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A Model for Designing Sustainable Agroforestry Systems

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Abstract

In order to monitor the impact of agroforestry development on the organisation of farming systems a simulation model is developed on the basis of concrete farm projects. It assesses how diversifying production in time and space by three agroforestry techniques (agroligniculture, silvopastoralism and farm forestry) may develop a more sustainable management of forest and pasture resources. Agroforestry is integrated into the farming systems by its interactions with the livestock farming system (stock number, livestock husbandry practices) and the woodland management (planting, coppicing, clearing). At the farming system level, the model simulates the impact of agroforestry plots on labour organisation and product flows (firewood, timber, lambs). The model is considered as a steering tool for supporting farm decision and planning agroforestry development.

Objectives

For improving the sustainability of Southern France livestock farming systems, agroforestry techniques have been developed. Farm forestry (dense planting of trees on grasslands), agroligniculture (planting wide-spaced trees on grasslands) as well as silvopastoralism (clearing and oversowing oak woodlands) have been proposed as alternative techniques which reduce forage or crop production but shift drought periods, diversify forage quality and production, improve landscape aesthetics and guarantee a more sustainable functioning of the farm. But transforming a conventional agrosystem into a sustainable agroforestry system implies an evaluation of the impact of agroforestry plots on the organisation and functioning of a farm. This paper designs and tests a resource dynamics model for supporting farm decision and planning agroforestry development.

Methods

With farmers who decided to establish farm forestry, agroligniculture or silvopastoral plots on their farm for developing it in a more sustainable way, an interactive model was developed for testing scenarios designing agroforestry systems on the basis of concrete projects aiming at securing farm production. These scenarios were based on the current functioning of the farm and the main probable trends in land tenure, labour availability and subsidy opportunities.

First, farm management was analysed by mapping land use units, soil potentialities and farm equipment (tracks, buildings, fences and water points) and by describing grazing and labour

calendars. Forage and timber production were assessed by sampling farm plots. Animal requirements were calculated according to the flock structure and level of productivity. Once the farming system was described, the impact of the scenarios on the farm dynamics was assessed by a resource dynamics model simulating changes in land use, time organisation, forage and firewood production and labour requirements.

Model Characteristics

The model is based on three hypotheses:

- land use and management changes lead to a succession of vegetation dynamics, the duration and speed of which are related to the agroforestry technique applied and to the site condition;

- this dynamics can be easily described by a step-by-step model based on transition matrices (Tab.1) from grasslands to dense woodlands through several intermediate steps (shrublands, open woodlands, ...). Step duration is related to site condition and time of rotation given by the type of planted tree;

- forage production on agroforestry plots is gradually modified by tree canopy cover development while timber or firewood production are mainly related to site condition and tree density managed through clearings.

Table 1 : Transition matrix for St Pierre according to rotation duration

		time (years)							
management	sward potentiality	de	p?	la	al	bc1	bc2	bf	Rotation
agroligniculture	ph		9		9	17	17		50
	pm		10		10	20	20		60
	ps		12		12	23	23		70
farm forestry	ph	9					17	25	50
	pm	10					20	30	60
	ps	12					23	35	70
natural succession			5	5		10	5		
silvopastoralism						5*	5	1	

* if oversown

The model is concerned by four management techniques:

Land abandonment leads to natural succession through progressive shrub encroachment and woodland colonisation. It decreases forage production but gives the opportunity of building up a silvopastoral system after 40-60 years (Droin, 1994).

Agroligniculture leads to planting 400 stems/ha on a grassland for reaching a final density after clearing of 100 stems/ha. It has at first no effect on forage production (step p*), enhances it for a while (step al), then competition for light and water appears (step bc1) until forage production stops completely (step bc2) (Figure 1).

Farm forestry requires a period of exclosure (step de) followed by a tree-grass balance supplying some forage (step bc2) which disappears totally when shading is too strong (step bf) (Figure 2).

