TREE ARCHITECTURE AND SECONDARY FORESTS IN ARARACUARA. THE USE OF A NEW METHODOLOGY

Introduction

An important issue in the Tropenbos-Colombia programme is management of natural resources in areas with an indigenous population. One of the projects in this context is titled 'Tree architecture and secondary forests in Araracuara, Colombia', financed by the Dutch Canopy Foundation (Stichting Het Kronendak) and Tropenbos. The project generates knowledge on forest regeneration after agricultural land use by indigenous people along the Caquetá river in the Amazonian lowland rain forest. In this article the rather unknown methodology is described and its potential is shown through the presentation of some results.

Architectural studies

Most vegetation or forestry researchers study a set of vegetation characteristics such as stem diameter, species composition or biomass. Usually, these characteristics are measured and the values are calculated, averaged and compared over hectares or square meters. In this way, certain overall features of the studied vegetation can be understood, such as biological diversity or plant mass. In these non-architectural studies, the distribution of the measured objects in the ecosystem is averaged away and artificial compartments are made. Much spatial information and the relations between organisms is lost because it is impossible to retrace the steps. Therefore, this kind of abstraction is a one-way process. This process is illustrated in the figure below, showing that it is impossible to reconstruct the real spatial distribution of trees from the abstract bar diagram. The vegetation (left hand side of drawing) is translated into pixels (middle of drawing) which are numerically assessed and averaged in categories (right hand side of drawing).

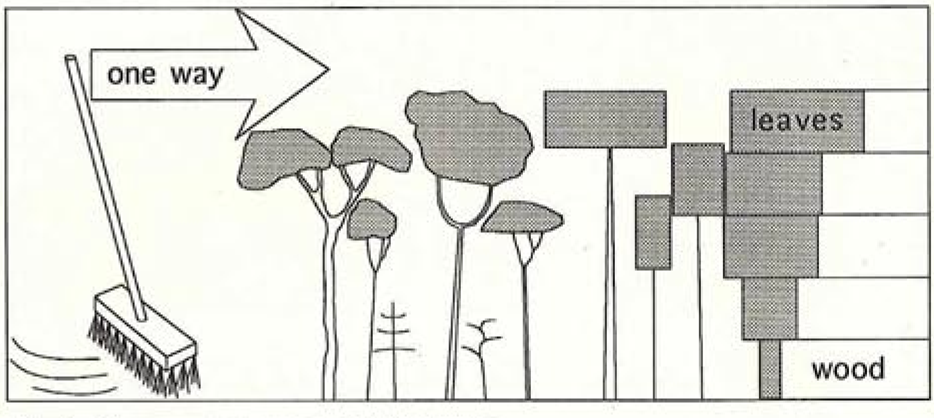


Illustration of the one way process in non-architectural studies

Architectural analysis looks at the vegetation in another way. From the outset, it focuses on the spatial relationships in a tree, between individual trees and between trees and other organisms. Within a tree for instance, the real branching pattern is mapped as clearly as possible by making drawings to scale in the field. Between trees, architectural analysis focuses on characteristics like the position a species occupies during its lifecycle in relation to other trees.

The scale of observation depends on the different research questions. For the landscape scale, a method was developed in the 1930's by the French-Swiss school of Braun Blanquet. This method describes and names similar parts of the landscape. Available species, climate and soil determine the character of the vegetation units. The spatial organization of the units or landscape pattern is drawn on a map interpreting colour, texture and structure from satellite images or aerial photographs.
About the same time, German botanists wrote about patterns in the branching of trees. Several decades later, 24 different branching patterns were described and named (Hallé and Oldeman, 1970; Bell, 1991). It was found that these 'tree models' were related to both genetics and environment. Also the spatial organization of a patch of forest can be drawn to scale, interpreting structure and recognizable tree models in the field. From these drawings it can be seen that also spatial organization is adaptive to the environment.
Architectural methods do not replace, but complement other methods used in vegetation studies. The methods are particularly useful for management, because they allow a manager to make decisions on specific, 'mapped' situations that conserve ecological complexity.

