

Ecology and management of residual forests or How to lodge one thousand species in one cubic meter

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INTRODUCTION

Residues of earlier extended forests exist or have existed in most parts of the world at some moment of their history. This is due to the fact that in most historical periods forests are of the lowest priority rating, if they are not outright forgotten. We are today in a country and at a moment which are exceptional in this respect. Hundreds of serious people are united in this second Brazilian symposium to consider not only whether they can understand the forest remnants, but also what can be done to conserve them with at least some chances of success.

This is not self-evident. In fact, the past 30 or 40 years in general were one great fiasco as to the responsible conservation and use of forests worldwide. There were indeed a few success stories, such as the ecological forest management in Indonesia of the last twelve years now menaced by forest fires, the stability of European forests still menaced by their industrial environment, or the Brazilian industrial wood plantations. However, the forest area in the world has shrunk incessantly with tens of thousands of square kilometers per year, and the remaining ecosystems have become increasingly poor in biotopes and in species.

Nothing in the real forests today reflects any effect of the political slogans of sustainability, biodiversity and ecocertification or labelling. This sorry state of the forests is at least partly due to the fact that very few of the ecological theories today reflect real forests. A forest in a computer, alas, has as little in common with a living forest under the sun as bookkeeping has in common with a real shop and the people in it, buying, selling, chewing gum. Unfortunately, students are taught the bookkeeping skills first and no serious attention is paid to the real, hard enterprise of sustaining the real, living forests in an indifferent, living human society.



HOW TO LODGE A THOUSAND SPECIES IN ONE CUBIC METER?

Yesterday, this was done by sampling a thousand plant and insect species, to dry and stock them in large cupboards. The estimate that a thousand specimens can be stocked in one cubic meter then is conservative. A famous Brazilian botanist from Belém do Pará, the late Dr. Adolfo Ducke, fulminated against scientists who based their views on such collections, calling them scathingly “herbar-botanists”.

Today, this is done in the following way. All data concerning a species, including its ecological role, are stocked in computers. The printouts for a thousand species would occupy a cubic meter or so.

Of course, we now can do still better and stock ten thousand species on one CD-Rom which occupies 11.3 cubic centimeters ($\pi \cdot R^2 \cdot h = \{3.141 \cdot 6^2 \cdot 0.1\} \text{ cm}^3$).

However, the forest itself does quite a good job too. This is only visible if we abandon the bad habit of looking only at tree species, or only at species visible with the naked eye, or only at species that interest us for one reason or another. Including *all* species, from bacteria to giant trees, the average species content of a cubic meter of natural tropical forest might not be so far from the thousand mark. As an example, look at one leaf colonized by a phyllosphere community composed by bacteria, fungi, algae, tiny seed plants and the associated insects.

Scientists usually link the theoretical to the real “species volumes” by a process of species identification followed by processing of population counts, yielding the well-known indices of species richness, biodiversity, rarity and abundance. Not only are these numbers restricted, in the current type of study, to certain categories of species, such as trees or woody plants. In addition, they do not explain the forest well, although they are often associated to site classes and/or forest types. This is due to sites and forest types not being counted - but being mapped.

Maps and numbers can only be made to fit together if the legend of the map accommodates the numerical vegetation properties resulting from species counts. This indeed makes it easier to understand why a forest has become poorer in species after some site or some forest type was damaged or killed. Still, this is insufficient to either forecast the natural restoration process or design a precise management plan to help this restoration take place and sustain it.

This is why we are going to turn the question upside down, and work from the whole forest to the biotopes it offers to species. This allows both to keep an eye on the whole ecosystem, and to “zoom in” towards any large or small specific biotope one needs to examine. The image of the forest evoked here is called since 1992, when published in Dutch (1994 in English and French), the folded forest (Oldeman 1992, 1994; Oldeman e Sieben-Binnenkamp 1994).

Figure 1 shows the folded forest [bosque plegado (Esp.) floresta pregada (Port.)]. The forest is shown as a folded green blanket. The fat, black lines on top symbolize the layer of leaves with their exchange capacity. In nature, it is usual that the increase of an exchanging surface is increased by folding, like for instance in our lungs. The largest forest folds are built by small and/or narrow clumps, low fields, or forest blocks (Fig. 1a). However, these blocks or clumps are folded again, by the crowns of trees and shrubs representing a fold each (Fig. 1b). In their turn these are folded again, because a tree crown is built by numerous crownlets, the architecture of which corresponds to small trees of a specific model (Fig. 1c). Each of these crownlets is constructed by branches in a regular, inherited pattern (Fig. 1d), the architectural model defined by Hallé e Oldeman (1970), also cf. Hallé et al. (1978). Each leaf-bearing branch

