometimes half the number of stems per hectare as stands grown by similar methods in Europe (Sanger-Davies, 1932a).

Apart from Assam, Coorg, Cittagong and Madras (Champion and Griffith, 1948; Krishnaswamy, 1952; Kadambi, 1954), the tropical forest management ideas inspired by Brandis, Fernandez, Schich, Smythies and India generally found much more scope when extended to equatorial regions.

In Ceylon, from 1796 until early this century, forestry consisted mainly of the exploitation of natural forests for domestic requirements and export (e.g., Diospyros, Chloroxylon swietenia, Berrya cordifolia) (Anon, 1971). Initial attempts at T.R.F. management were European based, but these shelterwood and improvement fellings failed to produce regenerated stands. From 1938,

with a better understanding of the forest, true selection and irregular shelterwood systems have been used (Holmes, 1945; Rosayro, 1943, 1952, 1953, 1958).

Logging commenced in the Andaman Islands in 1857 and continued as uncontrolled exploitation up to 1911 when improvement fellings were introduced (C.C.F. 1968). The silviculture up to the 1930s was considered unsuccessful (Baur, 1964a). At this time selective logging was replaced by more concentrated logging which led to the introduction of a monocyclic regeneration treatment. This system is known as the 'canopy lifting shelterwood system' and is described in Table 1 (Chengapa, 1944; Griffith, 1947; Banerji, 1954; Dawkins, 1958a).

Despite the work done in India and Burma, the job of tackling the problem of rain forest silviculture in earnest fell to Malaysia. Unlike India and Burma, there was little forest organisation, no real technical or silvicultural skills and no market, as such, for timber and forest products. The Malays used an immense range of forest produce but would rarely be prepared to pay for it, due to the large resource available to them. By the time cities like Penang, Kuala Lumpur and Singapore developed with markets for forest produce, the goods desired were much more sophisticated (sawn and plywood, not just poles and rotans) being brought in by the Chinese. With these more sophisticated markets, only 20-30 trees were of any real commercial importance and so initially it was very difficult to initiate any form of technical

TABLE 1 *

SEQUENCE OF OPERATIONS OF THE CANOPY-LIFTING SHELTERWOOD SYSTEM. ANDAMAN ISLANDS.

YEAR	*OPERATIONS*
E-1	a) Climber cutting b) Enumeration of saleable trees c) Sample enumeration of advance growth If no regeneration, felling awaits seed year.
E (year of exploitation)	a) Exploitation b) Formation of a high canopy by girdling and felling.
E+1	a) Tending, clearing, climber cutting b) Second girdling and felling
E+2	a) Tending, clearing, climber cutting where necessary. b) Final girdling if necessary
E+3	a) Tending and climber cutting where necessary
E+6	a) Thinning

*Based on Chengapa (1944); Banerji (1954).

forest management.

Early forestry activities in W. Malaya were expolitive and destructive. Gutta percha (**Palaquium** gutta) trees were felled for their latex, and highly selective logging was carried out for the naturally durable heavy hardwoods, mainly Chengal (Balanocarpus hemii) (Sanger-Davies, 1932b; Barnard, 1954). Smith (1959) estimated that average yields of about 100 cubic feet/acre (9 m^3/ha) were obtained from this type of operation. There were some early attempts at enrichment by strip planting, and Walton (1932a, 1932b) and Oliphant (1932) discuss the relative merits of artificial and N.R.

In 1900, Hill (Wyatt-Smith, 1963a) observed that heavy weeding over a period of time was required for heavy hardwoods. He also noted that N.R. was very good for all except **Palaquium** species and suggested that instead of planting, it would be better to "assist the existing natural regeneration by giving them more light and space". This brought forth the Regeneration Improvement Felling (R.I.F.) Method, the results from which were so convincing that all planting was abandoned in its favour in 1912 (Barnard, 1954). In the 1920s the demand for fuelwood made such operations remunerative and the mining boom, which created a high demand for poles, further enhanced this method. However, it was the degree of demand for the available produce that decided to what extent the work could be carried out at a profit or loss (Watson, 1936).

A review of silvicultural practice in 1926 (Wyatt-Smith, 1963a) revealed that profuse young regeneration of the more valuable species had resulted and the improvement fellings had, in effect, been regeneration fellings (For. Dept. W. Mal., 1972). As a result of this review three classes of operations were distinguished:

1) Departmental Improvement Fellings;

2) Departmental Regeneration Improvement Fellings or R.I.F.;

3) Commercial Regeneration Fellings. (See Table 2.)

The Departmental Improvement Fellings, however, had virtually ceased by 1932 (Hodgson, 1932). The second and third methods had a great deal of similarity with the classical shelterwood systems where the original forest canopy was gradually removed over a period of 8-10 years, during which regeneration was expected to be established (cf. Troup, 1952). Repeated regeneration tendings were given (Blandford, 1929).

The Departmental Regeneration Improvement Fellings involved girdling rather than felling. Girdling helps to reduce damage to the residual stand, deprives climbers of the convenient ladder of a fallen but still strong crown, and slows down the increase of light, thereby giving trees more chance of competing with the more rapidly responding light demanding climbers. The action of girdling may be slow and erratic, hence the introduction of arsenical poison-girdling into Malaya (Sanger-Davies, 1919). The method had been used in Queensland since the turn of

TABLE 2*

SEQUENCE OF OPERATIONS OF THE REGENERATION IMPROVEMENT FELLINGS

MALAYA

YEAR	*OPERATION*	
COMMERCIAL REGENERATION FELLINGS		
n-1	P	Felling of unmarked class 2 poles under 20 cm d. (30cm d)
n	S1	First seeding felling of marked class 2 trees
n+2 or +3	C1	First clearing if necessary
n+4	S2	Second seeding felling of marked class 2 trees
n+5 (n+6 or +7)	C2	Second clearing
n+6 (n+7 or +8)	F	Final felling of marked class 1 trees provided successful regeneration verified in C2
n+7 (n+8 or +9)	C	Clearing after final felling if necessary
DEPARTMENTAL REGENERATION IMPROVEMENT FELLINGS		
n	GC1	First girdling of inferior species and clearing
n+3 or +4	GC2	Second girdling and clearing
about n+5	C3	Clearing if necessary
about n+7		

*Based on Durant (1937a) and Wyatt Smith (1963a) (modifications - Hodgson (1932).

the century (Dawkins, 1958a), and by the 1930s Malaya came to realise that here was the tool for all systems of rain forest improvement (e.g. refining, liberation thinning, etc.) (Strugnell, 1934, 1937, 1947; Durant, 1936a).

Another development during the 1930s was based on the need for some form of sampling (Edwards, 1931; Shrubshall, 1934; Watson, 1934; Walton, 1936) or a "prognosis as a guide to treatment instead of empiricism in treatment followed by a survey of results" (Oliphant, 1932, in Wyatt-Smith, 1963a). Linear sampling using milliacre quadrats was introduced in 1935 as a guide to clearing treatments and to the desirability of carrying out final felling. It became widely used in determining the extent and nature of desirable regeneration (Browne, 1936). Large scale surveys and inventories were also carried out during this period (e.g. Edwards, 1930; Browne, 1934; Strugnell, 1936, 1941; Noakes, 1937; Sanger-Davies, 1937; Landon, 1940). Suggestions for other forms of silvicultural treatment were occasionally voiced (Somerville, 1932; Durant, 1936b, 1937a, 1937b; Oliphant, 1937a, 1937b; Arnot and Landon, 1937).

In other parts of the Indo-Malaysian region T.R.F. management was also having its beginning. The earliest silvicultural work in Queensland T.R.F. occurred shortly before the 1914-18 War when attempts were made at inducing regeneration of Toona and at the enrichment planting of the same species. During the War further work was carried out, and open plantations of Toona, Agathis palmerstoni

and Araucaria cunninghamii were commenced. From 1918-24 emphasis was placed on inducing regeneration of Toona, Flindersia brayleyana and Cardwellia. Despite successful results, it was considered that the efforts at inducing fresh regeneration were a "costly affair" (Swain in Baur, 1964a). Proposals similar to the Malayan R.I.F. system were made but the treatment was never applied in the form suggested. Enrichment planting and the establishment of plantations became prevalent again with some of the former producing excellent results (Volck, 1960).

In the British Solomon Island Protectorate where the problems of managing mixed stands appeared insurmountable, artificial regeneration in the form of line planting was being used along with selective logging - "creaming" (Walter, 1948). In Indonesia, T.R.F. areas were being planted with teak and other species. The yield tables produced at the time by van Wulfing show four species reaching 20 tonnes per hectare per year on first quality sites (Champion, 1934; van Wulfing, 1938; Wadsworth, 1938). Whether such results were due to the extremely rich volcanic soils or the plantations being grown at higher-than-lowland altitudes is not clear (Dawkins, pers. comm.).

In Africa, early commercial cuttings were, as elsewhere, generally selective in character. The few economically valuable trees per unit area were removed without much or any concern for the condition and quality of the residual stand. Aubréville (1947, 1949) and Shantz (1948) have

repeatedly emphasised the inevitable resulting impoverishment of African rain-forest, and in fact the forest exploitation as generally practiced was the very opposite of the fellings required by a true selection system. It was originally thought that Nigeria's rain-forest would be self-perpetuating and could easily and economically be worked on a selection basis. On those principles concessions were granted in the Benin area based on the simplest of working plans prescribing a 100 year felling cycle with a minimum girth limit (100 cm d.) (Kio, 1978). It was ultimately realised that these were over-mature forests with an absence of younger age classes (Mildbraed, 1930; Richards, 1939; Jones, 1955, 1956). Various research plots using N.R. methods were established (MacGregor, 1934; Kennedy, 1928, 1935; Lamb, 1940, 1941; Nichol, 1940). Those adapted from the European uniform systems were relatively successful and showed that natural regeneration could be obtained and made to grow with the control of light (Roseveare and Lancaster, 1952; Lancaster, 1961). However, in 1939, the Chief Conservator in British Nigeria noted that "artificial regeneration has been the tradition in the Southern Provinces, and natural regeneration has never gained much favour as a method of renewing forests" (Rosevear, 1947).

As the timber industry was highly selective and concentrated on a few species - the Meliaceae - which found ready markets overseas, economic species were therefore very few, the vast bulk of the trees being unsaleable,

posing the silviculturist with an almost insoluble problem. The main aim of the foresters was, therefore, to provide a routine technique that was, above all, practicable - one that, seeking moderate results at a low outlay, made no pretence at silvicultural perfection, but was within the capabilities of an illiterate labour force working with very little skilled supervision (Jones, 1950). This situation made the technique difficult to criticise, for all suggestions had to be tested both for their practicability and their economic value, and the administration was the final judge of what they could do and what they could spend.

The presence of a number of experienced forest officers from Malaysia, who were serving in Nigeria during the Second World War, helped to formulate the prescriptions of the Tropical Shelterwood System (T.S.S.). The aim of T.S.S. was to produce a more or less even-aged forest by establishing a pole crop of economic species before logging. In this method, the commercial exploitation may be regarded as equivalent to a final felling in the European compartment shelterwood system, but there would rarely have been complete removal of the old stand; individuals of valuable species that were too small to be exploited and also some large trees of unwanted species that were too difficult to girdle would usually have been left standing (Troup, 1952). The main features of the method can be seen in Table 3 and were based largely on Malayan techniques (Jones, 1950; Lancaster, 1961; Baur, 1964a; Anon, 1971). Along with the adoption of T.S.S. was another significant development in

TABLE 3*

SEQUENCES OF OPERATIONS OF THE TROPICAL SHELTERWOOD SYSTEM

NIGERIA

YEAR	*OPERATION*
E-5	a) 1st climber cutting and tending b) 1st poisoning
E-4	a) 2ndclimber cutting and regeneration count b) 2nd poisoning
E-3	a) 1st clearing and tending b) 2nd clearing
E-2	a) 3rd clearing b) 4th clearing and 2nd regeneration count
E-1	a) 5th clearing
E	a) Exploitation b) Repair of exploitation damage
E+1	a) 6th clearing and 34d regeneration count
E+6 or up to E+10	a) 7th clearing b) Removal of overwood c) 4th regeneration count

100 year rotation

* Based on Rosevear and Lancaster (1952); Barnard (1955) and Baur (1964a).

the decision to introduce systematic and orderly working of the forests by the concession holders (Rosevear, 1947). This decision was an essential pre-requisite to the application of T.S.S., and at the same time it converted the picture of forest operations in the rain-forests from one of exploitation in its worst sense, to one where the aim of most managers of production forests, sustained yield management, became feasible.

In Ghana, T.R.F. management was similar to that of Nigeria in the first half of this century. Logging was highly selective (Foggie et al., 1952; Foggie, 1953), and enrichment and open planations were established (Haig et al., 1958). T.S.S. was first tried in 1945 and adopted the original form used in Nigeria. Various modifications were made to the method to produce varying canopy intensities to aid regeneration of desirable species (Taylor, 1954, 1962; Lane, 1958) (see Table 4). T.S.S. was only applied to those forests with a moderately normal structure and sufficient seed trees to provide the regeneration. Several factors, however, including costs, led to the adaption of more extensive refining treatment where the stocking of desirable species was satisfactory, and planting where it was not (discussed in next section).

