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GSH-3 NEW ECOLOGICAL PERSPECTIVES ON THE MANAGEMENT OF TROPICAL FORESTS

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There is a growing concensus among foresters and organizations involved in tropical forestry that it is both ecologically and economically unjustifiable to manage tropical forests. This trend is highly evident in the numerous industrial companies currently converting tropical forests to single-species plantations, and in the rush to climb aboard the agri-silvicultural "bandwagon". (Agri-silviculture is the planting of valuable trees with seasonal agricultural crops; tending of the crops gives the young trees a head-start as well.) Mr. Alf Leslie's (reader in forestry economics, University of Canterbury, Christchurch, New Zealand) recent assessment in the journal UNASYLVA* of the ecologic and economic difficulties of managing tropical forests illustrates the current disdain for considering management of tropical forests. Though tropical forests may be justifiably managed for watershed protection, recreation or esthetic reasons, I believe a much stronger case for timber production management of tropical forests can be and needs to be made.

Advances in our knowledge of forest dynamics, natural regeneration, ecological heterogeneity, land use capability, and secondary species utilization, for example, suggest that natural forests are not as inferior to plantations as is commonly believed. I believe it is urgent that tropical foresters free themselves of their traditional species-based managerial concepts and revitalize their ecological thinking with fresh,

* Specific literature citations are available from Hartshorn.

innovative and even revisionist ideas. In this report I will reassess the ecological advantages and constraints to management of tropical forests. Since my present field experience is restricted to the American tropics, most of my comments and examples will be necessarily taken from Neotropical forests.

HISTORICAL PERSPECTIVE

The roots of tropical forest management trace to the British presence in India and Malaya. These early British efforts around the turn of the century evolved into two major forest management schemes--the Malayan Uniform System (MUS) and the Tropical Shelterwood System (TSS), the latter first developed in Nigeria. The MUS developed in the very species rich forests dominated by the Dipterocarpaceae tree family, which has the unusual feature of flowering and fruiting very infrequently but synchronously. Dipterocarp seeds germinate quickly, forming "carpets" of shade-tolerant seedlings covering the forest floor. For the MUS to be operational, an adequate number of seedlings have to exist before logging the forest, thereby allowing vigorous development of a uniform-aged second growth forest of dipterocarps.

Transferal of the MUS to British colonial Africa was not successful, primarily due to the lack of adequate regeneration prior to logging. Preoccupation with the regeneration problem led to the development of the TSS, which only selectively opened up the forest canopy to stimulate seedling establishment of the preferred species. The TSS is the primary management scheme in tropical Africa and the Caribbean. Tropical forest management experience in Latin America is practically non-existent, no doubt related to differences in colonial history.

Both the MUS and the TSS, as well as variations on their basic plans, are management programs based on favoring the regeneration of desired species. Silvicultural treatment, such as selective thinning is often required to favor the desired species. This is particularly true in the African and American tropics for the TSS, due to the absence of a dominating tree family like the Dipterocarpaceae and the maintenance of an overstory shelterwood to protect the desired regeneration.

The traditional emphasis on the demand for preferred timbers is changing so rapidly in several Neotropical countries that the forest management objectives of the TSS are no longer valid. Silvicultural treatments were performed to reduce the abundance of fast-growing trees to favor the slower-growing preferred timbers. Many of those previously useless, fast-growing trees are now locally marketable. In countries such as Costa Rica, with a limited supply of timber, increased demand for preferred timbers coupled with decreasing availability, has resulted in very substantial price rises for the preferred timbers. As the prices of preferred timbers rise, other, cheaper timbers enter the market. These secondary timbers are generally of quite acceptable quality and are a major component in the construction trades. The Costa Rican market now accepts any log of acceptable size and form. Trends such as these indicate that tropical forest managers should be less preoccupied with favoring particular species and should be more concerned with producing as much timber as possible.

