

Eucalyptus Forest Information System for the Portuguese Pulp and Paper Industry

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Abstract.—To support the management of the Portuguese eucalyptus forest, the Association of Portuguese Pulp and Paper Industries (CELPA) decided to develop a Eucalyptus Forest Information System (EFIS). The specific goals of the EFIS are: characterization and development of the eucalyptus forest over time; planning of successive national eucalyptus forest inventories; estimation of sustainable eucalyptus pulpwood yield; development of growth and yield models; and monitoring of mean and current annual increment. This paper gives a concise image of the Portuguese eucalyptus forest and explains the structure of the system and the expected results.

THE PORTUGUESE HARDWOOD PULP FOREST AND PULP AND PAPER INDUSTRY

The Portuguese Hardwood Pulp Forest

The Portuguese hardwood pulp forest area is composed of various eucalyptus species, of which *Eucalyptus globulus* Labill. clearly predominates, and covers about 590 thousand ha of pure and mixed stands (CELPA 1996). Most of this area is located in the coastal area due to its favorable edapho-climatic growth conditions. About 30 percent of the eucalyptus area is owned or managed by the pulp industry; the rest belongs to mostly small private forest owners. According to the Eucalyptus Forest Inventory of 1997, the current annual wood production in 1996 was estimated to be 4.8 million m³ inside bark. However, the harvestable volume inside bark in 1997 was estimated to be 3.5 million m³ due to the unbalanced age distribution of the stands; therefore standing volume is assumed to increase during the coming years (CELPA 1997).

The stands are managed in a treatment-intensive coppice system with an average cutting age between 8 and 12 years. Most stands are replanted after three cutting cycles. The mean annual increment (MAI) at cutting age oscillates between 5 and 20 m³ per hectare inside bark for most stands, with a national average of 10 m³ per hectare

per year. Recent studies indicate an optimal cutting age of 12 instead of the most commonly used 10-year cutting cycle (Ribeiro *et al.* 1997). Governmental forest policy limits a further expansion of the eucalyptus area on a national level, promoting the trading off of eucalyptus stands in areas of poor productivity for new areas in highly productive regions (DGF 1998).

The first steps have been taken to define and control sustainable yield for the eucalyptus area, both at a national scale (DGF 1998) and at the enterprise level, and some of the pulp enterprises are working towards the certification of the forest management and its products.

The Portuguese Pulp And Paper Industry

The Portuguese pulp industry is composed of six companies with a total of seven mills; two of these mills also consume softwood. The total hardwood consumption in 1997 was about 4.5 millions m³, which was used to produce almost 1.4 million tonnes of bleached pulp. Most of the pulp is produced using the sulphate (kraft) process; less than 1 percent is produced with the sulphite method. Total pulp production has increased by about 20 percent in the last 10 years. Thirty percent of the pulp production is used directly in an integrated pulp/paper production system. The national market consumes another 5 percent, and the remainder is exported mainly to European Community countries. A total of 100 thousand tonnes of pulp is imported (CELPA 1997).

The Portuguese paper and board industry consumes 410 thousand tonnes of hardwood pulp, 305 thousand tonnes of softwood pulp and 320 thousand tonnes of recovered paper, annually producing 1.1 million tonnes of paper and board, of which 50 percent is graphic paper. The total Portuguese pulp production is about 4.7 percent of European production and 0.9 percent of the world pulp production. About one-third of the production is consumed by the internal market, and the rest is exported (CELPA 1997).

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GOALS OF THE SYSTEM

Introduction

The Portuguese pulp and paper industry uses mainly eucalyptus wood as its raw material. To be able to estimate the availability of eucalyptus pulpwood on the national market, CELPA has implemented successive national eucalyptus forest inventories on a 5-year cycle since 1986. These inventories were preceded by aerial photograph coverage, which was used to estimate the area of eucalyptus forest.

After three inventory campaigns, it was decided to create a forest information system that should be able to integrate not only the existing information from the aerial photographs and the inventories, but also other sources of information concerning growth and presence of eucalyptus in Portugal and other related data. This forest information system would also perform analyses that were previously not feasible. The main goal of this Eucalyptus Forest Information System (EFIS) is the production of information required by the industry for their strategic planning concerning the optimal forest area, and its extent and distribution, that balances national wood production and consumption, minimizing the need of wood importation.

Goals

The EFIS will be used to archive, integrate, and manage all the available and obtainable information on eucalyptus forests in Portugal using georeferenced data together with other types of data in a digital format. Once it is fully operational, the system will produce concise information, it will have the ability to update systematically existing data, and it will allow a rapid response to information requests.

The specific goals of the EFIS are to support the characterization and distribution of the Portuguese eucalyptus forest; monitoring of the development of the Portuguese eucalyptus forest over time; planning and organization of the successive national eucalyptus forest inventories; determination of actual standing volume; estimation of sustainable eucalyptus pulpwood yield at short, middle and long term; development of general and regional growth and yield models for eucalyptus stands; and monitoring of mean and current annual increment in the different types of eucalyptus forests.

