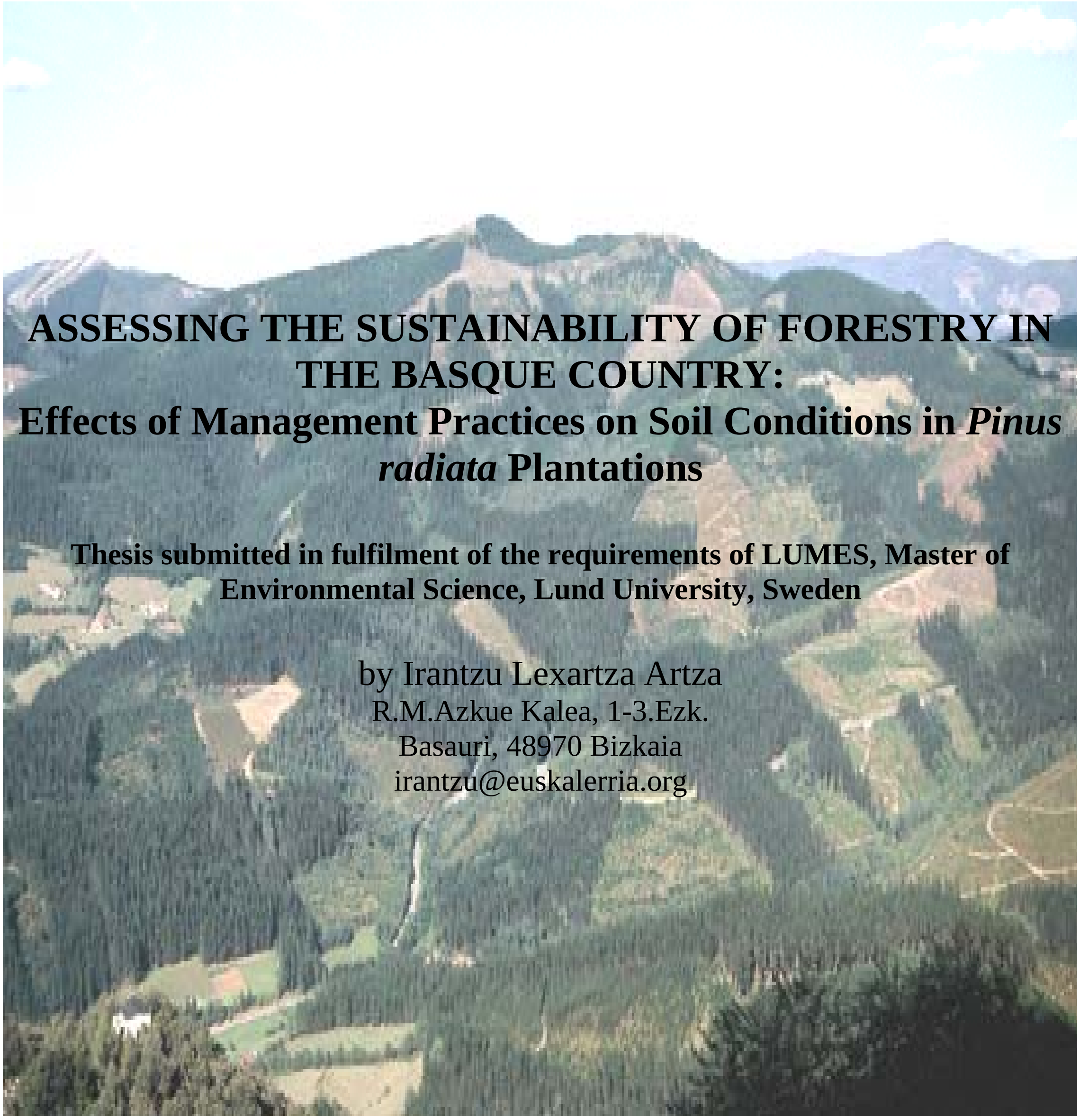

ASSESSING THE SUSTAINABILITY OF FORESTRY IN THE BASQUE COUNTRY:
Effects of Management Practices on Soil Conditions in *Pinus radiata* Plantations

Thesis submitted in fulfilment of the requirements of LUMES, Master of Environmental Science, Lund University, Sweden

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ABSTRACT

In the second half of the 20th century, the forested surface in the oceanic area of the Basque Autonomous Community increased four fold in a process that took less than three decades, mostly by the introduction of monocultures of the non native species *Pinus radiata* D. Don. Soil nutrient content is an important factor for the growth of the forest, and has been considered one of the least renewable components if nutrient cycling in the ecosystem is disturbed. This paper aims to study the sustainability of the dominant management practices of these plantations, such as mechanized whole-tree harvesting, litter removal, intense soil preparation with down slope ripping, etc., by using their effect on soil nutrient conditions as an indicator. By analysing research done on forest ecosystems and modelling nutrient conditions, it is concluded that those procedures often result in negative nutrient budgets, where outputs are increased by the removal of biomass and organic matter and the enhancement of erosion and leaching, and inputs from litter decomposition are reduced. Natural sustainability is therefore not supported, and some effects in fertility have been forecasted and even already observed. Economic reasons adduced to choose certain practices might thus not be justified in the mid-term, especially if to the reduction in production and the already unstable market, the use of chemical fertilizers or other soil improvement techniques have to be added. Legislation regarding the promotion of sustainable forestry practices is not effectively applied and private forest owners operate independently often without reporting or coordination. Better planning and monitoring, together with communication between institutions and forest owners seems to be of importance in order to achieve a sustainable use of resources.

A man has made at least a start on discovering the meaning of human life when he plants shade trees under which he knows full well he will never sit.

D.E. Trueblood

ACKNOWLEDGEMENTS

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I. INTRODUCTION

I.1 Aim and objectives

The question this paper aims to investigate is whether the present dominant forestry practices of *Pinus radiata* plantations in the Atlantic Basque Autonomous Community (BAC) are sustainable in terms of soil nutrient balance.

More specifically, it will examine several aspects dominating forestry management at present and their consequences on the nutrient state of the soil. Those aspects include intensive exploitation of the monocultures of this non-native species, mechanized whole-tree harvesting and complete-tree harvesting and mechanized soil preparation techniques on steep slope hillsides.

I.2 Motivation

Radiata pines are present in practically every valley and hillside of the Atlantic side of the Basque Country. This massive presence, therefore, can imply widespread consequences in the ecosystems if management is not done in a wise, forward looking manner. Although some concern has been shown in different spheres of interest about the way forestry is managed (Michel Rodríguez, 2004), the discussion has been startlingly minor, and for many unnoticed, compared to the relevance of the activity in the landscape and ecosystems. In fact, the issue of forestry management, although present in environmental strategies, has been nowhere near the top of the environmental agenda and discourse (Ruiz Urrestarazu, 1992). There are, however, reasons for question the sustainability of present forestry practices and incipient research is being carried out on that field. The effects of those practices on the soil and its nutrient content has been one of the grounds of interest (Merino *et al*, 1998, Olarieta *et al*., 1999), and that has been considered as a key factor to establish which management practices should be used, since the recharge of the nutrient supplies is most likely the slowest among the natural processes taking place in the forest ecosystem (Wallman, 2004).

I.3 Scope and limitations

This paper will focus on the effects of management of *Pinus radiata* D. don on soils in plantations in the oceanic climate zone of the Basque Autonomous Community, Spanish State. The study will concentrate mainly in the provinces of Gipuzkoa and Bizkaia (figure 1) were practices such as complete tree harvesting and down-slope ripping are most common.

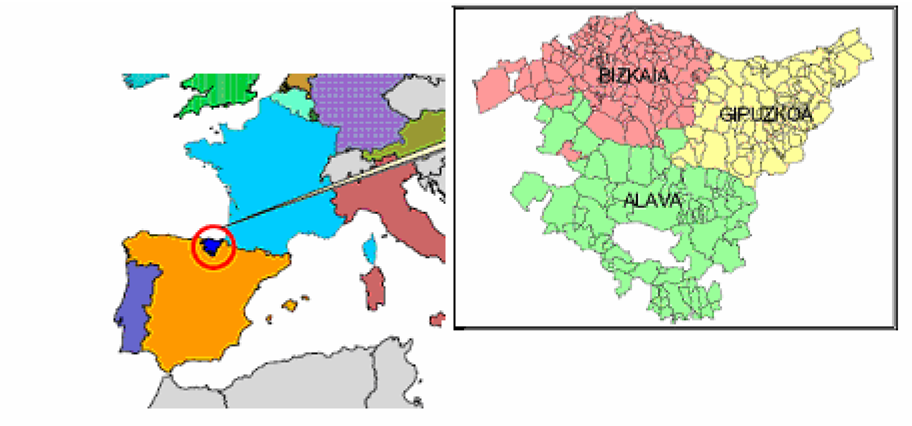

Figure 1. Location map of the Basque Autonomous Community in Europe.
(Source: PDSR, Eusko Jaurlaritza, 2004)

Within the natural sphere of sustainability, only soil conditions and their implications will be studied. Other aspects of importance, such as biodiversity issues, loss of cultural landscapes, tree health, etc, are outside the scope of this thesis. Related economic and social aspects will then be considered.

Possible effects of climate change have not been taken into account, and standard temperature and rainfall conditions have been assumed. Furthermore, the effects of the increasing use of pesticides or atmospheric pollution on the soil are not within the reach of this paper.

II. BACKGROUND TO THE STUDY SUBJECT

The terrain in the study area is very hilly, and most slopes exceed 25% gradients, and reach often gradients over 35%. The annual average precipitation varies from 1200 mm in the lowest coastal areas to 1600 mm in the higher altitudes, and the mean temperature ranges from 13-15 ºC. The average vegetation period is around 9 months. Winter is the season with the highest humidity, even though precipitations distribute homogeneously in the year, and the most intense rainstorms take place in autumn and spring. (Euskalmet, 2005).

Most soils in the study area are acid, ranging from 4.5 to 5 in pH (Merino *et al*., 1998), and derive from argillaceous sediments with sandstone interbedding. O horizons are shallow, and in pine plantations they are composed by slightly decomposed needles and twigs. The organic matter content ranges in mature plantations from moderate to high, and the effective cation exchange capacity is relatively low (*ibid*.).

II.1 The history behind: driving forces for the spread of *Pinus radiata*.

The extent of forested areas in the European Union has been increasing in the last decades (European Commission, 2003). That has also been the case of the Basque Country, especially in its Atlantic provinces, mainly since the 1940's. In this specific case, the increase wasn't slow and steady, as in many other European regions, but rather swift, as the previous forested surface was quadrupled in less than three decades, and the tree species that took most of the newly reforested land was radiata pine (Michel Rodríguez, 2004).

Previous to the 20th century, the natural forest cover, formed by deciduous species such as *Fagus sylvatica*, *Quercus robur*, *Fraxinus excelsior, Alnus glutinosa*, etc., had been dramatically reduced. This happened mainly due to its use as building material, the ship building and iron industries, and to obtain charcoal, as well as for warfare (Michel Rodríguez, 2004). This process brought Basque hills to a barren state in many cases (Ruiz Urrestarazu, 2002).

