TERAFOR: DEXI-BASED MULTICRITERIA MODEL FOR CONSIDERING ALL MULTIPLE FONCTIONS OF TREE FORMATIONS IN TEMPERATE AGROFORESTRY AREAS

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Introduction

Tree formations, such as isolated trees, hedges, woods, are ubiquitous in most temperate agricultural areas. Multiple functions are conferred on them, e.g. biomass production, shade, windbreak, source of crop pests and diseases (Vigan, Deconchat and Andrieu 2015). The links between all these functions and the characteristics that influence these functions are complex and laborious. It is difficult to consider all the multifunctionality of tree formations because of its multiplicity and complexity. That probably explains why each scientific or technical work focuses on just some functions and/or some types of tree formations and provides seldom a systemic analysis. For the same reasons, tree formations management (planting, maintenance) often takes into account one or a few functions. This is the case of hedges planted to reduce erosion or protect against high winds, isolated trees preserved to mark a property line or keep the landscape aesthetics, coppice maintained for firewood production.

We assume that the difficulty in considering all the functions of tree formations can be raised by mobilizing multi-criteria approaches. The diversity of criteria to be taken on board led us to a qualitative multi-criteria analysis and the DEXi software. We built the Terafor model to meet the challenge of representing exhaustively and intelligibly functions of tree formations. We describe this model and its foundations in a poster presenting i) the conceptual part of the model representing the potential functions of tree formations in general and ii) the operational part representing the effectiveness of these functions for a tree formation in particular. We characterize as operational this second part of the model because it is able to concretely evaluate the functions of any tree formation. It could be used to share views and perceptions of various stakeholders concerned by tree formations.

Material and methods

The construction of Terafor model proceeded in three main steps. The first based on an inventory of the functions of tree formations. This inventory was performed through a review of scientific and technical literature and aimed at the completeness of functions. Our attention focused on the beneficial functions (services) as well as detrimental ones (disservices) for the different stakeholders. A particular attention was paid to disservices because they are less well reviewed in the majority of works. The inventory was carried out by type of tree formations in order to facilitate bibliographic research.

At the second step, all inventoried functions were structured to clearly represent them. The structuring consisted to aggregate the functions according to activity on which they impact. The aggregation was performed hierarchically and formed supra-functions spread over several levels. In this way we highlighted the potential beneficiaries (crop growers, stock breeders, foresters, inhabitants, hunters) (**Figure 1**). This second step produced the conceptual version of the model that represents the potential functions of tree formations for different stakeholders.

