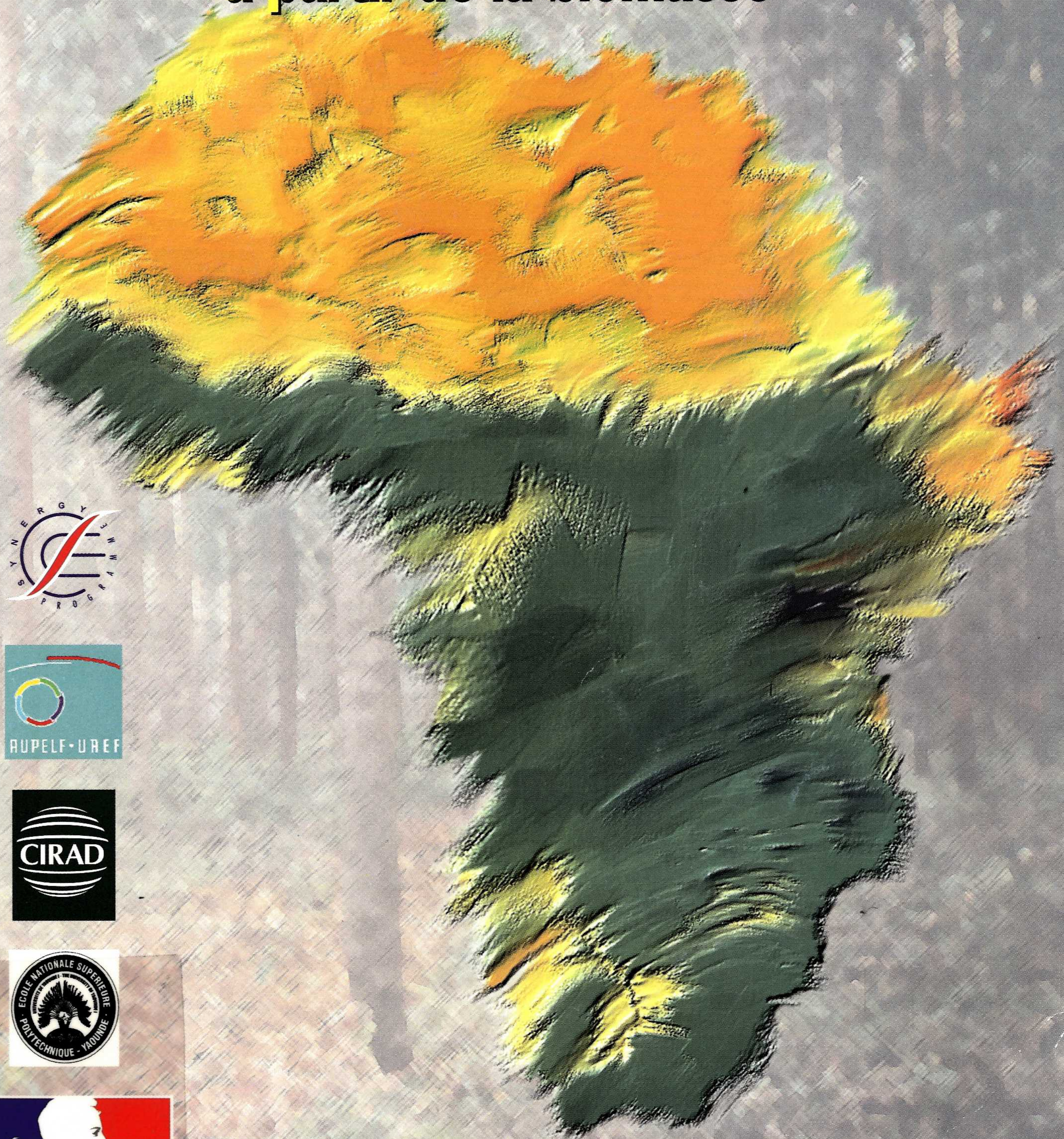
Faisabilité de projets d'électricité rurale décentralisée à partir de la biomasse



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A MULTIPLE CRITERIA DECISION TOOL FOR THE INTEGRATION OF ENERGY CROPS INTO THE SOUTHERN EUROPE ENERGY SYSTEM

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ABSTRACT

A multiple criteria model for the establishment of integrated bioenergy chains in Southern Europe has been developed. This model is useful for the detailed regional analysis of energy crop potential and for the definition of the most promising bioenergy schemes. It can support decision-makers and farmers with their decision, regarding the cultivation of energy crops and the exploitation of the produced biomass. Several tasks were carried out: 1) development of a GIS platform and the computer-based information system including agro-economic data and 2) development of the models along the biomass energy chain: the energy crop production, harvesting, storage and transportation, biomass supply, biomass energy conversion, environmental and multiple criteria model. This tool permits the assessment of the most optimised alternative to integrate energy crops, according to the criteria established by a particular decision-maker. The multiple criteria has included variables that affect the environment, the economy, the agriculture and the employment as well as the subsidies necessary. This was done considering that the decision-maker could place his preferences from different points of view. The results show the environmental and socio-economic impacts of the alternative selected as well as the cost for implementation.