Pinus radiata, also known as insignis or monterrey pine, was first introduced in the region in the 19th century (Lavery & Mead, 1998). Also at that time, much public land was sold, and land went from being mainly public to be divided into small plots with private owners, a situation that remains similar nowadays (Eusko Jaurlaritza, 1992). It was not until the 20th century that pines started spreading in the Basque land, covering many of the hills that had been emptied from tree cover. Most of the plantations are family holdings less than 6 ha in size, with irregular boundaries and located in steep terrain (Lavery & Mead, 1998).

In the 1940's, a slow abandonment of agricultural land started. Agriculture was no longer economically profitable, and younger generations were moving to the cities that offered more attractive opportunities (Eusko Jaurlaritza, 2002). In that situation, introduction of trees seemed a good alternative, favoured by the low price of planting and the fast growth of radiata pines. Temperate areas with marine climate are most favourable for their growth, and given those climatic conditions, it is very tolerant of site (Sutton, 1999). That is actually the reason why it has settled so well in the Atlantic Basque Country, in heights up to 700 m above sea level.

That massive repopulation created what has been known as the "culture of pine", which had an underlying concept of a faster and more profitable forestry than that known previously. Private initiatives were leading this process, which nonetheless had the support of the authorities (Gordoa, 1992). Basically all of the Basque Autonomous Community is included in the mountain agriculture area, and forest activity was considered an opportunity for employment and rent regeneration in rural areas (*ibid*.).

Intensive exploitation of pine plantations started, thus, providing economic return to a weakened agricultural sector in a relatively short of time. Nevertheless, the planting and the subsequent management were considered by some (Gordoa, 1992, Michel Rodríguez, 2004) unplanned and uncoordinated, and there was also a certain amount of opposition mainly from urban citizens. A main common line, however, was that pointed by Perry (1998) in which "uncritical acceptance of the untested hypothesis that maximizing economic efficiency in the short term was the path to maximizing social and economic benefits into the future", and thus the change in the landscape was accepted as a necessity (Gordoa, 1992).

Trees were firstly used for the pulp industry, and cut after rotations of 20-25 years (Eusko Jaurlaritza, 1997). Later, however, and due to the loss of competitiveness and economic return of that sector, better quality timber has been the aim, with rotations of 30-35 years. The economic instability of the sector and the lack of available and inexpensive labour force brought a new change in the late 80's and early 90's, when mechanization of forestry works became more and more generalized (Schmitz *et al*, 1998). This evolution driven by economic reasons has been criticized for not taking into consideration social, ecological and cultural factors.

II.2 Present situation

Pinus radiata D. Don plantations occupy 20% of the total surface area of the Basque Autonomous Community, and 40% of forested land (Eusko Jaurlaritza, 1994). 80% of that area is located in the two Atlantic provinces, Bizkaia and Gipuzkoa. It accounts for 80-90 % of the timber harvested in the BAC every year and it represents around 20% of the total agricultural production of the region.

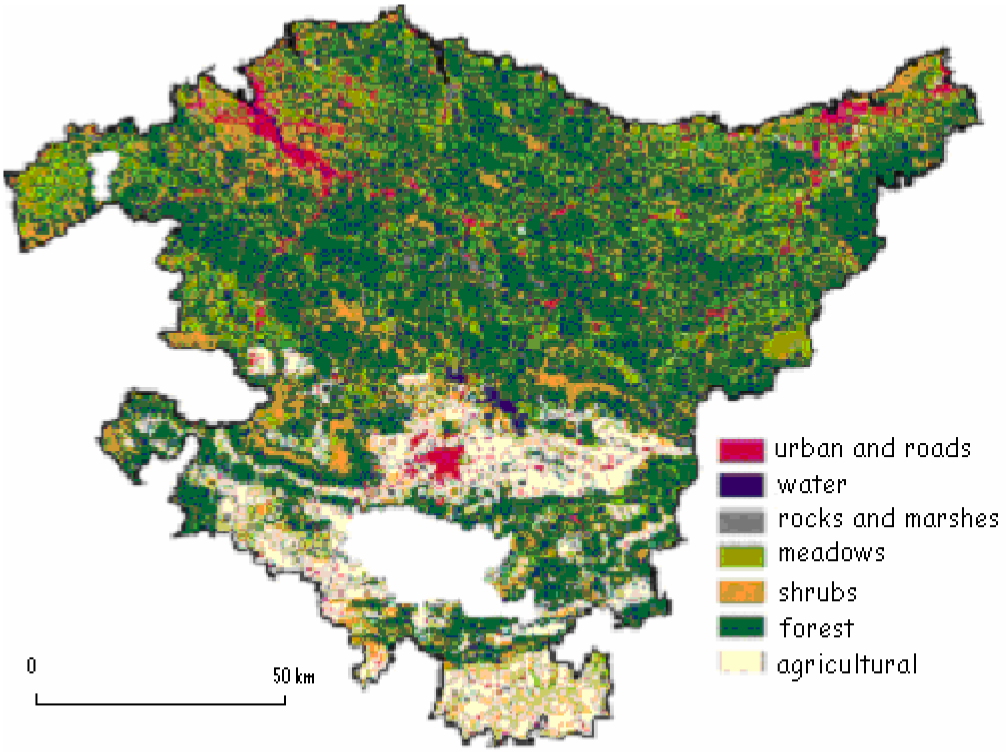

Figure.2. Distribution of soil use in the Basque Autonomic Community (Department of Territorial Planning and the Environment, Basque Government).

As it can be observed in figure 2, the forest cover is dominant in the Basque Autonomous Community, especially in the north. Nowadays the state of autochthonous forest vegetation, mainly deciduous, in that area is reduced, and radiata pine is the prevailing tree species among the non native tree plantations. 85% of the pine plantations belong to private owners, as opposed to only 15% for land of public ownership (Eusko Jaurlaritza, 1994).

Pines are grown in 30-35 year rotations, with an average growth rate of 9-11 $m^3ha^{-1}y^{-1}$ (Michel Rodríguez, 2004). Mid spacing and mid rotations regimes for mixed use are applied (Ruiz Urrestarazu, 1992). When conventional stem-only harvesting is carried out, branches and needles are left on-site and no mechanized operations are used. This practice has been replaced in many plantations by mechanized whole-tree harvesting.

Although the extraction of underground biomass has not been considered necessary regarding economic reasons, the potential damage to the soil and the fact that stumps do not compete with the plantation (Eusko Jaurlaritza, 1992), it has become a more and more common practice (Edeso *et al*, 1999) to remove all of them together during soil preparation works. The reasons argued for underground biomass removal by many foresters and owners is the potential for diseases in case of leaving them in place and that the preparation becomes easier (Merino *et al*., 1998). Thus, it might be said that harvesting becomes in those cases complete-tree, as all the biomass is removed from the forest system. That procedure is accompanied by scalping, in which all aboveground organic residues, under story vegetation and the humus layer are pushed away by heavy machinery and accumulate outside the stand. The extent of each practice changes from place to place, but that in which the removal of all biomass and scalping are carried out has become dominant in several areas, especially in the province of Bizkaia.

Traditionally, soil preparation and planting used to be manual, mainly due to the steep slopes dominant in the region. That preparation is, however, costly, and has been increasingly substituted in many areas by mechanized operations. Often machines intended for other civil works, such as bulldozers, are used. To be able to work on slopes over 20%, bulldozers need to establish terraces or to work down slope, deep ploughing, which increases the risk of erosion. (Eusko Jaurlaritza, 1992). Deep ploughing also implies mixing of soil horizon and the subsoil is often exposed.

Thinning operations are recommended three times per rotation. In practice, whether it is done and how many times varies from property to property (Ruiz Urrestarazu, 1992). Felling time is also chosen by the owners, and according to Schmitz *et al.* (1998) it is often related to their financial situation. Fertilizer use is rare. Harvesting is carried out by a “rematante”, who does any maintenance work requested and organizes the logging and the consequent sale of the timber, and suggests the method to be used. The method that is cheapest is usually chosen, frequently with forest roads opened in steep slopes in precarious conditions (Eusko Jaurlaritza, 1994). According to the mountain regulation, replanting must be done within 2 years of clear cut. That rule, however, is usually not fulfilled according to the administration itself (*ibid*.).

The high prices paid when radiata pines were first established are not increasing at the same speed in the last decades. After a decrease in the early 90’s, a slight recovery was observed at the end of that decade. In the last five years, though, prices paid for timber have been slightly receding. That fact has led many owners with mature stands to delay harvesting until prices rise again. (Begitu, 2005).

III. MATERIAL AND METHODS

- Literature review**.** Secondary sources on general forestry issues were used, together with more specific works focusing on the study area. Some of the studies used provided also relevant data for the construction of the nutrient model.

- Systems analysis**.** A systemic approach was used to design the line of research of this thesis. System dynamics provides a methodology for exploring, interpreting and managing complex feedback systems (Wallman, 2004). Those feedback systems can be shown in a Causal Loop Diagram (CLD), which's function is to map out the structure and the feedbacks of a system in order to understand its feedback mechanisms (Haraldsson, 2004). Causal relations between the different elements in the system are shown in those diagrams.

A causal loop diagram was created to model mentally the focus of this study. The initial version was constructed from personal knowledge and notions. It was modified all along the way after knowledge was increased and refined though reading and discussion, until reaching the present version.

According to Ranger & Turpault (1999), nutrient budgets can provide a notion about the direction of changes that take place in soils. Nutrients in the soil system will follow the mass balance expression based on the principle of conservation of mass: IN + PROD = OUT + ACC[1] . Following that notion, a nutrient balance model was constructed using STELLA 8.1 software (Appendix 1). Analytical data from different sources regarding soil conditions in pine plantations was used (Merino *et al*., 2005; Ouro *et al*., 2001; González Arias *et al*., 2000). Further data such as tree growth and nutrient cycling were used to model the effects of different management practices, considering also implications on fertility and profitability (European Forest Institute, 2005; González Arias *et al*., 1998, Olarieta *et al*., 1999). The basic model was built and reflecting the dynamics of the system. Once completed, different scenarios were created to simulate the processes driven by different management practices. Different stocks, inflows, outflows and controllers are further described in section V.2.1.

Some processes and relations are not understood with exactitude, and therefore average values from the proposed estimations were used.

[1] Where IN is what comes into the system, PROD is biomass production, OUT what leaves the system, and ACC what accumulates in the system.

IV. THEORETICAL FRAMEWORK

IV.1 Sustainable forestry

In the last decades, concerns about the sustainability of the use of resources have been widespread, which has been shown by many international, regional and local declarations. Following the definition of the Brundtland Report from 1987 of Sustainable Development "Our Common Future", UNCED produced a definition for sustainable management that states that *"(f)orest resources and forest lands should be sustainably managed to meet the social, economic, ecological, cultural and spiritual needs of present and future generations"* (United Nations, 2000). Other definitions have developed to be more specific following those lines, such as that of the Helsinki Process, according to which sustainable forest management should "*maintain their biodiversity, productivity, regeneration capacity, vitality and their potential to fulfil, now and in the future, relevant ecological, economic and social functions, at local, national, and global levels, and that does not cause damage to other ecosystems*" (Helsinki Process, 2003).