Prior to 1952, the majority of work in Ugandan T.R.F. consisted of group, line and occasional close planting of exploited forest mostly of the enrichment type, but more intensive over limited areas. Early work using N.R. methods had largely failed (Harris, 1934; Eggeling, 1940,

TABLE 4*

SEQUENCE OF OPERATIONS OF THE TROPICAL SHELTERWOOD SYSTEM

GHANA

YEAR	*OPERATION*
E-5	a) Climber cutting b) Poison girdling or cutting all useless stems up to 10 cm d.
E-4	a) Poison girdle all large crown trees in lower storeys
E-3, E-2, E-1	a) Annual clearings and one regeneration count
E	a) Exploitation
E+1	a) Clearing and repairing damaged regeneration b) Regeneration count
E+4	a) Climber cutting

*Based on Taylor (1954) and Lane (1958).

1947a, 1947b, 1952; Philip, 1961; Anon, 1971). However, during the late 1940s evidence from enumerations showed promising quantities of N.R. and further research plots were established (Brasnett, 1940; Philip, 1965). In some areas a girth-limit system, based on Brandis-type selection and possibly best described as a Stratified Uniform System was practised aimed at creating a forest stratified into two or more age classes. The development of the monocyclic N.R. system practised in Uganda from the early 1950s will be discussed in the next section.

Methods of artificial regeneration, either in the form of enrichment plantings in lines, bands, blocks, groups, etc., or replacement of the forest by pure planations were the main attention of silviculture in West Africa. Attempts were made as early as 1905-6 by German and British foresters in the region, some 20 years ahead of their French and Belgium colleagues, to secure the planting of seedlings to replace trees felled. British attempts at enrichment planting were often failures due to insufficient opening of the canopy and it was the French and Belgian foresters who perfected the technique. In the 1920s in French Africa, and in the 1930s in the Belgian Congo, the marked emphasis on artificial regeneration led to extensive trials of forest enrichment by planting en layons (Letourneux, 1956; Donis, 1958; Haig et al., 1958; Humblet, 1958). On the French island of Reunion, enrichment planting was also practised but by the rare method of directly sowing seed (Miguet, 1955).

However, T.R.F. management in W. Africa was not solely artificial. Research into N.R. was carried out in the Congo by the agricultural research organisation (INEAC) at Luki (Donis, 1958). It was here that Donis and Maudoux (1951) developed the technique termed 'L'uniformisation par le haut'. The method was essentially a weeding on a grand scale, designed to remove all climbers and canopy weeds and such understorey weeds as were not considered of silvicultural value, for the benefit of the younger age-classes, which otherwise suffered chronic suppression (Hombert, 1954; Dawkins, 1955a). In French Africa, the complexity of the problem of T.R.F. management was shown by the contrasting veiws and the wide scope of investigations and large-scale trials undertaken (Chévalier, 1948; Morellet, 1952; Aubréville, 1954; Donay, 1954; Foury, 1956; Bergeroo-Campagne, 1957). In the Côte d'Ivoire, the growing appreciation of some of the difficulties of tending planted strips and other forms of artificial regeneration revived interest in natural regeneration (Bergeroo-Campagne, 1957). The importance of inventories needed to show the existence of established seedlings by both number and distribution was also recognised (Donay, 1954).

Although the major developments in T.R.F. management during 1900-1950 occurred in Malaysia and Africa, some investigations were occurring in South America and the Caribbean. Methods in Trinidad were the most advanced due to good markets, infrastructure (roads), funds (from oil) and a succession of research-minded foresters, although work was

also going on in British Honduras, Guyana, Puerto Rico, Grenada, Dominican Republic and Jamaica. As in Africa and Asia, commercial cutting followed the pattern of logger selection (creaming), removing the few and scattered valuable trees per unit area, with no attempt at silvicultural control or management other than the establishment of minimum girth-limits for some forests and areas. The attempts to understand the silvical and silvicultural characteristics of leading species and forest types will be more fully discussed in the following section.

CHAPTER 4

PANTROPICAL EXPLOITIVE PHASE 1950-1980

The early years of this phase were probably the most important in T.R.F. management. A number of things happened around the same short period following the Second World War. Basically, the necessary use of mechanised extraction methods, and the rising demand for a greater range of species combined to produce pressure for heavier exploitation in a single, more profitable operation. Prior to the War, elephant, buffalo, horse and manpower were widely used in exploitation (Webb, 1950; Smythies, 1951, 1952; Cernak and Lloyd, 1962; Martyn, 1966a; FAO, 1967; Whitmore and Ho, 1968; Dept. of Op. Eff. 1970). Afterwards, the same work was done more effectively by crawler tractors as they allowed faster extraction and larger loads. The rise in demand for a greater range of tree species was due to a change in fashion. Lighter woods, both in colour and weight, became acceptable to timber merchants especially in

the developed markets of Europe and the U.S.A., and in the developing tropical markets. An interesting phenomenon of this was the rise of Triplochiton scleroxylon from obscurity to fame in Ghana. Whereas in the five years 1934-1938 the average annual cut was 1.3 million cubic feet, by 1947 it was 6.2 and by 1957 47 million cubic feet. It has fluctuated between this and 60 million cubic feet since then (Anon, 1971). Although demand for heavy, dark durable hardwoods (e.g. Khaya, Entandrophragma, Balanocarpus, Afrormosia, Cynometra, Ocotea, Mora and Erythrophleum) continued, it was the new acceptability of many light hardwoods that pushed T.R.F. management forward. Also this period saw T.R.F. develop in the S. American mainland T.R.F. region (areas such as Belize (Br. Honduras) and various Caribbean islands having been exploited since the 18th century), so that all the world's T.R.F. areas were under some form of exploitation - hence Pan-tropical exploitive.

The Asian Region

Probably the countries that were most influenced by these changes were Malaysia, Nigeria and Ghana. As an example, it was estimated that virgin Malayan rain-forest carried some 360 m^3/ha. of stemwood and at the start of the century only 9 m^3/ha. were being extracted (Smith, 1959). By 1960, logging yields were averaging 75 m^3/ha. (Vincent, 1960). During the early 1950s a monocyclic method known as the Malayan Uniform System (M.U.S.) was developed for management of the T.R.F. of Peninsula Malaya. Ecological and economic reasons resulted in a shift of

silvicultural operations from pre-treatment and a series of fellings (R.I.F.) to one of a single felling and post-treatment. The M.U.S. has been defined as a "clear felling release of selected natural regeneration" (Cousens, 1957).

The M.U.S. was partially the result of observation of untended clear-fellings made during the Japanese occupation and of suspected storm forest in the natural T.R.F. (Walton, 1947 ; Strugnell, 1947; Browne, 1949; Barnard, 1950a; Collier, 1952; Walton et al., 1952). This confirmed that advance seedling regeneration, present on the ground at the time fellings occurred, would survive undamaged, develop rapidly, and even grow through to crop dominance without assistance, while slower growing 'economic species' survive as sub-dominants. The slower growing, heavier hardwoods were to be given additional and more intensive care. The objective of management was an even-aged (though two or more storied) forest with a high proportion of the best quality indigenous timber species. This type of system seems to be what Hodgson (1934) was advocating in the mid-1930s when he stated, "the most successful method, according to present indications, being the least conservative". Table 5 shows the series of operations involved in the M.U.S.

The success of the system depended on four essentials: 1) adequate stocking of seedlings of economic species at the time of exploitation; 2) complete removal of the canopy; 3) no tending until the regrowth has passed the ephemeral climber-stage and is relative clear below ('sticket' stage);

TABLE 5*

SEQUENCE OF OPERATIONS OF THE MALAYAN UNIFORM SYSTEM. MALAYA.

YEAR	*OPERATION*
E-?	a) Felling of poles of non-timber species allowed up to 1 m girth at any time b) Treatment of areas heavily infested with bamboo, Bertam, climbers
E-2	a) Climber cutting
E-1	a) Milliacre sampling of regeneration b) Enumeration of saleable trees
E	a) Exploitation b) Poison girdling unwanted trees down to 15cm d. c) Repair of damaged regeneration
E+5	a) Quarter chainsquare regeneration sampling b) Clearing and tending as necessary
E+9	a) Half chainsquare regeneration sampling b) Thinning and treatment as necessary

70 year rotation.

*Based on Barnard (1950a) and (1955).

4) maintenance of adequate new canopy to prevent the redevelopment of climbers (Barnard, 1954; Landon, 1955; Wyatt-Smith, 1959a). In order to establish the adequacy of initial stocking of regeneration, and subsequently to determine the need for and nature of treatment in the developing regrowth, periodic sampling of the regeneration had to be carried out, using linear sampling with quadrat size varied according to stage of development of the new crop (LSM - milliacre; LS ¼ chain-square; LS ½ chain square) (Barnard, 1950b based on work done by Landon; Wyatt-Smith et al., 1958; Wyatt-Smith, 1959b).

Not all the lowland forest areas could be managed using M.U.S. Some areas which had been felled during the Japanese occupation were subsequently used to cultivate temporary food crops due to a food shortage after the War. The forest/farmland was later abandoned and the sites were colonised by 'belukar' (e.g. Imperata cylindrica ('lalang'), Melastroma, Eupatorium, bamboos, etc.). As natural succession would take too long to produce a commercial timber crop, enrichment planting with fast-growing 'meranti' species was suggested (Wyatt-Smith, 1949). Problems arose in line planting so spaced-group planting was suggested following Anderson's (1951) group planting experiments (Ironside, 1954). Similar methods were tried in areas not endowed with abundant N.R. and thus unmanageable by M.U.S.

Between the early 1950s and 1960s, the M.U.S. was modified in various ways, mostly in a relatively minor way, in the light of experience gained during the period. Malaya

was extremely fortunate that most of the economic species of the period regenerated fairly freely, and that the natural forests in the region had a one family predominance (Dipterocarpaceae) of large trees of which the majority of species had valuable timber easily grouped for marketing into relatively few grades (Shorea leprosula, S. parvifolia).

During this period and up to the present day experiments and trials were carried out with poison-girdling using various chemicals (e.g. sodium arsenite, 2, 4, 5-T, 2, 4-D). These trials were not just restricted to unwanted trees but also shrubs. Bertam palm (Eugeissona triste) and various bamboo species were and are a major problem in some of Peninsula Malaya's forest areas (Beveridge, 1957; Wong, 1959, 1966; Wyatt-Smith, 1959c, 1960, 1961a, 1961b, 1963b; Watson and Wyatt-Smith, 1961; Liew, 1973; Liew and Charrington, 1972).

In the early 1960's attention was focussed on methods of assessing regenerated T.R.F., in particular methods of studying the development of regenerated forest in its later stages and the treatment, if any, that would be necessary, practical, and economic (Wyatt-Smith, 1959a, 1959b). Wyatt-Smith and Vincent (1963) introduced a new linear sampling technique based on standard LS½, called Linear Sampling of Regenerated forest (LSR) which provided the required diagnostic tool in regenerated stands. Techniques of quantitative assessment of parameters were also defined, in some cases modified from techniques used elsewhere in the tropics, such as Uganda (Wyatt-Smith and Vincent, 1962).

Treatments considered in regenerated forest included intermediate fellings or liberation thinnings, which were considered possible using a high minimum felling girth limit and contractors who were careful, conscientious, and had a reliable work force (Wyatt-Smith and Bin Sudin, 1961; Wyatt-Smith, 1963c).

Also research was undertaken to determine the existence of lowland evergreen rain-forest of any distinct associations, since these may have required modified treatment as may have been the case with the recognised **Dryobalanops** aromatica consociation (Wyatt-Smith, 1959d). At this time too there was discussion on basing yield control on volume rather than on the rather coarse control by area method (Vincent, 1961; Wyatt-Smith, 1962). It was felt that the enumeration technique of inventories would have to be improved to include defect, etc., (Vincent, 1961). Work done by Cousens (1957, 1958) was of great use, but his sampling scheme was such as to only include the principal sawlog species and was therefore conservative.

Forestry was not confined to Peninsula Malaysia, but was also developing in East Malaysia - Sabah and Sarawak. In Sabah where dipterocarps form a larger portion of the big trees, felling opened the forest more than in Pen. Malaya. Parashorea species, also light demanders, were very important as well as Shorrea spp. As evidence showed that there was nearly always adequate seedlings present on the forest floor, the M.U.S. was applied with good results - especially if the forest was virgin before logging (Nicholson, 1958a,

1965a; Burgess, 1961; Cousens, 1965; Martyn, 1966b; Meijer, 1970; Wong, 1973). This followed the R.I.F. methods which were applied prior to 1955 (Fox, 1968a). Further investigations and trials and, with the pressure for increased, utilisation, a formal code of practice providing for a sequence of operations was introduced (Fox and Hepburn, 1972; Fox, 1972). (See Table 6.) The M.U.S. had become modified to become a minimum girth limit system (Stratified Uniform System, M.U.S. (modified)), but retained the principles of M.U.S. following recommendations by Dawkins (1968) (Chai and Udarbe, 1977; Munang, 1978, 1979).

Similar developments have occurred in Sarawak and Brunei (Ashton, 1964; Lau, 1978; Chai, 1979; Hutchinson, 1979). Investigations were also undertaken to find better ways of defining regeneration stocking adequacy standards in sampling and to define appropriate silvicultural treatments for individual forest classes (Seng, 1973; Tang, 1978; Smith, 1978).

The mangrove areas of both Sabah and Sarawak have also been exploited and regeneration methods investigated (Chai, 1974; Liew et al., 1975).

