II. LITERATURE REVIEW

2.1. Tree Architecture Models

Tree architecture and its influence on whole-plant function and forest processes have been approached from a variety of perspectives, involving both the spatial arrangement of leaves considered in physiological process models and the genetically influenced programme of development considered in morphological models (Room et al. 1994). The concept of architectural modeling is a dynamic one, since it refers to the genetic information which determines the succession of forms of the tree. In order to understand architectural models, one has to observe trees as individuals at different stages, including at least the earliest part of their life and in an optimal environment as possible so that the model is expressed freely.

Building on previous morphological studies, Halle, Oldeman and Tomlinson (1978) proposed that tropical trees could be described in terms of 23 architectural models (Fig 1), based on the behaviour of apical meristems in producing branching systems. According to this concept of ‘architectural analysis’ each plant conforms throughout its ontogeny to an architectural model that is an abstraction for the deterministic genetic blueprint on which the construction of the plant is based.

To a large extent, architectural models can be interpreted in terms of the behaviors of meristems and the phytomersthat they produce: whether meristems are active continuously or intermittently; whether they undergo a fate change (e.g. vegetative to reproductive); whether branchingis terminal or axillary; whether branches grow orthotropically, plagiotropically, or with some intermediate orientation; and whether phytomers elongate equally, unequally or not at all. This system is a typology of the genetically controlled component of aerial axis organisation based on character states for number of main axes, branching, presence of resting periods in development, relative apical dominance and positions of inflorescences. These aspects of meristem and axis behavior are currently the subject of physiological, genetic, and molecular analyses that are expected to lead to new ways to regulate meristem function and to generate new plant architectures.
Under optimal growth conditions, the development and architecture of plants conform strictly to the model, but varied environmental conditions and interactions with other organisms may result in deviations from the model. Thus, most developmental morphologies of plants represent a balance between deterministic genetic and opportunistic environmental events (Hallé, 1999).

Recently, Robinson (1996) has used symbolic logic to represent and analyse the Halle´ and Oldeman system. He inferred the possible existence of several, as yet, unreported models. Many trees in the forest do not appear to conform to one of the 23 basic models, even when allowance is made for loss of branches due to damage or disease. This failure to conform is often due to a process that Halle´ and Oldeman called reiteration (Halle´ et al. 1978). One or more meristems, instead of carrying on with the original model in the appropriate place, begins again, sometimes with a completely different model altogether. Reiteration appears to be an important process in the development of tree form. It allows the tree greater architectural flexibility. Some trees never reiterate but conform to a single model throughout their lives. For large trees, Halle´ (1986) pointed out three groups where this occurs quite commonly. These are conifers, angiosperm families and fast-growing tropical trees.
2.2. Soil Water Balance

All the water that is transpired by natural communities comes from precipitation, if the locations are such that the groundwater is well below the rooting zone. Before plants can use precipitation, it will be stored temporarily in the pore space of the soil in a plant-available form. By considering the precipitation as intake into the soil and the water transpired as an output from soil, the concept of a water balance has been developed (Gerten et al. 2004). The surplus rain water that does not add to the plant available water in the soil reservoir, and therefore does not contribute to meeting the actual transpiration, will drain through the subsoil towards the groundwater. But depending on local conditions part of the precipitation may not infiltrate the soil profile but flows away as surface runoff. It therefore follows that the soil water balance comprises the input quantity of precipitation and various output quantities. The balance acts as a feedback system with plants (Fig 2), which have a great need for water, taking priority. The water balance equation reads:

\[ P = E + I + T + D + R + \Delta S \text{ (mm)} \]

Fig 2 Schematic representation of the water balance computed for each grid cell by the dynamic global vegetation model (Lund-Posdam-Jena, LPJ). The thick arrows indicate water fluxes; the abbreviations of these fluxes are defined in the text (Gerten et al. 2004).
The P stands for precipitation, E for evaporation (the unproductive loss of water from the soil surface to the atmosphere), I for interception (the evaporative loss to the atmosphere of precipitation that was retained on leaf surfaces), T for transpiration (the productive loss of water by the plants to the atmosphere via stomates), D for subsoil drainage, R for runoff and ΔS for change in soil water storage. The change may be positive (gain of soil water) or may be negative (loss of moisture from the soil profile). All the terms listed are considered for specified time intervals, i.e. days, months or years.