According to Sverdrup and Stjernquist (2002) private forest owners (the majority in Bizkaia and Gipuzkoa) have often difficulties understanding the theoretical concept of ecological sustainability, and, as Wallman (2004) points out, nowadays the dominant approach comes from economic, then social, then ecological focus rather than considering the environmental conditions of forest ecosystems as a principal issue. This is inherently a short-term approach that, in order to address sustainability concerns, should expand from considering a scale of the life of a tree crop to regard also several successive tree crop rotations (Kimmins, H, 1997). Forest resources have always been considered renewable, although many times management practices have not considered the scales of that renewability when approaching their activity (Eusko Jaurlaritza, 1998). In that context, "the nutrition of the ecosystem, upon which its performance depends, has often been considered as an inexhaustible or totally renewable resource" (Ranger & Turpault, 1999). Soil and its nutrient content, however, is the least or slowest renewable resource (Kimmins, 1997), and since this is closely related to productivity, that could be used to establish management practices within a sustainability approach (Wallman *et al*, 2004). Although certain practices are more profitable, they can not be taken as acceptable if they cause a detriment in the regeneration of the forest (Kimmins, H, 1997), since that would have sooner or later a strong effect in all aspects of the sustainability of the exploitation.

IV.2 Soil nutrient cycling

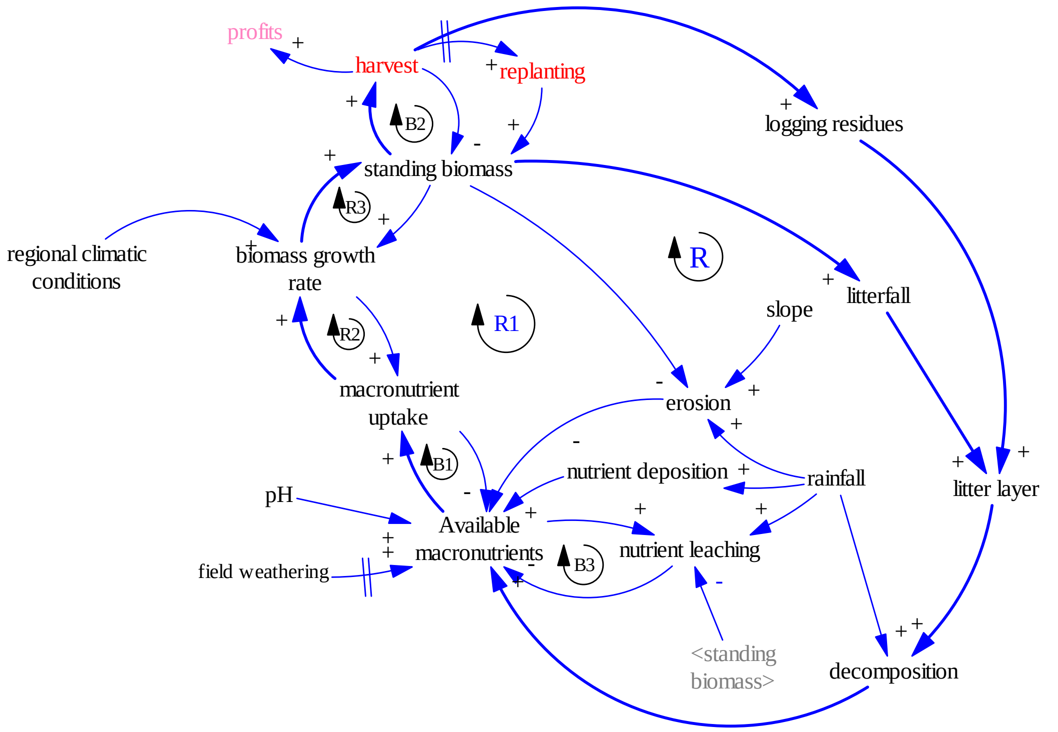

Figure 3. CLD of nutrient cycling in forest plantations assuming regional standard conditions.

The CLD in figure 3 shows the main causal relations in soil nutrient cycling processes. Of course, the processes are much more complex than those shown, but simplicity has been chosen over completeness in order to obtain a clear understanding of the relevant interactions within the system and relate them later to management practices.

The cycling of nutrients in the soil is essential for the development of the forest. This natural process has largely been affected by human activity. Thus, soil is a medium that besides, for instance, providing anchorage and supply moisture for plants, is the most important source of nutrients for plants (Kimmins, 1997).

As it is shown in the CLD in fig. 3, plants obtain an important amount of nutrients from the available nutrient pool of the soil (Jenny, 1980). There are three main sources of those nutrients, field weathering, deposition and mineralization of nutrients cycled by the decomposition of plant litter. The latter becomes a major source within the biogeochemical cycle, in which nutrients are cycled within the ecosystem (Kimmins, 1997), as shown by the main loop in figure 3, R. Litterfall is therefore considered important as the source of the majority of the nutrients taken up annually by plants. Direct nutrient cycling by this means provides a very efficient way to recover nutrients lost from plants (Jenny, 1980) and it may create an almost closed biogeochemical cycle. Litter contributes thus to the formation of an organic layer on the forest floor that protects the soil from erosion and regulates soil moisture. That soil organic matter contributes to the cation exchange capacity (CEC) of the soil, this is, the amount of exchangeable cations other than hydrogen and aluminium in the soil (Allaby & Allaby, 1999).

Nitrogen, base cations such as calcium, potassium, magnesium, etc, and anions like phosphorous are important nutrients for plant growth, and different nutrients will have preferred source routes. The source for N for instance, is atmospheric deposition, and Ca is mostly added to the nutrient pool by slow weathering of parent rock (Miller, 2004).

The main output for soil nutrients within the biogeochemical cycle is uptake by plants, as the other outputs shown in the CLD, leaching and erosion, actually transfer nutrients into the geochemical cycle, where once a nutrient has left a particular ecosystem, it will probably never return (Kimmins, 1997).

Hydrological mechanisms can have an influence in both inputs and outputs of available nutrients. Rainfall contributes to decomposition processes within a range of favourable climatic conditions, and also contributes to the nutrient pool via wet deposition. It can also have a role in the output of nutrients by taking them away through erosion (runoff) and leaching. The former can also be enhanced by slope (Jenny, 1980), as shown in the causal relation in figure 3.

Once nutrients have been taken up by plants, the biomass growth rate will increase, which in turn will increase the standing biomass within the limits allowed by the limiting factor, as stated by Liebig's law of the minimum, (Liebig, 1855, in Jenny, 1980), that the factor present in minimum controls the yield, and growth is directly proportional to the input of this limiting factor. In the case of the BAC the main limiting factor has been reported to be phosphorous, followed by calcium and magnesium to some extent (Zás & Serrada, 2003).

Although the CLD shows a general trend for simplification as mentioned, not all nutrients behave in a uniform manner. In fact, although the decrease in some elements might lead to the depletion of others, in might also enhance the accumulation of other ones (Kimmins, 1997). Excess accumulation of nutrients, on the other hand, is not always favourable for plant growth, and might sometimes even reach toxic levels (Torres Juan, 1993).

To some extent, the increase in standing biomass will feed back increasing the growth rate until a limit (Ford, 1984). In forest plantations, however, trees are often cut down before reaching the age at which growth rates decline (Pérez, 2003). Harvesting of trees will remove biomass, and therefore nutrients, out of the system, but depending of the amount and type of biomass removed, cutting remains and litterfall decomposition can return a certain amount of nutrient to the nutrient pool. Replanting in active forest exploitations will increase again some of the biomass influencing the loops in the system, producing more litterfall in one hand, and promoting nutrient uptake in the other. Since all factors are related to each other, the biogeochemical balance might be altered if either or both from the uptake of nutrients by vegetation or the rate of the release of nutrient from decomposition are altered.

IV.3 Soil nutrients and fertility

The amount of exchangeable nutrients in the soil will therefore affect the growth of vegetation in the site. According to Burger & Kelting (1999), “maintaining the productivity of the soil is a criterion in most sustainability initiatives”. Soil productivity is therefore an important indicator of the nutrient conditions of the soil. As Kimmins (1997) stated, shortages of nutrients can result in biochemical effects that negatively affect growth and metabolic performance.

Many trees are capable of growing in nutrient poor conditions, since they are able to retranslocate nutrients stored in reserves (Nambiar, 1984). However, younger seedlings planted after the soil being impoverished by harmful management techniques might no have that much possibility to store already diminished nutrients, even if site to site conditions have to be considered (Kimmins, 1997).

As previously mentioned, when any of the necessary nutrients in the soil, or any other influencing factor is lacking, the trees growing on it might show, sooner or late, anomalies in its growth and productivity will be conditioned by the limiting factor. Nutrient deficiencies can also be perceived by the loss of resistance of the plants to certain diseases that would not affect them under favourable conditions (Torres Juan, 1993).

Predicting long-term impacts of nutrient deficiencies, though, is rather complex (Perry, 1998). Soils buffering capacity and resilience, for instance, might cause that damages to the soil are not noticeable until they are advanced (European Environmental Agency, 2000).

IV. 4 Forestry management and soil nutrients

It has long been known that certain forestry practices could have a negative effect on tree growth, although those effects need to be considered on a site specific basis (Proe *et al.*, 1997, Kimmins, 1997). It was not until well into the 20th century, nonetheless, that the effects of those practices on soils and nutrients were considered a matter of concern (Perry, 1998).

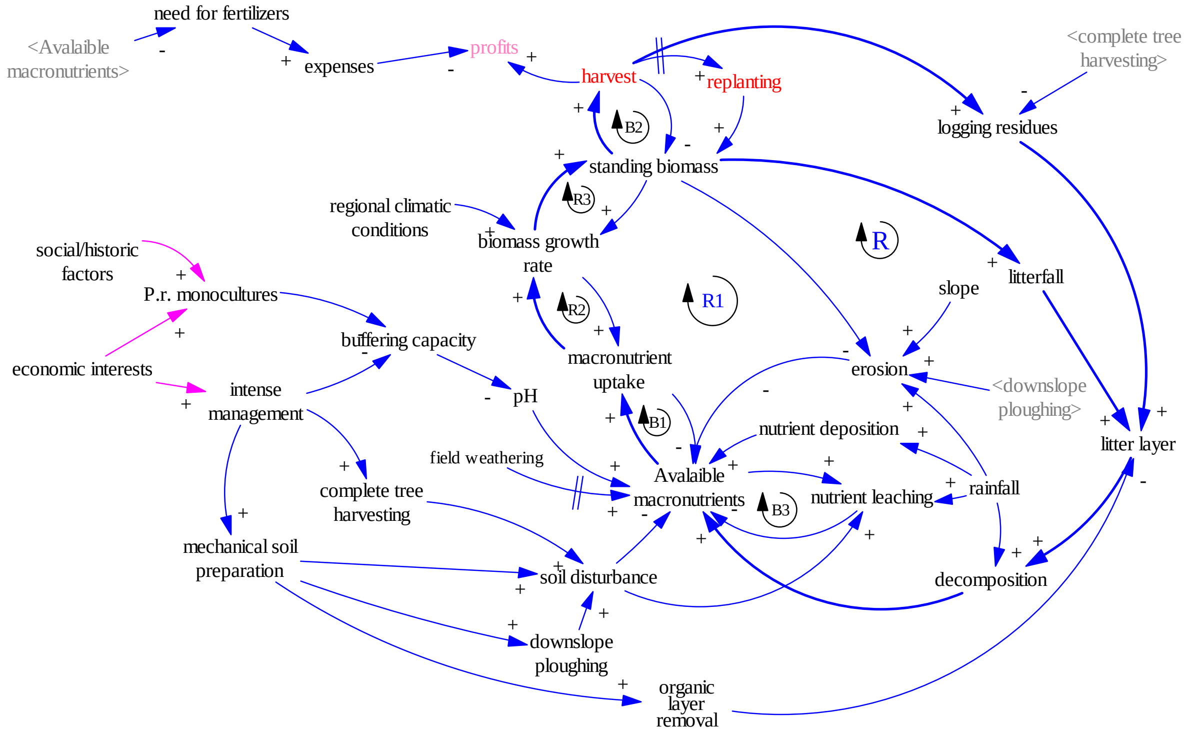

Figure 4. CLD showing the interaction of dominant management practices and nutrient cycling processes.