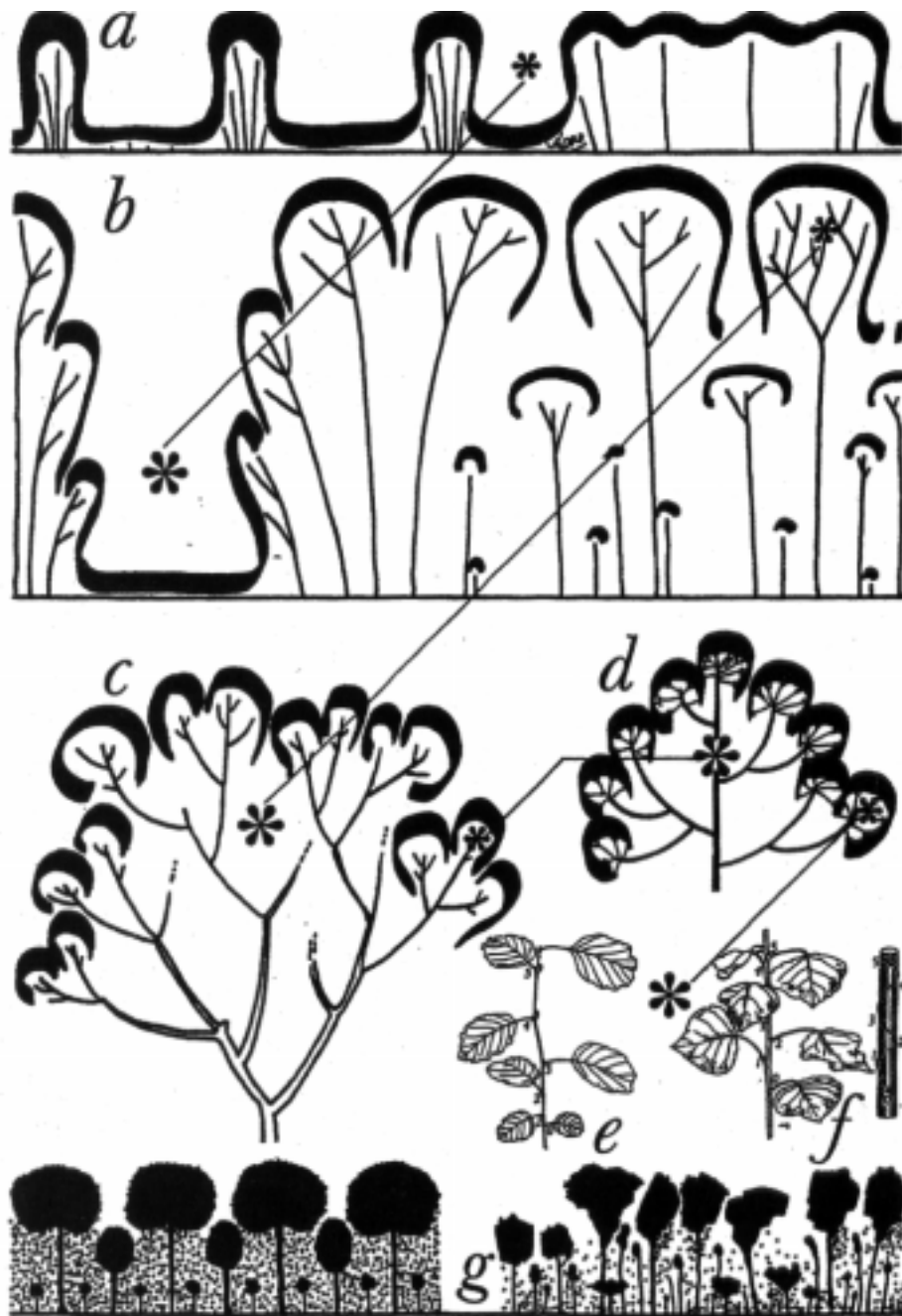


Figure 1
The folded forest
Floresta pregada



is folded by virtue of its leaves which are inserted in a regular spiral described by the well-known series of Fibonacci (Fig. 1e). Now if every folding would increase the total surface over 1 m² of forest soil by a factor of 1.33, the five green folds over 1 m² would cover $1 \cdot (1.33)^5 \approx 4.16$ m² * m², a value close to the usual leaf area indices found in forests.