Quite frequently the terms E and T are put together. ET, the evapotranspiration, is often used, as it is quite troublesome to separate E and T when measuring the balance in the field. Also the interception, I, is usually not recorded as a separate term, and therefore is often included in ET.

2.3. Water Erosion

On a global scale, water erosion is the most severe type of soil erosion. Rain-splash and running water are two of the most important detaching agents that remove soil particles from soil surface. Detached soil particles are transported by running water (Fig 3). When sufficient energy is no longer available to transport soil particles, a third phase, deposition, occurs.

According to previous studies, relevant variables for soil erosion can be grouped into rainfall impact, flow characteristics, and bed conditions (ICHE 2006).
2.4. Factors Affecting Water Erosion

2.4.1. Climate

All climatic factors (precipitation, humidity, temperature, evapo-transpiration, solar radiation, and wind velocity) affect water erosion. Precipitation is the main agent of water erosion. Amount, intensity, and frequency of precipitation determine the magnitude of erosion. Intensity of rain is the most critical factor. The more intense the rainstorm, the greater the runoff and soil loss. High temperature may reduce water erosion by increasing evapotranspiration and reducing the soil water content. High air humidity is associated with higher soil water content. Higher winds increase soil water depletion and reduce water erosion.

2.4.2. Topography

Soil erosion increases with increase in field slope. Soil topography determines the velocity at which water runs off the field. The runoff transport capacity increases with increase in slope steepness. Soils on convex fields are more readily eroded than in concave areas due to interaction with surface creeping of soil by gravity. Degree, length, and size of slope determine the rate of surface runoff. Rill, gully, and stream channel erosion are typical of sloping watersheds. Steeper terrain slopes are prone to mudflow erosion and landslides.

2.4.3. Plant cover

Vegetative cover reduces erosion by intercepting, adsorbing, and reducing the erosive energy of raindrops. Plant morphology such as height of plant and canopy structure influences the effectiveness of vegetation cover. Surface residue cover sponges up the falling raindrops and reduces the bouncing of drops. It increases soil roughness, slows runoff velocity, and filters soil particles in runoff. Soil detachment increases with decrease in vegetative cover. Dense and short growing (e.g. grass) vegetation is more effective in reducing erosion than sparse and tall vegetation. The denser the canopy and thicker the litter cover, the greater is the splash erosion control, and the lower is the total soil erosion. Vásquez-Méndez et al. (2010) reported that greater canopy and ground vegetation covers in vegetation patches of semiarid areas in Central Mexico reduced significantly runoff and soil loss as compared to the Control surface.
Moreover, the litterfall of native vegetation mulches prevented the direct impact of raindrops on bare soil and thus decreased surface sealing and lengthened the residence time for water to infiltrate into the soil (Bhatt and Khera 2006).

Plant strips protected soil from the erosive action of runoff water, by offering resistance to the movement of water and shielding the soil from such effects. The plant strips also interrupted raindrop splash and overland flow, thereby reducing erosion. Francia et al. (2006) and Martinez et al. (2006) reported that plant strips efficiently buffered the mechanical impact of the raindrops on the soil surface, diminishing runoff. Duran zuazo et al. (2009) reported that more soil erosion and runoff were registered in the Non-tillage without plant strips (NT) compared to the Non-tillage with native vegetation strips (NVS) treatment in olive orchards.

The plant roots penetrating the soil matrix favoured porosity and thus infiltration, allowing the root zone to act as a partial sink for runoff. Root species that deployed their roots mainly in the topsoil helped reduce soil erosion by bolstering soil shear strength, while the increased root density with higher species numbers enhanced soil antiscourability (Francia et al. 2006; Martinez et al. 2006). The differences were clearly visible in the field—both the roots and stems increased the roughness of the soil surface and thus soil permeability, improving infiltration and avoiding soil disturbance treatment with detached soil particles.

2.4.4. Soil properties

Texture, organic matter content, macroporosity, and water infiltration influence soil erosion. Antecedent water content is also an important factor as it defines the soil pore space available for rainwater absorption. Soil aggregation affects the rate of detachment and transportability. Clay particles are transported more easily than sand particles, but clay particles form stronger and more stable aggregates. Organic materials stabilize soil structure and coagulate soil colloids. Compaction reduces soil macroporosity and water infiltration and increases runoff rates. Large and unstable aggregates are more detachable. Interactive processes among soil properties define soil erodibility. Soil erodibility refers to soil’s susceptibility to erosion. It is affected by the inherent soil properties.