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Bergez J.E., Msika B.

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A silvopastoral model for the EU

Bergez Jacques-Eric[1] and Msika Bruno[2]
1 : MLURI, Craigiebuckler, Aberdeen AB9 2QJ, United Kingdom
2 : INRA, Agroparc, 84914 Avignon Cedex 9, France

Résumé : Dans une perspective de meilleure articulation des activités agricoles, forestières et environnementales, le programme européen de recherches coopératives en agroforesterie (AIR3 CT92 0134) fonde ses objectifs : utiliser de manière alternative les terres agricoles pour éviter la destructuration du paysage rural ; développer une production de bois de qualité dans les exploitations agricoles afin de diversifier leurs activités et de réduire les importations ; garantir le multiusage sur les terres agricoles en maintenant une possibilité de changement rapide d'affectation de production.
Dans le cadre de ce programme, les auteurs ont bâti un modèle biophysique de prédiction de la croissance du système herbe-arbre et de l'évolution des productions sylvopastorales ; ce programme est développé en langage C++ et basé sur 5 modules descriptifs (l'arbre, le mésoclimat, l'herbe, l'animal et le sol) et sur leurs interactions dynamiques. Le modèle est alimenté par des données biophysiques, issues des expérimentations du programme européen, ou à défaut, extraites de la bibliographie existante.
Ce modèle biophysique est construit de façon à permettre la liaison avec un modèle bioéconomique développé sur tableur au Royaume Uni. Il permettra alors d'intéressantes simulations à l'échelle de la parcelle. Dans une deuxième phase, c'est-à-dire après validation de l'outil, un transfert d'échelle devrait permettre de prendre en compte, au niveau d'un massif, les aspects concernant le système d'élevage et le paysage.
Mots-clés : système sylvopastoral - modèle biophysique - caducifoliés.

INTRODUCTION

Agroforestry in Europe is potentially important with respect to sustainable production on agricultural land. Indeed, it could help reduce agriculture products that are in surplus, maintain rural employment, create new environments and landscapes, and reduce European importation of good quality timber.

Well established in developing countries but largely neglected in Europe, agroforestry is a potentially valuable land use option. Agroforestry systems can include a range of crop, animal and tree species but in agriculturally less favoured areas, the tree/animal combination (silvopastoral systems) is the most promising.

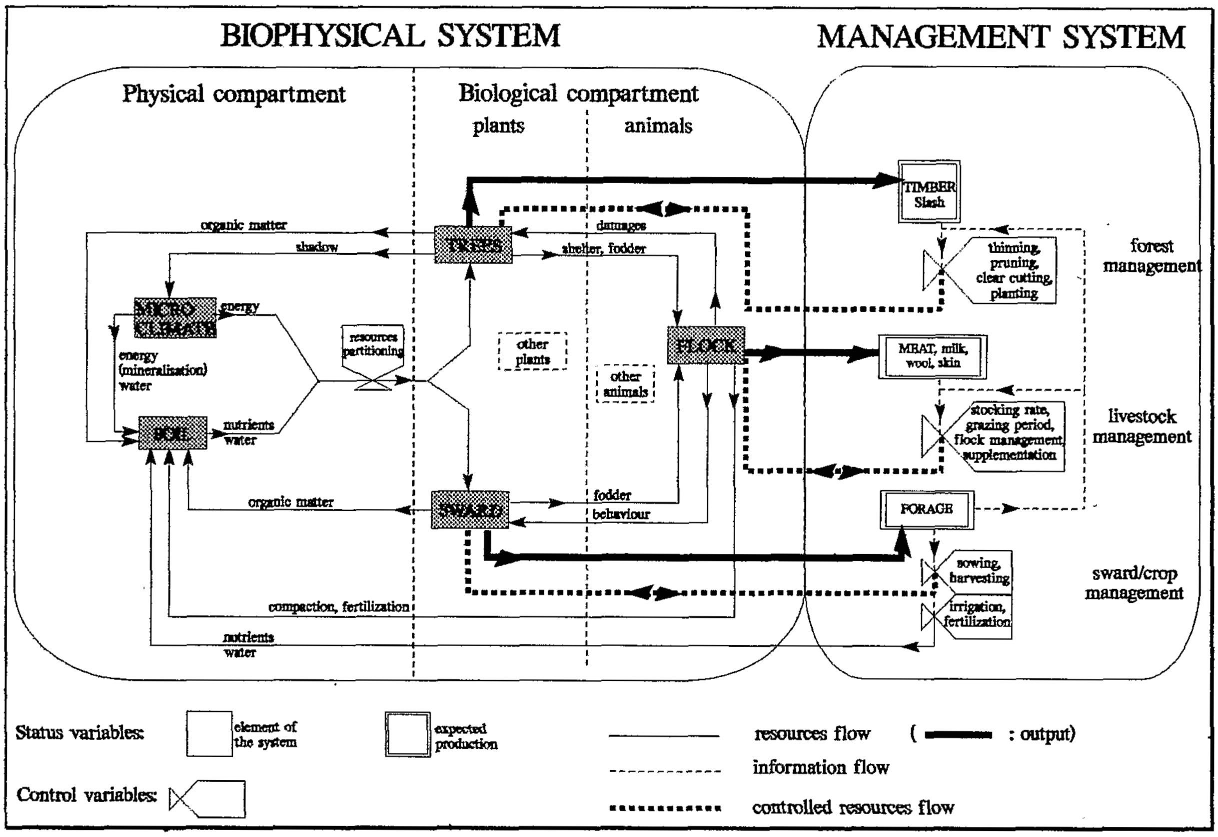
Modelling can help overcome a major problem facing both the policy maker and the farmer when assessing the potential contribution and impact of silvopastoral systems that is the length of time necessary to see the full results of tree planting. Several models of agroforestry already exist but these are either restricted to coniferous species (Tabbush *et al*, 1985 ; Etherington, 1985 ; Anderson, 1991 ; Anonymous, 1992) or fail to consider the role of animal production. The sale of animal products is a key difference between silvopastoral systems and more conventional forestry as it provides a regular cash return to the farmer, at the start of a tree cycle, in addition to that from the timber at harvesting.