6 Tree architecture and the environment of trees

Like all organisms, plants are adapted to a certain environment. The direct environment of a tree is the forest patch.
Any forest in a well-defined environment and at a well-defined moment in its development is a mosaic of forest patches in different development phases. Any patch in its turn is structured by trees of different species. Many other organisms are related to the same patch, but it is the trees that give it its structure. Some tree species complete their life cycle in an early stage of patch development. Other species persist over several successive phases, or appear later. A patch is characterized by the presence or absence, and phase of development of the species that shape the patch.

Tree species with a short life cycle in patch development usually form large but short-lived patches. Such species are commonly called pioneer species. The term pioneer refers to the temperament of these trees. Tree temperament is an old European forester's term indicating 'the set of growth-and-development reactions shown by a tree towards its environment during its life-cycle' (Oldeman and van Dijk, 1991). For example, if a *Cecropia* species grows fast in a sunny, open spot its growth rate is an aspect of its temperament. Other species would dry out and die in such places. Architecture and development of trees are directly related to this temperament.

The set of architectural characteristics expressed by one single tree species during its life cycle can be described in a sequence of drawings showing the branching pattern in different phases of its development. This sequence of drawings is called an architectural diagram.

The notion that temperaments can be described by architectural and developmental characteristics is important. It implies that two species with the same set of characteristics can replace each other in their structuring role in the forest. If the sets of characteristics differ per tree species it can be expected that mixed forests only develop harmoniously when the sets match perfectly. Two different species match for instance when one of the species produces a low crown that can stand the shade of the other which forms a high crown.

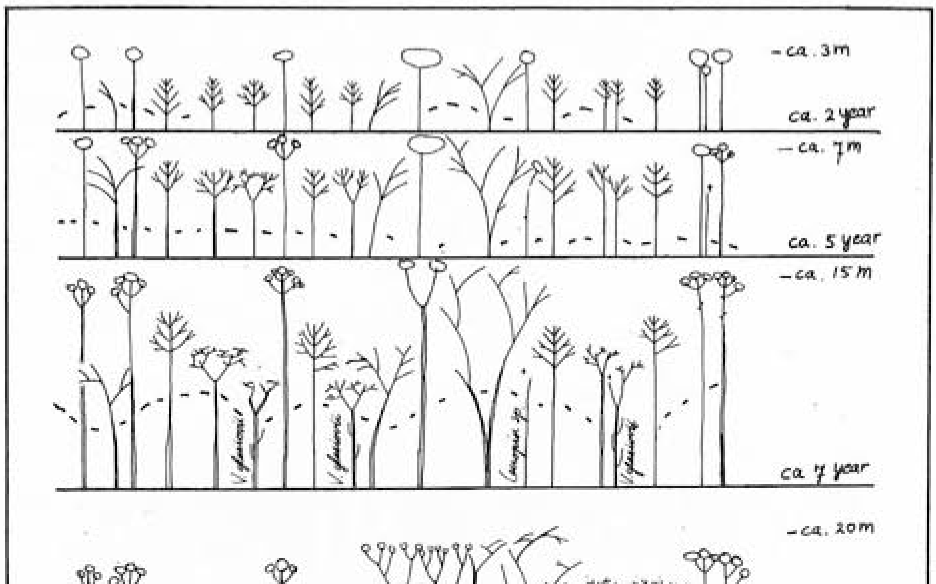
In the secondary tropical rain forest in Araracuara we distinguish two groups of pioneer species. The first group is formed by species occupying the highest positions in the growing canopy. This group is dominated by several *Cecropia* species with similar temperaments. Their only difference is the time they survive in the upward growing canopy. Some species disappear early, others survive longer. Meanwhile, the canopy they form grows higher. Another pioneer species in the upper canopy is *Jacaranda copaia* ssp. spectabilis. This group is characterised by big leaves, and rapid unbranched growth over the first 4-10 meters.