Logging damage was and still is a major concern in the T.R.F. (Leong, 1978). Much discussion has occurred with reference to the Malaysian situation but aspects of the problem have been discussed earlier (Part 1, Chapter 4) (Brown, 1950; Walton, 1954; Nicholson, 1958b, 1963; Wyatt-Smith and Foenander, 1962; Fox, 1968c, 1968d, 1969a). It was partly due to the damage done to the residual stand

TABLE 6*

SEQUENCE OF OPERATIONS OF MALAYAN UNIFORM SYSTEM (MODIFIED)

SABAH

YEAR	*OPERATION*
E-2 - E-1	1st silvicultural treatment - climber cutting and protective marking
E	Exploitation
E+0-1 month	Clearance inspection
E+0-2 months	Assessment of regeneration
E+3-6 months	2nd silvicultural treatment - poison girdling of unwanted and defective stems, climber cutting if necessary
E+10 or +15	3rd silvicultural treatment - following regeneration assessment - poison girdling, climber cutting and tending as necessary

*Based on Fox (1972) and Fox and Hepburn (1972).

that led to the change in Sabah's silvicultural treatment following Dawkins' (1968) report (Albazo and Corpuz, 1969; Liew, 1973a).

During the late 1960s and early 1970s, Government Land Development Programmes (Lee, 1974a) caused the destruction of many choice forest fertile lowland sites so as to be converted from forest to agriculture. Forest management was thus displaced to the hill forests and lowland forests on poor sites. It is these areas from which the main bulk of the country's future timber resources will have to be derived. M.U.S. is not successful in such areas due to the lack of seedlings in virgin stands, heavy seedling mortality due to felling damage on steep slopes, and poor visibility of Shorea curtisii which is the main commercial species (Burgess, 1968, 1971). It has been suggested that the Tropical Shelterwood System is possibly the only system applicable to the hill forests (For. Dept. W. Mal., 1972), but at present the method is economically unworkable. (Dawkins (pers. comm.) believes that due to the precipitous nature of most of the Malayan mainland hills, the first (final) fellings would remove all the soil, and therefore he doubts that any system other than pure plantation has any chance, and that for only one rotation.) Enrichment planting has also been suggested, especially in particularly poor forest sites (Haji, 1964; Lall Singh Gill, 1970; Haji Ghazali et al, 1972; Tang and Wadley, 1974; Chai, 1975). However much research has been done in trying to identify silvicultural methods which will be successful

in hill forests (Burgess, 1968, 1970, 1972, 1973; Tang, 1974, 1980; Burgess and Tang, 1972; Lall Singh Gill et al., 1968). Burgess (1970) has emphasised that a silvicultural system for forests in so complex an environment as the hills of Malaysia can do no more than lay down the general guidelines, and that it must be executed with care and intelligence by officers who really understand the principles upon which it is based (see Table 7). The Bertam palm (Wong, 1959) is a major weed problem in the hill forests and a lot of research has been done on methods for its control or eradication (Chong, 1970; Burgess and Lowe, 1971).

F.A.O. has been assisting Malaysia in their forest development (e.g. F.A.O., 1970, 1973, 1974c), and they too have been involved in silviculture and management. At present interest is in selective silvicultural methods (Cheah, 1978; Makmud, 1979) and in particular liberation thinnings have been researched, showing good results in Sarawak (Hutchinson, 1977, 1979, 1980; Laursen, 1977; Korsgaard, 1981). They are being investigated because the M.U.S. (classical or modified) is inappropriate in hill forests, but also because of an increasing anti-poisoning attitude. This has led to growing interest in adopting a polycyclic system of felling where only the over-mature trees of commercial species are felled first leaving the less desirable species for future fellings and to promote faster growth of immature stems. Some of the problems of economically viable logging and damage to the residual stand are not resolved as yet (Lee, 1974; Cheah, 1978).

TABLE 7*

SUGGESTED SILVICULTURAL SYSTEMS FOR STEEP LOWLAND FORESTS, HILL DIPTEROCARP FORESTS AND UPPER DIPTEROCARP FORESTS

MALAYSIA

* Based on Burgess (1970).

	YEAR	*OPERATION*
MID-SLOPE FORESTS	E-1	a) Poison bamboo
	E	a) LSM (intensive) immediately before exploitation b) Exploitation to 1.2 m girth c) Girdle unwanted trees to 30 cm girth, retaining relic Dipterocarp trees
	E+5 (and after next seed yr.)	a) Regeneration assessment - LS½ (all sizes) b) If regeneration adequate, girdle Dipterocarp relics c) If regeneration is inadequate, enrichment plant and tend
SERAYA-RIDGE FORESTS (*Shorea laevis* and *S. faguetia*)	E-1	a) Poison bertam
	E	a) Visual assessment of regeneration or LSM (intensive) immediately before exploitation b) Exploitation to 1.5 m girth, retain proportion of stand if necessary
	E+2	a) Girdle unwanted or defective trees to 1 m girth
	E+7	a) Regeneration sample - LS½ (all sizes) b) Regeneration adequate, girdle to 30 cm girth c) If regeneration is inadequate, enrich and girdle, tend

Precipitous forests - no exploitation or treatment (slopes 45°).

Marginal or non-commercial forests: a) Enumerate stand and regeneration (LSM extensive); b) Regeneration fair and good log market - exploit to 1.2 m girth and enrich; c) Regeneration inadequate and poor stand - replace by compensatory plantation.

A comprehensive forest management development programme has been implemented in Malaysia with the object of evolving optimum forest management regimes as well as sound forest management and operational plans to ensure that sustained maximum economic and social benefits materialise (Mok, 1977). Unfortunately, the benefits of current forest management strategies and practices tend to be offset by excessive wastage of the forest resource and serious damage to the residual forest, thus undermining the concept of sustained yield. Malaysian forestry is now in a major state of flux as it tries to bring the hill forests under management control. Ideas of socio-economic development, sustained availability of resources, and conservation are being voiced, and the recognition of specific problems in forest management (e.g. lack of manpower, technical skill, and scientific knowledge) (Fox, 1970; Tang, 1976) suggest to the author that a period of reassessment is taking place (Ismail, 1964; Lee, 1974b; Meijer, 1974a; Synnot, 1976; Manan, 1978; Chan and Liew, 1978; Whitmore, 1978; Lau, 1979; Saad, 1979). Possibly this is a new phase in T.R.F. management in the country.

As in Malaysia, the dipterocarps are the most important group of timber trees present, and are estimated to take up 75% of the standing timber volume in the Philippines, in all types of forest (Baur, 1964a). Past silvicultural work in the Philippine rain-forests have been limited, although since 1953 the emphasis on management has been selection felling relying on stocking of intermediate size to provide the timber for subsequent fellings without assistance (Serevo, 1949, 1955; Egerton, 1953; Walton, 1954; Tagudar, 1966;

Bureau of For., 1965). The Philippines became committed to polycyclic felling partly through a misunderstanding of the M.U.S. (Fontaine et al., 1978). Unfortunately, the theoretical basis of the "Handbook on Selective Logging" (Bureau of For., 1965) is rather weak and has been criticised by Fox (1967), Nicholson (1970) has made various suggestions for improvements and he believes that the dipterocarp forest, in all the climatic regions of the Philippines, can probably sustain a 30-45 year felling cycle provided that the prescribed management is carried out, which is not what happens at present. However, there are indications that the forest is rich enough in desirable species to tolerate considerable maltreatment, especially as fast growing dipterocarps seem to be able to regenerate healthy crowns provided that at least half of the original crown was left undamaged at the time of logging (Raiz, 1968; Chinte, 1970, 1972).

The selection system as practised in the Philippines basically involves three phases: tree marking, residual inventory, and timber stand improvement (T.S.I.) (Reyes and Tagudar, 1963; Mauricio, 1967; Utleg and Reyes, 1967; Castillo, 1973; Faustino and Bascug, 1977; Blanche, 1978). This system, however, will not be successful in all Philippine T.R.F.s. There are stands in the forests which are not rich in medium sized advance growth, for example, in areas liable to typhoon damage (parts of Samar and Negros), where large felling cycles may be necessary and relying on seedling advance regeneration like the M.U.S.

One worry the author has about the system is that as it is a girth limit system rather than true selective, it may well prove to be dysgenic and lead to a deterioration of the forests (cf. Gulcur, 1967).

However, there does seem to be some indication that true selection felling may be initiated in the Philippines or a bicyclic system similar to Malaysia, following studies by Reyes (1979), Tomboc and Bruzon (1979), Chinte (1980) and Torres-Uriarte (1980). Like Malaysia, the Philippines now seems to be entering a phase of re-appraisal. Numerous authors have written papers on problems in Philippine forestry: ecological and environmental aspects, multiple use of forests, social and economic development, sustained yield, etc. (Mendoza, 1979, 1980a, 1980b; Rosario, 1979; Esteban, 1980/81; Doó, 1980). This development is particularly encouraging at a time when the forests are under an accelerated demand for wood by the booming forest industries, aggravated by the conversion of more forest land to agriculture (Virtucio and Torres, 1978).

Australia, or more accurately Queensland, also uses an irregular system to manage its T.R.F. Logging is carried out on a minimum girth limit system, but tries to avoid dysgenic effects by a method of all-size thinning which leaves only a limited number of trees/ha. in each size class. Provided those left are the most vigorous in appearance it would seem that the forest can hardly fail to improve (Haley, 1954; Baur, 1964b). The initial treatment rules became effective in 1946 and were largely stand improvement

treatments following logging. Rules introduced in 1954 were considerably more detailed, a particular difference being the introduction of tree marking. (See Table 8.)

Research undertaken during this period has shown good results and trials involving underplanting with the most valuable cabinet woods have been successful. Results of trials with the T.S.S. have also proved useful (Haley, 1954; Volck, 1968, 1975).

The point that Queensland is probably better staffed and markets better organised than most other tropical territories has favoured the development of the selection method. However, there are problems involved in polycyclic systems - the main one being damage to the residual stand. Damage studies have been undertaken (Gilmour, 1971; Queensland Dept. For., 1977) and methods suggested and implemented to reduce residual stand damage as well as environmental damage caused by roading, etc. (Jessop, 1978; Evans, pers. comm.). Along with paying more attention to environmental concerns, T.R.F. in Queensland is now undergoing a changing role as timber production finds itself classified along with protection, recreation, and conservation in importance (Cassells and Gilmour, 1978). Compensatory plantations are in the investigation phase (Bragg, 1979). Again, this suggests the start of another phase in T.R.F. management. As management so far has really only been used in localised studies, it is difficult to assess the selection system as a whole, because it may not be so applicable if used on a larger scale. This will be something

TABLE 8*

SEQUENCE OF OPERATIONS OF NORTH QUEENSLAND SELECTION SYSTEM

YEAR	*OPERATION*
E-1	a) Climber cutting and clearing b) Eradication of any seedlings/shrubs of Laportea moroides c) Tree marking but aiming to k) retain any oversize stems of more desirable species for seed where the existing regeneration stocking is low, ii) remove any undersize stems of poor form or vigour, and iii) to thin any dense patches of undersized trees
E	a) Exploitation of marked stems b) Further eradication of L. moroides c) Removal of useless stems and, where necessary, to favour potentially more valuable stems, of stems of the less desirable species d) Soil treatment where regeneration is scarce, but seed trees present; enrich where seed trees also scarce
E+3 or 4	a) Liberation/refining

Cutting cycle 15-20 years.

*Based on Baur (1964b).

for consideration and study in the future.

The main commercial rain-forest stands in Indonesia are in Sumatra and Kalimantan, and as in otherparts of S.E. Asia, dipterocarps are the main timber species. Management of the T.R.F. has been slow developing, but since 1972 there have been three systems, two of which involve N.R.: the Indonesian Selective System (Tebong Pilih Indonesia), and clear felling with natural regeneration (Anon, 1973; Daryadi, 1978; Sudioni and Daryadi, 1978). In practice the silvicultural systems and other aspects concerning forest utilisation based on the sustained and optimum yield principles are still very far from being properly implemented. This is largely as a result of lack of equipment and budget for control in the field and, from the concessionaries' side, refusal to follow the regeneration. Meijer (1974b) has criticised the indiscriminate granting of felling licenses and concessions stating, "Even a colonial government would never have dared to sell out so much of its resources to foreign timber interests".

Damage from logging is commonplace (Hamzah, 1978; Soerianegara, 1978a; Sudiono and Daryadi, 1978; Tinual, 1978) and areas that, prior to exploitation, had sufficient regeneration of exportable and commercial species are often found inadequately stocked following exploitation. However, research is going ahead into this problem and monitoring studies have been established to help to interpret the ecology of the rain-forest (Soerianegara, 1978b, Sastrosumarto, 1978; Soekotjo and Dickman, 1978; Riswan, 1979;

Kartawinata et al.,1981). Although exploitation is going on over large areas in Indonesia, a period is emerging where environmental considerations and a better understanding of the T.R.F. ecosystem is being attained due to research and the UNESCO Man and the Biosphere programme (MAB). Despite the population pressures on some islands (e.g. Java), Indonesia has indicated a figure of 10% of the land area to be established as nature reserves (Poore, pers. comm.) - whether they attain this degree of designation is yet to be seen. However, this does seem to indicate a fifth phase in T.R.F. management.