1 INTRODUCTION

This paper is based on the project "Multiple criteria decision tool for the integration of energy crops into the Southern Europe energy system - MULTISEES", partially sponsored by the European Union (EU), under the framework of the ALTENER programme.
The main purpose of the work performed was the development of a multiple criteria decision making tool (GIS-based) for establishment integrated bioenergy systems in rural regions in Southern Europe, considering that future schemes fulfil targeted goals established. To this purpose, woody crops (eucalyptus and robinia) as well as perennial herbaceous crops (cynara and elephant grass), which are of specific interest for Southern Europe, have been considered.
Decision-making often requires analysis of huge amount of data and complex relations. Usually, the analysis carried out by a mathematical model can support rational decision-making. Tools developed for such purposes are called Decision Support Systems (DSS). A DSS helps in the evaluation of consequences of given decisions and advises what decision would be the best for achieving a given set of goals. Thus, regional goals such as economic development of depressed areas, environmental constraints, management of energy supply, technology integration and improvement can be analysed through a multiple-criteria model analysis (MCMA).

Geographic Information Systems (GIS) are continuously becoming an important feature for the management of geographically distributed facilities. Designers of transportation systems, municipal and county engineers, environmentally engineers increasingly rely on GIS to manage and manipulate the large quantities of geographically derived data.

Up to this moment, GIS have been applied to biomass schemes in aspects such as studies of forestry, industrial, agricultural or livestock residues. In particular, they have been applied to map biomass potential in specific regions.

2 METHODOLOGY

2.1 Overview

The multiple criteria decision support tool was build to evaluate the supply of energy crops derived biomass and also to locate bioenergy plants into the selected regions. These plants might be evaluated by different objectives like economic, social, environmental, technological, and political (Figure 1).
The tool consists of two main parts
- Geographic information system (GIS) and
- Multisees integrated model.

The two main parts of the GIS are the agro-economic and the energy database. The Multisees integrated model consists of seven parts
- Model of energy production,
- Storage and transportation model,
- Management of supplymodel,
- Energy conversion model,
- Energy distribution model,
- Environmental model and
- Multiple criteria model.

Using GIS, the methodology can be applied to estimate the potential size of the fuel supply in a region, thus the size of bioenergy plants for its exploitation, the location of the fuel supply and the feasibility of transporting biomass to bioenergy plants.
The GIS tool is able to support and analyse the different types of data necessary, to study bioenergy systems, including raster satellite images, scanned images, non-spatial databases, etc. Different algorithm procedures (mathematical models) has been used in order to simulate bioenergy chain and to evaluate bioenergy schemes.

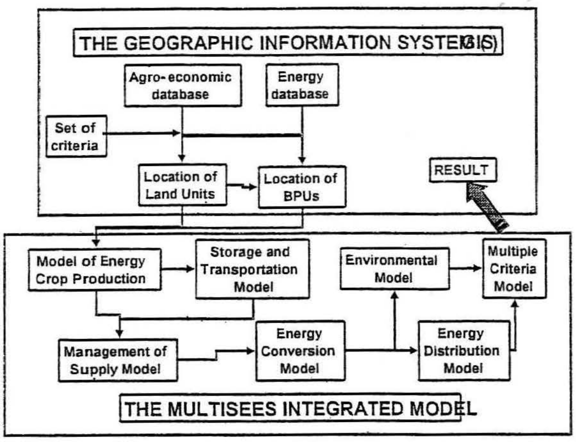

Figure Schedule of data flow in the MULTISEES model

2.2 Model of energy crop production

A model is used to provide a detailed cost analysis of traditional and energy crops. The features of the model include the following :

- Easy understanding of the interrelations of the magnitudes involved, because of the open character of all spreadsheets.
- Convenient arrangement of input data and results tables facilitating user understanding of the whole setup.
- The results are offered in a format capable of further manipulation and exploitation.
- Both annual and perennial crops can be analysed with the model.
- Energy and labour balances are available

More specific features include: types of machinery equipment, labour, fuels, and variable inputs, together with the definition of all necessary operations of the plant are determined at the outset.

2.3 Storage and transportation model

This model is capable to estimate the harvesting, storage and transportation costs for biomass derived from energy crops. It has been structured to characterise biomass harvesting with the distinction of herbaceous and woody biomass.
Concerning herbaceous energy crops two harvesting methods are identified:

- using a combined-harvester (cutting, lining and packing of the biomass is done in one unique process)
- using two different machines, one for cutting, another for packing.