Now a whole forest may be computed with Fibonacci values as an algorithm (Fig. 1e). Leaf axils bear branches, so branching follows the same spiral. The crownlets also can be assumed to grow in regular patterns. If such computations were visualized, the result would be a mathematical forest like shown at the left side of figure 1g, which implies ecophysiological consequences. Tree crowns fill up all places with enough light, humidity and gases to grow. They consume all resources, so the stippled volume between crowns is dark, dry and without CO₂. This mathematical forest hence is self-defeating, for in the ecologically dead space between the trees no seeds can germinate and no young trees can grow up. Even adult tree crowns can not grow, because existing branches leave no resources for new branches.

This image, similar to Holdridge's "idealized forest", proves that ideal plantations, in which one tree crop completely monopolizes all "production factors", is an illusion. Real forests are like figure 1g at the right hand side. Small deviations occur in the building of leaves, branches, branched models and whole trees, due to the fact that biological structures may be similar, but never identical. Trees of one species have slightly different architecture, different growth rates and a different lifespan, some dying younger than others. Moreover, the forest is exposed to a very irregular regime of rain, storm, thunderstorm, lightning, different sized inundations and other impacts setting its growth locally back to zero. This results in a very irregular forest architecture. It is an eco-mosaic with eco-units of different ages, sizes and shapes, each unit having its own species composition. Figure 1a shows 7 eco-units. A forest eco-unit is a small ecosystem, composed by many species including at least one tree, born at one spot at one and the same moment, and growing up according to one development process.

The right-hand forest of figure 1g is a normal forest configuration, as shown for instance by the scale-drawings of the Mata Atlântica in the ecological station of Pau Brasil by Van der Linden et al. (1988) or the three-dimensional sketches in Góes-Filho (1991). Pioneer and mature forest ecosystems have different architectures, but the same principle of determinate chaos applies. In each fold order this creates biotopes for many species. The very irregularity of the forest explains its high species diversity. We also can prove that irregular forests exert high stresses on plant species building them, for instance by the far red radiation near the forest floor, under which plants and animals strongly tend to mutate and speciate (Rossignol et al., 1998 in press). The more the variation and the smaller the size of the eco-units, the richer their interactions like mutual shading, whirling air around, or distributing rainwater. The complexity of forest architecture hence is a strong indicator for species richness.

Please note, that the complexity of forest architecture can be managed. Indeed it is managed in silviculture and agroforestry. Biodiversity can not be directly managed.

Fragmentation of eco-units often occurs when parts of an eco-unit are broken down by some natural or artificial impact. Many call this a "disturbance", but we will not follow this habit because the factors are natural and hence they do not disturb any natural process of forest building. On the contrary, without these impacts biodiversity would be inferior and so would be ecological production, because a regular crown canopy has a smaller green, photosynthetic surface than an irregular, tormented canopy. When contiguous, eco-units of distinct ages grow up



together, after some decades the oldest one is overtaken by the younger ones. All finally reach the same height approximately. This process is called fusion of eco-units because they fuse into one larger functional unit, which is not very stable because generally the oldest eco-unit will die again before the younger ones, like it also was the first to reach maximal height.

This analysis clearly shows that biodiversity is no fixed property. On the contrary, if one tries to fix an ecosystem in a state of biodiversity, it tends to lose the very dynamics that produce species diversity. In a study on local agrosystems in the Mediterranean, Remmers (1997) says that biodiversity can not be conserved, only reproduced.

Management of complete ecosystems, with a view to sustain their completeness, hence should be done by biotope multiplication. This is a normal property of intact ecosystems, because every process in forest dynamics opens biotopes. There are the rhizosphere or phyllosphere biotopes, for instance, at the interfaces between the leaves and the atmosphere and the small roots and the soil. In the case of the rain forest phyllosphere (Ruinen 1956, 1974), the leaf surfaces are colonized successively by bacteria, fungi, algae, small seed plants and associated tiny insects and other animals. In this way, the forest itself lodges a thousand species in a cubic meter.

Biotope multiplication is not at all new, and exists in old, traditional agroforestry systems. Among the many known in the world, Bahri (1992) studied the practices of the inhabitants of the Amazonian Island of Careiro downstream from Manaus. She analysed the different fields, plantations and home-gardens using very precise transects to scale. These lands evolve from intact forest through monoculture to cattle ranges, but developments as determined by local inhabitants are reversible. Rubber cultures may become, for instance mixed rubber/cocoa plantations and from there derive to strongly mixed home gardens with many crop species, creating places for many wild species too. And home gardens may be converted to cocoa, etc.

The shift from one agricultural type (De Jong 1995) to another is strictly dictated by the preferences and market forces influencing the agricultural behaviour of the local inhabitants. This fits in with conclusions from other parts of the world. For instance, Laumonier (1997) in an Indonesian study emphasizes the importance of the agroforestry systems that cover some 10% of the area of the island of Sumatra. These maintain floristic diversity on cleared lands, so being a reservoir of those menaced genetic forest resources that are indispensable for balanced land use. His study was done before the forest fires of 1997. Their aftermath will require the greatest array of available species for ecosystem restoration.

