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STSM: Assessing the feasibility of Agent Based Modelling to investigate the impact of governance interventions on the development of the coppice industry

Eulalia Gómez Martín
University of Greenwich
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1. INTRODUCTION

There are diverse interacting factors influencing coppice management decisions. In Europe, different approaches have been adopted to create legislations affecting forest management. For example, in many European countries, such as Spain, measures have been taken in order to promote the conversion of abandoned coppice to high forest, whereas in England subsides are given to rural landowners to promote active coppice management (Harmer 1995).

In the last decade, active coppice management across Europe has been declining leading to an increase of over-mature coppice forest (Forestry commission, 2016). However, recent literature has highlighted the importance of this type of management and the ecosystem services associated with it. These include not only specific plants and animals, but recreational/cultural benefits as well as protection against avalanche and landslip, especially in alpine areas (Fuller and Warren 1993).

Understanding how different legislation affects traditional coppice management is crucial to evaluate how different governance regimes will alter ecosystem service delivery.

As it has been previously stated, complex factors influence decision making in forestry management. For this reason, new computational approaches can help to understand, compare and evaluate different scenarios in order to determine the efficiency of coppice management decisions.

In this Short Term Scientific Mission, the feasibility of Agent-Based Models (ABM) was investigated for its potential as a tool to evaluate the effect of governance regimes on coppice management. ABMs are computational models that simulate the interactions of autonomous agents (e.g. land owners, government, energy markets) between each other and the environment. The final purpose of ABMs is to improve the understanding of a system's behaviour by evaluating the effect of agents' actions on the system as a whole. ABMs have been widely used to simulate different types of complex systems from urban planning to air traffic control. Coppice management systems can benefit from this technology in order to reproduce the effects of new management strategies. ABMs would be able to provide advance information about the long term effects arising from new policies and regulations in coppicing, based only on previously established parameters such as growth rates of coppiced forests, rotation length, end product or the type of harvesting. If applied correctly, it would be a safe and cost-effective way of designing and implementing new management strategies.

2. PURPOSE

The purpose of this STSM was to improve the applicant's knowledge of ABM in order to investigate the potential use of this type of model to understand the potential effect of governance interventions on the development of the coppice industry and contribute this to Work Group 5. The aim was to take advantage of the knowledge and expertise of the researchers from the Basque Centre for Climate Change (BC3). The BC3 in Bilbao is a cutting-edge institution in the application of ABMs to environmental policy making. For instance, they created the k.LAB software platform, integrated into the ARIES project, a policy support system aimed specifically to assess ecosystem services. The ARIES system links natural science (e.g., process-based models) and human behaviour (e.g., agent-based models) in order to support interdisciplinary decisions (ARIES, 2016).

3. METHODS

During the two week duration of the STSM I was introduced to the concept of modelling during different meetings with the experts (see figure 1). I received advice that enabled me to complete the first steps of a complex model that these experts have suggested could   lead to future scientific publication.

Figure. 1. Meeting with the BC3 team.

Although the major part of the studies in ABM use Object Oriented programming languages (Java, C++, Python…) we decided to describe the model using Unified Modelling Language (UML) which provides a standard way to design and visualize a system. This graphical representation allows the modeller to spend more time on modelling rather than on programming.

The first step to build the model was to identify the ‘agents’ that will be used for the model. In the context of ABMs, agents are defined, according to Wooldrige and Jennings (1995), as any entity within the model fulfilling a set of properties, specifically:

- **Autonomy:** The ability of operate without direct human intervention.
- **Social ability:** The capacity of interacting with other agents.
- **Reactivity:** The ability of perceive and react to an environment.
- **Pro-activity**: The possibility for an agent to take initiative, without the need of external stimulus.

In this case, the agents were defined as those being relevant to coppice management, based on the literature. It is important to take into account that, according to this definition, not all the agents within this ABM are necessarily stakeholders involved in coppice management. Other factors influencing coppice can also be considered as agents in this context.