These negative effects have often been related to the harvesting method used, and one of the main aspects considered has been the removal of biomass that would disrupt the biogeochemical cycle.

There are several harvesting methods used in the studied region, as explained in chapter II.2. According to several authors, whole-tree harvesting increases the export of nutrients out of the system as compared to stem only harvesting, and the nutrient budget in the system is always more negative (Olsson *et al*., 1996, Ranger & Turpault, 1999). According to Proe *et al.* (1997), even when the nutrient capital of a site is high compared to what is being removed when harvesting trees, it might actually have a strong effect on the exchangeable nutrient pool available. In complete tree harvesting, that effect might be even more accentuated, as compensating the export of nutrients becomes more difficult as more biomass is removed from the site (Merino *et al*., 2005).

The negative effect of litter removal on tree growth has also been underlined (Perry, 1998). As it can be observed in the CLD in fig.4, complete tree harvesting disturbs nutrient cycling loops in more that one way. When logging residues are removed, a source of organic matter for decomposition is reduced, which will affect the input of nutrients to the soil by this means. Short rotations with intensive biomass use have been considered a threat to soil fertility (Kimmins, 1997). It has been stated (Olsson *et al*., 1996) that in commercial forest plantations weathering and organic matter decomposition do not compensate the export of base cations removed during harvest.

According to Nilsson *et al.* (1982, in Olsson *et al*., 1996) "nutrient accumulation in tree biomass causes a decline in base saturation and soil pH". Acidification as a consequence of forest growth would be counteracted if all nutrients assimilated by the trees returned to the soil by decomposition (Olsson *et al*., 1996). Harvesting might thus have an acidifying effect on the soil, which tends to increase with harvesting intensity (*ibid*.). In soils with a high buffering capacity, this property will be first reduced if there is a tendency for acidification, as shown by the CLD in figure 4, and changes of soil pH will not be observable until the buffering capacity has been sufficiently decreased.

Sometimes it has been reported that the mineralization of forest floor materials has been accelerated after harvesting. Microbial activity may be enhanced by the reduction of competition and the increased moisture status of the soil, and a post harvest flush of nutrients might happen (Assart effect). An enhanced growth can be observed then due to that factor if the new plants lack competition (Kimmins, 1997). However, although conifers in such conditions have been reported to grow better when young, as plantations reach a more mature stage, relatively poor growth has been noticeable in sites that were intensively prepared or where litter was removed (Perry, 1998). On the other hand, as shown in the CLD in figure 4, the removal of the vegetation cover after clear cutting leaves the soil unprotected, which might increase erosion by runoff and leaching (Jenny, 1980).

Together with the removal of biomass, another important factor of management is the type of harvesting equipment used. Negative effects on yield have also been related to the removal of soil organic matter and nutrients as a consequence of site preparation for planting (Perry, 1998; Kimmins, 1997, Burger & Kelting, 1999). Windrowing, for instance, displaces plant residues, enhances soil compaction and removes large amounts of SOM and nutrients, to make stand preparation easier. The use of mechanized techniques is promoted when it is cheaper or there is a shortage of labour (Perry, 1998), as it has been the case in the Basque Country. The use of heavy machinery can also have a much more negative impact on soils, since it can alter soil structure, density, porosity, hydraulic conductivity of the soil, etc. That can in return affect the leaching of nutrients out of the systems and their physical removal by erosion (Cossalter & Pye-Smith, 2003), as shown in fig.4. In spite of the potential for mass erosion, down slope ripping for soil preparation is applied often on steep slopes in the Basque Country without any soil conservation practices. It is thought that, in these fine textured soils, such site preparation improves water balance, encouraging infiltration capacity and water permeability (Merino *et al.*, 1998).

In cases where harvesting and preparation techniques result in soil erosion and decreased soil fertility, the recovery of the forest might be delayed, which will further lead to erosion due to the lack of protection offered by tree cover (Cossalter & Pye-Smith, 2003). If performed on steep slopes, those practices might trigger mass wasting such as slums and landslides. Following clear cutting, remaining roots may support stability for 3-10 years, until they lose strength due to decomposition. When stumps are removed for soil preparation, therefore, the onset of instability will be much faster (Kimmins, 1997).

Conifer plantations such as those of radiata pine have been regarded as soil degraders. However, that statement has been challenged (Binkley, 1995, in Kimmins, 1997), and it has been argued that the effects of specific species on the soils are related to aspect such as the quality or the litterfall rather than to what specific species is growing in the site. In fact, according to Pérez (2003), the problems radiata pine might bring to the Basque forests is not that that the species itself may cause, but that they do not have time to develop a mature ecosystem due to the management practices.

IV.5 Regulations

The European Commission (2003) requests to members to be committed to sustainable forest practices, with a specific mention of the maintenance of the soil characteristics.

The Autonomous Government of the BAC, with full competencies in forestry issues transferred from the Spanish Government since 1979, following later trends and European guidelines, has several documents in which concern about environmental issues is shown and regulations for sustainability are set. Some of them, general, should apply to all fields, including forestry, such as the objective of the Basque Strategy for Sustainable Development (Eusko Jaurlaritza, 2002) of reducing environmental impacts, for which effects of activities should be evaluated in advance and corrective measures taken in accordance.

Complying with Paneuropean criteria for sustainability (MCPFE, 2003) is an aim within the Basque Forestry Plan (Eusko Jaurlaritza, 1994) and the Rural Sustainable Development Plan (PDRS) (Eusko Jaurlaritza, 2004). Some of those criteria, although general, are especially relevant in the case of soil and its role in the forest ecosystem. Criterion 2, for instance, stresses that forest ecosystem health and vitality should be maintained, and those are closely related to the nutrient conditions. That is also the case of criterion 3, which concentrates on the maintenance and encouragement of the productive functions of forest, and criterion 6 that underlines the importance of maintaining socio-economic functions and conditions.

In a more specific way, the Basque Forestry Plan declares that subsidies should consider only actions that are environmentally sound. More specifically, it is stated that activities that promote soil erosion or degradation must be substituted by other methods. Furthermore, it asserts that there should be a strong coordination between forest owners and forestry and environmental institutions, keeping special attention on highly mechanised activities. Objectives and guidelines assumed by province governments (Eusko Jaurlaritza, 1994) and since 1992 impact reports are compulsory for intervention in plots over 10 ha, and the use of heavy machinery is restricted in slopes over 30 %. (Michel Rodríguez, 2004). However, the average size of the plots results in no need for many owners to work on impact reports.

V. ANALYSIS

V. 1. Literature review.

V.1.1. Nutrient conditions in forest plantations under different management practices.

Several studies have been carried out regarding a number of aspects of nutrient conditions in *Pinus radiata* plantations in the region (Merino *et al*, 1998, Olarieta *et al*, 1999, Ouro *et al*, 2001, Zás & Serrada, 2003, González Arias *et al*., 2000). Only two research groups have considered management factors as a key element, however.

Analysis by Ouro *et al*. (2001) have shown that the strong uptake of nutrients of fast growing stands can lead to negative nutrient budgets, considering the low release of many minerals (e.g. Ca, Mg, P) by weathering. They conclude that the budget can be balanced by the decomposition of logging residues, a process that seems to be enhanced after clear cutting in stands where residues remain on-site.

No major changes have been observed in general in the nutrient status of plantations under conventional management practices at the sites that have been studied (Merino *et al*., 1998). Under practices in which humus removal happened, on the other hand, a decrease of nutrients was observed in the upper layer of the soil in the months after harvesting (*ibid*.). Ouro *et al*. (2001) found as well lower levels of P, N and S in soils in those plantations where removal of logging residues was carried out. Those authors observed a difference of removal of P from the forest system (P in vegetation, humus layer and available P pool) of 50 % between stem only and complete tree harvesting, 17 % and 76 % respectively, and have suggested that the available stores of this nutrient might be reduced in the long term by intense harvesting.

This finding is also confirmed by Schmitz *et al.* (1998) that reported a lower amount of exchangeable cations in soil after mechanical harvesting and soil preparations have taken place compared to those under conventional practices and covered by mature stands. A reduction of organic matter and nutrients in the surface horizon of the soil has also been recorded (Olarieta *et al*., 1999) in the months following soil preparation. The reduction for which each nutrient accounts ranges from study to study, but the decreasing trend has been shown consistently in areas where complete tree harvesting has been carried out. Effective cation exchange capacity was also reduced in some stands according to Merino *et al.* (2004), but the results were not show to be significant.

It has also been found in some stands that the reduction of organic matter and nutrient content was still visible several years after mechanical complete tree harvesting (Merino & Edeso, 1999, Merino *et al.*, 2004), although some nutrients had recovered partially due to the inputs from weathering, deposition and the decomposition of organic residues once new biomass was established (Merino *et al.*, 2004). The recovery rate has shown to be rather slow in some of the studied sites for the nutrients analysed. In some stands, contents were still lower than initial pre-harvest values even after 9 years for N and Mg, and the recovery had been even slower for P and Ca (*ibid.*). The lowest values were found in those stands in which ploughing had taken place.

Romanyà & Vallejo (1996) suggested that the reduction of nutrients after clear cutting, organic matter and logging residues removal and tilling of soil preparation, mixing of horizons could also be a reason for the reduction of available stock, since the deeper layers are less rich in organic matter and available nutrients.

V.1.2. Other soil properties

Besides the mentioned direct reduction in nutrient content due to biomass and humus removal, some management practices also affect other soil properties that might further have an effect in the nutrient cycle. An increase in bulk density, for instance, has been reported in many studies following the use of heavy machinery and the mixing of soil horizons which accompanies complete tree harvesting in the region (Merino *et al.*, 2005, Edeso *et al.*, 1999). That increase in bulk density is often accompanied by a decrease in soil porosity, according to those authors, as was observed in soils under intense preparation years after harvesting and planting took place, when the new vegetation had already established. Increased bulk density might affect negatively the hydraulic conductivity of the soil and increase runoff.