If forest products other than sawn or sliced wood are considered, the potentials for more-complete utilization of tropical forests are very impressive. At the recent international conference on improved

utilization of tropical forests at Madison, Wisconsin, the technologic and economic feasibility of making reconstituted wood-fiber products (for example particleboard, fiberboard, linerboard, paper) from mixed tropical hardwoods was illustrated (see Hartshorn's ICWA Report #2).

Clearly, managers of tropical forests should concern themselves with total cellulose production rather than destroy valuable growing stock to favor preferred species.

ECOLOGICAL BASES FOR MANAGEMENT

The complexity of tropical forests, slow growth of preferred species and frequent difficulty of regenerating preferred species are often cited as being prohibitory to the management of natural tropical forests. These features have often made the management for a few preferred species impossible or too difficult, but when viewed from the objective of total timber or cellulose production they might even become advantageous features. Furthermore, improved understanding of tropical forest dynamics and the roles of species in tropical forests should also contribute to their successful management.

Ecological Heterogeneity

Descriptive phrases such as "tropical rain forest" or the more currently in vogue "tropical moist forest" or "humid tropical forest" are often used in such a general sense, they actually tell us practically nothing of the ecologic conditions of a particular tropical forest. The temperate bias of nearly all world vegetation (for example UNESCO, Udvardy) and climatic (for example Koppen) classification schemes fails to adequately account for the much greater ecological heterogeneity in the wetter tropics. Dr. Miklos D. F. Udvardy's (zoogeographer, California State

University, Sacramento) recent map of world biogeographic provinces is illustrative of this temperate bias. In the great Amazon basin only three biogeographic provinces are recognized by Udvardy, yet Argentina has seven and Mexico has nine. It is inconceivable to me that the Amazon basin, which may contain as much as one-tenth of the world's species and where at least five in every six plant or animal species is unknown to science, is less heterogeneous ecologically than extra-tropical regions. Dr. Ghilleen T. Prance (tropical botanist, New York Botanical Garden, Bronx) recognizes seven major phytogeographic regions in the non-flooded Brazilian Amazon. If one were to include the Andean slope forests of the upper Amazon, several additional biogeographic provinces would have to be added.

The only world vegetation classification system to adequately represent the great ecological heterogeneity of the tropics is the World Life Zone System developed by Dr. Leslie R. Holdridge (ecologist, Tropical Science Center, San Jose, Costa Rica). Each Holdridge life zone is precisely defined in the isogonal chart (Fig. 1) by two independent parameters, mean annual precipitation and mean annual biotemperature, and one dependent parameter, potential evapotranspiration ratio. The mature, natural vegetation of each life zone has a distinct physiognomy and complexity. Although a very low percentage of species are restricted to only one life zone, a species will have a different growth form in each life zone in which it occurs. The pan-tropical kapok tree, Ceiba pentandra (Bombacaceae) is an excellent example: it reaches 60 m in height and 2 m in trunk diameter at breast height (dbh) in tropical wet life zones; less than 40 m tall and 1.5 m dbh in tropical moist life zones; and in tropical

dry life zones it is a squat tree less than 25 m tall and 1 m dbh.,

The tropical rain forest of Dr. Paul W. Richards (plant ecologist, University College of North Wales, Bangor, England) includes 13 Holdridge life zones. With over 100 life zones known for the world, the majority occur in the tropics; for example, Peru has 34 tropical, 37 subtropical and 10 warm temperate life zones. In traveling the road between Lima (12° S) and Pucallpa ($8\frac{1}{2}^{\circ}$ S), Peru, 22 life zones are encountered in only 850 kms. In contrast, the entire eastern United States has only 13 life zones.

Although Holdridge and Dr. Joseph A. Tosi, Jr. (tropical geographer and forest ecologist, Tropical Science Center) have used the life zone system to map all of Latin America except Argentina, Chile and Brazil, the system is applicable on a world-wide scale. In the eastern hemisphere the Holdridge Life Zone System has been used in the Mediterranean region, Thailand, Mozambique, Timor and Japan. Provisional life zone maps of Australia, Nigeria and Cameroon have also been prepared by Holdridge and Tosi.