The empirical principles used in the most refined traditional mixed land use types have been examined by Oldeman (1995), then Neugebauer et al. (1996). They are the rules of the pacemaker, the spacemaker, and the placemaker.

Pacemaker plants are the plants of which the rotation beats the basic land use rhythm. For instance, in a monoculture like rice, the pacemaker is rice and its beat is of 3 or 4 months. In coppice cultures, the pacemaker is a tree species, the mechanism is periodic coppice cutting. The period depends on climate, tree species and product, usually between 3 and 20 years. All other plant rotations, and the calendar of labour, depend on the basic cycle of the pacemaker plant. There is evidence that in nature, the same principle applies, and that no cycle may remain empty. An empty cycle is an empty biotope which will be filled by a species.

Spacemaker plants are plants of which the architecture divides the vegetation in subvolumes with distinct functions. In coffee plantations, shade trees are spacemakers. Spacemaker plants make layers and other volumes in which special processes unroll. In a managed forest, trees as



spacemakers may split up the whole forest volume in a wood volume, a coppice volume, a fruit volume, an ornamental plant volume and others. In natural forest, the spacemaker principle operates too. In traditional agroforestry it has been applied to combine different products and to diminish certain spaces, e.g. the weed volume. Canopy farming © is a modern expression of the spacemaker principle.

Placemaker plants are those plants that create biotopes, i.e. biological places, for other species. In principle, every plant does this. However, typical placemaker plants like giant trees create biotopes going from those hosting smaller trees and shrubs to the epiphyte and liane biotopes on its branches and the phyllosphere and rhizosphere biotopes at its extremities. It is to be remembered that biotopes which are emptied of their species, e.g. insect biotopes emptied by biocides, will fill with other occupants. It should be noted too, that biotopes hosting no immediately commercial species may host organisms that have a supporting function for crops, such as the long forgotten mycorrhizal fungi which became so trendy in the last decades.

The three ecological cultivation principles can be adapted to any form of land management or use. We will consider in the following paragraphs how they apply to the ecology and management of residual forests, spread over a wide landscape.

These forest rests, like the remains of the Mata Atlântica or the isolated groves in Yucatán, México, have to be considered as a network of ecosystems of which the inhabitants are responsible. Without the inhabitants, these forests are doomed. There hence is a network, not only of forest remains but also of responsible people. There may be two parties in this network. The first party is that of the local inhabitants, who will have to perceive the remains of the forests as eminently useful and agreeable to themselves. This of course is the principle of the *reservas extrativais*. However, there is another party, which is the group of people that can monitor and correct the processes and structures. This is a task that in the past has been done by state foresters and other public servants, sometimes by latifundistas. We proposed (Oldeman et al. 1993) to supplement these professionals by a new private one, the ecomed, a doctor healing ecosystems like a veterinarian heals animals.

Some technical principles could link together the people and the residual ecosystems in such a network.

The first one is, that the best forest product has the *minimum* biomass for the *maximum* value added. Wood hence is a bad forest product, because it generates very low income per cubic decimeter. On the contrary, orchids generate much income per cubic decimeter and microbes for bioindustrial selection are still better income raisers. Wood harvest always unsettles the forest ecologically, although the vegetation is adapted to natural onslaughts. However, the harvest of a few cc of bacteria to be cultivated and sold leaves the forest intact.

The second one is an old and traditional one, that of cultivation stops (as bus stops; *paragem de cultivo*) recently rediscovered by Remmers (1997). This involves the exchange of nice plants between farms, where they have a “cultivation stop”, in different regions, in our case forest remains. If several botanical gardens and other gene banks could be included in the network, every forest residue could be supplemented with the pacemakers, spacemakers and placemakers lost, and brought in from the best corresponding locality. Genetically, this also would reactivate selection, adaptation, co-adaptation and speciation. Biodiversity would be reproduced, without vainly trying to conserve it.



The third principle would be new and expressly formulated for the case of forest rests. It would involve establishing well-chosen forest remains as “focal forests” of the network, where the reproduction of biodiversity and the selection of new low-biomass but expensive crop plants would be particularly concentrated. Perhaps these would be good places for private ecocomes to establish a practice, from where they could be consulted by their clients, the forest managers.

This is my overview of the ecology and management of forest remains at the beginning of this Second Symposium on the subject. I have been pleading for an innovative approach. The principles mentioned should allow it to fit in with the new, coming Century, the young people who will bear the responsibility for these last forests in that Century, and Agenda 21 which has so well set out the future needs without bringing practical solutions.

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