Such changes in soil properties may enhance leaching of nutrient ions, according to Merino *et al.* (1998), due to a “lack of vegetation cover that would act as a sink for nutrients”. In the case of nitrogen, the reduction in organic matter could boost the leaching of that element. No significant results have been, though, found in that sense.

In soils in which intense harvesting and preparation were used, a decrease in microbial biomass and activity has been suggested (Merino *et al.*, 2005), most probably related to the disappearance of the humus layer. The need of more research in that aspect seems to be necessary, nonetheless.

Changes in pH have not been observed related to different management practices (Merino & Edeso, 1999). However, Olarieta *et al.* reported a reduction in buffering capacity (1999).

V.1.3. Erosion

Related to the increase in bulk density, runoff has also been observed to increase, leading to erosion processes (Edeso *et al*., 1999). Erosion can affect the stock of available nutrients negatively (figure 3) both in a direct way, by the physical removal of nutrients from the system, and in a longer term, by the degradation or even elimination of the media in which trees grow.

The physical characteristics of the study area, very hilly with slopes often exceeding 25% gradients, and heavy rainfall throughout the entire year, makes it potentially susceptible of experiencing concerning erosion processes. The region, nevertheless, has not been considered a region of high erosion risk due to the extent of its forest cover (Eusko Jaurlaritza, 1994).

The permeability of the soil is high, and therefore runoff/rainfall ratios are high regardless the management practices chosen (Edeso *et al*, 1999). In studied sites where mechanized soil preparation and ploughing took place, however, the decrease in soil organic matter and increase in bulk density lead to a decrease in hydraulic conductivity of the soil, which increased the runoff and the erodibility of the soil. This effect has been reported to be enhanced by soil compaction due to heavy machinery use (Olarieta *et al.*, 1998).

The alteration of the structure of the soil is also though to influence erosion. Soil losses accounted for four times more in ploughed soils that in those with no mechanized procedures (Edeso *et al*., 1999). In the later, when stem only harvesting was practised, logging residues and the humus layer were observed to control to some extent runoff and soil loss. During high precipitation periods, those residues could intercept splash and prevent runoff generation.

Soil loss has been observed to decrease after the establishment of grass vegetation. However, in some cases, after intense practices, the development of the pioneer vegetation cover was seen to be delayed with respect to other stands, which made the erosion period longer. That delay might be due to the reduction of nutrients needed for biomass growth (figure 3 and section V.1.1), and that in return could also have a longer term effect as new vegetation would help to increase the reduced organic matter content of the soil besides providing stability (Merino *et al.*, 1998).

Sediment transport by runoff was measured by Olarieta *et al.* (1999) who found that mechanized practices created favourable conditions for highly erosive runoff and high erosion rates were recorded until the time for next planting. A slight enrichment of Ca, Mg and P was found by those authors in sediments transported by runoff, although the difference was not significant.

V.1.4. Effects in forest growth.

Similar or even better growth in aggressively prepared land than in conventionally managed stands was observed in a few young plantations in the first 3-4 years (Edeso *et al.*, 2005), which may be related to lack of competition. After 10 years, however, much lower production and in some cases deficient development was found in some analysed sites. Merino *et al.* (2004) found a reduction in tree growth in places where removal of logging residues and humus layer took place, and deep ploughing seems to enhance even more that effect. In fact, the timber growth decreased in the sites studied by those authors up to 60 % in some of the stands, and tree height was up to 6 metres higher (9 m and 3 m in the smallest growth respectively) in trees planted in stands where conventional harvesting had been practiced 8 years after planting. It has been predicted that the difference in growth might still be noticeable in the future.

There is a close relation between tree growth and foliar concentration of nutrients and soil content (Zás & Serrada, 2003). Foliage levels showed out low P content, below the critical level, in soils where complete harvesting was carried (Merino & Edeso, 1999). The reduction of Ca seems also to be reflected in foliar Ca concentrations (Ouro *et al.*, 2001).

Those decreases in tree growth have been attributed mostly to the depletion of Ca and P in soils (and also Mg to some extent) after intensive management. Some specimens showed also diseases that have been related to nutritional deficiencies, such as chlorosis in pine needles (Torres Juan, 1993, Merino *et al*., 2004).

V.2. Modelling results

V.2.1. Nutrient balance

The study of inputs and outputs of nutrients has been considered a good early indicator to predict future soil changes even before their effects on soils and vegetation are visible (Ranger & Turpault, 1999). Nutrient balances under different management practices have been modelled using a computer model in which inputs and outputs are shown. Different results have been shown by different management harvesting and soil preparation techniques. Future evolution has also been predicted considering the effects of the management practices on the available nutrient pool.

Most of the radiata pine stands in the Basque Country are in the end of their second rotation or in the third rotation. Many of those in their third rotation are in their first rotation after mechanized harvesting and preparation, which the mature plantations ready for harvesting are likely to experience if they follow present trends. From the data from several studies on mature stands, and younger plantations under different management practices, nutrient evolution for a mature stand and the next two rotations has been projected for a 1 ha stand. Thinning has been included within the harvest factor. The budget for phosphorous, as the main limiting factor, calcium and nitrogen is shown for each scenario by the model. The bioavailable stock of exchangeable cations, organically bound nutrients and P and N adsorbed on solid phase are calculated by subtracting the outputs from the inputs. There are many formulas that consider all possible inputs and outputs. In most cases, it can be simplified, (Ranger & Turpault, 1999), as in this case, where main inputs to the available stock are weathering, atmospheric deposition, and decomposition of litter, and main outputs are leaching and nutrient uptake by plants, as shown in figure 3. The amount of nutrients in the soil of the stand and the biomass growing on it are all stocks in the model. Since there is human intervention in this plantation the way to recycle nutrients taken up by trees by decomposition of litter will be through litterfall and harvesting residues that remain to decompose.

In soils in which conventional harvesting and preparation were carried out, no major changes were observed in the nutrient conditions of the soils (figure 5) assuming that logging residues were those normally left by most conventional practices (Ruiz Urrestarazu, 1992). Fluctuations in soil nutrients were observed during stand development, as nutrients were removed from the soil by biomass, as shown in the balancing loop B1 in the CLD in fig.3. After harvest, decomposition of logging residues restored nutrients to the soil pool.

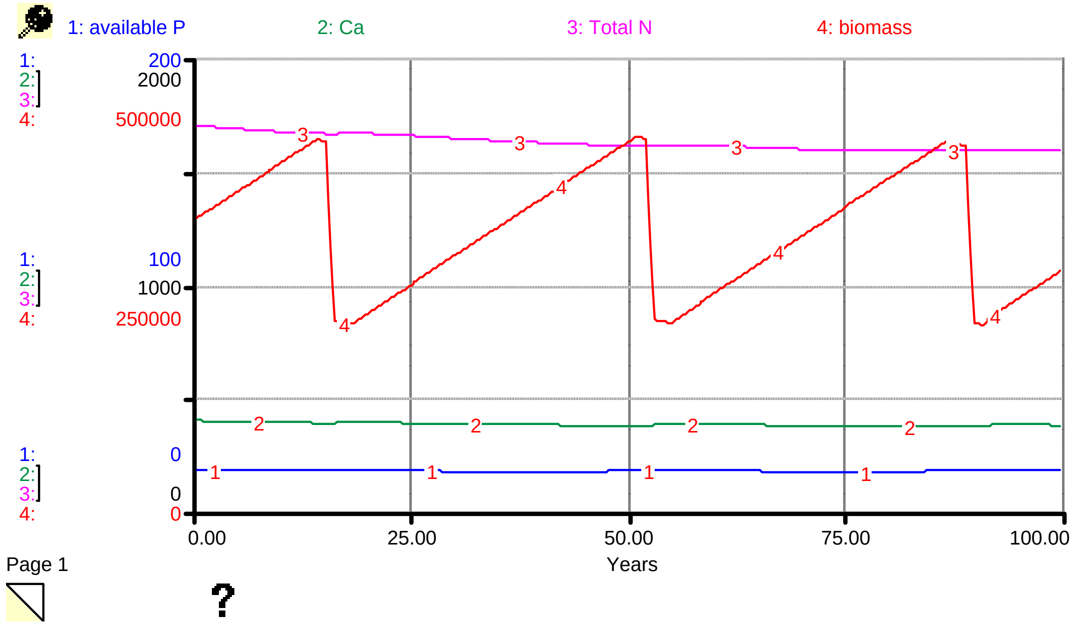

Figure 5. Nutrient evolution under conventional stem only harvesting. (Unit in y axis kg).

In a scenario in which whole tree harvesting was performed, on the other hand, there was a negative outcome (figure 6). Although uptake was reduced after clear cutting, that reduction was not enough to counteract the removal of nutrients from the system.

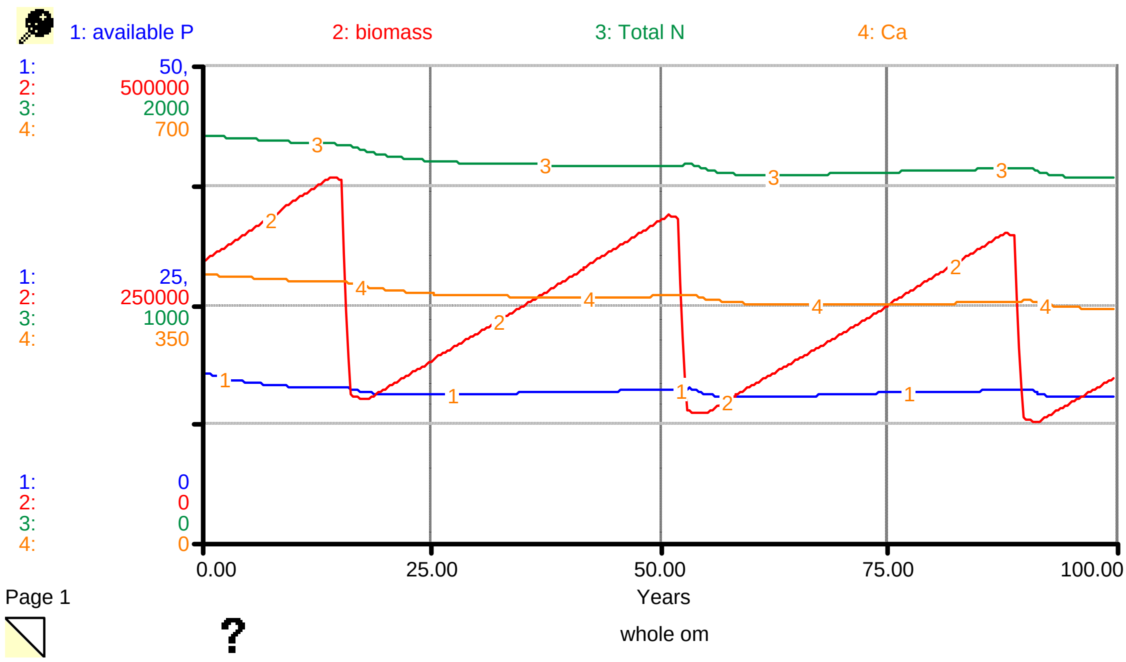

Figure 6. Nutrient evolution under whole tree harvesting. (unit in y axis kg).