The first group of pioneer species does not form a closed canopy. In the canopy openings a second group appears. Initially, this group seems rather homogeneous, with only two branching models. One branching model, shared by *Vismia macrophylla* and several *Inga* species, shows a bent trunk and branches with leaves on both sides spreading like a fan or feather. The other model is represented by species like *Vismia glaziovii*, *V. japurensis*, *Miconia poeppigii* and *M. minutiflora*. Their trunk grows upright with many branches, easily shed. During the first 10-15 meters of height growth the first mortality occurs. It concerns individual trees in a slightly disadvantaged position. It appears that all species of this group have the same probability of death in this development phase. Their death does not depend on the species characteristics, but on their position in the forest. *Miconia poeppigii* for example, can live much longer and grow much larger than *Vismia glaziovii*. We should say that species in this group are temporarily interchangeable.

Above the level of 10-15 meters, differentiation takes place, most strikingly in the group of *Vismia glaziovii*, *V. japurensis* and *Miconia poeppigii*. *Vismia glaziovii* disappears.
From then on *Vismia japurensis* and *Miconia poeppigii* differ in branching characteristics. As a result, they differ in their position in the forest patch. *Miconia poeppigii* grows on to form a canopy at about 20-25 meters. *Vismia japurensis* never reaches the height of *Miconia poeppigii*, and only takes part in canopy formation if there is enough space. This is seen in the figure below, which illustrates the modelled development of secondary forest after

Secondary vegetation with one year old *Cecropia ficifolia* (Moraceae)

slash and burn on the low terrace of the river Caquetá. The model is based on development sequences of some important species and transect drawings in the succession. Species densities and undergrowth (indicated with a broken line) are hypothetical. Some inter-actions between species are included, e.g. *Vismia japurensis* without open space (on the right hand side) and with open space (on the left hand side).



Development of secondary forest after slash and burn in Caquetá

Practical implications

How can architectural analysis contribute to the practice of forest management and conservation? It contributes knowledge on the organization of a forested ecosystem and the interactions between its parts, which can be used in the selection of conservation areas or in the design of silvicultural systems.

At a landscape scale the extension, form and – often overlooked – relation between different vegetation units should be taken into account in the selection of nature reserves. Vegetation units do not stand alone. They are mutually related by processes and dynamics. In the Middle Caquetá, for instance, Duivenvoorden and Lips (1993) and Urrego (1994) showed that landscape units are related to past and present influences of the river Caquetá. The river has changed, and thus keeps changing the size, form and position of landscape units.

At the scale of forest patches, developmental dynamics of a single tree can never be regarded without considering its direct environment (Oldeman, 1990; van Hees and van Meel, 1993). The architectural diagram shows the inherited potential of a tree for branching, but the environment selects one version of that branching pattern. Therefore, the architectural diagram is a useful instrument for the analysis of trees in their environment. From a forest transect drawn to scale, including branching patterns, the mutual influences among trees are easily read. By just depicting crown sizes or volumes, this is not possible.

Many forms of management directly influence trees in their environment. A planted tree is influenced by other trees, planted or spontaneously germinating around it. The level at which dynamics and processes should be understood is the tree and its direct environment.

Architectural analysis should be used in forest management, which is illustrated by the development of the secondary forest near Araracuara. We observed how an open space in the canopy permits trees of *Vismia japurensis* to survive longer under dominating *Miconia poeppigii* than without the open space. This seems evident. However, as a consequence, these two species can only co-exist up to a certain moment in the development of the patch without the constraint of openness. On the other hand *Miconia poeppigii* and *M. minutiflora* can easily co-exist throughout their existence in one and the same patch. They can be interchanged in the patch. Observations of this type and their explanation are crucial for rational management of the forest, because the design of mixed forests becomes feasible.