One of the major advantages of the Holdridge Life Zone System is the detailed specificity it offers in classifying tropical vegetation, whether for comparing vegetation in different tropical regions or using the life zone system as a framework for forest inventory, land use capability classification, floristic studies, crop recommendations or patterns in timber quality.

An interesting pattern of wood density in tropical basal and tropical premontane life zones in tropical America is reported by Dr. Martin Chudnoff (tropical wood technologist, U. S. Forest Service Forest Products Laboratory, Madison, Wisconsin). In tropical moist and premontane wet

life zones (between 2000 and 4000 mm annual rainfall) there is a preponderance of species with wood densities greater than 0.69. The lower rainfall (1000-2000 mm) tropical dry and premontane moist life zones have a fairly uniform distribution of species in the wood density classes. The higher rainfall (4000-8000 mm) tropical wet and premontane rain life zones have a high proportion of species with intermediate densities. In detailed field studies at 47 sites in 10 life zones in Costa Rica, Holdridge and a group of scientists working with him have documented how numerous physiognomic features vary between life zones. Another example of the utility of the life zone system is the high species fidelity of epiphytic Bromeliaceae with tropical life zones found by Mr. John Utley (botanist, Duke University). It is likely that as more data become available from tropical ecosystems other interesting correlations with life zones, such as in primary productivity, nutrient cycling, tree growth rates, etc. will emerge.

Growth Rates

Slow growth of trees in tropical forests is the most frequently cited constraint to management. Mean annual diameter increments of less than 1 cm are reported as typical for tropical forests. Yet it is appropriate to review the forest types from which growth data are available and their representativeness of tropical forests. Four years of growth data for 22 Philippine species were cited by Richards in his classic book The Tropical Rain Forest (1952) as the best growth data available for trees in natural tropical forests, but the original authors, Brown and Matthews, studied forests on Mt. Maquiling; thus it is unlikely that the growth rates obtained are representative of trees in lowland tropical forests.

Possibly the longest-term tree growth data come from permanent plots established in 1957 by Dr. Frank Wadsworth (director, U. S. Forest Service, Institute of Tropical Forestry, Rio Piedras, Puerto Rico) in the Luquillo Mountains of eastern Puerto Rico. Wadsworth's associates Dr. Thomas Crow and Mr. Peter Weaver report the results of a 1975 re-measuring of more than 2,000 individuals of 18 species. Mean annual diameter increments for the 18 species ranged between 0.30 and 0.60 cm. The 18 year hiatus between measurements may have missed significant growth spurts--as suggested by the authors. However, there are more serious questions about the interpretations of the growth data. That two classic pioneer species, Cecropia peltata and Didymopanax morototoni, have the slowest diameter increment rate is quite anomalous, suggesting to me that severe soil or nutrient restrictions on the study sites may inhibit tree growth. If so, the authors' extrapolation of their results to all moist tropical forests is unacceptable. Ecological classification of the study sites within the subtropical wet forest life zone in the Holdridge system by Dr. Jack Ewel (plant ecologist, University of Florida, Gainesville) and Mr. Jacob L. Whitmore (forester, Institute of Tropical Forestry, Puerto Rico) strongly indicates that tree growth rates should not be representative of trees in tropical life zones. Crow and Weaver apparently attempt to make their results as broadly representative as possible by using several different ecological descriptions to describe their study sites: "moist tropical forest" (title); "the three study sites were in the lower montane rain forest" (p. 1); and "tropical rain forests of the Luquillo Mountains" (p. 9); yet fail to mention that the study sites are in the subtropical wet forest life zone as mapped by Ewel and Whitmore in 1973.