More common than whole tree harvesting, however, is complete tree harvesting, in which tree stumps are removed from the site and intense site preparation is carried out. A hundred per cent of the plant biomass in the site is thus taken away from the stand, together with the humus layer. This disruption of cycling processes, shown in figure 4, leads to more marked negative results in the nutrient balance under those conditions (figure 7). 40 % reduction in P is shown by the model after the first rotation, and around 20-25 % and 15 % for Ca and N respectively.

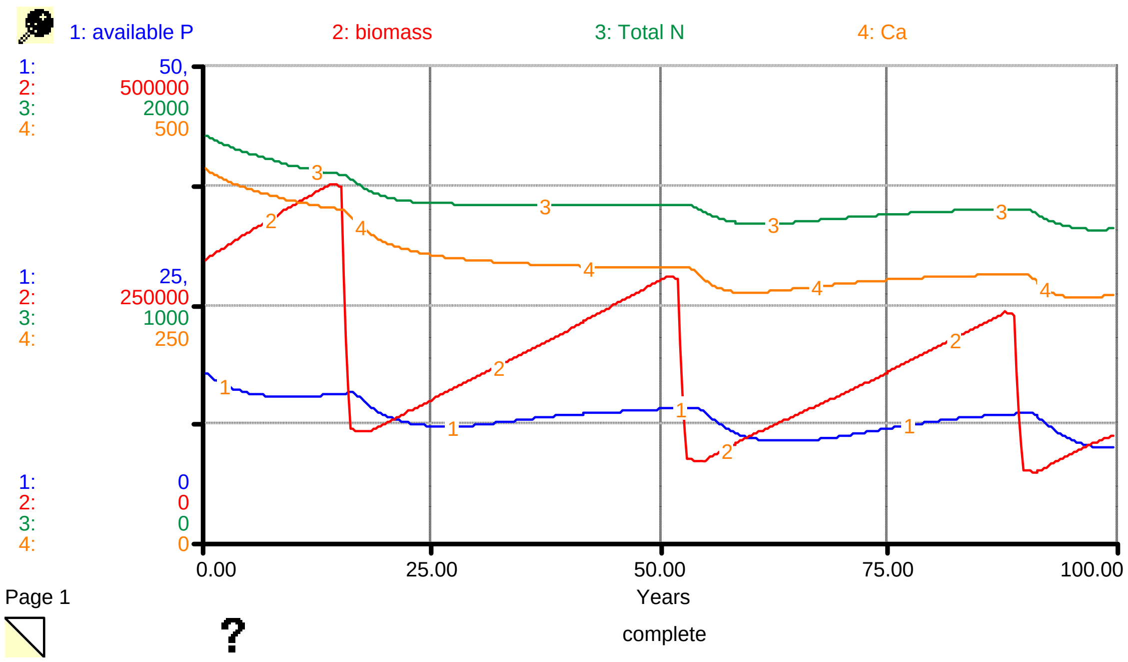

Figure.7. Nutrient evolution under complete tree harvesting, when all biomass is removed (including intense preparation practices). (Unit in y axis kg). Evolution of above ground biomass as part of all biomass shown by biomass curve.

V.2.2. Effects in forest growth

The effects of the nutrient evolution shown in figures 5, 6 and 7 in biomass production are also shown by the model, (based on information about optimal nutrient ratios, uptake and production).

As it can be observed in figure 8, the production shows a reduction in the next two rotations after the more aggressive techniques, whole tree harvesting and organic layer removal and complete tree harvesting, with respect to stem only harvesting and the first production shown by the model. Biomass production is reduced by 20 % and 25 % in each case as compared to the stem only harvesting with abundant logging residues. The production rates are reduced in relation to those in mature forests (and previous rotations under conventional management) measured on several sites (Ruiz Urrestarazu, 1992; Eusko Jaurlaritza, 1994).

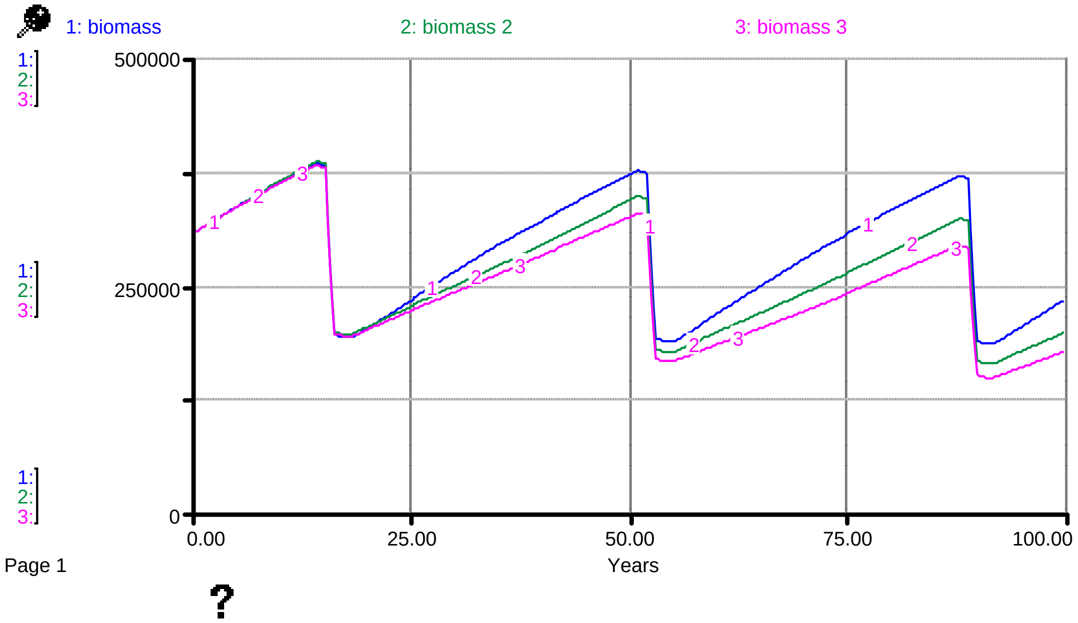

Fig.8. Biomass production under different harvesting techniques. Evolution of above ground biomass as part of all biomass shown by biomass curve. (Biomass: stem only harvesting, Biomass 2: whole-tree harvesting and removal of humus layer, Biomass 3: all biomass removed). (Unit in y axis kg).

V.2.3. Economic effects

The reduction in production has an effect in the revenues produced by forest exploitations. As shown in figures 3 and 4, there is a direct positive relation between the yield and the profitability of the exploitation. It has to be considered, on the other hand, that in complete harvesting the amount of biomass removed is not all used to sell, as a part is only removed to ease later operations.

If a stable present price for timber and present management costs are modelled, the loss of revenues under the studied conditions seems to be notorious (figure 9) for the most intense practices with respect to conventional stem only techniques. Inflation has not been considered, which might not seem very realistic. It may be useful, however, to see trends, and that if there are significant differences in production they will counteract differences in management costs.

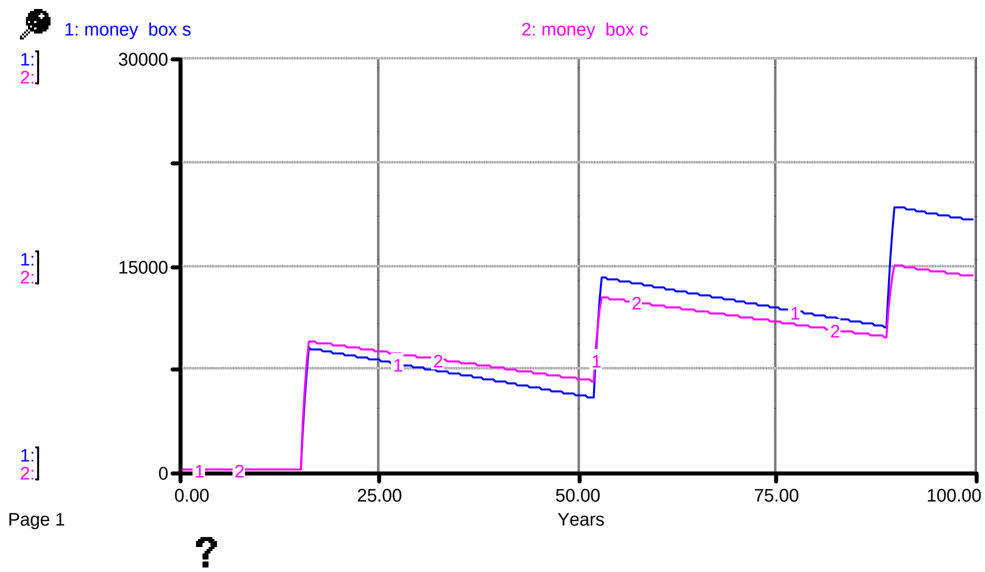

Figure 9. Net revenues under different management practices. (Money box s: stem only, Money box c: all biomass removed, money calculated in euros).

It has to be considered that the prices paid per m^3 of pine timber (in the model calculated as price in euros per kg) have been slightly decreasing in the last five years. On the other hand, if fertilization is needed to sustain production due to the lack of nutrients, the costs for that practice will have to be added as extra costs which will further reduce profits in the exploitations in which it is applied.

V.2.4. Erosion

The risk of erosion brought by some aggressive management practices has already been underlined above and in figures 3 and 4, and some such processes have already been observed in some sites in the study area. Although it is difficult to assess the exact effects of erosion in nutrient content, estimates have been done in the years following mechanical harvesting and preparation in some steep slopes. Projecting those estimates in a longer time for another rotation and same techniques afterwards shows the behaviour that might be expected (figure 10). The negative outcome for phosphorous in further enhanced below the critical level to an extent of which the consequences might be difficult to address in the long or even in the mid term.

