VEGETATION - ENVIRONMENT INTERACTIONS

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Summary

This paper gives brief details of a computer simulation model of light penetration within a structure of leaves. It is a direct model in three dimensions with as few abstractions as possible. The aim of the work is two fold (a) to investigate the changes in spectral characteristics of the light at different levels in the crop with different plant spacings, (b) to investigate the relationship between model sophistication and computing cost for the various features within the model.

Previous Plant Models

There have been a number of models of plant communities using computer simulation techniques[1,2,3,4,5]. In most cases the aim has been to estimate the photo-synthesis at various levels in the crop by calculating the radiation incident on the leaves in each layer. The description of the leaf structure has been in terms of probability distribution functions and L.A.I. (Leaf Area Index) or in some idealised form. The complexity of the system forces the introduction of many compromises and simplifications. Present models tend to be designed for a particular crop and as such have given useful predictive results. They exhibit some generality and precision but lack realism and flexibility. In spite of R. Levin's comments[6] it is the author's contention that a model should possess, to a reasonable degree, all the qualities of realism, precision and generality.

General Research Plan

As part of a continuing study of the environmental interactions in plant communities it was decided to investigate the possibility of using digital simulation to model the growth of plants subject to the physiological variables in their environment. This paper describes work on a model of one aspect of the system namely the penetration of light into the plant community.

Particular Model

It is necessary to know both the amount and quality (frequency spectrum) of the light striking a leaf to calculate its photosynthetic effect. This light may be direct sunlight or diffuse skylight and in general will have been reflected by, or transmitted through, other leaves, stems etc. before hitting any particular leaf. The amount of light will decrease with depth in the canopy and due to selective absorption the frequency spectrum of the light will also change. This latter feature of changing spectral characteristic has not been investigated before by a model. As this is obviously an important effect and as comprehensive field data on this factor has recently been obtained for a particular crop, it was decided that this should be the first area studied with a generalised model.

In order to maintain generality and allow for maximum flexibility it was decided to use the simulation programming language, SIMSCRIPT. The basic entities in the model are leaves and light. The leaves are defined in position, area, elevation and azimuth in terms of the coordinates (x,y,z) and direction cosines (l,m,n). The light entity is also defined by position and direction with the continuous frequency spectrum represented by 16 ordinates. Each leaf also has 16 attributes to accumulate that proportion of each part of the frequency spectrum that is absorped. Each ray of light is tracked through the canopy until it either hits a leaf, hits the ground or escapes upward from the canopy. If a leaf is hit, two new light entities resulting from the light reflected and light transmitted by the leaf are created. These in turn are tracked and produce further entities until, due to absorption, the amount of light is not significant.

In the present model there are no external random effects though they are envisaged. There is for example the effect of changing incident radiation due to cloudy and other climatic conditions. Another important effect is the change in leaf structure due to wind.

Some attention was paid to facilities for validation and experimentation.

As the model uses a direct three dimensional approach it was decided to

check the operation of the model by visual means wherever possible. This is done by displaying dynamically on a T.V. device (VISTA Control Data 252) the tracks of the light rays in two graphs, one for the z - x plane the other for the z - y plane. Other information relating to the accumulated statistics for light received at each level is also displayed.

A similar scheme is used for experimentation with interaction between designer and model via a Display Console (Control Data 211). Using a keyboard parameter changes can be introduced and using the visual output from the model it is possible for the designer to try out different courses of action and observe the effects directly. It is also possible to edit and recompile the subroutines in the model and re-run[7,8,9].

Applications

As explained earlier the leaf structure in the model is defined in a general way so that it may be possible to validate the model against differing plant communities. Experimental data for radiation received at different levels in a crop of bullrush millet is being used at present. Bullrush millet is a tall plant with long narrow leaves for which the structure is fairly easily defined.

The first application of the model will be to assess the changing pattern in light penetration with variation in plant spacing.

Another application will be to investigate the value of the various refinements in the model to see if they are justified on a computing cost - accuracy basis. If the present model is to be incorporated within an overall model of the plant and its environment it will be important to know the sensitivity of the various sections of the model to simplification.

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