Unfortunately, the virtual absence of published reports of growth or diameter increment rates for trees in natural forests of the tropical lowlands makes it impossible to accept any generalizations, either pro or con, about growth rates of tropical trees. Even though the information on tropical forest productivity is meager, it is generally accepted that tropical forests are more productive than extra-tropical forests. Young secondary (early successional) tropical forests accumulate biomass at an impressive rate, but it is not known how quickly the rate of biomass accumulation slows down with advancing succession. Data on growth rates of early secondary forests is essential to the evaluation of the management potential of natural forests. Most tropical foresters would agree that young secondary forests do not accumulate biomass as rapidly as plantations of the fast-growing exotics, like eucalyptus, pine or gmelina, for example, but it is important to any such comparison that realistic assessments of true plantation establishment costs be included.

Forest Dynamics and Natural Regeneration

The ability (or luck) in obtaining adequate regeneration of preferred species is often the key to successful management of natural tropical forests. This key role of natural regeneration in the development of the two main management schemes, the Malayan Uniform System and the Tropical Shelterwood System, has already been described (p. 2). Numerous failures in obtaining adequate natural regeneration have led to the widescale use of enrichment plantings or conversion to plantations. I believe that most of these failures are directly attributable to a lack of understanding of tropical forest dynamics.

Practically nothing is known about the ecology of native tree species, so if the germination requirements and light regime of the preferred species are not known, how can one expect to employ or modify a management scheme to favor natural regeneration? Our ignorance is compounded by the simplistic division of trees into successional and climax species and the assumption that mature forests should contain predominately climax species. It is now clear that most mature tropical forests contain a substantial number of successional or shade-intolerant species. I have reviewed elsewhere how the misunderstanding of the status of shade-intolerant species in mature forest has led to misinterpretations of the successional status of some Neotropical forests. Correct assessment of the successional status of a forest is essential if that forest is to be managed for timber or secondary forest products such as water or wildlife.

Detailed forest dynamics studies in a mature tropical wet forest in northeastern Costa Rica show nearly half of the tree species to be shade-intolerant, that is, successful regeneration only occurs in gaps (areas where direct sunlight can reach the ground). The proportion is even higher (63%) if only species attaining the canopy are considered. Preliminary evidence indicates that shade-intolerant species grow substantially faster than do shade-tolerant species. The abundance of shade-intolerant canopy species is particularly important from a management perspective, because many of the fast-growing shade-intolerant species regenerating in gaps are commercially valuable timbers.

Since successful regeneration of many tree species depends upon gaps, management attempts must take into account the patterns and processes of local forest dynamics. Some of the major drawbacks of selective logging system are (1) that reproductive trees of the preferred

species are not left to provide a seed source; (2) just the poorly formed individuals are left resulting in genetic degradation; and (3) canopy openings stimulate reproductive activity of understory trees, which are of no commercial value, thus significant seed inputs come from the non-commercial canopy and understory species.

One solution to discriminatory selective harvesting would be to remove all stems in an area, that is, simulate a large gap or "blowdown" which also destroys the understory vegetation. In other words, clear cut patches of tropical forest. Even though clear-cutting has been heavily criticized in drier temperate regions, it appears to offer considerable potential as part of a management scheme for the humid American tropical forests. The regenerative ability of tropical trees in colonizing natural clearings or abandoned fields is well known. Colonization of clear-cuts should proceed in a similarly rapid manner, as long as there is an adequate nearby seed source. It may even be feasible to grow an agricultural crop the first year after clear-cutting. The size and shape of the clear-cut may be extremely important in facilitating dispersal of seeds into the opened area. Long, narrow clear-cuts may be the most propitious shape for obtaining good seed input from fruit-eating birds and bats. Unfortunately, we do not know how the size and shape of tropical clear-cuts affect the rate and quality of natural regeneration.

Plantations

I want to emphasize that I believe there is a definite need for plantations in tropical forestry. In denuded watersheds, on degraded agricultural lands or in dry savanna areas, reforestation with plantations is the only means of reestablishing tree cover. But what is objectionable

is the increasingly prevalent view that plantations are a panacea for tropical forestry. A major contributor to this viewpoint is the large scale international exchange of fast-growing exotic trees, for example, a weedy species native to Malaysia is brought to tropical America for use in plantations. Many so-called wonder trees have been tried throughout the tropics, but very few have become successful plantation trees. There are numerous examples of exotic species growing beautifully in plantations for a few years then abruptly ceasing to grow or even dying.