Once the agents were defined within the ABM, the relationships among them were established, again based on the literature and expert consultation. These relationships represent the interactions between agents within the ABM. It is important to note that ABMs and models in general need to be kept as simple as possible to ensure their efficiency and interpretable results (Bonabeau, 2002). Therefore, the agents and their relationships considered here represent only those processes identified as major drivers of coppice management.
After the relevant agents and their relationships were identified, they were implemented into a UML diagram type known as class diagram. This type of UML is a visual representation of the static structure and composition of a concrete system (Bersini, 2012). It is widely used for simplifying the interrelations and interactions between objects within a system in the first stages of more complex models, as it is the case for this ABM (Purnomo and Guizol, 2006). Specifically, this class diagram was built using the software Star UML version 5.

Within class diagrams, the objects of a model are represented as a box with three subcategories, first, the name, then the attributes in the middle, and the operations at the bottom (Figure 2); these terms are explained below:

- **Name:** Noun with which each agent is identified.
- **Attributes:** These are features associated with the agent and relevant to the processes modelled, in this case, coppice management. For instance, the agent 'Product', would have the attributes 'Type', 'Certification' or 'Price in market'. In the diagram class, the attributes are listed with each one on its own line, along with its type, specified after a colon. The type refers to logical classifiers used in most programming languages such as 'numeric' for continuous numeric factors or 'boolean' for binary attributes.
- **Operations:** The last subcategory of an agent specifies the actions that an agent is going to undertake within the context of the model. These operations can either be interactive or non-interactive with other objects of the system. As with attributes, operations are displayed in a list format. Each operation has a name, followed between brackets by the parameters needed to generate the output, which is specified after a colon. As with attributes, each parameter within an operation has a type assigned.
  For instance, the agent 'Product' would have the operation 'Increase product price' with the parameter 'increase price', which can either occur or not (a boolean parameter), giving as a result the 'price' of the product.

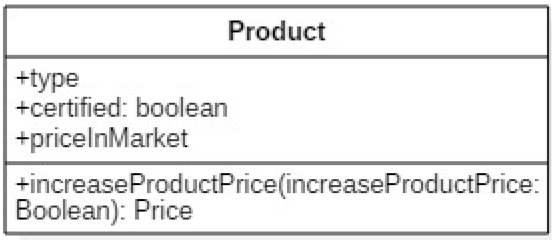


Figure 2. Object from a class diagram

It is important to note that only the name is required to define an object, the attributes and operations are optional.

A class diagram, the interactions between agents and other objects are represented with different arrows (Figure 3). Each arrow has a specific meaning, and define different types of relationships between objects. In this class diagram, four types of association were used, namely:

- **Directed associations:** An object causes another to perform an action on its behalf. For instance, the management type defined by ‘Government’ has a direct effect on how ‘Forest’ will behave (coppice or high forest).

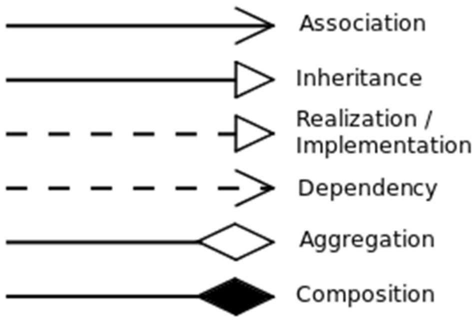


Figure.3. UML relationships

- **Aggregation:** Represents an object as being part of another. For instance, in the model the ‘owner’ can own many ‘forests’. In this type of association, the contained object can survive the ‘container’. In this case, the ’owner’ can lose the property of the ‘forest’, but the latter will still existing.
- **Inheritance/generalisation:** An object is a specific type (child) of another object (parent) and the former inherits the attributes of the latter. Unlike aggregation associations, the child object will disappear whenever the parent object does so. For instance, ‘private owner’ is a specific type of ‘owner’.
- **Realisation:** This association specifies that an object implements or executes the behaviour that another object specifies. For instance, ‘tax types’ executes the behaviour defined by the object ‘type’.

The different types of relationships can also have attributes, like objects, and the multiplicity of instances by the connected objects. These indicators represent the range of number of objects participating in the relationship. They can indicate no instances (0), no instances or one (0..1), only one instance (1), zero or more instances (0..*) or one or more instances (1..*).

