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Report of Travel

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Participation in the European Society of Agronomy International Symposium on Modelling Cropping Systems. Lleida, Spain, June 21-23, 1999.

My aim on attending the conference was to present my work "**Carbon and Nitrogen Cycling in a Tree-Grass Inter-Cropping System in the Humid Tropics**". I also intended to learn about the current work being done in modelling in agriculture and to meet researchers and research groups that share my interest in the mathematical simulation of physiological processes in crops.

My presentation consisted of a poster, which was exhibited during the Poster Session of Tuesday 22 June. During this time I answered questions from the participants to the symposium. All the oral presentations were presented in the same theatre and the demonstration of software was also carried out in a single session for all participants, thus I had the chance to attend the full programme.

Apart from the presentations, I did take the opportunity of meeting some scientists that presented talks on subjects that I found interesting for my own research. Among them I met Dr. G. Hoogenboom, of the Department of Biological and Agricultural Engineering, The University of Georgia, who collaborated in the team that presented a paper on the linkage of DSSAT (The Decision Support System for Agrotechnology Transfer) and CENTURY (A Model of Soil Organic Matter Dynamics) for improved simulation of smallholder agricultural systems. We agreed that it is of our common interest to explore future collaboration upon the modeling of silvopastoral systems in the tropics of Mexico. I had a talk with Dr Claudio Stockle (Washington State University) who developed the CROPSYST (Cropping Systems Simulation Model) and presented one of the Key Notes of the Symposium. We agreed on the necessity of integrating field crops and pastures into a common, comprehensive framework; agroforestry modelling being an important contribution in this matter. Possible collaboration on the development of a model of tropical silvopastures within the framework of DSSAT was suggested. I also meet Dr. Francisco Villalobos (Instituto de Agricultura Sostenible, CSIC, Spain) who has been developing a silvopastoral model for olive plantations. As to my own research, this was the closest related work I learned about during the Conference. Oddly enough, no agreement for future collaboration was achieved. However, it is certainly a potential contact for the continuation of my project on modelling the interactions of tree crops and pastures.

Based on the above mentioned, I consider that the objectives of my journey were achieved, for which I want to express my gratitude to the James Rennie Bequest Committee for the travel funding awarded.

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A simulation Model of Carbon and Nitrogen Cycling in a Tree-Grass Inter-Cropping System in the Humid Tropics. The Silvopastoral Model.

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Introduction:

One of the problems that many tropical regions share is the replacement of natural forest by pasture for cattle with resultant soil degradation. Small farmers in the tropics do not normally use fertilisers or herbicides on pastures as the nutrients demand of the traditional grass species, combined with low stocking rates permit the lengthening of the life span of natural soil fertility, thus allowing a sustained though limited production. Concerns about natural resources and scarcity of land are pushing institutions and farmers towards more intensive technologies. The introduction of new species of grass, to allow an increase in stocking rates and a consequent reduction of pressure on the surrounding forest depends on grazing systems gaining additional sources of nutrients. We consider that organic fertilisation from tree prunings can be an alternative to fertiliser that suits the circumstances of small farmers. Pollarding maintains a permanent supply of nutrients to the pasture while minimising light competition. The introduction of trees into grazing systems affects many aspects of the development of the pasture, making it difficult to continue with the traditional management practices. We developed a simulation model to test the potential of trees as a source of green manure for improved pastures. The aim of the model is to allow the simultaneous utilisation of the large amount of information which has been produced in agroforestry trials. Also, the model allows the replication of experiments under changing conditions, making it useful for the design of silvopastoral systems.

Methods:

For the design of the model (fig. 1), we assumed the following premises: High yielding tropical pastures are strongly demanding of soil nutrient availability. Nitrogen fixing trees can partially contribute to the restoration of soil fertility, although external inputs may eventually be needed to maintain soil fertility. Inter-specific competition for soil nutrients is based on root biomass, root activity and root resilience. Light competition arises as upper-storey canopy grows and light interception reduces the solar radiation that reaches the grass canopy. Carbon and nitrogen cycling are accelerated by pruning the tree canopy. Such action produces both mulch and dying roots and nodules, all of them high in readily decomposable organic matter. Organic matter decomposition depends on litter quality and on the natural abundance of soil microbial biomass.

Grass and Tree sub-models: The tree and grass sub-models are based on the growth of structural carbon pools and partitioning of assimilates (carbon from photosynthesis and nitrogen from soil) among the different components of the plant. The rate of synthesis of structural dry matter of grass is determined by substrate carbon and nitrogen concentrations and a shoot:root partitioning coefficient leading to maximum growth based on the existing structure (Thornley and Verberne, 1989). Similarly, the specific growth rate of tree components is determined by a growth coefficient (activity parameter) and the substrate carbon and nitrogen concentrations of the component.

Animal sub-model: This sub-model calculates the fluxes of carbon and nitrogen to faeces from animal intake. It then dynamically represents the pools of carbon and nitrogen in faeces on soil, based on the actual production of faeces and the decomposition-mineralisation rates.

Mulch and litter sub-model: Like CENTURY (Parton, et al., 1987, 1988), the model considers three groups of decomposing materials, mulch, surface litter and roots litter. Unlike litter, mulch is cut from the trees before the tissues get old, preventing reduction of quality. Decaying mulch and litter is divided into metabolic, cellulosic and lignin fractions. Two major features influence mulch and litter quality: a) C to N ratio, which rises due to the translocation of substrates before natural turnover and b) lignin fraction, which increases with ageing of plant tissues.