The proponents of the plantation panacea fail to give due consideration to several potential ecological hazards of single-or few-species plantations. One of the commonly given justifications for using exotic species is that the trees' pests are left behind in their native habitats. Hence in the absence of natural or native pests, the exotic species can be grown in pure plantations. Some well-known examples are the rubber tree native to the Amazon but grown commercially in southeast Asia, and coffee native to the Ethiopian highlands but with major commercial production coming from Latin America. Implicit in the success of exotic crops is the assumption that considerable time is required for local pests to adapt to the "foreign" crop, thus it is both economically and ecologically justifiable to continue the international exchange of exotic species. However, recent analyses of parasitic pests on cacao (cocoa) and sugar cane by Dr. Donald R. Strong (ecologist, Florida State University, Tallahassee) indicate that area (or the local range of the crop) is the most important determinant of the richness of pest species. It has also been demonstrated that pest buildups on exotics result from pests switching hosts rather than the evolution of new pests. This means that the larger

the area planted to a species the greater the probability of pest problems. Thus we can expect Mr. Daniel Ludwig's hundreds of thousands of hectares of pure plantations of Gmelina arborea (a native of southeast Asia and the Indian subcontinent) along the Jari River in Brazil to encounter local pest buildups in a relatively short number of years.

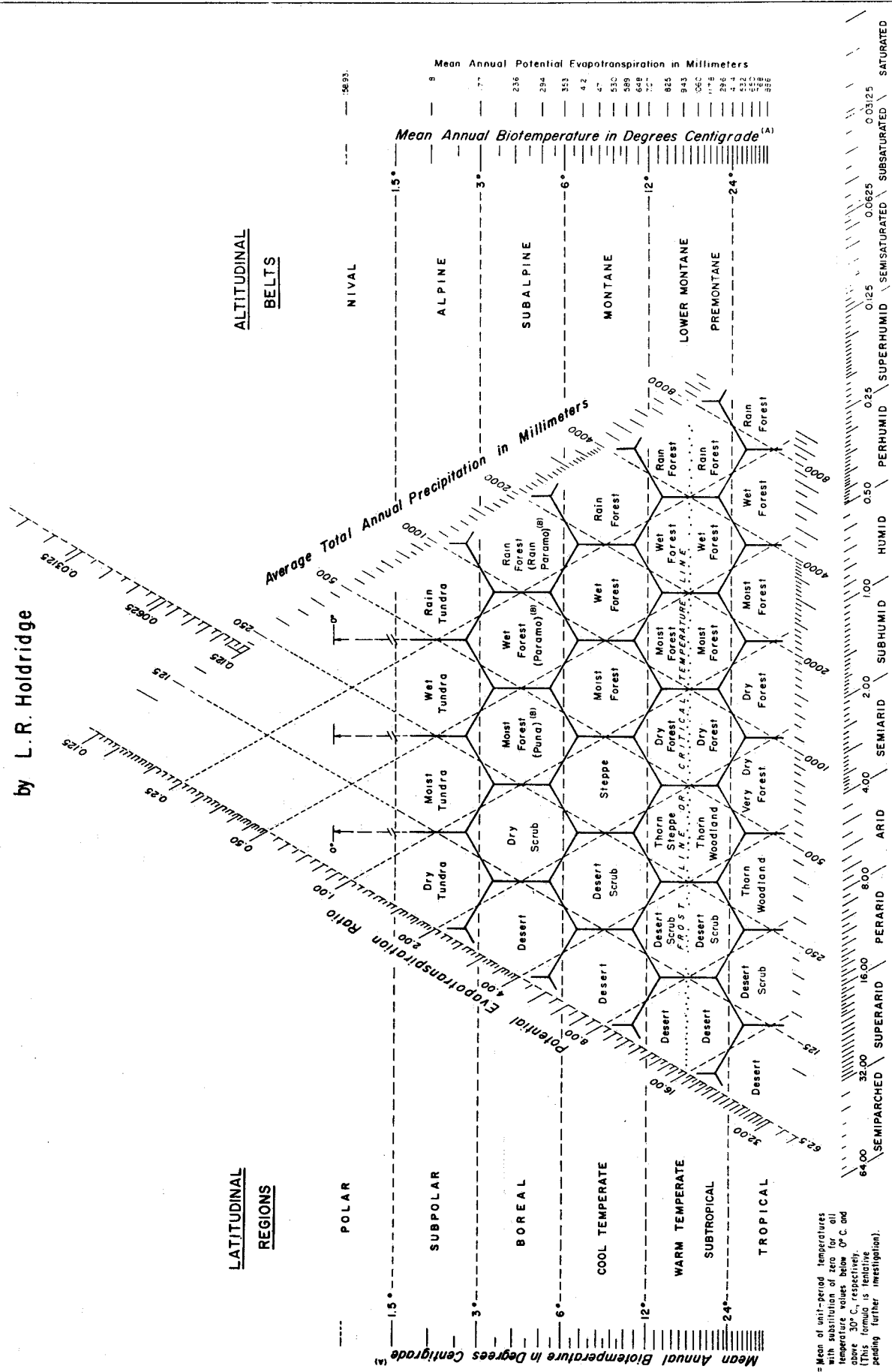
Another aspect of plantation forestry in need of considerably more attention is the relation of pure plantations and soil fertility. It is well known that most tropical soils are relatively poor in nutrients and that substantial quantities of nutrients are kept in the forest ecosystem by very tight recycling mechanisms involving mycorrhizae--fungal associates of the tree roots. The ecological complexity and species richness of tropical forests is thought to be very important in maintaining the tight recycling of nutrients. It is highly unlikely that a single species even in a dense plantation can maintain the tight nutrient