Until 1940, the impact of forests for timber was of no significance in Papua New Guinea, in comparison to the areas converted to agricultural plantations. Exports of timber were non-existent until nearly the beginning of the Second World War, when a small log trade of some 7-8 thousand m^3/year was built up (White, 1975). The war years stimulated a local demand for timber and this demand increased rapidly during the post-war reconstruction and development programme. Selective logging was practised in which a few valuable species of large size were harvested up to 1963 (e.g. Pometia tomentosa; P. pinnata; Dracontomelum puberculum (magiferum)) (Davidson, 1976a). In submontane areas, once logging had occurred direct conversion to plantation was initiated using Araucaria cunninghamii and to a lesser extent A. hunsteinii It is these submontane areas of Araucaria forest and Nothofagus forest which are the territory's most valuable forests (Havel, 1971; Gray, 1975; Elliott, 1977, pers. comm.). In the lowland T.R.F.s it was felt that there was neither an adequate age

class distribution of advance growth of suitable species, nor a sufficient quantity of these species in the regeneration phase to allow N.R. techniques to be used on their own for wood production purposes (White, 1976b). Consequently, enrichment planting following a girth limit selective logging or a timber stand improvement treatment is advocated (White, 1976b, 1977).

Really the only N.R. silviculture practised in New Guinea, on New Britain around Kerwat, uses a system similar to the M.U.S. principally to regenerate Terminalia spp., Pterocarpus indicus, Pometia spp. and Dracontomelum spp. (Morel, 1967). However, at the 9th World Forestry Conference, New Guinea reported two instances of the successful use of N.R. (Dept. For. P.N.G., 1968) but, by 1972 both areas had gone: one to fire, the other to squatters. The problem of land tenure is a continuing one in this country (as it is in Indonesia).

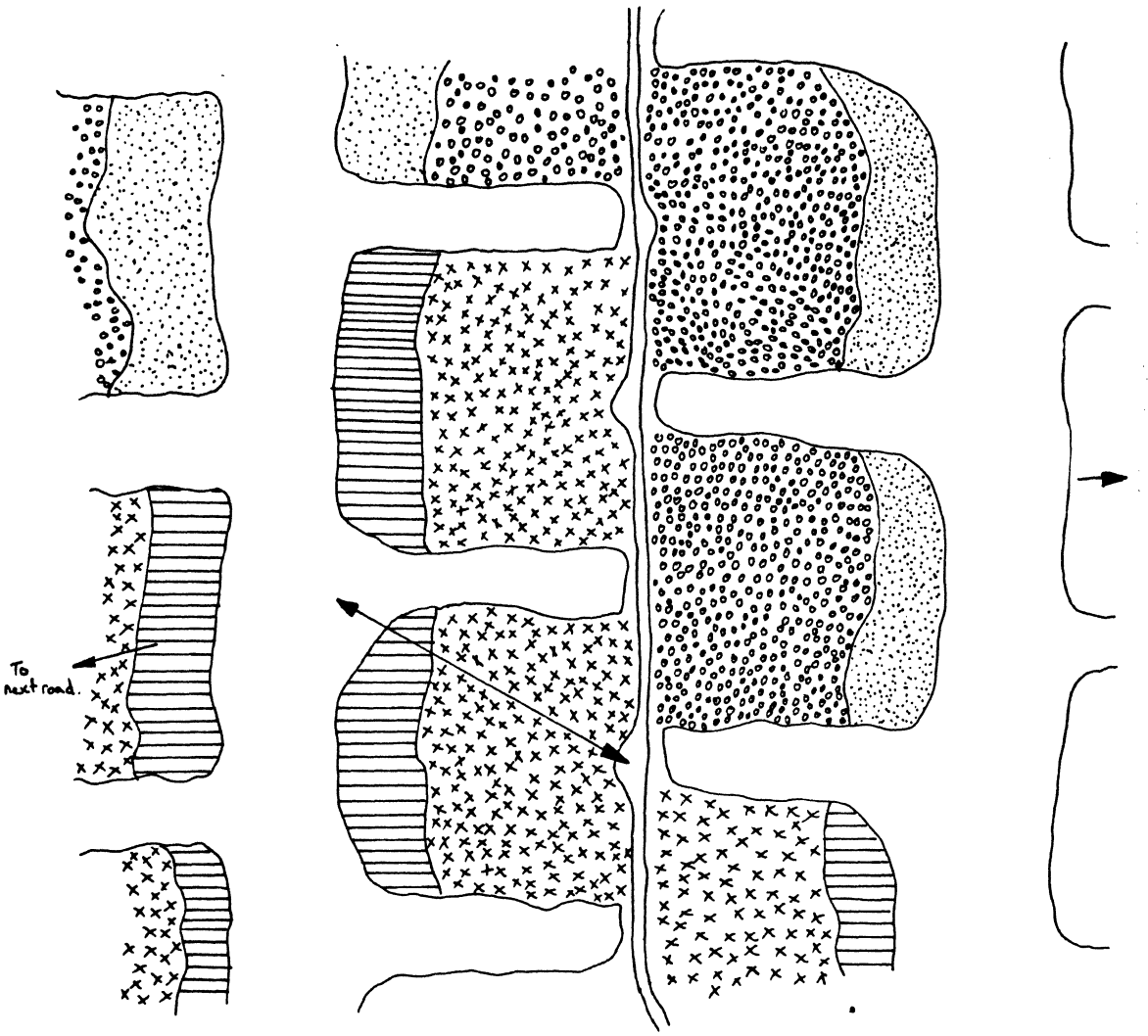
Problems of damage done to the residual stand during selective logging is common in P.N.G. and their effect on the future crop as well as other environmental and social issues (e.g. damage to soil, increased run-off, flooding, etc.) have been and are being investigated (Nagle, 1976; Webb, 1977; Edwards, 1977; Edwards and Grubb, 1977; Dun and Fenton, 1974; Evans, pers. comm.). Nagle (1976) has proposed a system termed a 'mixed cover' strategy for harvesting the T.R.F., which he suggested offers the potential for a more stable social and environmental strategy of logging in the forest than does the strategy of massive clear-cutting and

replacement with plantations (White, 1977). The objective of the mixed cover strategy was to outline a pattern of clear-cut settings interspersed with residual T.R.F. which had been selectively logged, but retains most of its protective value for soil, water and wildlife (see Figure 3). These investigations into more judicious and conservational exploitation of the T.R.F. support the author's suggestion of a new phase in T.R.F. management.

The Solomon Islands is continuing its programme of selective logging followed by enrichment planting with such species as Campnosperma brevipetiolata, Terminalia spp., and Swietenia macrophylla (Self and Trenaman, 1972; Thomson, 1980; G. Chaplin, pers. comm.; Kemp, pers. comm.). It is understood that the Forestry Division has considered the merits of N.R. compared with planting but that available evidence on growth rates (Whitmore, 1974), species composition and density, is discouraging. Furthermore, the problem of logging damage and soil disturbance due to tractor movement (Webb, 1973, 1974; Marten, 1973) and the Merremia weed problem (Terry, 1981) does not increase the chances of N.R. methods being successful. This is supported by studies in Vanuatu where Johnson (1971) described a stand of Agathis obtusa as generally having sufficient seedlings "to probably maintain the species in its present abundance". When exploitation commenced it was considered so destructive that there was no chance of regeneration and erosion was being encouraged. Research has been and is being done into reducing the effect of logging damage on soil properties and

FIGURE 3.

SKETCH MAP OF "MIXED LOGGING" PATTERN.



LEGEND

Selectively logged up to 25% of volume.

Logged up to 50% of volume ..... underplanted.

Clear cut ..... replanted.

Truck and skidder roads and landings.

Maximum skidding distance.

0 200 400 m.

AFTER NAGLE (1976)

tree growth (Webb, 1974) and on the reduction of the Merremia weed problem (Terry, 1981). It is the opinion of the author that the weed problem could be greatly reduced if soil disturbance and exposure during logging operations were minimised. Figures of up to 70% soil disturbance are quoted in Terry (1981).

The Solomons, like other S.E. Asian countries, seems to be recognising environmental and similar problems in its forest management and is analysing these and trying to correct them to help sustain timber production in the future.

The African Region

In Africa tropical rain forest management also developed in a number of countries generally continuing investigations and treatments started in the early 1900's. In Nigeria, the development and operation of the T.S.S. was continued. The results were generally considered encouraging but the spread of climber tangles (Jones, 1950, 1955, 1956; Barnard, 1955) was beginning to cause some anxiety. It is stated in the working plan for Owo (Dept. For. Ibadan, 1953) that the system of management was the "Uniform Shelterwood Compartment system" with exploitation controlled by the limitation of annual coupe, but that regeneration was by T.S.S. (Nigerian Dept. For., 1953). Other areas were managed under a "selection shelterwood compartment system" on a 25 year felling cycle (Allinson, 1955). However, though the aim was to produce even-aged forest in the areas managed, no attempt was made at clear-felling as in the uniform system, nor was the fullest use made of all the merchantable trees

of the economic species, to the lowest possible girth limits. In these basic pre-requisites, the system was far removed from the M.U.S. (Barnard, 1955; Onyeagocha, 1962). Logging in practice averaged about 3-5 trees/ha., corresponding to an average volume of 50 m^3/ha. consisting mainly of over-mature emergents between 270-490 cm in girth and sometimes larger (Kio, 1978).

Revisions in the T.S.S. treatments were investigated in 1953, 1955 and 1961, prompted by the need to reduce the cost of carrying out the operations and by arguments about the degree of canopy opening through poisoning and the level of clearing. The 1961 instructions contained a reduced programme of treatment and changes were mainly in degree and in the direction of increasing simplicity (Lancaster, 1961; Okon, 1962). By 1962, various austerity measures, growing alarm at the inexorable spread of climber tangles in many treated forest reserves, and increasing intensity of exploitation whereby virtually all woody species of merchantable size were sawn and sold in local timber markets, led to the virtual suspension of T.S.S. and abandonment of the uniform system. Lowe (1975) suggests that abandoning the T.S.S. had little to do with its success *per se*, but gives *inter alia*: independence, pressure for land, and change of emphasis to agri-silviculture as contributing to its abandonment. Most of these developments occurred in Western Nigeria, but Eastern Nigeria was having just as hard a time on the natural regeneration front. March (in Okon, 1962) says that in

E. Nigeria there was no endorsed method for regenerating the poorly stocked forests other than by clear-felling and replanting, which could only be done on a limited scale due to limited funds (Adeyoju, 1975).

Despite the situation in the mid-1960s and arguments for plantations (Wyatt-Smith, 1964; Adeyoju, 1974; Lowe, 1975), research into methods of N.R. has continued (Mervat, 1972; Bangbala and Oguntala, 1973; Lowe, 1975; Kio, 1976, 1978, 1979, 1980). It was felt that modifications of the T.S.S. practice was essential for ecological reasons and that the situation pointed to the urgent need for a systematic and more statistically based silvicultural experiment, as casual observations could be very misleading. In the non-degraded high forest of Nigeria, conditions for N.R. were fairly favourable (Onyeagocha, 1962; Lowe, 1966, 1975) and generally, the disappointing results of the T.S.S. seem to have been due to the use of uniform prescriptions over forest areas of different types and varying environmental conditions. With a greater understanding of the response mechanism of different forest types, appropriate management and silvicultural prescriptions may be applied to produce predictable results (Kio et al., 1975; Kio, 1976).

The T.S.S. in reality seems to be a modified form of selection system with the young regeneration (seedlings, saplings, poles) existing adjacent to unexploited mature and over-mature adults, as well as adolescents. If it is in fact a crude form of polycyclic system, then it is not surprising that the intention of producing a uniform stand

and the performance of the system were unrelated. It seems from the various references that if a uniform crop is the aim, then a N.R. system is totally inappropriate and an outright monocyclic system of clear-felling and planting should be adopted. If N.R. of the T.R.F. is the aim, then T.S.S. could be practised. However, it must be accepted that due to selection of more valuable trees at the start, the next group of merchantable trees would not be as valuable as the first, but that if subsequent selective felling is carefully controlled, room will be created for the saplings and poles of high grade species such as the mahoganies, etc. (Entandrophragma, Khaya, Triplochiton). Selection methods, of course, lead to problems of felling damage, but such damage is felt to be less of a problem in Nigeria compared with other T.R.F. areas (Redhead, 1960; Kio, 1978, 1980). Today, the general tendency throughout Nigeria is towards intensive silviculture or "compensatory plantations" (Anon, 1971) and the research efforts of F.A.O. and the Nigerian Federal Department of Forests (Lawton, 1978; Kio, 1976, 1979) suggest that here too, T.R.F. management is taking a new, more conservational direction.

As mentioned in the Afro-Malaysian section, Ghana only used the T.S.S. in some forest areas, but selection methods have been the ones most widely used. This was because forest assessments in the country indicated that with most species, including the valuable Meliaceae, there were ample smaller stems present to replace the large areas removed

in logging (Mooney, 1958; Quist-Arcton and Jack, 1959; Foggie, 1960; Taylor, 1960). Therefore where this was the case, the silviculture was selection and N.R., while in other areas, due to lack of smaller stems, selection with enrichment planting was practised. The selection system involved stock mapping of all economic trees over 2.1 m girth, improvement thinning of the immature stock and selective fellings on a 25 year cycle to a calculated yield based on time taken for trees to reach next size class (cf. Brandis).