Soil sub-model: This sub-model consists of two parts, soil organic matter (SOM) and the pool of mineral nitrogen, connected by the soil microbe pool. The dynamics of nitrogen in organic matter are driven by the fate of carbon, whereas the mineral nitrogen pool's size depends on the abundance of microbial biomass. An adequateC to N ratio in soil solution is essential for the microbial activity, for which mineral nitrogen from the ammonium and nitrate pools may be immobilised. Litter decay produces SOM which mineralises into the ammonium pool or becomes passive SOM (very low mineralisation rate) depending on the silt-clay content in the soil (Heal, *et al.*, 1997).

Simulations:

The model runs on ModelMaker 3.03 (Cherwell Scientific Publishing Limited, 1997). The method of integration used in these simulations is Runge-Kutta with a time step of 0.4 days. The present paper explores the relationship between components in terms of the biological effect of inter-cropping on the two species and the soil. We concentrated on pollarding, being one of the options built into the model to make possible the control of nutrient cycling by the user. We analysed various aspects of the system in response to this practice. By translocating structural C and N and meristems to the mulch and litter pools, pruning triggers a number of processes in the system that can be observed in the model. The amount of radiation transmitted to the grass canopy is proportional to the fraction of leaves removed from the tree canopy. The model predicted a consistent increase in substrate carbon in the grass in the days following pruning, suggesting that grass photosynthesis is sensitive to the level of light interception by the tree canopy. Grass leaf area increased with radiation availability and leaf production was suppressed as the tree canopy recovers. Young grass leaves were produced in response to increased incident radiation. Old leaves survived during the period in which light interception by trees limited the production of new leaves. We found that although root population growth continued, there was a decrease in structural dry matter fine roots after every pruning event, which suggests a natural self-thinning of roots in order to attain a balance when assimilates become scarce. Specific leaf area ($m^2\ kg^{-1}$) involves, on one hand, the light intercepting surface of the canopy and, on the other, the potential mulch production. Specific leaf area was shown to affect the tree gross and maximum photosynthesis significantly. Nevertheless, as the maximum photosynthetic rate increases, the gross photosynthesis decreases as the incremental SLA parameter becomes larger. The incremental SLA parameter controls the feedback of leaf production to photosynthesis. The model suggests that a higher SLA will reduce radiation transmission faster, increasing competition between species and requiring a more intensive pruning schedule, thus compromising the survival of the trees. Higher tree SLA also affected the structural dry matter of the grass shoots which may be interpreted as a result of the reduction in transmitted solar radiation.

Conclusions:
The results we obtained in the simulations suggest that the model can be used to predict the status of the pasture under different management practices. The model can be used to assess the amount of radiation being intercepted by the tree canopy and whether this is affecting grass survival. It also provided insights into the desirable characteristics of the tree species for fostering the complementarity in the system.

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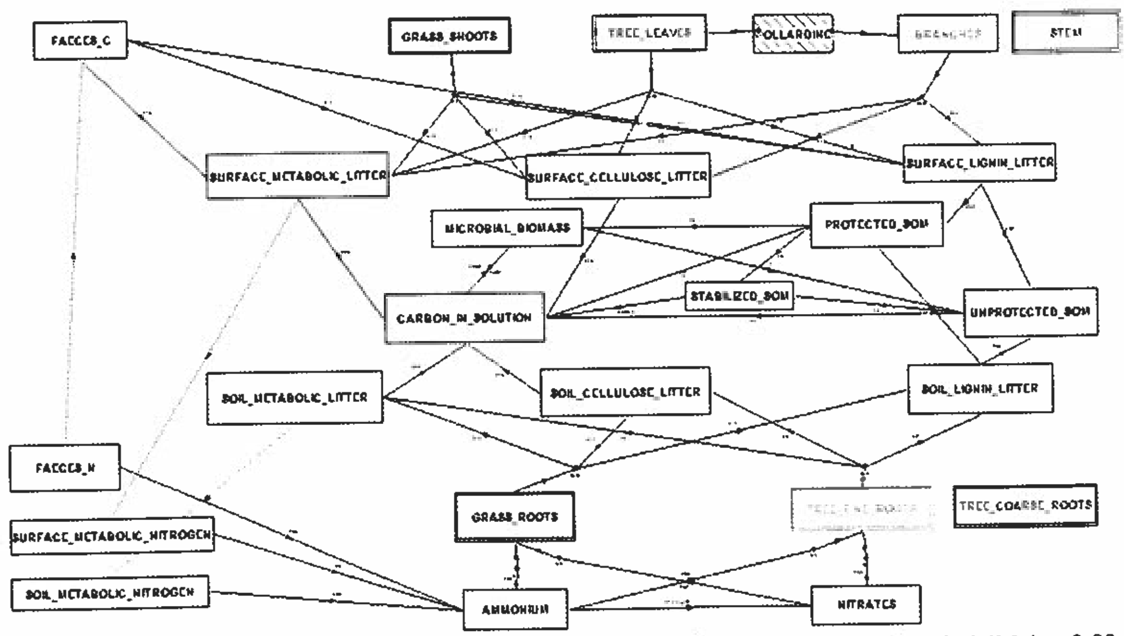

Figure 1. A summarised view of the Silvopastoral model as it looks in the MAIN view in ModelMaker 3.03.