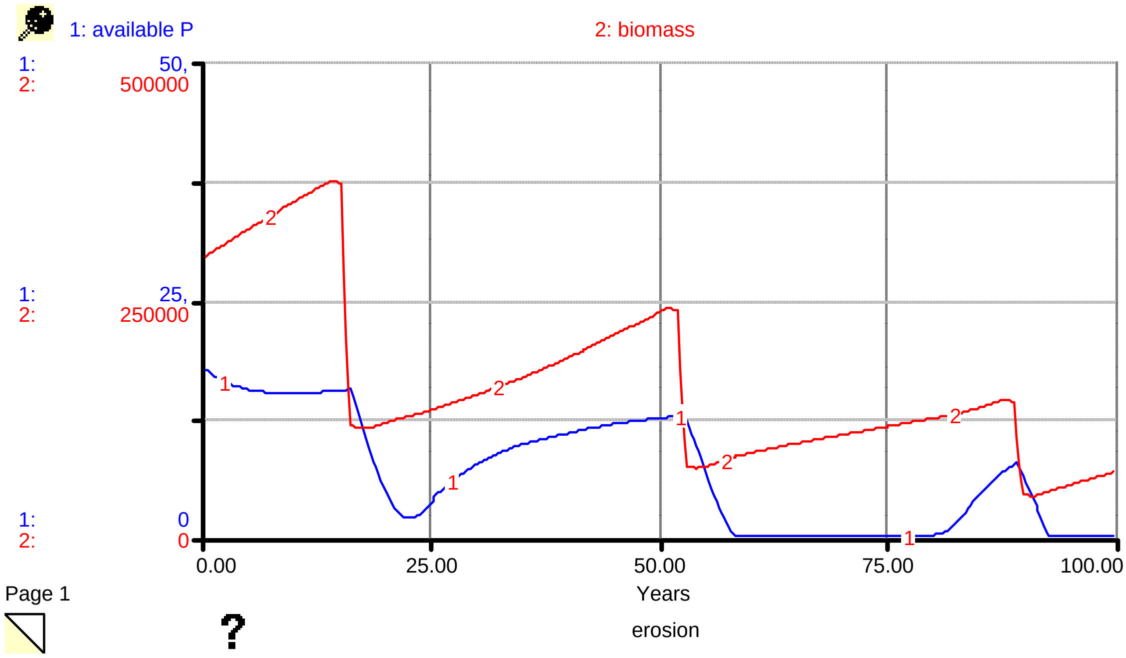

Figure 10. Effects of erosion after complete harvesting on available P and biomass production. (Unit in y axis kg).

V.3. What is happening with regulations?

As previously mentioned, there are nowadays guidelines and regulations, proposed by the EU, the Basque Government and the province governments of Bizkaia and Gipuzkoa to promote sustainable forest management. However, there seems to be a gap between what is stated in official documents and what is happening in reality and the regulations have mainly remained merely a statement of principles (Rojas Briales, 2001).

It has been considered (Lavery & Mead, 1998) that the fragmented land ownership makes planning by government agencies quite irrelevant. In public forests, less aggressive management is dominant and even replacement of pines by autochthonous broadleaves has taken place increasingly in the last years. The case is completely the opposite in private property (Michel Rodríguez, 2004). There is a tradition of working independently, and decisions about the schedules of harvesting, for instance, are made usually according to each owner’s circumstances and ideas. That seems to be one of the reasons why implementing new rules seems complicated. The fact that small stands need no impact reports in some areas might also lead to undesired effects.

One of the measures adopted is to change the procedure for subsidies, to ensure that forest resources are kept in a sustainable manner. Replanting after clear cutting, for instance, might be subsidised up to 85% in conifer forests, and up to 100% for deciduous, given that the practices are considered acceptable. There is a stated commitment to promote the Paneuropean Forest Certification System (PEFCS). The fact is that all forest owners receive subsidies nowadays (Michel Rodríguez, 2004), regardless of the methods they are using.

According to the PDRS, a new measure to be applied to promote their objectives is the training of forest owners and stakeholders on forest management practices to improve the economic, ecological and social functions of the forests. Nowadays there are courses planned and proposed to those forest owners that receive subsidies (i.e., all). If they are invited, assistance is required. There is not nowadays, though, monitoring about the application of the learned methods. This lack of monitoring seems to be generalized regarding also management practices such as harvesting methods, time for replanting, etc.

According to Michel Rodríguez (2004), the profitability of the forestry sector increased due to public subsidies in the last decade. However, although subsidies could cover more costly operations and support more sustainable practices, there is within forest owners a sense of mistrust towards the “real” aim of those subsidies, since they might reduce somehow their decision power.

Nowadays there is an important investment from the Basque Government (Eusko Jaurlaritza, 1994) regarding research on *Pinus radiata* plantations. Most of the effort concentrates however, in genetic studies to the seedlings used for replanting. Studies and research from Basque institutions about erosion risks is still incipient.

VI. DISCUSSION

VI.1. Sustainability of current forestry practices

The results of both research done in the region and modelling are consistent. The exact numbers vary but the trend of nutrient balance under different management regimes and its results is similar. No major changes in physical or chemical properties of the soil were observed after conventional harvesting, where logging residues were left on-site. It also seems to confirm the suggestions of previous studies by Ouro *et al*. (2001) that the stability of the nutrient status of the pine radiata systems depend on the input of nutrients by decomposition of logging residues left on-site.

The result also agree with highest concentration of nutrients in the canopy (Mälkönen, 1976), which shows the importance of returning this material to the system. It was also pointed out by Kimmins (1997b) that retaining woody debris is important mainly in intensively managed plantations, since removing it also destroys microenvironments for fungi and microorganisms which might interfere with forest processes. The removal of residues implied lower amounts of nutrients in soil elsewhere (Proe & Dutch, 1994, Mälkönen, 1976). It would be important to estimate how much debris would be necessary to ensure an appropriate nutrient return to the soil, and to assess the need of bringing larger residues to smaller size to ease and accelerate their decomposition.

On the other hand, more aggressive practices that imply removing logging residues, humus layer and even tree roots show an imbalance between nutrient inputs and outputs, the latter being higher. Such a negative result in the budget shows that the nutrient is being depleted and the forest ecosystem is therefore not sustainable (Wallman, 2004). The management practices leading to this situation are interfering with nutrient recycling loops (figure 4) and removing out of the forest system nutrients that are not replaced at the same pace. Conventional stem only harvesting and leaving logging residues on site seems to be much more sustainable in natural terms.

It is important to point out, nonetheless, that the consequences of a negative result are difficult to quantify with exactitude (Ranger & Turpault, 1999). Total stocks, not all that accurately known, will determine the depletion time. However, trends can be shown by simulations, and a reduction of a nutrient already scarce, such as P, for instance, might show a rather reliable negative effect in fertility.

The effects of dominant intense management practices in nutrients in radiata pine plantations in the BAC are important in the early growth of the next rotation, and might be observed even in the consequent yield. Other soil properties that might affect the nutrient content are also affected. Compaction, which has been observed in the area, for instance, has been considered a major factor reducing tree growth following whole tree harvesting and windrowing in *Pinus radiata* plantations in New Zealand (Proe & Dutch, 1994). This effect has been related to the negative influence of compaction on water penetration, nutrient adsorption, etc. It also has to be considered that in those occasions where negative effects were reported stumps had not been removed, as is the case in the present study. Thus, this procedure might enhance even further the negative effects found in other regions.

Although the risk of erosion is high in unprotected slopes, especially under conditions of heavy rainfall, the dominant practices lead to barren hillsides that might remain so for two years or even more, until the next rotation is established. As the forested area in the region is high, erosion has not been considered a threat, but results show there is reason to consider that time after harvesting of concern. Erosion has a direct effect already in the reduction of nutrients. However, in the future potential consequences even more important might need to be dealt with. A loss that looks small might have big effects (Miller, 2004). Besides a source of nutrients for trees, soil provides the supporting material for them to grow. It must be kept in mind that soil is not renewable in the timescale of forest plantation development, and if it is lost, it might be ecologically and/or economically unviable to restore it.

At present, wide extensions are cut down around the same time, because they reach felling age at the same time (Schmitz *et al*., 1998). There can be an added problem in the future since many people are waiting for prices to rise to harvest their forests. If prices do not rise, sooner or later they will be forced to sell before the trees pass the suitable age. If prices do rise in the near future, everybody will want to sell their timber then, those who were waiting and those whose forests have reached maturity in the meantime. In that case, excess offer will reduce the price, and will also lead to more extensive barren hillsides than ever that might enhance even further all the negative effects above discussed.

V.2. Are reasons adduced to choose more intense practices justified?

The increase in runoff leading to more erosion, in stands where deep ploughing has been practiced, shows that the believe that the system enhances hydraulic productivity on soils is not supported in this case. That may be related to the fact that subsurface horizons are brought to the surface, and those horizons are denser and have a smaller content of organic matter.

The negative effects of the dominant forest management practices in the Basque Autonomous Community are already affecting the fertility of some soils, and will likely affect many of them in the future to significant levels. Such effects have also been observed in other areas such as radiata pine plantations in New Zealand (Proe & Dutch, 1994). Regarding this aspect stem only harvesting with logging residues seems again to be the most sustainable choice.

It has been mentioned that leaving tree stumps on sites is thought to create a risk for diseases, but no reports of such problem have been found. Further research could maybe be carried to suggest how relevant that risk is and whether it is necessary to take other measures to address it.

It was expected that the most intense techniques would lead to better growth due to the fact that new plants would have less competition, but that believe is not confirmed by observations or modelling. It seems that the factors leading to poorer growth related to these practices are more important than having less competition.

This negative effect in production will lead to a reduction in revenues from timber in the future in the intensively managed stands. The magnitude of this reduction will have to be considered together with management costs. Economic considerations, however, are driving the choice of more intense practices against the more conventional and naturally more sustainable ones. These practices are not contributing to improve growth, in one hand, and will produce less profit than projected. It does not seem, therefore, that they are the most sustainable choice in economic terms either if taking a longer term view.

In any case, even if other techniques might be more expensive to apply and bring a theoretical loss to the private owner, compensations through subsidies can counteract that, since sustainable practices are entitled to receive bigger subsidies. However, a lack of effective monitoring mechanisms seems to be preventing the application of such subsidy policies.

In also has to be considered that, unlike when radiata pine plantations spread in the region, the market is much more unstable nowadays and caution is consequently needed in this field as opposed to the euphoria experienced in the past.

The deficiency in nutrients created by the dominant management practices might require “borrowing sustainability” by fertilizing the soil adding the nutrient(s) of shortage (Wallman, 2004) but the decrease in the humus supplies may under certain conditions be a more severe problem (Mälkönen, 1976). Phosphorous or phosphorous and calcium fertilization has already been recommended (Ouro *et al*., 2001). *Pinus radiata* has responded well to fertilization experiences, but responses are difficult to predict, and the level of the damage will determine how effective those experiences can be addressing it. If fertilization is required in the future, at it has already been suggested, that needs to be added to the economic considerations also. It is important to consider regarding commercial fertilizers that, besides their market costs, their external costs are high due to the large amounts of energy used to produce, transport and apply them (Miller, 2004).

VI.3. Socio-political considerations

The existing legislation regarding forests in the Basque Autonomous Community expresses an interest to support and promote sustainable forestry practices. It seems, however, that the implementation phase of the regulations is not working effectively. The division of competencies and the fact that environmental concerns are not high in the daily agenda as opposed to other issues, as pointed out by Carter (2003) might be one of the problems leading to this situation.

Looking at the Paneuropean criteria the Basque Institutions aim to follow, criterion 2 is not complied with in most cases, since the maintenance of forest health and vitality is not ensured under the present dominant management practices due to the reasons above mentioned. The productive functions of the forest are not maintained and encouraged, and nor are therefore the socio-economic functions, failing thus at criterion 3 and 6 also. It seems therefore necessary a commitment from the authorities to enforce their own regulation and promote the objectives adopted so they do not remain just a statement of principles. Strict regulations are needed for works on steep slopes together with applying subsidy policies that really support sustainable practices.