Silvopastoral management applies to successive clearings of existing coppices or high forests for maintaining the tree canopy cover under 60% in the case of *Quercus pubescens* (Msika, 1993). If the understorey is oversown, forage production increases (stepbc1) otherwise it is mainly based on oak resprouts and acorns (step bc2). If the woodland is cleared during summer, a supplement of green leaves is available for grazing.

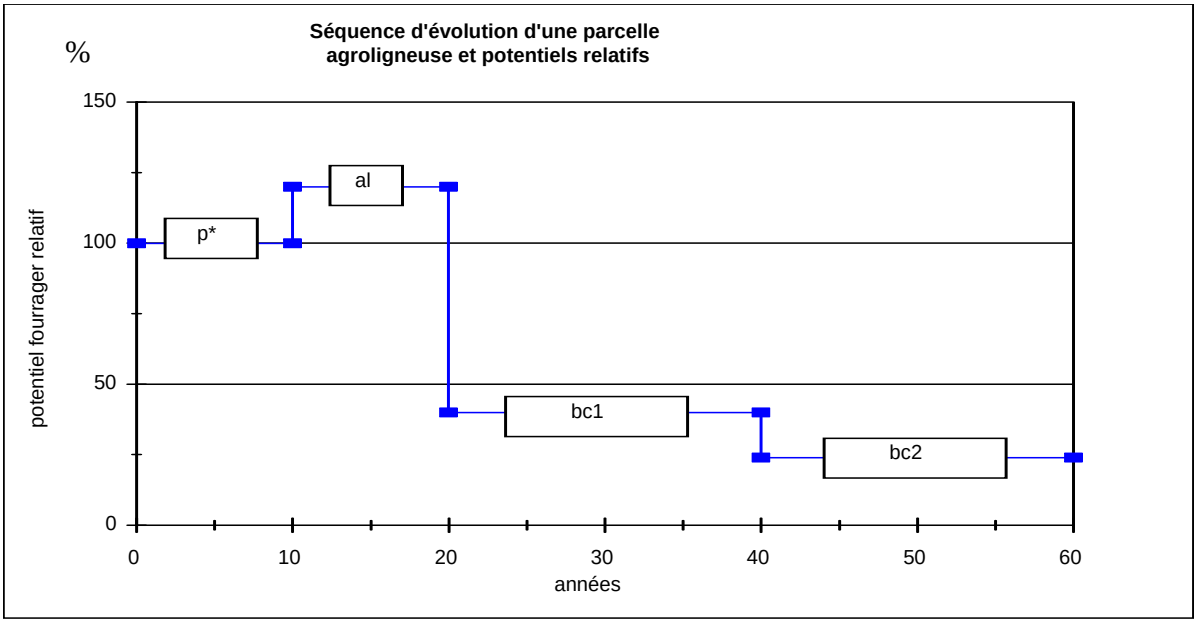

Figure 1: Dynamics of an agroligniculture plot according to forage potentiality

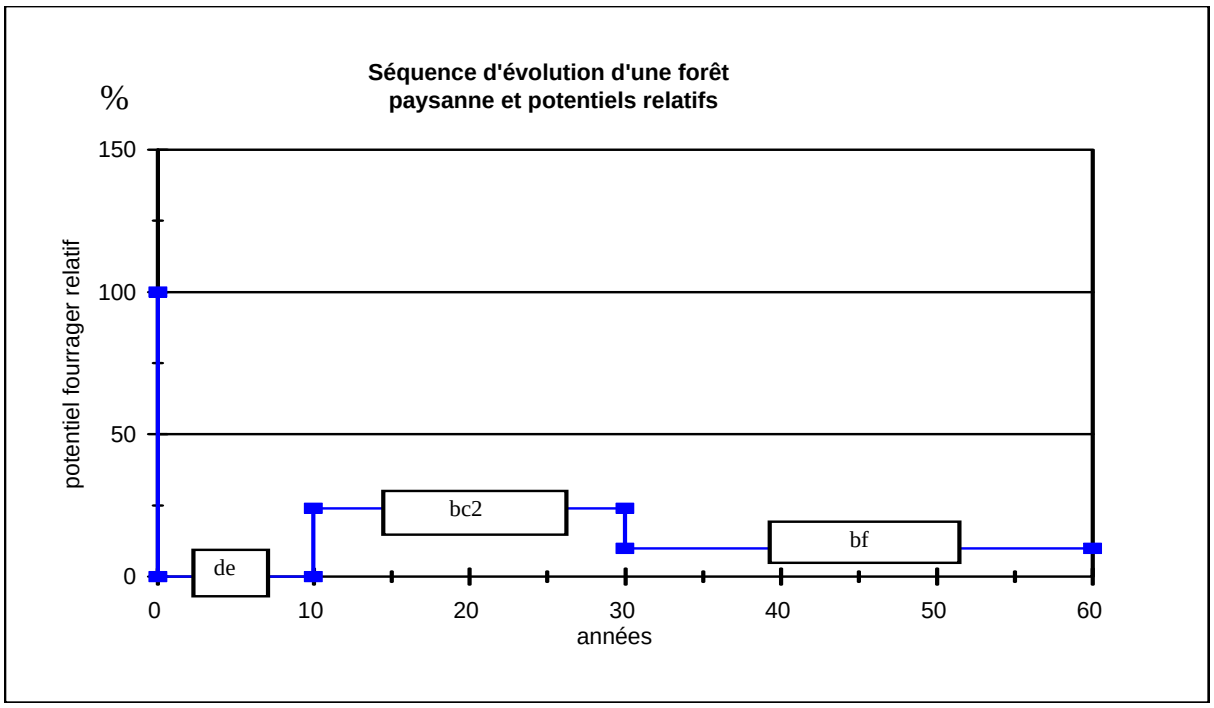

Figure 2: Dynamics of a farm forestry plot according to forage potentiality

Case Study

St Pierre's farm is a livestock farm settled on Chalabrais hills (570m) in Southern France. It covers 83 ha of grasslands and oak woodlands grazed all year round by 330 ewes for lamb meat production (Herlant, 1995). The 44 ha of grasslands are fertilised and refused herbage is periodically cut. In winter and summer, part of the flock is supplemented with hay (20 T of lucerne and 10 T of hay).

The farmers have decided to clear progressively their woodland and to increase forage production by oversowing. The leaves of the cut trees are directly grazed by the flock. The farmers also want to establish agroligniculture plots for providing shade to the driest pastures and for aesthetics. The farm development plan (Tab.2) aims at strengthening the farming system by securing a sustainable production of lamb, meat and firewood and creating a pleasant environment for promoting farm tourism. 20% of the farm surface has already been transformed into agroforestry plots, the farm development target beeing 40%. Four scenarios have been built and evaluated in terms of flock number, labour and firewood production:

- scen.1-0 : the current farming system
- scen.1-1 : the current silvopastoral plots are maintained by regular clearings
- scen.1-2 : scen.1-1 + progressive (2ha/year) transformation of all the remaining woodlands into silvopastoral plots + 2 agroligniculture plots. The woodlands are cleared in August-September and oak foliage is grazed. The farmer provides labour and consumes firewood.
- scen.1-3 : scen.1-2 + hiring of neighbouring grassland and rangeland.

Table 2: Main objectives of St Pierre's farm development plan

sheep rearing unit	forest management unit
maximising forage sufficiency	maximising forage and browse
maximising ewe lamb production	production and utilisation of the
optimising spring growth utilisation	woodland
reaching a threshold of 350	guaranteeing an annual firewood
productive ewes	production
	creating a more diversified landscape

Flock number (Figure 3): the current land use and management did not permit to reach the farming system objectives (curve scen.1-0). Generalising silvopastoral management to all the woodlands and creating 2 new agroligiculture plots lead to a forage production covering the requirements of 300 ewes around 2010 but the sustainable level of production averaged 280 ewes from 2017 onwards (curve scen. 1-2). But taking into account local conditions which make winter supplementation compulsory, the global forage balance with a supplement feeding similar to the current one allowed to maintain sustainably a flock of 320 ewes (dotted curve).