Under selection work it was not considered possible to give any great assistance to trees larger than 1.5 m girth, but treatment was given to assist trees under the size down to about 0.3 m girth. It was hoped that this would show dividends in 30 years, although no effective increase in the number of larger and more valuable trees of exploitable size were expected for something like 50 years (Mooney, 1958; Kesse and Jack, 1959). The assistance given to the desirable stems in the residual stand was in the form of liberation thinnings, favoured species, including Tarrietia, Afrormosia, Triplochiton scleroxylon, Chlorophora, Khaya, Nauclea, Entandrophragma, etc. (Taylor, 1962; Baidoe, 1970). Thinnings involved cutting or poisoning by sodium arsenite, all worthless trees within a radius of 3.7 m of the most desirable trees (Class I) being assisted, and also any poor trees, even if they were of Class I or II (Guarea, Lophira, Mansonia, Mitragyna beyond the 3.7 m circle, which were suppressing or likely to suppress the development of

the tree being assisted (Baidoe, 1970). Improvement thinning was done either before or after exploitation. In the former case it was coupled with the stock survey, the dual treatment being referred to as 'Combined Operation'.

In 1972, the felling cycle was reduced from 25 to 15 years (Baidoe, 1972). It was suggested to the Ghanian government that a long cycle allows deterioration of the trees due to be harvested last. The author feels that this may be true in a forest that is in a strongly seral transition, but various calculations on the longevity of desirable species in W. Africa (Redhead, 1960) provides no support for a change from 25 to 15 years. Quite obviously, this is a commercial move to allow the removal of the biggest and best trees in large quantities as soon as possible. The consequences are obvious, and even before the change in felling cycle, the yield from second cycle felling in the Pra-Annum Forest Reserve already showed the harm being done to the forests by the dysgenic effects of a girth limit system (Baidoe, 1970). Despite what seems to be a totally economic reason for the change in felling cycle, there is evidence to suggest that Ghana is trying to rationalise its forest management, which may herald a new era in T.R.F. management in the country (Baidoe, 1970; François, 1977).

Studies in Uganda in the 1950s as well as observations in T.R.F. elsewhere showed that any kind of polycyclic system, whether true selection, Brandis or stratified uniform, was quite incapable of achieving the highest

yields of which a T.R.F. was capable (Dawkins, 1959; Philip, 1962). The conversion to a monocyclic natural regeneration system in Uganda was also due to a rise in costs (especially labour), labour shortages at the time of planting (in enrichment), heavy losses due to game, stagnation of seedlings due to constant shading in of the lines, and finding that N.R. was more plentiful than the artificial, and frequently also more healthy (Dawkins, 1958a, 1958b; Uganda For. Dept., 1958; Onyeagocha, 1962).

See Table 9 of the complete operation. The treatment applied relied on the removal of the original crop in one operation. Prior to this logging, a refining operation (Dawkins, 1955b) was carried out, aimed largely at getting the existing regeneration on the ground firmly established before the economic stems were removed. While it was financially more desirable to carry out the refining at or about the same time as logging, it appeared that the regeneration was in a better condition to respond to logging if the refining was carried out several years beforehand. The form of refining treatments depended on the results of a regeneration sampling (diagnostic sampling) adapted from the linear sampling techniques defined by Dawkins in a study in Malaya, 1954 (Trenaman, 1956; Dawkins, 1958a, 1958b; Osmaston, 1959; Hughes, 1961; Philip, 1965). Scattered regeneration was freed from vines and interfering stems, while in areas of abundant regeneration, all undesirable stems over a minimum size were removed. As sodium arsenite was banned on health grounds, a lot of

TABLE 9*

SEQUENCE OF OPERATIONS OF MONOCYCLIC NATURAL REGENERATION SYSTEM

UGANDA

YEAR	*OPERATION*
E-5 to E-2	a) Climber cutting and understorey weeding
E	a) Exploitation of all or selected exploitable trees based on condition of stand and girth limit b) Repair damage of regeneration c) General weeding of all weed trees still effective after felling
E+5 to E+10	a) Regeneration sampling b) Climber cutting, clearing and tending as necessary
E+10	a) Thinning either by felling if log market or poison girdle - aim to retain 50 final crop trees per ha.

Rotation 40-80 years.

*Based on Dawkins (1958a, 1958b)

research into other arboricides was conducted, particularly into hormonal arboricides (2, 4, 5-T and 2, 4-D). A mixture of these in diesel oil was applied as a basal bark spray to remove the unwanted stems (Dawkins, 1953, 1958a, 1958c). Subsequent tending treatments of the new crops were similarly based on the results of linear sampling.

The monocyclic system was introduced under a long-term plan for conversion (Hughes, 1962; Hughes and Lang Brown, 1962) which seemed to work well in Uganda, but yields from the forest were still low. This was because the desirable trees exploited were those demanded for veneer or saw logs (Philip, 1962; Dawkins, 1959). Plumptre (1968, 1972, 1974) argued that production of the T.R.F. could be greatly increased if larger numbers of trees, larger proportion of the tree, were utilised along with the thinnings from management under the uniform system. This problem was also recognised by Earl (1968) and he proposed the abandonment of poisoning undesirable trees and converting them to charcoal instead. This was first introduced in the Mengo district and Ugandans were persuaded to use earth kilns to make charcoal from weed trees as well as from the lop and top from exploited areas. Basic market research had indicated that there was a large expanding domestic market for charcoal, which was only partly being filled by imports. Steel kilns were also tried and became operational (Earl, 1972a, 1975a, 1975b; Mabonga-Murisaka, 1972). This was an extremely important step in the management of Ugandan T.R.F. and greatly reduced the need to use arboricides for

refining which were both more expensive and less environmentally desirable. From this, Uganda was able to greatly increase its wood utilisation by lowering merchantable size limit from 60-30 cm d., increasing the number of acceptable species, and converting residues to charcoal (Kio, 1976). T.R.F. areas have shown an interest in this development including Nigeria, the Ivory Coast and Madagascar (Earl, 1971, 1972b).

Some problems have been encountered recently in Uganda - apart from the political situation. Entandrophragma utile regeneration and establishment are being greatly reduced due to 40% of the seeds being eaten by rodents before and immediately after germination, and nearly 30% being killed as seedlings by antelope browsing. Other losses are caused by seed rot, fungus, drought, insects, etc. (Synnot, 1973). This is particularly important in the Budongo forest which has an exceptionally high stocking of large mahoganies, but is seriously deficient in the smaller sizes and in very young plants, thus affecting the future quality of the forest. Synnot (1973) has suggested remedies. Other major problems affecting the success of the silvicultural system are basically managerial and administrative. Encroachment is causing problems in some areas, and the simple but important factor of using the correct concentration of arboricide in refining treatments is being carried out incorrectly (Hughes, pers. comm.). This latter matter is due to rank bad management and means that some areas get the correct refining, while others get only a poor treatment, which reduces the success of the

whole silvicultural operation. Uganda is not alone in its poor management of personnel or incorrectly implemented operations. However, if T.R.F. management is to be successful, treatments must be carried out when and exactly how they are prescribed.

The present political situation in Uganda does not give the author any hope of a more rational, conservational approach to T.R.F. management as has been the case in other T.R.F. areas.

In Sierra Leone, T.R.F. management developed along three lines, namely natural regeneration (Fox, 1970), enrichment planting and taungya (Sawyer, 1965; Anon; 1971). Under N.R. the lack of high quality species in the original forest made it difficult to obtain a greater concentration of valuable species in the regeneration. Consequently MacGregor (1940) instigated line planting in 1940 to enrich exploited areas in Kasewe and Kenema, and in some protected forests. The main species used were Terminalia ivorensis, Nauclea diderrichii and Tarrietia utilis. In secondary growth this was successful, but at Kenema, in high forest, these light demanders and other more shade bearing species gave disappointing results under the natural forest canopy, although this had been considerably opened by removal of the merchantable timber and by poison-girdling. By 1963, the forest department was turning more to plantation forestry, but some areas were still being managed on N.R. methods. The Gola forest area was being managed on a minimum girth limit system (2 m girth) to try and attain a

sustained yield (Fox, 1968).

T.R.F. management in W. Africa in the French and Belgian colonies continued mainly in artificial methods, planting the desired timber species into the natural forest in cleared or poisoned forest ("Methode du Recu") or in cleared lines in the forest ("Methode Sous-Bois") (Wood, 1971). Initially canopy opening in these forests was too light causing checks and failures. A change in technique was needed and it was concluded that, due to the high costs of the opening operation, such work was only economical in not too dense secondary growth or near to a potential firewood market (Aubréville, 1954; Fays and Huygen, 1956; Cebron, 1957; Catinot, 1965).

These various West African countries are now independent and have treated their T.R.F. in different ways. Generally speaking the Ivory Coast has allowed highly selective exploitation of its forest areas and indiscriminate encroachment (Lanly, 1969; Schmithüsen, 1977, in N.A.S., 1980a.) The afforestation currently occurring is minimal and in no way compensates for the vast deforestation. Gabon, Congo, Zaire and Cameroon have been more judicious with their exploitation. Population pressures are generally less in these countries than in the Ivory Coast. Zaire has large areas set aside for protection and President Mobuto has repeatedly declared that he will increase his country's system of protected areas. In Congo, most log output comes from the southern forests which make up about 20% of the entire forest area. As a result, however, these

southern forests are being rapidly depleted of their best hardwoods, but since exploitation has hitherto been highly selective, a second harvest may soon become available. In Cameroon and Gabon, exploitation is also highly selective but access to interior areas is generally poor, thus restricting the forest operations. One concern of the author is that all these methods are girth limit systems, and are probably dysgenic, especially if continued over a few felling cycles. Catinot (1974) has proposed three management systems of different intensity to apply to W. African T.R.F. depending on classification and forest type. In the Gabon, exploitation was based on minimum felling **diameters** and it was hoped that a regeneration potential would be maintained and the existing young growth would survive. More complex methods are now being started experimentally to provide a sustained yield within the framework of autonomous management units (Catinot, 1978). Regneration operations are planned to fit in with felling in both time and space and thus is an extrapolation of the classical systems of management as practised in countries with an older forest tradition. Donis (1978) has recently suggested that liberation thinnings, as described by Wadsworth in Puerto Rico, could be a very useful method to try and retain and improve the desirable species in the African T.R.F.

Conservation type attitudes do seem to be a new part of T.R.F. management in the former French and Belgian colonies. The Ivory Coast, despite its population problems and great exploitation, is trying to find methods of sustaining the

forest along with other developments (Clement, 1981; Dosso et al., 1981). Hopefully these attitudes are a new phase.

The American Region

The Pan-tropical exploitive phase not only saw developments in T.R.F. management continue in Asia and Africa, but their spread to mainland S. America. Preliminary investigations of possible silvicultural techniques have involved, as elsewhere, attempts to improve existing rain-forests by tending, and an effort to enrich or replace degraded (creamed) forest by planting. For the most part, however, except in the heavy soils of Trinidad, attention was largely concentrated on N.R. techniques. In Trinidad, a shelterwood system was applied on sandy soils, with the emphasis on the regeneration of aggressive lighter hardwoods, usually light demanders which were in great demand. The system was developed on the Arena Forest Reserve generally on the well drained sites where the forest is typically Carapa-Eschweilera seasonal evergreen rain-forest (Brooks, 1942; Beard, 1944a). Silvicultural work commenced in 1927 on the reserve and Brooks (1941), Ayliffe (1952) and Bell (1971a) describe the early work. It seems that the early implementation in 1939 and success of the shelterwood system was due to a reasonably good understanding of the ecology of the T.R.F. and a fairly specific forest policy (Swabey, 1932; Duthie et al., 1936; Marshall, 1939; Brooks, 1940, 1941, 1942; Barbour, 1942; Beard, 1942, 1944a, 1946a, 1946b). N.R. was found to be widespread in the natural forest, largely due to the efficient seed dispersal of

certain species by birds and bats. At the same time it was determined that a high shade shelterwood was necessary if the dual objectives of protecting the soil and permitting the new crop to develop were to be achieved. (Indeed, 'Arena' means sand in Spanish, Latin, etc., and the soils in Arena F.R. were exceptionally **erodible** and even on the gentlest of slopes deep gulleys could form even in the forest.) (See Table 10 for the system.) Ayliffe (1952) notes that the success and cheapness of the system depended largely on the charcoal burners who used all the wood (even partly rotted trees on the ground) not sold for timber.

With the changing pattern of timber consumption in Trinidad and with the additional knowledge gained from the application of the T.S.S. over 20 years, the silvicultural technique underwent certain changes in the 1950s (Moore, 1957; Lamb, 1960). Originally a 60 year rotation was fixed with an annual coupe of 63 acres on the Arena F.R. Regeneration was more abundant than expected and, therefore, it was decided to forget sustained yield and treat as much of the forest as the charcoal burners wanted. This was so as to treat previously exploited forest as quickly as possible and to make use of the charcoal outlet while it existed. Consequently, the coupe was increased to 165 acres in 1950 (Moore, 1957). The felling cycle was reduced from 60 to 30 years because of the increase in desirable species on the local markets and the fact that many of these species were fast growing attaining their maximum economic size in about 30 years before starting to deteriorate.

TABLE 10*

SEQUENCE OF OPERATIONS OF HIGH SHADE SHELTERWOOD SYSTEM

TRINIDAD (ARENA F.R.)

YEAR	*OPERATION*
E-1	a) Climber cutting
E	a) Exploitation of mature timber, leaving some shelterwood
E+1	a) Felling of remaining small wood for charcoal
E+2	a) Clearing and tending
E+3	a) Clearing and tending
E+4	a) Climber cutting, clearing b) Understorey tree poisoning (liberation)
E+5	a) Climber cutting and tending b) Poison shelterwood trees not required in new crop
E+6	a) Thinning

Rotation 60 years.