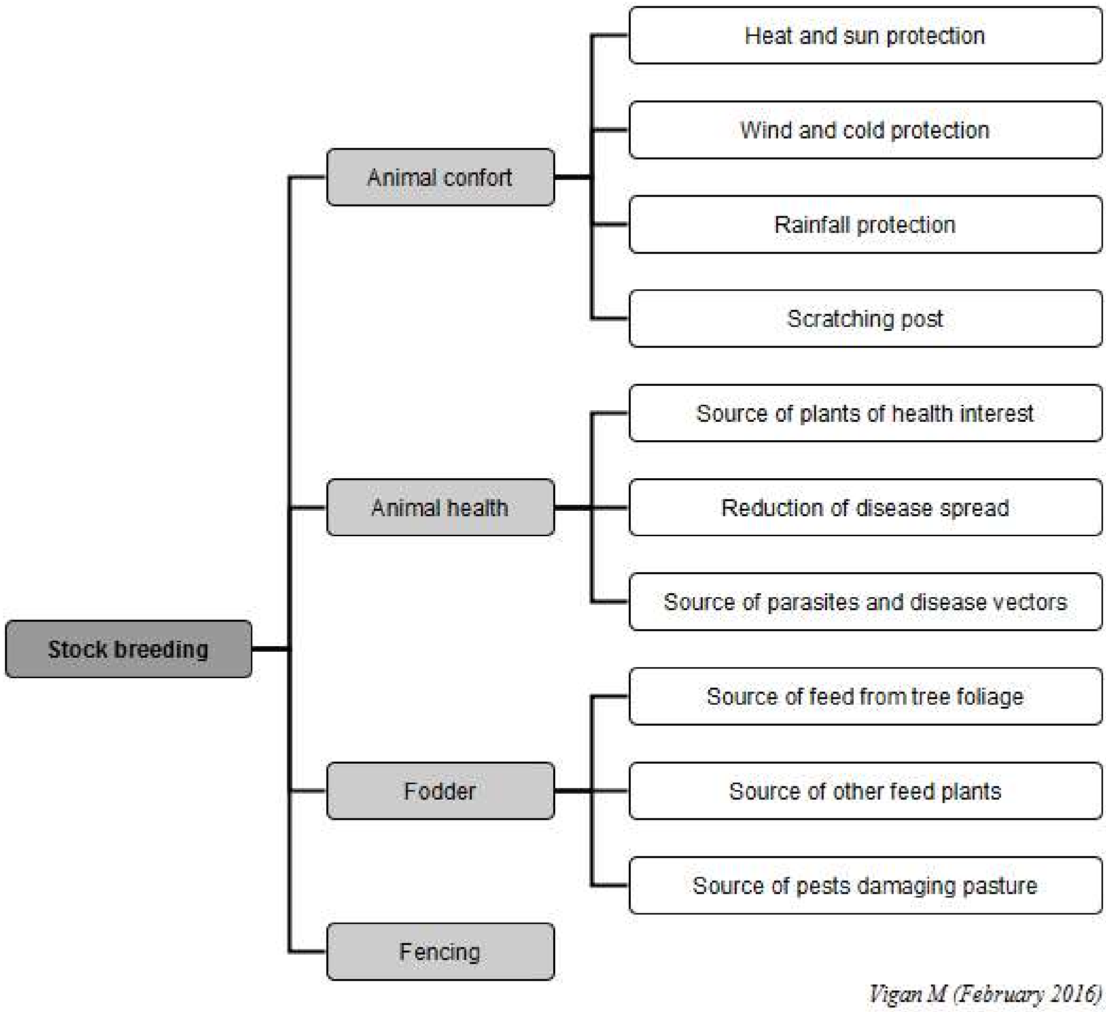

Figure 1: Example of the representation of functions and supra-functions aggregations identifying the beneficiary "stock breeder" in the Terafor model

The third and final step made the model operational to move from the representation of the functions of tree formations in general to the representation of the functions of a tree formation in particular. In order to do so the model determines the degree of effectiveness of the functions for the given tree formation. The effectiveness of each function often depends on many criteria. For example, the effect of a hedge on limiting the wind depends on its height, density, thickness, length, topographic position, relative orientation to wind, the presence of a low vegetation layer. Therefore, to include multiple functions, we also needed to use many criteria. Then we opted for the use of a multi-criteria approach. Additionally, criteria are very diverse, knowledge levels to measure them are variable and some of these criteria are difficult to quantify. In these circumstances, it appears appropriate to mobilize a qualitative multi-criteria analysis support. The study and comparison of several support softwares led to our choice of DEXi in order to implement the operational model. DEXi is used to develop complex decision-making or evaluation model. It is based on the hierarchical decomposition of a problem into smaller and easier to solve sub-problems (Bohannec 2015). In our case, it is used to break down a complex system into simpler subsystem to analyze. The construction of the operational model consisted of five tasks:

1) Selecting the functions that a type of tree formation can potentially fulfill. It based on bibliographical research result made for each type of tree formations for the construction of the conceptual model;
2) Selecting from literature quality criteria to evaluate the effectiveness of each function and the definition of possible values for each criterion;
3) Defining possible values of effectiveness for each function and supra-function,
4) Defining the criteria aggregation rules for functions evaluation,
5) Defining functions and supra-functions aggregation rules for the evaluation at all other levels of the hierarchical structure.

After performing these tasks, the model became operational: effectiveness evaluation of functions of a tree formation can be initiated by filling in all the necessary criteria to characterize this tree formation. The result for each function and supra-function is automatically obtained based on the defined aggregation rules.

Results

The conceptual model has 77 functions of tree formations. These functions was aggregated into over thirty supra-functions spread over three levels. The four supra-functions of the ultimate level represent large activity sectors (**Table 1**). The structure clearly identifies beneficiaries (forester, stock breeder, crop growers, beekeeper, inhabitant). Other beneficiaries or activities are distinguished less formally (tourism and recreation, community).

Table 1: Distribution of 77 functions into 4 impacted activity sectors

Impacted activity sectors	Number of functions	Examples of functions
Sylvicultural activities and forest productions	10	- Timber production - Production of fruits from trees
Agricultural activities and productions	29	- Heat and sun protection for farm animals - Competition for light with crops
Social and cultural processes	20	- Lanscape integration of buildings and facilities - Place of recreational hunting activities
Functioning of natural environment	18	- Habitat for sciaphilous forest species - Regulation of hydrological flows
TOTAL	77	

We proposed the conceptual model to the review of 14 experts. These experts are field trees and agroforestry operators, forest scientists and agricultural advisers. They confirmed that, to their knowledge, such a work does not exist but would be helpful. It also emerged that our first aim of exhaustiveness is almost reached, the format responds well to our second aim of intelligibility and the result is satisfactory overall.
A first version of the operational model was produced for hedges and has 51 functions (Ottogali 2015). It was tested on a farm. This implementation facilitated the discussion with the farmer on the expected and effective roles of two hedge sections. The result of this test was promising. He also revealed possible improvements of this first version.
Operational models for isolated trees and agroforestry plots and an enhanced version for hedges are being completed and a test phase is scheduled. A feedback on these experiments will be proposed in the poster.

Discussion

Technical requirements of DEXi influence the structuring of the Terafor model: the organization is hierarchical and it is recommended to limit each aggregation to three or four criteria, functions or supra-functions. Although the result is operational and adapted to the expectations initially defined, these requirements are very constraining. They influence the final representation and require to keep only main criteria to evaluate functions. The effect of these constraints should be analyzed.
When building the model, choices had to be made. As an example already mentioned before, the choice of aggregations and criteria to be used. Therefore, we had to arbitrate and sometimes despite a lack of knowledge or information. The model testing will continue on tree formations with stakeholders to ensure the validity of these choices. In-silico tests should also reveal the effects of some of these choices. Knowing these effects will disclose them for transparent use of the model and of what it contains.
The Terafor model proposes to represent the functions of tree formation for various stakeholders. The output representations are intended as a support to engage dialogue between stakeholders and to share views and perceptions. Our model satisfies tool needs for successful application of agroforestry systems identified by Ellis, Bentrup and Schoeneberger (2004). Our ambition has been a discussion-making rather than a decision-making tool to design shared projects involving trees in agricultural areas.

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