cycle, thus there may be substantial losses of nutrients even without harvest of the planted trees. Many plantation prescriptions call for maintenance of a vegetative ground cover to help tie up nutrients not absorbed by the planted trees, but in practice you seldom see any significant ground cover vegetation in plantations of gmelina, eucalyptus or pine.

The rapid loss of tropical soil fertility through conversion of forest to agriculture or pasture makes it clear why foresters prefer to cut down virgin forest in order to establish their plantations on "virgin" soil rather than try to reforest worn-out, nutrient poor agricultural land. Everyone from the shifting cultivator to the industrial forester wants to capitalize on the nutrients accumulated by the virgin forest for the gains of one or two quick crops. The ability of non-alluvial tropical soils to produce several successive crops of planted trees is highly suspect.

It should be clear from the above discussion of potential pest and soil fertility problems associated with plantations that the ecological complexity of natural forests greatly minimizes these particular difficulties. Even though my suggestion of clear-cutting as a management tool for natural tropical forests would cause some nutrient loss, the rapid colonization by native second growth would probably result in substantially less loss of nutrients than if the clear-cut were converted to a plantation. It is easy to recommend that research be done to answer these critical questions, but is there time to wait for the answers? Multinational corporations, international agencies and local governments are already making decisions about the fate of tropical forests. It is my thesis that conversion of tropical forests to plantations may not be a wise use of a valuable natural resource and that the management potential of natural tropical forests should be reconsidered in light of our better understanding of renewable, tropical forest resources.

DIAGRAM FOR THE CLASSIFICATION OF WORLD LIFE ZONES OR PLANT FORMATIONS

by L.R. Holdridge



(A) t_{bo} = Mean of uni-period temperatures with substitution of zero for all temperature values below 0° C. and above 30° C., respectively. (This formula is tentative pending further investigation).

(B) = in Tropical Subalpine Only.