DESCRIPTION OF THE SYSTEM

Operational Environment

The team that runs the system is composed of three operators: a GIS specialist, a Forest Inventory specialist,

and a technical operator. The system uses a Workstation Sun Ultra 1 Model 170 and three Pentium PC's, a printer, an A0 plotter, and an A0 digitizing table. The computers are linked through a network in a Unix/Windows95 environment. The EFIS includes a GIS environment, equipped with ESRI software such as Arc/Info, ArcPress, and ArcView. The database is developed under Microsoft Access.

Functional Components

The first component of the EFIS is the collection and input of existing data from three different sources: CELPA supplies information regarding national forest inventories, aerial photography data and orthorectified digital aerial photographs, a national eucalyptus forest map, a cartographic base map of Portugal rasterized from a 1:250000 map, and geographic locations of pulp and paper mills and operational centers of forest fire control; associated forest companies supply data from their Continuous Forest Inventories (CFI), digital cartographic information, and data from silvicultural field trials; external sources like national cartography and forest services, universities, and research institutes supply cartographic data, administrative data, thematic data, and information from silvicultural field trials.

The second component is the organization and management of the information. The existing data are used to construct spatial or non-spatial databases that allow queries and systematic data integration, manipulation, and analysis. The cartographic information (spatial databases) is stored in a GIS environment for spatial analyses such as overlay of the different inventory themes.

The third component is the supply of existing information and production of new information meeting the needs of both industry and forest managers. The EFIS is used as an information center of forest data for the associated forest and pulp companies and, to a smaller extent, for the public in general.

Results

The system has been in a construction phase since January of 1997. At the moment, the photointerpreted data and field plots collected for the Eucalyptus Forest Inventory (EFI) in 1996 have been entered into the system and the constructed database is already fully operational. These results were described and analyzed in a thorough statistical study to characterize and map the eucalyptus stands. To support and complement this study with a spatial interpretation of the data, thematic maps regarding distribution and occupational rate of mixed and pure stands, age, volume, MAI, harvesting, and several other thematic maps were produced by the system. A geostatistical approach concerning spatial distribution of

age and site index classes has proven useful in identifying homogeneous forest regions based on these variables. It is also a promising methodology whose analyses complement the inventory results.

The aerial photography data are composed of 4,889 photographs that cover the whole country. This analogic data set is being converted to digital orthophotos. Pixel resolution is approximately 1 m, providing a useful tool for cartographic applications. This database provides a quick overview of the photography/orthophoto characteristics and, as it is georeferenced, allows geographic queries as well as visualization of the position of the records.

The digital orthophotos are used in the GIS environment as an updated land-use document where it is possible to position the georeferenced inventory plots. Presently these images are used to map forest properties and are proving to be a powerful and efficient mapping method. They are also the cartographic base for producing the national eucalyptus forest map. This map is still being produced and, at this primary phase covers the center of Portugal where the eucalyptus is preferentially distributed. More precise information derived from this map will be used to compare with the last forest inventory, and the results will be used to help plan and support future inventories.

The properties explored by the associated forest companies from CELPA are stored in the EFIS where they are used as an important layer on the Forest Fire Fighting Map, together with a cartographic base map. This Forest Fire Fighting Map was printed at a 1:250000 scale, and a complementary digital format was produced for forest fire fighting GIS applications. This map will be updated and improved every year.

All these data are constantly being updated and subjected to further manipulation as required.

Future Developments

In the near future, CELPA plans to enter all existing data concerning previous inventory campaigns. These data will be georeferenced to be able to integrate them in the EFIS and perform an analysis of the development of the eucalyptus area, both in extent, and in growth, at regional and local levels. It is also interesting to study the actual eucalyptus area and its relation to the geographic position of pulp and paper mills and the road network.

The geographical analyses of the results of the last inventory will lead to the identification of the areas with major potential production capacity of *Eucalyptus globulus* Labill. within Portugal, as well as the areas with

marginal potential production capacities. Combining these data with geostatistic tools, it is possible to produce an optimal eucalyptus forest distribution map that satisfies the industry wood requirements. Once accessible for associated forest companies, the system can be used for the selection of potential expansion areas. This analysis will have to reflect the existing legislation as well as local and regional management plans that supervise the forest and natural resources exploitation. The inventory results, the national eucalyptus forest map, the area and inventory results from the properties managed by the associated forest companies, and decision support models will act together to help plan future inventory campaigns toward better forest management for production, sustainability, and protection.

The system will continually archive new data needed for future analyses such as protected areas, forestry perimeters, inventory data from other institutions, meteorological data, environmental data, burned areas, digital terrain models, and road networks.

For forest fire control, there is a need to develop an application that involves GIS tools to georeference forest burned areas and to better manage the forest fire control resources. This application involves the mapping of existing water bodies, planning the distribution of water deposits, mapping helicopter bases from other entities, integrating maps of forest fire index risk, and mapping forest fire surveillance towers. It is essential to monitor the affected areas and study the fire distribution evolution on a multitemporal basis to determine fire tendencies or preferential areas.

Integration of satellite data in the EFIS can be a valuable and economically interesting source of information. As in the past, CELPA will be attentive to the development of new and sophisticated technology and methodologies that might improve EFIS functionality and results.

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