Introduction

A simple model of light interception was designed to represent light resource variability in multi-strata multi-species agroforests. Dealing with many different species makes it unpractical to develop a detailed model of light interception taking into account structural characteristics of each species (follage lay-out, distribution of leaf orientation, radiation characteristics of leaves, etc.) as it has been done in other cases (Cescatti 1997; Bartelink 1998). The hypothesis to be tested was that a simple 3D description of trees inside a plot with average crown "density" estimated by photographs would allow a reasonably precise description of light received at any point. The model was tested against hemispherical photographs taken at ground level.

Material and methods: model description

Tree representation: Trees are positioned on a one-hectare 3D scene. Tree crowns are represented as convex hulls. Crown envelope is approximated by a revolution ellipsoid. The ellipsoid dimensions are derived from field measurements of crown vertical extension, crown width, height of crown base and height of maximum crown width (Figure 1). Porosity to light of the crown envelope is species specific. It is estimated by taking photographs from underneath the crown towards the sky and measuring what portion of the sky is visible.

Light index computation. The amount of light received at any point in space is calculated by exploring a range of directions (combination of azimuth and zenith angles). Each time a beam originating from that point intercepts a crown envelope of a given porosity it reduces its contribution correspondingly. Total canopy openness at that point is obtained by summing up results for elementary beams. Weight of each beam is determined by the relative surface of the associated sky vault fraction.

Results: model validation

Data on tree size and tree position were collected on a one-hectare plot totaling 396 individuals. Porosity was estimated on a per species basis for the most common species (altogether accounting for 81% of the population). Infrequent tree species were attributed a default value for crown porosity of 50%. Model predictions of canopy openness estimated at one meter above ground level were compared with a set of 45 hemispherical photographs scattered across the plot. Canopy openness is determined for a restricted sky vault fraction (above 45 degrees zenith angle) corresponding to inner disk in figure 2. This allows to limit distance at which space should be explored to find potential shaders.

Discussion: sources of discrepancy reviewed

Simulations done by changing crown porosity and crown diameter have shown that the bias cannot be accounted for by mere underestimation of crown size or crown porosity. Although inaccurate estimate of both parameters may contribute to the random error term.

A systematic error may be due to the fact that only the crown envelope is considered to have certain opacity to light whilst the inner volume is considered as totally transparent. This idealized monolayer foliage layout is quite accurate for most of the species encountered except that it neglects completely the shading effect of supporting structures.

Forcing asymmetric crowns into regular shapes brings about some distortion. This constraint could be relaxed by using asymmetric envelopes (see Cescatti 1997). This was not done because the light interception model is intended to be used in a growth simulator that does not allow deformation except originating from crown encroachment. The use of an ellipsoid as the unique generic shape is probably too restrictive. Funnel shape trees for example like some palm trees or some leguminous trees will be transformed into a nearly flat horizontal ellipsoid of same maximum diameter (the constraint being that the height of maximum diameter should be the same). In such a case the shading effect of that tree is considerably underestimated. This constraint could be easily relaxed by considering other generic shapes such as cones, inverted cones, inverted ellipsoid etc.

The major component of the random error could well be due to inaccurate positioning of trees. Sensitivity tests to tree positioning were carried out. For instance a random noise of Normal Law with 0 mean and variance of 1 was added to the X, Y, Z coordinates of trees (X,Y,Z expressed in meters). Canopy openness along a regular grid was then estimated for both the original data set and the noisy data set. The regression coefficient was only 0.86. Thus, precise positioning of photos and trees in the 3D space appear to be of crucial importance.

Conclusion: further ameliorations

Future steps to improve the model include enhancing crown description by adding different generic shapes to describe the crowns or alternatively a user defined equation of a crown profile. Another improvement would be to approximate the crown by a set of embedded hulls instead of one unique envelope. This multi-layer model would take into account the non-zero opacity of the inner part of the crown. Canopy openness would be estimated at one meter above ground thereby setting a maximum distance from site of photograph at which potential shaders may stand of about 50 m.

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References


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