*Based on Ayliffe (1952) and Moore (1957).

Two effects of this were that dominants were no longer needed to form a shelterwood as satisfactory regeneration could be obtained from a shelterwood of pole size trees, and a shelterwood of pole size trees was preferred since they would remain sound during the 30 year felling cycle. The cost of poisoning the shelterwood was reduced or eliminated, allowing dominant trees to be exploited during shelterwood formation.

During the late 1950s there was a decline in the demand for charcoal which meant unwanted trees had to be **poison-girdled** The success of the system was reduced as more debris was present, more fires occurred which killed large areas of shelterwood, and due to a poorer seedling surface because of reduced scarification of the ground, germination was less (Bell, 1971a). More recently it was realised that in areas of Trinidad where Mora is common, the silviculture was either through a shelterwood method, or by clear-felling and replanting (mainly with Pinus caribaea) trying to replace Mora with other species. Bell (1971b, 1972) argues that this is wrong and that in most tropical countries management is aimed at trying to simplify the composition of the mixed forests which are thought to be too heterogeneous. In Trinidad the aim was the opposite: to convert forests where Mora was dominant to a mixed forest. The increasing demand for Mora timber has caused a change in silvicultural operations. Conversion is, as before, to produce an even-aged crop by the shelterwood system while future management will be under a selection system (Bell, 1971a,

1971b, 1972). In fact it is a girth limit system (3 m girth) and Bell suggests that this limit and the low exploitation per unit area should keep felling damage down.

Bell's ideas suggest that Trinidad is entering a conservation period in its forest management as, by managing the Mora forests by a natural selection system, the need to clear-fell and plant up with other species is reduced.

The treatment in natural but cut-over forests (Holdridge, 1940; Wadsworth, 1943) of the Luquillo mountains of Puerto Rico started in 1943 following the success being obtained by such work in Trinidad (Wadsworth, 1947). At that time market conditions for timber sales were good and all accessible trees, regardless of size and species, were of sufficient value to warrant cutting and extraction. Under such conditions intensive management was justified and early cuttings were directed towards the elimination of the inferior species in the stand. The factors determining the form silvicultural treatment should take in the Luquillo mountains were that: 1) they contained cabinet and construction timbers, 2) due to the low percentage of desirable volume it was essential to improve the growing stock composition, 3) clear-cutting had to be avoided in the mountain catchment area, and 4) regeneration of the desirable species appeared to occur under continuous shade (Wadsworth, 1943b, 1943c). For a number of reasons including soil protection and greater wind firmness of uneven-aged stands a selection system was chosen (Wadsworth, 1943a, 1947). It was also decided that treatment should

entail a stand improvement operation primarily aimed at bringing the forest into a state where it could ultimately be managed by a true selection system on a sustained yield basis. Marking instructions were produced to translate the policy of the system into simple, clear instructions for the untrained field staff to understand and apply (Wadsworth, 1951, 1954; Baur, 1964a). The rules only underwent minor changes after being introduced.

However, during the post-war years the local timber industry virtually disappeared, the never-very-strong sawmilling industry finding it difficult to cope with cheap timber imports. Widespread electrification and the change to oil fuels, as occurred in Trinidad, led to a sudden decrease in fuelwood demand, and consequently, the silvicultural treatment could only be applied in the original form envisaged occasionally. As the Luquillo Experimental Forest is within the Luquillo mountains, trials of the treatment were carried out with good results on the ridges and steep slopes. Enrichment planting with Swietenia macrophylla was used to establish regeneration and difficult sites (Wadsworth, 1954; 1960, 1974). The pilot studies have shown this system to work well in the tropical mountain environment. Although management is not on a large scale due to the lack of markets, the Luquillo mountains are providing an extremely valuable insight into the T.R.F. ecosystem and how it functions naturally and when managed by man (Odum, 1970; Crow, 1980; Lugo and Brown, 1981). (Although both Trinidad and Puerto Rico are

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reasonably well documented and attract interest in T.R.F. management, it must be noted that the Arena F.R. and Luquillo Mountains are very small areas, and the systems used were successful on a very localised scale. In comparison, studies and treatments in Nigeria, Malaysia, Ghana, etc., were undertaken over vast areas and, therefore, demand more attention as successful systems for T.R.F. management.)

Elsewhere in the Caribbean and in countries bordering the Caribbean, T.R.F. management generally started in the 1940s. Highly selective methods of exploitation were initially common in Jamaica (Swabey, 1940), Dominca (Pidduck, 1940), Grenada (Hagley, 1940), Dominican Republic (Scarff, 1940), British Honduras (Belize) (Stevenson, 1927, 1940; Miller, 1941), Guyana (Clarke, 1956; Gordon, 1961; Anon, 1971), Suriname (Schulz, 1960), Venezuela (Hamilton, 1976) and Costa Rica (Holdridge, 1958). Some of these countries, however, looked quite seriously at shelterwood methods including British Honduras (Stevenson, 1927, 1940), while others, such as Suriname (Schulz, 1960; Boerboom, 1964), Guyana (Gordon, 1961; Anon, 1971), Costa Rica (Holdrige, 1958) and Grenada (Hagley, 1940) tried to introduce methods of improvement fellings and liberation cuttings on a girth limit system. By and large, most of these countries now concentrate on plantations dominated by Pinus spp. This is probably due to over-exploitation in some areas, problems of small yields per hectare of marketable species due to restricted markets, lack of infra-structure, and possibly

also lack of enthusiastic foresters in T.R.F. management (cf. Gane, 1966). Problems of shifting cultivation are also often quite widespread in these countries. In some of these countries, deforestation of the natural T.R.F. has caused serious national problems (Vogt, 1948). Panama is a good example of this, where the deforestation and drought of 1977 affected not only the hydro-electric output and domestic water supplies, but international shipping as the Canal was closed with insufficient water (Wadsworth, 1978).

The Amazon contains the world's largest continuous rain-forest zone but compared with other T.R.F. areas, it has a minimal amount of research and investigation into its management. In 1952, the Brazilian government called in an F.A.O. team to advise on the measures need to establish a permanent forest industry in the area. The team made a number of recommendations (Gachot et al., 1953) which led to the establishment of an F.A.O. Mission based at Belem and covering various aspects of forestry work including forest inventories, saw milling and mechanical logging studies, and development of silvicultural techniques. Studies in the latter aspect commenced in 1956 and included planting studies both in open and enrichment situations, as well as treatments aimed at inducing and encouraging regeneration ahead of logging (Pitt, 1961a, 1961b). In these treatments, an initial climber cutting was followed by selective poisoning to open the canopy to various degrees, the climber cutting being more necessary in disturbed as

compared with virgin forests. Results showed that the larger the opening, the more the regeneration, particularly with light demanders (e.g. Goupia alba, Didymopanax morototoni and Jacaranda copaia).

Attempts to induce regeneration of Cedrela odorata were also made around a number of seed trees. In well cleared plots regeneration was excellent following a seed year, but where the undergrowth was dense, heavy mortality occurred.

Methods of obtaining regeneration after logging were also carried out and Pitt found that following exploitation and further opening of the stand by poisoning and undergrowth clearing, regeneration was prolific (e.g. Ocotea spp, Virola spp., Jacaranda copaia. Pitt (1961a) concluded that "In these early stages, management must be extensive rather than intensive; stress should be made more on natural regeneration than artificial, at least until exploitation for special purposes starts. The principle should be: follow Nature, perhaps guide her, but do not dictate to her". He went on to suggest that from the point of view of N.R., it was better to have an area with a relatively high volume of a second class desirable which is fairly easy to regenerate and encourage (e.g. Goupia) than to aim at a first class desirable which can be established only with difficulty (e.g. Cedrela). Unfortunately, these silvicultural treatments and investigations have been very localised while, in other parts of the country, vast tracts of forest are being indiscriminately exploited or cleared for highways,

ranches, and agriculture (Camargo, 1958; Carnheiro, 1971; Sioli, 1973; Fosberg, 1973; Goodland and Irwin, 1975; Davis, 1977; Lewis, 1979; N.A.S., 1980; Herrera et al., 1981).

Under present logging and transportation patterns, timber harvesting in Amazonia is limited to about 100 m on either side of navigable rivers and even less on either side of roads. This means that hardly 1% of the dense forest zone (terre firma) has been considered operable to date. Only 25 tree species are generally acceptable on commercial markets at present (Elliott, pers. comm.). Plans for future production by the Brazilian forest agency (I.B.D.F.) suggest an increase of nearly nine times the present amount by the end of the century. Whether these forecasts are reached or not is a matter of conjecture, but at present very little management of the T.R.F. is carried out - it is all exploitation. The economic and political situation is, at present, preventing the silvicultural system from being implemented. Studies are still continuing into the workings of the T.R.F. ecosystem (e.g. M.A.B. studies) but these will give little direct help in finding silvicultural treatments for the forest. What really is needed is more manipulative experimentation and a commitment from the government to help to reserve T.R.F. areas. In the meantime the clearing of T.R.F. for purposes other than forestry continues with serious consequences to nutrient budgets, water control, etc.

In **Paraguay**, exploitation of the T.R.F. is also occurring, but research has been undertaken to find successful

silvicultural treatments. Some areas are managed under a girth limit system with liberation treatments used to improve the residual stand (Wadsworth, 1969). Hamilton (1976) has studied the forestry problems and practices in Venezuela and concluded that a first step in relieving the situation would be to overcome the numerous socio-demographic problems. What little is left of the T.R.F. in El Salvador is now being destroyed in the guerilla war where government troops are using defoliators (cf. Vietnam) or burning areas of forest to reduce guerilla hide-aways.

Thus T.R.F. management has spread from its early beginnings in the dry deciduous and moist deciduous forests of India and Burma to all countries where the complex ecosystem exists. Some treatments have been more successful than others possibly for silvicultural reasons, but more commonly failures when they have occurred have done so due to political, economic, social or administrative factors. Consequently, and most importantly, the future of many of these systems is unsure. The following chapter reviews the situation and the possibility of a new phase in T.R.F. management.

PART 3

FUTURE PROSPECTS: PHASE OF INDIFFERENCE OR PHASE OF CONCERN?

T.R.F. management seems to be entering a new phase in many tropical countries. In some, this trend is along the conservation line where methods are being tried to reduce injurious effects on the natural ecosystem during management, at the same time as increasing investigations in solving the mysteries surrounding the ecosystem's workings. The aim is to achieve a more judicious use of the T.R.F. as well as increasing productivity. Other countries are concentrating on short-term factors, over-exploiting the T.R.F. and not even trying to establish plantations in its place.

The issue of plantation versus N.R. is central to the future of T.R.F. management methods. The following section is a review of some of the aspects of this contentious situation. In the interests of brevity, it may, however, appear somewhat dogmatic - this is not the intention.

CHAPTER 1

NATURALISTIC SILVICULTURE OR PLANTATION?

A controversy prevails over the issue of whether to retain or abandon N.R. of T.R.F. ecosystems. One view advanced is that after several decades of exploitation and experimentation on a large scale, many foresters have concluded that N.R. systems may be ecologically impossible (Wyatt-Smith, 1968; Adeyoju, 1974; F.A.O., 1974b; Jones, 1974;

White, 1978). Others (e.g. Gane, 1966; Earl, 1968) think that there is a tendency for some foresters to regard the management of T.R.F. as an inferior form of silviculture as compared with that of plantations. Even using social benefit/cost analysis, it is difficult to endorse N.R. management as an economic proposition. It is argued that sustained yield (Smith, 1962, 1969), one of the initial management objectives, is inconsistent with the realities of tropical countries' national economic underdevelopment, it being rational to replace natural forest with plantation (Leslie, 1966, 1971, 1977; Fontaine, 1976; Spears, 1979).

N.R. is said to be uneconomic on two counts. Firstly low productivity/unit area. Plantations of high yielding crops grown on short rotations are attractive as it becomes profitable to apply methods used in agriculture and may produce yields of 40 m^3/ha./yr. or more. Similar sites of T.R.F. and N.R. systems can only average 1-3 m^3/ha./yr. (Tagudar, 1974; Bangbala and Oguntala, 1973; Momoh and Gibson, 1975; Johnson, 1976, Adlard, 1979; Miller, 1980; Andel, 1981). The second charge is that silvicultural operations are costly in terms of return for expenditure (Leslie, 1966, 1971, 1977; Chauvin, 1976). Little intervention is necessary when desirable species regenerate freely (Walker, 1948), but some of the now discredited systems involved numerous repetitive operations (cf. Nigerian T.S.S.; Baur, 1964a; Ogbe, 1968; Kio, 1978).

As land is the main cost advantage of concentrated plantations they are likely to be a luxury where land is

plentiful having only theoretical advantages over N.R. Silvicultural treatments of forests represents a rare opportunity to convert labour into capital assets (Wadsworth, 1974), and it enables a given unit of money to be more widely spread in N.R. operations. It is not correct that N.R. is always uneconomic (Gane, 1966; Fox, 1976a; Kio, 1976, 1979).

"Wood consuming industries prefer to use as few species as possible... Concentration on a few species makes the foresters' work easier" (Lundquist, 1964). In T.R.F., however, methods have been used to increase yield/ha. by using more of the less desirable species (e.g. Tosi and Voertman, 1975; Erfurth, 1976; Young, 1977; King, 1977 - and references). Where a large proportion of potentially useful species in any forest is rendered unmerchantable due to remoteness and inaccessibility there is an indication that exploitation is premature (Gordon, 1957). Conversion of T.R.F. involves ecological risks greater than the selection fellings originally common in many countries and in some still today. Most of the monocyclic and even-aged systems used recently involve considerable reduction in species (e.g. two-thirds reduction in Puerto Rico; Wadsworth, 1974). Sustained yield is being ignored and many foresters accept that closed forest is the best place for plantation, not the areas of shifting cultivation, derived savannas, which conservation policies suggest (Lamb, 1967; Poore, 1974, 1976a, 1976b; Roche, 1979).