An example is a former agricultural field which is destined to produce hardwood of *Brosimum rubescens*. The red hardwood of this species is extracted in large quantities from the primary forest around Araracuara. From a viewpoint of forest and species development, it is not advis-

able to plant young trees of this species in an open field. The species shows a very flexible branching temperament and would develop a bushlike habit in the open field. To develop a valuable trunk it needs to be surrounded continuously by other trees. However, these should not obstruct its growth in height and its uptake of energy and nutrients. Traditionally this was achieved by planting many trees of the same species close together and by regular thinning – cutting down part of the trees at regular intervals – to give the others gradually more space.
In tropical rain forest monocultures lead to many ecological problems, and maintenance of species diversity is preferred. But, how to arrange different species in such a pattern that the desired results can be obtained? For many species around Araracuara we developed architectural diagrams that show the branching pattern of those species as it develops in space and time. The flexibility of the species in interaction with others can be read from the forest transects drawn to scale. Together with the architectural diagram they form the tools to arrange and select species for plantation design serving the specified objective. No estimates of trunk diameter or biomass are made, but the optimum development situation is created to favour biomass development as wanted by the manager.

The knowledge of forest development in space and time is a condition for the quality of silvicultural design. In practice, it should be combined with knowledge of soil, water, type of planting material and other important factors in forest management. Architectural simulation thus can be a tool in designing, implementing and monitoring the process of forest development. ■

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References
Bell, A.D. (1991). Plant form; An illustrated guide to flowering plant morphology. Oxford, New York and Tokyo, Oxford University Press. 341p.
Duivenvoorden, J. and Lips, J. (1993). Ecologia del paisaje del medio Caquetá. memoria explicativa de los mapas. Estudios en la Amazonia Colombiana III. Tropenbos Colombia.
Hallé, F. and Oldeman, R.A.A. (1970). Essai sur l'architecture et la dynamique de croissance des arbres tropicaux. Paris: Masson. Translation in English by Stone, B.C. Malaya, Kuala Lumpur: Penerbit University, 1975. Pp. 156.
Hees, van, I. and Meel, van, S. (1993). Tree architecture and development of Miconia poeppigii and Clathrotropis macrocarpa, Colombian Amazon. Internal report no. 294. Amsterdam: University of Amsterdam.
Oldeman, R.A.A. (1990). Forests: elements of silvology. Berlin, Springer Verlag. Pp. 624.
Oldeman R.A.A. and Dijk, van, J. (1991). Diagnosis of the temperament of tropical forest trees. In: Gómez-Pompa, A., Whitmore, T.C. and Hadley, M. (eds.), Rain forest regeneration and management. Man and the Biosphere Series 6: 21-65. Paris, UNESCO and Carnforth.
Urrego, L.E. (1994). Los bosques inundables del medio Caquetá (Amazonia Colombiana) caracterización y sucesión. Academisch proefschrift Universiteit van Amsterdam. Pp. 235.
Vester, H.F.M. and Saldarriaga, J.G. (1993). Algunas características estructurales, arquitectónicas y florísticas de la sucesión secundaria sobre terrazas bajas en la región de Araracuara (Colombia). In: Revista Facultad Nacional de Agronomia Medellin. vol 46 No. 1 an 2. Pp 15-45.

Baka *(Pygmy)* women with mango seeds collected from the forest

NEWS FROM THE TROPENBOS SITES

Cameroon

Inventory of non timber products in the Bipindi-Akom area, south Cameroon

Han van Dijk, researcher in the Tropenbos-Cameroon programme (TCP), compiled an overview of names and functions of commonly used non-timber forest products (NTFP) in the TCP-study area. It is the first interim report in a one-year study that aims to provide insight in the possibilities to integrate the exploitation of NTFP in a multiple use system. Also the ecological and economic features of a selected number of NTFP species will be studied in order to determine the opportunities to increase the benefits of extraction and the degree to which logging affects the availability of the NTFP.

The list contains the vernacular and scientific names and the uses of some 300 plant species and 100 animal species. As far as plant species are concerned, it is also specified what type and part of the plant is used.
To gather the data, Han van Dijk interviewed 29 households in three Bantu villages and a Bakola (*Pygmy*) settlement. Gender and age differences in skills and knowledge were taken into account.

To identify products with commercial value, she carried out a market survey in Kribi and Ebolowa and interviewed retail sellers to obtain information on prices, uses and provenance of the products.