The aim of the biophysical model discussed here is to describe a silvopastoral system in temperate areas. This work is part of a larger European contract: *Alternative Agriculture Land-Use with Fast Growing Trees (AIR3 CT92 0134).*

GENERAL DESCRIPTION OF THE MODEL

Developed in C++ and designed to run under Windows environment, the model is based on five modules: Tree growth, Microclimate changes, Sward growth, Animal production, Soil nutrients and Water dynamics.

The model works on an individual tree basis for the growth of trees, but on a plot basis when dealing with sward and animal production. Sward and animal production are computed on a daily time step while tree growth occurs once a year (except for leaf area).



Outputs: The model is designed to be linked to a bioeconomic spreadsheet model (Thomas, 1991). Outputs of the model are a) production (thinning, timber, animal live weight) and b) information required by the bioeconomic model (planting needs, fertilizer, weeding, number of prunings and thinnings).

General information: The user describes the plot characteristics (area, orientation, location and soil type), the tree species to be planted (currently Acer, Prunus and Larix) and the planting pattern (currently regular or diamond).

Tree submodel: The tree submodel is based on the UK Forestry Commission growth curves (Forestry Commission, 1980) and with additional empirical relationships from either the literature (Tabbush et al, 1985 ; Doyle et al, 1986) or derived from the silvopastoral UK network data (Sibbald and Sinclair, 1979). The following variables are calculated: height of the stem, diameter at breast height, volume, current annual increment, mean annual increment, maximum width of the canopy, leaf area. The height of the bole (and consequently the height of the canopy) is entered by the user when pruning is required. Individual variation of growth is given by a random variation of the parameters of the growth curve. It is assumed that the canopy fits an ellipsoidal shape. The growth in width of the canopy is limited by the neighbouring trees. Tree growth is modified by extreme water stress.

Microclimate submodel: At sward level, the climate is modified by the tree. The site climate is read from a file provided by the user which should contain on a daily basis: total and diffuse photosynthetically active radiation (PAR), air temperature, wind speed, rainfall, mean relative humidity. A stochastic simulation creates a climatic series over 40 years with a frequency distribution as provided by the user and describing real events.

From the general climate and the state of the trees, the microclimate at the sward level is calculated:

1. A mean PAR on the plot is calculated by averaging the direct PAR and the transmitted PAR. It is assumed that the leaf distribution is uniform within the canopy. A vertical projection of the canopy is used to determine the shaded area.
2. The mean air temperature is unaltered. The minimum air temperature is modified depending on the per cent of cover and the leaf area of the trees. Empirical relationships are used (Msika, 1993).
3. The wind speed is not yet modified, but would be reduced according to results found in the literature (for example Green, 1991).
4. The rainfall is modified depending on the leaf area on the plot (Aston, 1979).
5. The relative humidity is unaltered.

From the climate data (either general or at the sward level), the potential evapotranspiration (PET) is computed by using the Penman-Monteith formula (Monteith and Unsworth, 1990).

Sward submodel: This module is a modified version of the Hurley pasture model[1] in which light, temperature, water and nitrogen are the driving variables (Thornley and Verberne, 1989). Currently the sward module simulates only one grass species (Lolium perenne). The model simulates the transformation of both Nitrogen (N) and Carbon (C). Light and temperature are provided by the microclimatic module while water and nitrogen come from the soil module. Growth (photosynthesis), turnover and grazing are taken into account. There is no spatial definition of the sward production. Quantity and quality of the sward are the outputs of this module.