Plantations are claimed to increase erosion and decrease fertility of vulnerable soils in the humid tropics especially

if they only produce little litter and suppress ground vegetation (e.g. eucalypts) (Cornforth, 1970; Brunig et al., 1975; Fittkau and Klinge, 1973). Brunig and Heuveldop (1976) suggest that monocultures with dense stands and high biomass prevent the equilibrium of the forest system and continued and possibly increasing inputs would be necessary to counteract the trend to instability and to "avoid catastrophic events which naturally dissipate accumulated energy and increase entropy".

Kio (1979) maintains that arguments against N.R. cannot be accepted as final, nor are those in favour of **plantations** entirely convincing. Though N.R., judged by commercial volume product appears inferior due to limited managerial capability, inadequate knowledge of the system, and market bias, it is insufficient reason for total rejection. Despite apparent economic advantages, it has yet to be shown that plantations of conifers and eucalypts can continue indefinitely without site deterioration (Dawkins, 1958a; Reynolds and Wood, 1977). Some plantations have failed due to unsuitability of site, insects and diseases, or lack of tending (Budowski, 1974; Johnson, 1976; Kio, 1976, 1979; Fontaine, 1976; Webb, 1977; Gray, 1978). Extensive failures of plantations in tropical countries are likely until more knowledge is available concerning the biology of species introduced (Stern and Roche, 1974).

Plantations are not deplored if factors including species being grown in appropriate climates and sites are considered with attention to pests, fire, wind and other damaging factors (Scott, 1966). Whether to naturally or

artificially regenerate forest is not a matter of ex-cathedra decisions, it can be taken only in respect of one particular forest or forest type as it actually exists on the ground (Foggie, 1960; Van Miergroet, 1967). Recognition of the importance of plantations does not mean substituting them for existing T.R.F., as they are not really competitive (Sirin, 1977), but complementary. Plantations may produce long fibred pulpwood, while T.R.F. can produce high quality veneer and sawlogs. A continuing and increasing world demand for wood can be predicted with confidence (Pringle, 1976; Enabor, 1977; CAS, 1980) and most tropical countries, with rapidly expanding populations and rising living standards, can expect increased local demand for all classes of wood products, particularly fuel wood (N.A.S., 1980b). A major objective may therefore be the maximum production of useful timber from a limited area of forest (Campbell, 1980) (e.g. see Lowe in Synnot and Kemp, 1976). Agrisilvicultural ("land-husbandry" - Stewart, 1981) methods can be used but problems of supervising such schemes mean that intensive planting under full forest authority control following clear-felling has greater likelihood of success in practice (Adlard, 1979). Enrichment planting may be used, but it "...now has fewer and fewer supporters in the tropics...on the whole it has not given satisfactory results" (Catinot, 1970). If plantations are to be established, overseas grants are likely to be necessary, tropical countries being unable to afford the investment needed because so much money is tied up for 5-20 years before income is received.

This all comes down to the question: Is the T.R.F. necessary? If it is then can the T.R.F. survive, and how can it be managed to retain its general structure and composition while remaining productive?

CHAPTER 2

SURVIVAL OR DESTRUCTION?

There have been numerous studies relating to areas of T.R.F. on a world scale and the speed of their conversion or destruction (Persson, 1974, 1977; Sommer, 1976; Lanly and Clement, 1979; N.A.S., 1980a, etc.). Despite contrasting conclusions (cf. Richardson, 1970; Richards, 1973; World Bank, 1978), one thing common to all these studies is that modification and transformation of T.R.F. (Poore, 1976b) is occurring at an extremelyrapid rate. The latter category which involves virgin or modified forest being totally removed and replaced by a man-made ecosystem or inanimate structures is of particular importance, as after such conversion, recreating the original state is practically impossible (Poore, pers. comm.) (cf. Garven, 1980). Doubts about the ability of T.R.F. to renew itself have been raised based on analyses of stability in model ecosystems (Gomez Pompa et al., 1972; May, 1973, 1975). These suggest that under present types of disturbance T.R.F.s cannot survive. Exploitation for agriculture and pastoral cases are the most important disturbances, but removal of timber alone has rarely destroyed a forest ecosystem unless

extraction damage to the soil has been so great as to make N.R. impossible (cf. Kennedy Bay, Sabah).

This situation is not a crisis as that is something that will pass being solved by temporary hardship and adjustment, and technological and political expedients. What is being experienced is a climacteric (Ashby, 1978). For the rest of man's history on earth, so far as one can foretell, he will have to live with this problem, unless something is done about it soon.

Man seems to have passed through a number of phases in relation to the earth generally, and forests more specifically. Primitive societies were able to live with the forest without causing it any harm, but with the coming of the Judaeo-Christian tradition, man was led to believe he was superior to other organisms (cf. The Book of Genesis). White (1967) wrote "Despite Darwin, we are not, in our hearts, part of the natural process. We are superior to nature, contemptuous of it". Fortunately, through the evidence of science, man once again seems to be identifying himself with the environment, and recognising his symbiosis with nature. As Hamlet comments, "We fat all creatures else to fat us, and we fat ourselves for maggots".

Consequently, many arguments have been expressed for the retention of T.R.F., possibly the most relevant being that the consequences for life on earth of virtual destruction of T.R.F. are uncertain. Leslie (1977) suggested that decisions based on N.R. being an uneconomic proposition may be mistaken which is supported by Gane's (1966) work on pine vs. Mora forest in Trinidad. Many

articles relating to the importance of T.R.F. are in the references (e.g. Janzen, 1973; Poore, 1976a; Myers, 1979a, 1974b; Grainger, 1980; Whitmore, 1980, etc.). However, just as a modern tanker takes three miles to stop once the order to halt is given, so even if the order to stop forest clearance occurred today, it would still take decades to have any effect. This could still mean massive areas of T.R.F. are destroyed. But what can be done to retain the T.R.F. existing today?

CHAPTER 3

FUTURE T.R.F. MANAGEMENT

The inference today seems to be to save T.R.F. and manage it in such a way so as to retain its viability. Thus primarily forest departments in T.R.F. countries must have definite, practical and understood objectives and policies relating to the particular country's national economic objectives. These objectives must be based on reasonably accurate data on the forest resource, which is lacking in many countries (Sommer, 1976) despite practically every forest area, other than the upper Amazon, having already been sampled. The lack of data is due to poor filing, storage and loss of inventory records and reports, as well as changes occurring in the forest for natural reasons (e.g. succession) or from human interference other than by foresters. Many methods are available for inventories, both ground based (Cousens, 1957; Dawkins, 1958a) and in the form of remote sensing by aerial photography

(Shields, 1965; Hutchinson, 1976; Kahirman and Mardjuki, 1978), by satellite imagery (E.R.T.S. (Nor, 1976) and by Side Looking Airborne Radar (SLAR) (Snobholm, 1972; Sobur et al., 1975). Numerous articles are included in the references on the application of remote sensing in T.R.F. inventory and monitoring (e.g. Berry, 1980, etc.) and today there is a general trend towards more ecological rather than solely forest inventories (Nedialkov, 1972; Lamprecht, 1972; Carron, 1974; Coulcombe, 1978).

Volume estimation and yield prediction (F.A.O., 1980) are important aspects of inventory and use of permanent sample plots (P.S.P.) rather than just temporary plots is extremely useful for continuous forest inventory (C.F.I.) and production forecasting from the forests (Synnot, 1976; Wright, 1980; Fries, 1981). Synnot (1979a) has produced a manual of permanent plot procedures for T.R.F. which is invaluable for all forest departments involved in T.R.F. management. Examples of C.F.I. in T.R.F. countries are Malaysia (Fox, 1969, 1970), Ghana (Baidoe, 1968), Nigeria (Dawkins, 1980) and Uganda (Uganda For. Dept., 1971). In the case of the latter, it is not known whether the P.S.P. or their data still exist due to the political situation in the country over the past decade. Computer programmes are available for sorting, correlating and computing data (Calabrese, 1978; Fontaine and Lanly, 1978b). Reviewing data produced from inventory plots, Andel (1981) has called for further research and yield studies to aid management.

Remote sensing methods can be very useful in producing land use classifications (e.g., Johnson, 1971; Dodge and Bryant, 1976; Driscoll et al., 1978; M. Berry; A. Blair-Rains; A. Greaves, pers. comm.). Land use planning is important for maintenance of T.R.F. as land is allocated to specific uses. Wadsworth (1974) and ITRI (1976) have suggested land allocation should be chosen in the order where forestry is dismissed to non-agricultural areas, and conservation areas to non-economic land. By following this method, forestry will always be pushed to poorer areas as will conservation sites. Poore (pers. comm.) suggests land allocation should be based on those land uses that are socially, environmentally and ecologically appropriate. There will always be conflict, but it means forestry will not always be pushed onto poorer land. This should help reduce encroachment and shifting cultivation problems by providing people with land, generally best suited to the uses to which they are put. Environmental impact assessments (Henwood et al., 1973; Munn, 1975) could be used to ensure any management implemented will not cause site deterioration (cf. Philippines - Esteban, 1981).

The T.R.F. is very poorly represented in terms of national parks and wildlife reserves (Roche, 1979) and there have been calls to improve this situation (Wyatt-Smith, 1957; Ashton, 1960; Lawton, 1974; Poore, 1976a, 1976b). Such conservation areas are termed virgin jungle, biosphere or strict nature reserves (S.N.R.) and could easily be incorporated in management systems (cf. Roche, 1979). They

could be used to provide 'base-line' studies or controls with which to compare and assess environmental changes affected by man's management. Dawkins (1979) has used the elegant argument of retaining, for comparison and study, a stable soil fauna capable of maintaining a perpetual forest ecosystem in Pasoh, F.R., Malaysia. S.N.R.s could yield valuable data for improvement of silvicultural treatments (cf. Man and Biosphere and International Biological Programmes) (UNESCO, 1973; Brunig et al., 1978; Lugo and Brown, 1981; DiCastri et al., 1981; Herrera et al., 1981), although extensive silvicultural trials of systems will probably still be of greater use. S.N.R.'s need some form of buffer to protect them from the influences of activities carried on outside the immediate conservation area. Various authors have discussed the importance of such buffers in maintaining stability of the ecosystem (MacArthur and Wilson, 1967; Hooper, 1971; Diamond, 1975, etc.).

Future T.R.F. management may be greatly aided by the use of computers, models and systems analysis. Various foresters are attempting to produce models that will help to find the optimum management system and in such situations the establishment and use of P.S.P. are vital (Andel, 1981; Fries, 1981). Models need a great deal of data and may be based on a stand of trees or an individual tree situation. The former is most likely in T.R.F. models as it is cheaper than single tree modelling, but can be just as accurate (Ek and Monserud, 1974). Data such as soil properties, biology of reproduction, shape of trees, structure and

properties of wood, and forest's response to various forms of silvicultural treatment are required (Bethel, 1971). This information is essential for the assessment of actual and potential biological and economic productivity. Models describing the behaviour of natural forest ecosystems can be verified and adapted as models describing the behaviour of manipulated forest ecosystems. In the highly complex question of conversion of the various types of tropical forests from the natural to the managed state, the use of simulation models of proposed management plans, based on data inputs concerning the biological productivity of natural forests can be of great assistance in decision-making on forest management practice. Also it avoids causing irreparable damage to fragile ecosystems if treatments are tested in models before being implemented in the field. All this assumes that the state of an ecosystem, at any particular time, can be expressed quantitatively, and that changes in the system can be described by mathematical equations (e.g. indices of air and soil temperature, water availability, atmospheric moisture demand, etc. - Reed, 1980). To obtain required data, studies must be performed in existing forest as well as of the effects of recent utilisation. Alternative methods leading to sustained yield and possibly improved yield have to be developed and tested. Thus, future research concerning development, growth and yield of T.R.F. must be widened to include silvicultural systems whereby these forests may be converted to more fast growing forests. The complexities of T.R.F. make modelling a

very complicated business and international cooperation will facilitate standardisation of data and analysis with common programmes, etc.