4. RESULTS

The main factors affecting the management of coppice, as defined by the literature, are included in this UML class diagram as objects, and are described in table 1.

Table.1. Positive and Negative factors influencing coppice management that have been taken into account in the model.

FACTORS INFLUENCING COPPICE MANAGEMENT		
Positive	**Negative**	**Context**
subsidies to recoppice Subsides for equipment	Seasonal restrictions subsides to convert into high forest Thought that high forest is more 'close to nature'	Policy context
Biomass fuel demand	New materials substituing small-diameter wood Alternatives sources of fuel	Demand
	Emigration to cities New owners with recreational focus low price of coppice land comared with agricultural land	Ownership
Increase productivity/profitability	Damage to wildlife and cultural heritage loans/interest rate burden (total labor costs: taxes, insurance…)	Mechanisation
Family groups Coppicing can be a 'live style choice'	lack of skilled people low wages Physically hard work	Workforce
Certification increases demand Local markets Co-operatives/Co-operative working	Cost of certification Distance to markets Low capital investment	Supply chain
	Deer browsing Novel diseases	Pest and diseases

The different relationships between these objects are described in table 2. In total, 19 objects were created, most of them with attributes, and some of them with operations. These are described in table 3, along with the parameters needed for each operation. Figure 4 shows the class diagram as a whole as generated by Star UML.

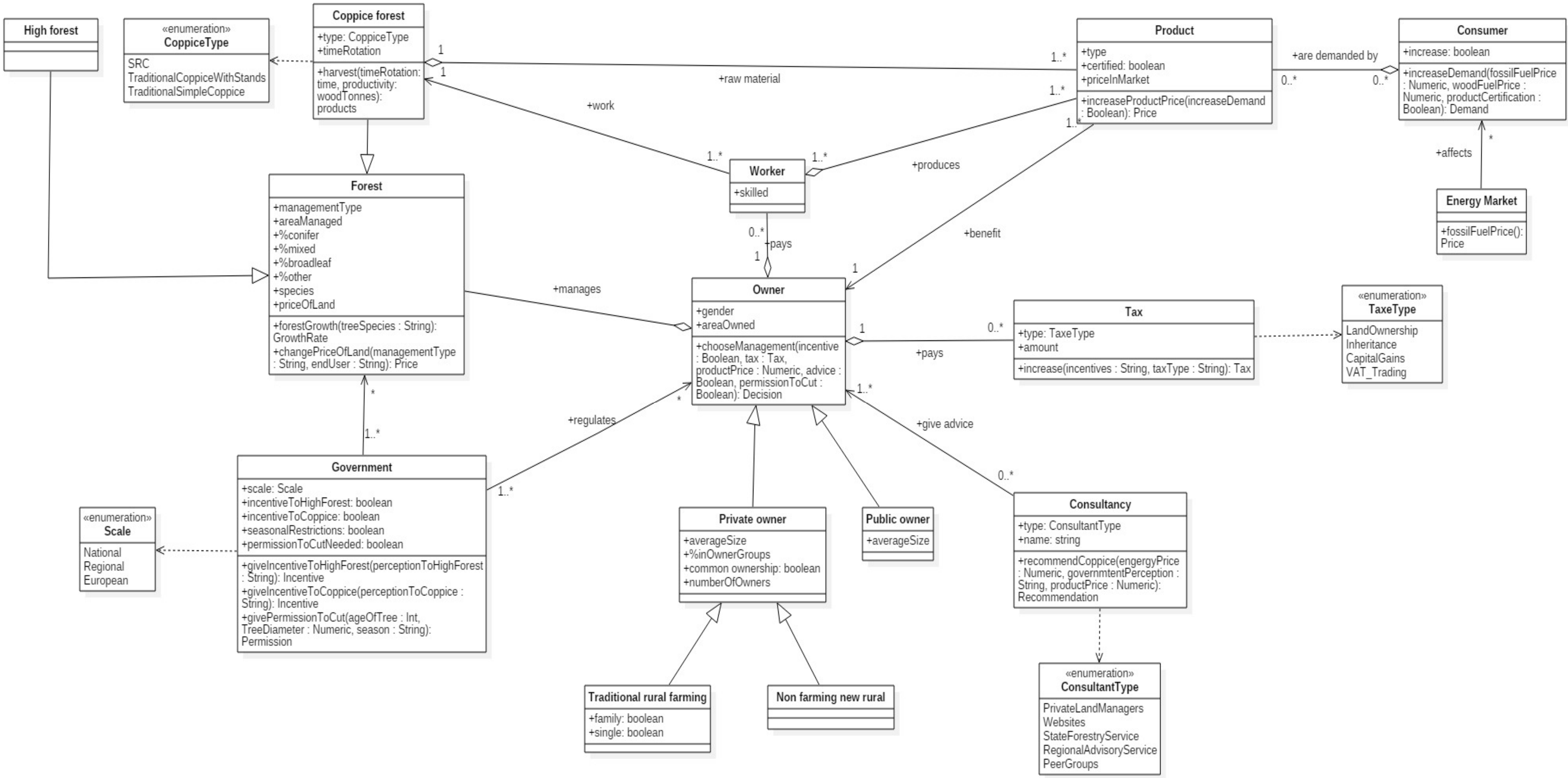
Table. 2. Relationships within the model.