Labour (Figure 4): if the farmer remained with the idea of performing the clearings himself, generalising silvopastoral management required too much work from 1996 to 2002. It was necessary to pay a wood-cutter the first 5 years. Then an average of 30 days of work per year would cover the maintenance of the silvopastoral agroligniculture plots.

Firewood (Figure 5): from 25 to 30 piles of wood would be harvested during the first 5 years. That means a surplus of 90 m^3 that could be used for paying the wood-cutter's work. After 2002, the firewood coming from the maintenance of the silvopastoral plots covered easily the requirements of the farm (15 m3 per year) until 2045. On the contrary, a lack of firewood was registered 2 years out of 3 if the current farm management was maintained.

References

Droin, E. (1994) Simulation de l'impact du développement de l'agroforesterie sur la dynamique du paysage. INRA-Ecodéveloppement Avignon, 86 p.

Herlant, P. (1995) Simulation de l'effet de techniques agroforestières sur la dynamique et l'organisation de systèmes d'exploitation. INRA-Ecodéveloppement Avignon, 84 p.

Msika, B. (1993) Modélisation des relations herbe-arbre sous peuplement de Quercus pubescens et Pinus austriaca dans les Préalpes du Sud. INRA-Ecodéveloppement, Avignon.

Annexes

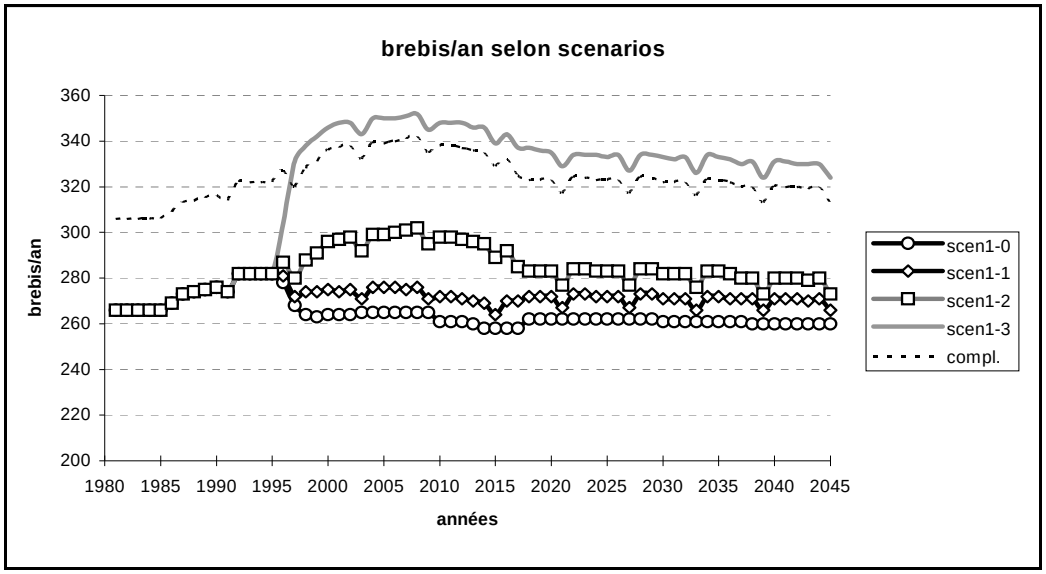

Figure 3: Flock size potential according to 4 scenarios at St Pierre farm

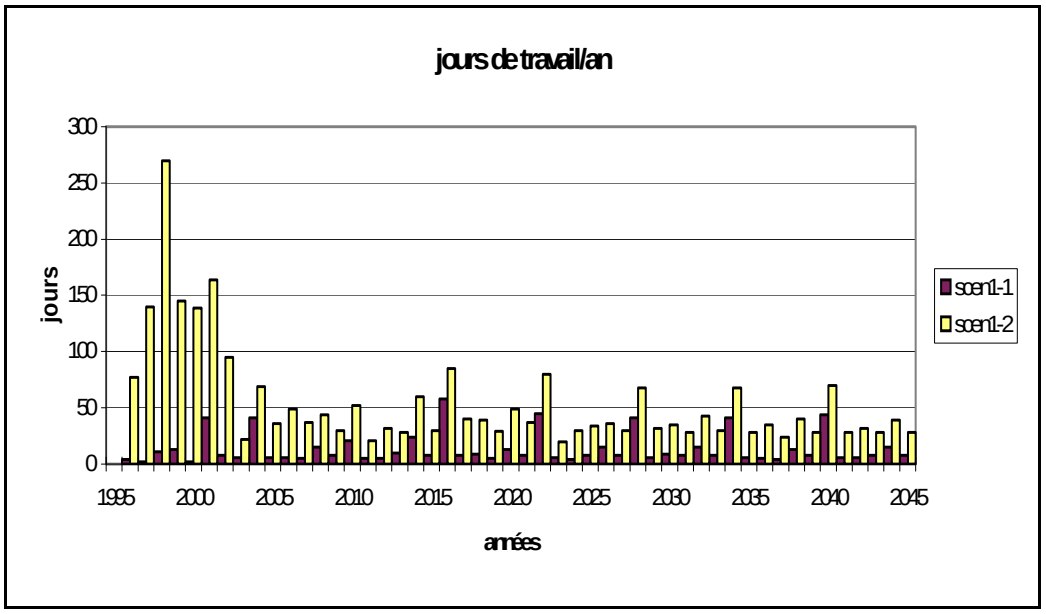

Figure 4: Workload imposed by agroligniculture and silvopastoral management according to 2 scenarios at St Pierre farm

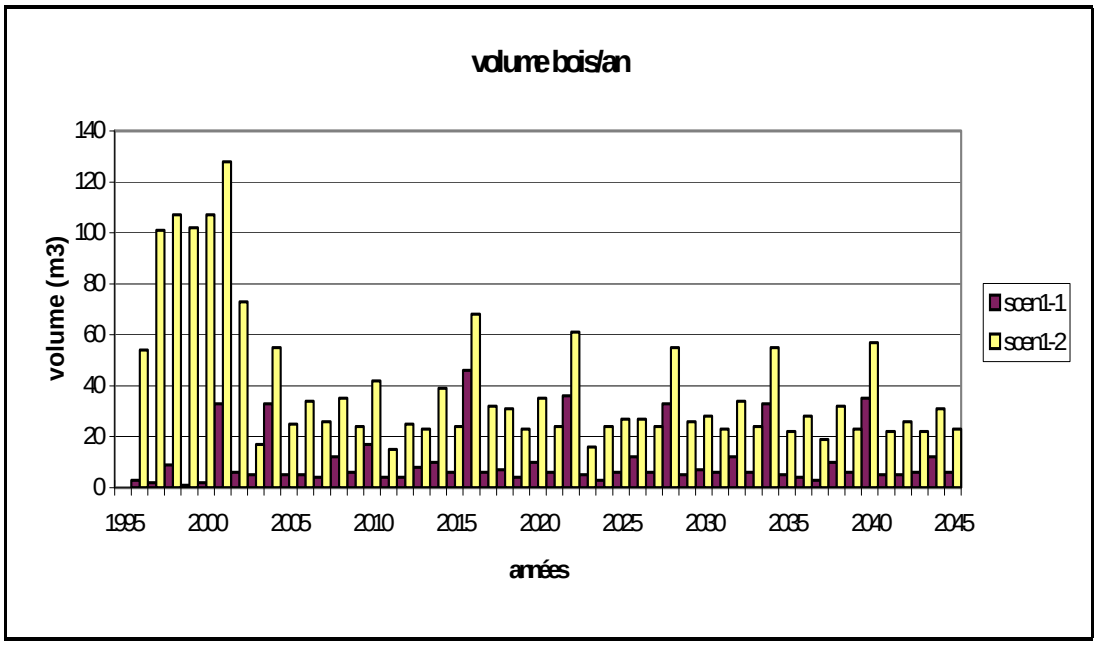

Figure 5: Firewood production according to 2 scenarios at St Pierre farm