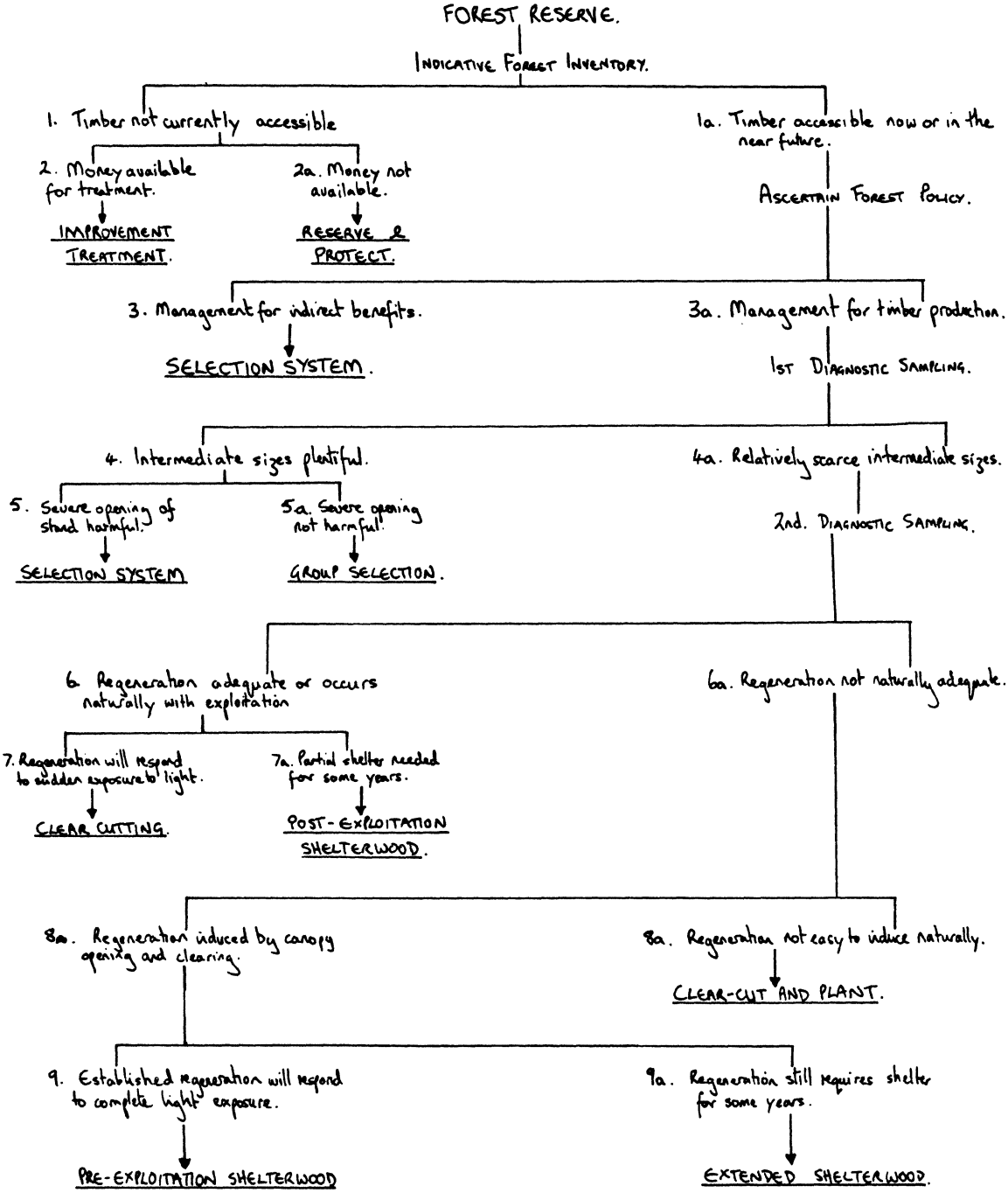
Recent work done in the U.S. (e.g. Fries, 1974; Buongiorno and Michie, 1980) has used matrices to predict the long-term growth of undisturbed and managed uneven aged hardwood stands. Parameters of the models represent stochastic transition of trees between diameter classes and in growth of new trees, which depends on the condition of the stand. Such models will probably be of use in T.R.F. situations (Wright, pers. comm.). Malaysia is probably leading model and computer use in T.R.F. countries (e.g. Canonizado, 1978; Nor, 1978; Korsgaard, 1981) and such methods are of particular use in providing options for treatment of the hill mixed dipterocarp forest. Computer work has also been used in operations research (Dixon, 1972; Adams and Ek, 1974; Adams, 1976; Torres Uriarte, 1980), forest development (Ghazali, 1978; Korsgaard, 1978) and production of yield tables, etc. Wright (pers. comm.) believes it may be possible to produce a standard model as a basic treatment for all T.R.F. This does seem possible if the parameters used are not too detailed as similar T.R.F. throughout the world reacts in the same way to the same treatment, often the only difference being the genera and species that are produced due to regional characteristics (i.e. the succession from gap to 'climax' is common to all T.R.F.). Brunig (pers. comm.) hopes to be able to produce a dynamic simulation model of T.R.F. which will be used for

simulation and sensitivity analyses based on data collected from the MAB project at San Carlos de Rio Negro (cf. Brunig et al., 1978). (See references for other model work.)

Studies of forest products' demands and supply, forest management inventories, and land capability surveys should indicate the production/use potential of different forests and specify what additional input of resources (in land, staff and finance) might be required to meet feasible production goals. The World Bank (1978) has defined the numerous roles forests can play which would be useful in defining objectives for T.R.F. management in a particular area. Figure 4 shows a management chart for T.R.F.s. From reviewing T.R.F. systems and factors in N.R. it would seem that management should consider the following silvicultural systems should be applied which retain a reasonably high diversity both floristically and structurally, a moderate biomass stocking but a large canopy or leaf area index, and the highest possible aerodynamic roughness and absorptive capacity which the site conditions can sustain. There should be moderate turn over rates and relatively high production rates per individual of the main crop. This should maintain the character of T.R.F. while producing useful yields and products. An even-flow sustained yield is not always necessary (Schallau, 1974). A modulated sustained yield may be more acceptable whenever social costs exceed the benefit of an evenflow policy and thus, depending on the situation, appropriate sustained yield policies should be

FIGURE 4

MANAGEMENT CHART FOR TROPICAL RAIN FOREST.



After KIO. (1979)

followed (Mok, 1977).

Many articles (see references) have been written about the future demand for wood and more recently the shortages of fuelwood already present in numerous countries. Obviously species treated as weeds at present will become much more important and poison-girdling treatment is likely to decline while Earl's (1975b) charcoal ideas will undoubtedly become more important (Arnold and Jongman, 1977). Also the demand for tropical hardwoods for pulp is likely to increase as is that for minor forest products due to the demands of expanding populations. The term minor forest products is rather inaccurate today where these products are extremely important (Roche and Cooper, 1980).

With large and expanding populations it would seem sensible to try and find employment for the often untapped labour resource of tropical countries. As these countries often do not have oil reserves and costs of fuel imports are high and increasing, instead of increasing mechanisation in forest extraction and logging, manpower could be used as this would provide jobs for the otherwise unemployed, would save the fuel bill possibly reducing a balance of payments deficit, and could well reduce the amount of damage to residual stands during harvesting. By avoiding a preoccupation with machinery for machinery sake, following energy saving rather than labour saving techniques, replacing blanket methods by more localised and intimate treatment of areas, economising on capital intensive operations and counteracting adverse effects with labour intensive operations, yields and quality may be increased (Price, 1973, 1977, 1978). Although T.R.F. covers large areas in a number of countries,

the author believes that by promoting intensive methods, the success rate will be higher in terms of N.R. of the natural forest. It would seem expedient to increase employment and thereby provide work in the 'hinterland' (Westoby, 1979) of the country, which may lead to a better base for socio-economic development rather than utilise machinery with little labour working large areas (ICIDI, 1980). The main problem is that it appears to be 'turning the clock back' to an era of greater husbandry, which may be felt to be the opposite of development.

This type of thing, however, has been studied in the Philippines, the conclusion being that using labour and hand tools not only offered more employment, but actually raised productivity, cut costs, improved working conditions and safety, and helped to protect the environment (Simon, 1978).

CHAPTER 4

WHO IS GOING TO LISTEN?

There have been numerous reports and recommendations on how T.R.F. should be managed and developed and these have been written by very competent individuals or groups of experts (e.g., R.C. Barnard; H.C. Dawkins; P.R.O. Kio; L. Roche; T.J. Synnot; M.E.D. Poore; F.H. Wadsworth; P.J. Wood, etc.). Many of these recommendations have been implemented with good results, but others have been implemented and failed due to inadequate maintenance (cf. Nigeria), or

because the political situation in many tropical countries is extremely 'dynamic' with frequent government, forest administration, as well as personnel changes. This does not help continuation and prevents a stable forest policy being developed. Furthermore, some recommendations do not seem to get further than the statement phase. These are certainly not misguided or incorrect, but basically, they are empty rhetoric unless accompanied by specific and political feasibility. That politics is the art of the possible is a cliché, but those who have not mastered that art cannot expect their political prescriptions to be taken seriously. The question is how to make such recommendations acceptable to the countries endowed with T.R.F.?

Developed countries usually seem to be the driving force behind the recommendations but cannot, beyond a certain point, preach conservation or land-use policies to the developing countries. The economic predicament of many of these tropical countries is often such that they cannot prevent or forego deforestation. However, the aid-giving countries can make sure that aid spent on development projects which currently involve deforestation is given more conditionally than at present. In some cases aid has actively encouraged destructive methods (Myers, 1978; Westoby, 1979) and although it does still occur it seems to be on a smaller scale. Pressure may be used for the creation of more and bigger reserves - the cost of creating and maintaining them being borne internationally. Efforts to persuade countries to provide S.N.R.s should involve

informing them of the prestige and great value they would provide to the country and man, respectively. There should be no intrinsic conflict between development and conservation and this should be stressed.

Unfortunately, Britain at present is not really in a situation where it can dictate to anyone as it cannot even sort out its own 'Wildlife and Countryside Bill' (Melchett, 1981). The U.S. is not much better, as the work of President Carter in setting up an Interagency Taskforce on Tropical Forestry has been shelved by President Reagan, who is prepared to pay up to £110,000 million to expand America's nuclear deterrent forces (Halloran, 1981).

Having visited China in 1978, the author has seen the development of forestry in that country and like South Korea (N.A.S., 1980b), it has a massive reforestation scheme which has worked solely because of propaganda and development of a deep forest consciousness in its people. ("To protect forests is an honour, and to destroy them a shame" (People's Daily, 1973).) In T.R.F. countries, if the rural people were consulted about their needs, they would say fuelwood was vital, and, as many have a forest tradition and forest consciousness already using products from natural forest, projects which help retain T.R.F. will help the people. It seems that the people of such countries need to be consulted and encouraged to cooperate with the various aid agencies who are likely to provide capital and technical knowledge to implement careful management. A 'bottom-up'

approach would appear to be much more effective than a 'diffusion down' process. This is not an attempt to usurp the present government of the country, but no doubt will attract claims of neo-colonialism. It is an honest attempt to provide the people with what they really need (not what the politicians say the people need), and at the same time to ensure continued existence of T.R.F.

Politicians must be convinced that T.R.F. is important not only in terms of foreign currency from log exports, but as a basis for long-term socio-economic development (Blake, 1978). Attitudes must change from "I split the rock, I felled the tree, the nation was because of me..." (Mary Gilmour), to one of "A thing is right when it tends to preserve the integrity, stability and beauty of the biotic community [and] it is wrong when it tends otherwise" (Aldo Leopold, 1949). They must stop thinking about decent land use as solely an economic problem and examine each question in terms of what is ethically and aesthetically right, as well as economically expedient.

Questions such as what is 'good' for society rather than what is 'efficient' for society need to be asked. Cost/benefit analysis uses the latter premise and is thus somewhat unreliable and unacceptable for decision-making in the protection of the environment, as it tends to warp the perspective of the policy maker. "By all means use the most cost effective way to achieve the end, once the end has been determined, but do not use cost/benefit analysis to determine the end" (Ashby, 1978).

T.R.F. management by N.R. cannot be treated in isolation. Other forms of forestry including enrichment plantings and plantations must also be considered. Their importance is undesirable in compensatory uses and in helping meet timber demands of large populations in tropical countries and the world as a whole. Despite recognition of the T.R.F. problem, conservation generally has come up against the old problem. People are quite happy to work within ecological laws when conserving plant and wildlife; the trouble arises when they try to solve the problems of human conservation which is closely linked with nature conservation. Man is still convinced he is unique and therefore exempt from ecological laws, despite all contrary evidence. If he was really prepared to accept the new ideas, he would be prepared to apply the rules to himself (e.g. he would rarely try to save or prolong life). It appears that if man is going to practise conservation and judicious use of resources, he is not going to abide by all the rules.

Although the issue of the T.R.F. is highly emotive and therefore tends to attract superlatives, and the description of its destruction is often utopian and apocalyptic, in the present social climate, some dramatisation is needed to get results. Man is not dominantly a rational animal - or he would not be so bedevilled by theism, and thus the author makes no apologies for being somewhat emotive in this last section. Possibly with a greater degree of coverage in the media about T.R.F. deforestation, more positive action would be taken, as until more pressure comes to bear

on the countries endowed with T.R.F. it will continue to disappear.

Forests have had over a hundred years managing T.R.F. with a number of major successes with N.R. systems. With continued research into T.R.F. ecosystems and trials of management systems, the future of the forest should be assured as long as deforestation is stopped soon. If a forest consciousness like that of the Chinese and endemic forest people could be fostered, (e.g. "The forest is a father and mother to us ... it gives us everything we need" (Turnbull, 1961), the survival of T.R.F. will be that much more certain. If native and human conservation are ignored and a major plan of conservation has to wait until the politicians and public gradually come to terms with the ethics and ideas, hunger, lack of resources, and over-crowding may well drive man to war on an unimaginable scale. Perhaps an ultimate holocaust is the logical and natural outcome of man's role in the natural environment, he shall become extinct and some other species will be faced with the conservation of nature. But conservation (and retention of the T.R.F.) is a much more attractive alternative, as without it, man has not got much to look forward to in the future.

This is the way the world ends,
This is the way the world ends,
This is the way the world ends,
Not with a bang, but a whimper.

The Hollow Men
T.S. Eliot (1927)

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