It has been pointed out that there has been a lack of planning and coordination in the development of *Pinus radiata* plantations. The property structure of the forests seems to be a key factor in this situation. This has brought a tradition of working independently and taking individual decisions. Involving and coordinating forest owners is important, consequently, in order to encourage them to enforce more sustainable practices as opposed to other apparently more beneficial economically. This involvement might be especially essential considered the traditional “resistance” in the area to “imposed” decisions (Rojas Briales, 2001) and could help relieve the sense of mistrust that has been said to be found about changes in policies or subsidies. The role of forestry associations could be considered to channel this effort.

The social views on forest plantations are complex and, as previously mentioned, differing from rural to urban areas, although no “open” conflict exists regarding this issue. In fact, there is a lack of knowledge from most of the Basque society regarding forestry matters despite the ubiquitous presence of pine trees. Popularizing the knowledge about the negative effects of certain management procedures might contribute to change the present views on forestry and stress the need for sustainable practices.

VII. CONCLUSION AND RECOMMENDATIONS

The study of soil nutrient content appears to be a good indicator of the sustainability of forestry management practices, since it reflects the effects of such practices and it is a key factor conditioning processes within the forest ecosystem, besides being the slowest renewable resource of the forest system. According to the nutrient balance in the soils in Pinus radiata plantations in the Atlantic side of the Basque Autonomous Community under different management practices, it seems that dominant practices are not sustainable. The outputs outweigh the inputs in the stock of available nutrients when all plant biomass, including logging residues and tree roots are removed from the forest system in complete tree harvesting with mechanical soil preparation. The removal or organic matter and mixing of soil horizons seems also to affect negatively nutrient balance in the soil. Other soil properties are affected that might lead directly or indirectly to further loss of nutrients, for example by means of erosion, which is favoured by the steep slopes and heavy rainfalls of the region.

These negative effects affect the productivity of the site to an extent that might be significant in the future yield of the site, which might lead to a loss of profitability of forest exploitations. This questions the economic motivations that drive the use of those intense practices instead of less aggressive techniques, and there is a possibility that in coming rotations the most intense exploitations will be less profitable than more conventional ones. Furthermore, counteracting the loss of nutrients and subsequent production by, for instance, fertilization, might bring further costs to forest exploitations.

Present legislation regarding forest management is more a statement of principles than something that is really being brought to practice. It is necessary that institutions commit as soon as possible to promote ideas that they are already supporting in writing documents. Strict regulations are needed for forest works and subsidies must be subjected to the set objectives. The need for monitoring resources seems to be necessary, since forest practices appear to be subsidized without control.

Good planning and coordination seems to be a key for a proper functioning, and the involvement of all the stakeholders, especially private forest owners, needs to be achieved. Communication channels between government bodies and forestry actors should be promoted, and the role of forestry associations could be important in that process. It would be necessary to popularize the knowledge about the convenience of different practices from the scientific spheres and some institutional levels to all social actors in order to work to maintain the services forest provide.

Further research might be needed regarding the sustainability of forest exploitations in the Basque Country. There are aspects not examined in this thesis that might be of importance, such as biodiversity, landscape richness, forest uses, etc have to be considered. Even the philosophy of the “pine culture” itself might need some consideration.

The widespread presence of pines plantations in the Basque hillsides underlines the importance of taking measures to protect the conditions of forest soils, as the spatial scale of potential damage might be vast. Whatever measures are taken, the fact that some of those damages might not be visible until they are permanent in the human life-time scale, suggests that they should be taken as soon as possible.

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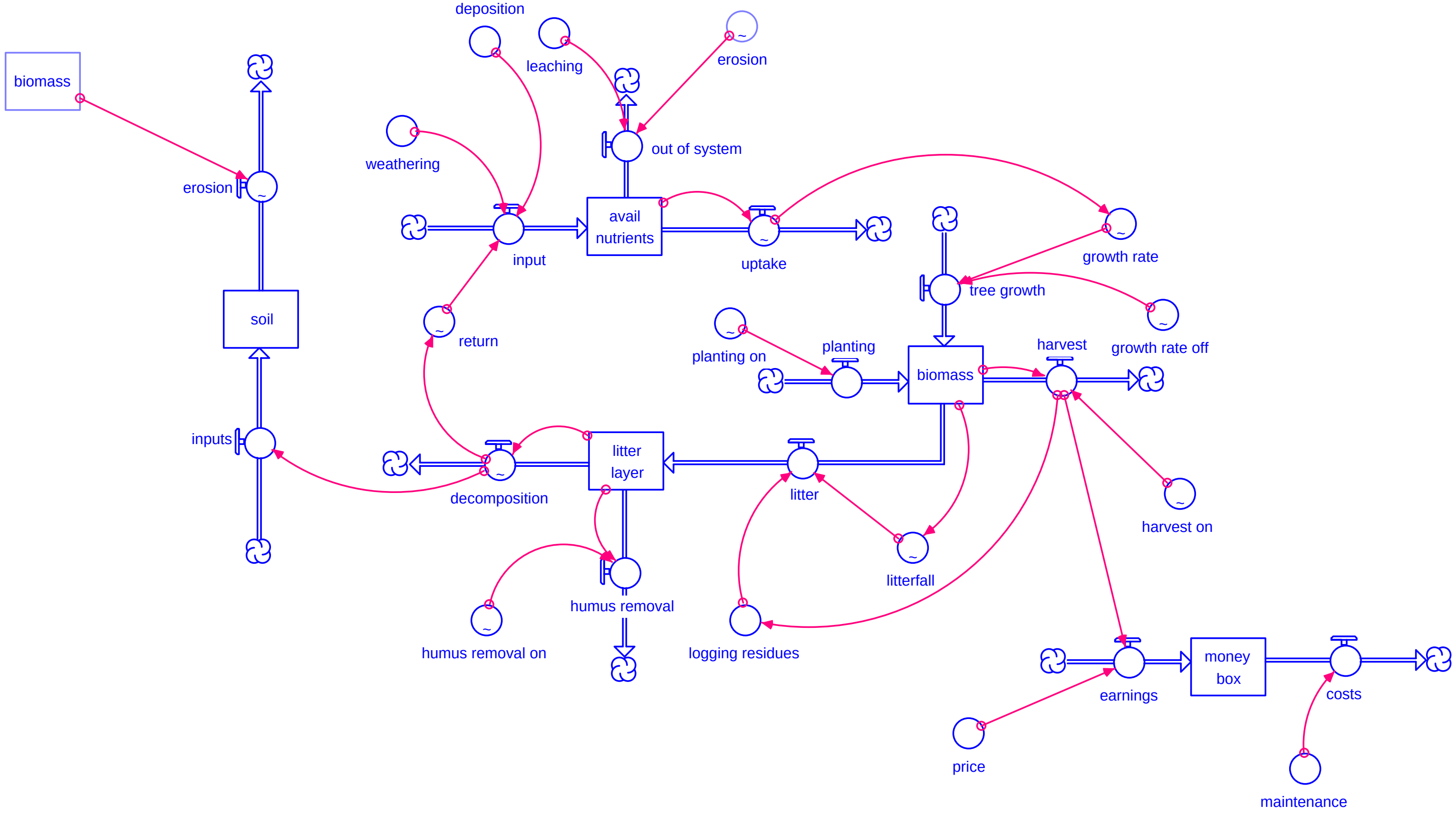
Photo Reference:

Photo on title page: Elhuyar 2004, Eneko Imaz.

Appendix 1- Basic Stella model



List of equations

avail__nutrients(t) = avail__nutrients(t - dt) + (input - uptake - leaching) * dt
input = weathering+return+deposition
uptake = GRAPH (avail__nutrients)
out of system = leaching +erosion
biomass(t) = biomass(t - dt) + (tree_growth + planting - litter - harvest) * dt
tree_growth = growth_rate*growth_rate_off
planting = 3000*planting_on
litter = logging_residues+litterfall
harvest = biomass*0.5*harvest_on
humus(t) = humus(t - dt) + (litter - decomposition - humus_removal) * dt
decomposition = GRAPH(humus)
humus_removal = humus*humus_removal_on
money__box(t) = money__box(t - dt) + (earnings - costs) * dt
earnings = harvest*price
costs = maintenance
soil(t) = soil(t - dt) + (inputs - erosion) * dt
erosion = GRAPH(biomass)
(0.00, 30000), (2000, 14750), (4000, 0.00), (6000, 0.00), (8000, 0.00), (10000, 0.00), (12000, 0.00), (14000, 0.00), (16000, 0.00), (18000, 0.00), (20000, 0.00)
deposition = 1
maintenance = 80
price = 0.06
weathering = 1
growth_rate = GRAPH(uptake)
(0.00, 4800), (0.5, 6000), (1.00, 6300), (1.50, 6900), (2.00, 9200), (2.50, 9400), (3.00, 9500), (3.50, 9500), (4.00, 9700), (4.50, 10100), (5.00, 10300), (5.50, 10500), (6.00, 10700), (6.50, 11000), (7.00, 11000), (7.50, 11200), (8.00, 11200), (8.50, 11300), (9.00, 11400), (9.50, 11600), (10.0, 11700)
growth_rate_off = GRAPH(TIME)
(0.00, 1.00), (1.00, 1.00), (15.0, 0.00), (16.0, 0.00), (17.0, 1.00), (18.0, 1.00), (52.0, 0.00), (53.0, 0.00), (54.0, 1.00), (55.0, 1.00), (89.0, 0.00), (90.0, 0.00), (91.0, 1.00), (92.0, 1.00),
harvest_on = GRAPH(TIME)
(0.00, 0.00), (1.00, 0.00), (15.0, 1.00), (16.0, 0.00), (17.0, 0.00), (50.0, 0.00), (51.0, 0.00), (52.0, 1.00), (53.0, 0.00), (54.0, 0.00), (87.0, 0.00), (88.0, 0.00), (89.0, 1.00), (90.0, 0.00), (91.0, 0.00),
humus_removal_on = GRAPH(TIME)
(0.00, 0.00), (1.00, 0.00), (15.0, 1.00), (16.0, 0.00), (17.0, 0.00), (50.0, 0.00), (51.0, 0.00), (52.0, 1.00), (53.0, 0.00), (54.0, 0.00), (87.0, 0.00), (88.0, 0.00), (89.0, 1.00), (90.0, 0.00), (91.0, 0.00),
litterfall = GRAPH(biomass)
(0.00, 0.00), (75000, 2325), (175000, 3150), (275000, 3125), (300000, 3250), (325000, 3150), (400000, 3200), (425000, 3225), (500000, 3350), (600000, 3550), (700000, 3875), (800000, 4200), (850000, 4225), (875000, 4225), (900000, 4225), (925000, 4325), (950000, 4475), (975000, 4475),
planting_on = GRAPH(TIME)
(0.00, 0.00), (1.00, 0.00), (16.0, 0.00), (17.0, 1.00), (18.0, 0.00), (53.0, 0.00), (54.0, 1.00), (55.0, 0.00), (56.0, 0.00), (90.0, 0.00), (91.0, 1.00), (92.0, 0.00)
return = GRAPH(decomposition)
(0.00, 0.00), (500, 0.5), (1000, 0.8), (1500, 1.13), (2000, 1.33), (2500, 1.45), (3000, 1.40), (3500, 1.60), (4000, 2.00), (4500, 2.00), (5000, 2.00)