Agents relationships	
Directed Associations	Government to forest
	Government to owner
	Worker to Coppice Forest
	Product to owner
	Consultancy to Owner
	Energy Market to Consumer
Aggretation	Forest to Owner
	Product to coppice forest
	Product to worker
	Tax to Owner
	Product to Consumer
Inheritance / Generalization	High Forest to Forest
	Coppice forest to Forest
	Private Owner to Owner
	Public Owner to Owner
	Traditional Rural Farmer to Private Owner
	Non Farming New Rural to Private Owner
Realization	Tax to Tax Type
	Coppice forest to Coppice Type
	Government to Scale
	Consultancy to Consultancy Type

Table. 3. Operations within the model

Agents name	Operations			
	Operations name	Parameters return		Value type
		Name	Type	
Forest	forestGrowth	treeSpecies	String	GrowthRate
	changePriceOfLand	managementType	String	Price
Coppice forest	harvest	timeRotation	Time	Products
		productivity	WoodTonnes	
Government	giveIncentiveToHighForest	perceptionToHighForest	String	Incentive
	giveIncentiveToCoppice	perceptionToCoppice	String	Incentive
	givePermissionToCut	ageOfTree	Int	Permission
		treeDiameter	Numeric	
		season	String	
Owner	chooseManagement	incentive	Boolean	Decision
		tax	Tax	
		productPrice	Numeric	
		advice	Boolean	
		permissionToCut	Boolean	
Product	increaseProductPrice	increaseDemand	Boolean	Price
Tax	increase	incentive	String	Tax
		taxType	String	
Consultancy	recommendCoppice	energyPrice	Numeric	Recommendation
		governmentPerception	String	
		productPrice	Numeric	
Consumer	increaseDemand	fossilFuelPrice	Numeric	Demand
		woodFuelPrice	Numeric	
		productCertification	Boolean	

Figure 4. UML class diagram



5. CONCLUSION

The results of this STSM show that Agent Base Modelling could be a potentially useful tool to study the underlying processes behind coppice management systems. Due to the complex situation of coppicing in Europe ABM can be a cost-effective and appropriate tool to assess the effectiveness of different governance regimes and explore the likely outcomes of specific interventions.

During this project a simple of important components of coppice systems have been described as well their relationships within the system. Future steps are needed in order to develop a more calibrated and efficient model. For example, stakeholder participation would benefit the model and ensure it represents the real situation in a specific context.

To complement this model, it would be beneficial to develop a sequence diagram to describe the time sequence over which the objects interact. Taking these steps will result in meaningful robust conclusions that could inform the future management of coppice forest in Europe.

An important aspect of this STSM is the way in which it can help with the work of Work Group 5 of the EuroCoppice project, who are considering governance issues, and a developing close collaboration between the members of the BC3 and the University of Greenwich on the issue of coppice management which could yield promising research opportunities for years to come.

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