Animal submodel: This module is based on the Ruminant Animal Model (Hutchings, in prep.). The growth of an animal depends on the quantity and quality of the pasture as a result of microclimate and soil conditions. Quality and quantity of pasture are given by the sward module and by using empirical relationships between N content, C/N ratio and the digestibility and the protein content. As an output of the microclimatic module, climate data are used to predict the energy required for maintenance, growth, pregnancy and lactation. Quantity of sward grazed, dung and urine production, number of lambs, and quantity of meat, are the outputs of this module.

Soil submodel: Two components are tracked in the soil: N and H_2O. The nitrogen cycle is based on the Hurley pasture model (Thornley and Verberne, 1989) modified to fit the purposes of the model. Fertilization and leaching are taken into account. Nitrogen inputs or outputs from the animal, from the pasture and from the trees are determined in the animal, sward and tree modules respectively. The water cycle is based on BILHY model (Msika, 1993). This model integrates the soil characteristics (water bulk) and the climatic demand (PET) and supply (precipitation).

The soil is divided in two layers, roughly above and below 30cm. The upper layer is colonised by the roots of the sward and the lower by the roots of the tree. However, during the first few years, the upper layer is used by both components.

The growth of the tree is not nitrogen dependent. However, it allows nitrate leached from the upper layer to be intercepted by tree roots and recycled to the soil surface in leaf litter.

Interactions: Simulating interactions between components is essential when modelling silvopastoral systems. The following interactions are taken into account:

1. Tree-sward: the tree mainly modifies the microclimate at the sward level.

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[1]However, a simpler model based on empirical relationships between climate, soil and water availability, and the sward production may be chosen by the user.

2. Sward-tree: there is a competition for water during the establishment phase of the tree. The consumption of water by the sward is computed first. The remaining water bulk may then be used by the tree.
3. Animal-tree: there is no direct effect of animals on the trees taken into account at this stage.
4. Tree-animal: the tree mainly modifies the microclimate. There is no spatial effect taken into account.
5. Animal-sward: the animal grazes the sward modifying the production and the quality of the sward.
6. Sward-animal: depending on the quality and quantity of the sward, the animal production will be different.

Trees, animals and sward modify the nitrogen and the water cycle in the soil and therefore have indirect interactions between one another.

VALIDATION - CONCLUSIONS

Based on a multi-disciplinarity and multi-institute project, this model should be completed by the end of March 1995. However, there are major obstacles to the validation of such a model as there is a lack of data from silvopastoral systems in temperate areas. Nevertheless, data from the UK agroforestry network will be used to validate at least the establishment phase. The link with the bioeconomic spreadsheet model will be made later in 1995. At a later stage, the plot-scale model will be incorporated into a field management scheme at the farm level.

RÉFÉRENCES

Aston, A.R., 1979. Rainfall interception by eight small trees. *Journal of Hydrology, 42: 383-396.*

Anderson, T.R., 1991. *Computer modelling of agroforestry systems.* Ph.D. Thesis, University of Edinburgh, UK: 287p

Anonymous, 1992. *Farm tree. Simulation model for economic evaluation of agroforestry and trees on farms. Introductory manual.* Published by the department of Food and Agriculture of Victoria, Australia: 18p.

Doyle, C.J., Evans, J. and Rossiter, J., 1986. Agroforestry: an economic appraisal of the benefits of intercropping trees with grassland in lowland Britain. *Agricultural Systems, 21: 1-32.*

Etherington, D.M. and Matthews, P.J., 1985. *Mulbud user's manual.* Third revised edition, National Library of Australia, Australian National University, 96p.

Forestry Commission, 1980. *Yield models for forest management.* Alice Holt Lodge, Wrecclesham Farnham Surrey.

Green, S.R., 1990. *Air flow through and above a forest of widely spaced trees.* Ph.D., Univ. of Edinburgh, 313p.

Hutchings, N.J., in prep. A model of pregnancy, lactation and growth in sheep

Monteith, J.L., Unsworth, M.H., 1990. *Principles of environment physics.* Edwards Arnold ed., 263 p + appendices.

Msika, B., 1993. *Modélisation des relations herbe-arbre sous peuplements de* Quercus pubescens Willd. *et* Pinus austriaca Höss. *dans les Préalpes du Sud.* Ph.D. thesis, University of Aix-Marseille III: 111p.

Sibbald, A.R., Sinclair, F.L., 1990. A review of agroforestry research in progress in the U.K.. *Agroforestry abstracts 3:149-164.*

Tabbush, P.M., White, I.M.S., Maxwell, T.J. and Sibbald, A.R., 1985. Tree planting on upland sheep farms - study team report. *Forestry Commission and Hill Farming Research Organisation: 27p.*

Thomas, T., 1991. A spreadsheet approach to the economic modelling of agroforestry systems. *Forest ecology and management, 45: 207-235.*

Thornley, J.H.M., Verberne, E.L.J., 1989. A model of nitrogen flows in grassland. *Plant, Cell and Environment, 12: 863-886.*