For both methods the packets are left on the ground and must be picked up before the transportation process.
Due to the characteristics of the woody crops a clear-cut management is assumed. The advantages of clear-cut practices are: minimum costs, homogeneous timber load which simplifies transportation and easy management which can be performed by non-specialised stuff.
When the profile of the terrain imposes no limitation to mechanisation, a harvester will be used for cutting, chipping and loading trucks. Otherwise, a chainsaw will be used to cutting the trees. When the features of the terrain limit the efficient use of machinery, biomass will be manually transported to a loading area. When the terrain allows a limited use of machinery, biomass can be either chipped on site or transported to the plant.
Biomass transportation methods depend on harvesting practice. Herbaceous crops are transported in bales. The woody biomass is transported as chips or sticks.
Harvesting and transportation options define the storage method. In most cases the characteristics of the plant (storage capacity) determine the choice of harvesting and transportation methods and therefore the choice of storage.

2.4 Management of supply model

The supply module is used to estimate supply curves for energy crops. The model assumes that land use change is driven primarily by individual farmers' responses to changing market and policy conditions. The model simulates market effects of energy crop integration on current traditional crops, adapted to economic and environmental characteristics.
It is assumed that the farmer expects the same income than the most profitable traditional crop. Taking into account the potential production of all land units, the costs at the farmgate and the transportation and storage costs, the marginal costs of supplying biomass to the plant are calculated.
The supply model considers a wide range of different production activities, policy instruments, constraints and links between activities (i.e. rotations). It is replicable using available standard statistics data and following theoretical principles.

2.5 Energy conversion model

This model evaluates different technologies for biomass electricity generation. All costs related to the power plants are taken into account and variables can be adjusted to the local economic conditions.
The model inputs are costs, amount and type of biomass available in the study area. The outputs are

- electricity generated
- electricity costs
- direct employment
- institutional subsidies

Technological experiences of biomass conversion in Southern European countries are mainly focused on fixed bed combustion technologies (grate). In some cases fluidised bed combustion technologies and combined heat and power systems are used to generate energy. Today biomass power plants operate on a steam-rankine cycle, steam-turbine technologies were introduced into commercial use some decades ago. A promising alternative for biomass power generation is a set of biomass-integrated gasifier/gas turbine technologies that offer the potential for high thermodynamic efficiency.

2.6 Energy distribution model

The energy distribution model calculates the costs of heat and electricity distribution including all components between the plant and the consumers.

Investment costs and annual costs are used to calculate the distribution costs referring to the transported energy. For electricity it is also possible to use market prices for electricity distribution.

2.7 Environmental model

Among all different environmental impacts of energy systems the emissions of greenhouse gases (GHG) are identified as major impact. The environmental model analyses all possible GHG emissions and is divided into two different parts assessing the GHG balances of

- land use changes and
- energy systems.

The Land Use Change model focuses on the carbon stock change when changing i.e. form agricultural cultivation to short rotation forestry. The model considers changes of carbon stored in three different carbon pools (Figure 2):

- vegetation pool: living below (woody and fine roots) and above ground (stems, branches, foliage etc.) biomass
- dead organic matter pool: dead plant material of woody and non wood debris as well as dead roots
- soil pool : dead organic matter (humus) in the mineral soil

The flux from the atmosphere represents the net primary production (NPP) of the crops as the net carbon uptake. Dead plant material is transferred from the "Vegetation" pool to the "Dead organic matter" pool, with woody litter production being a function of the vegetation pool size. Decay of organic matter in the "Dead organic matter" pool produces CO_2 that is directly emitted to the atmosphere, and some carbon is added to the "Soil" carbon pool, which itself also releases CO_2.

The results demonstrate a possible net carbon uptake or net carbon emission indicated by land use change

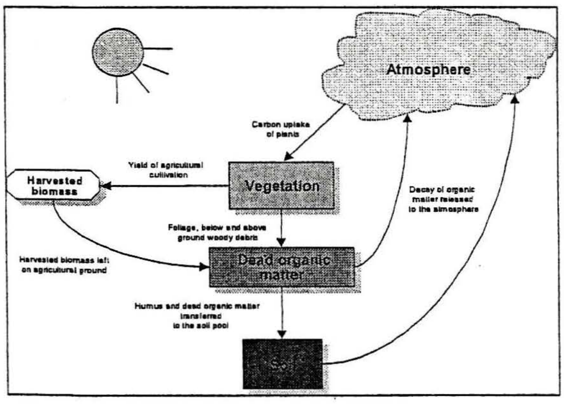

Figure 2: Carbon fluxes and pools as described by the Land Use Change Model

The greenhouse gas model is used for the GHG analysis of bioenergy and fossil energy systems based on the total life cycle. All GHG emissions - CO_2, CH_4 and N_2O - of construction, operation and dismantling of the facilities are included. The fuel chain includes all parts in electricity or/and heat supply, starting with the extraction of raw materials from nature and ending with the disposal from energy and material to the environment. Therefore the energy systems are described as production and harvesting of the fuels, transport, processing, combustion and distribution. GHG emissions are calculated for two different functional units :

- GHG per year in kg CO_2-equivalents/a and
- GHG of supplied energy in g CO_2-equivalents/kWh.

The results demonstrate the possible influence of greenhouse gas emissions by substituting fossil energy systems with bioenergy systems.

2.8 Multiple criteria model

This model concerns the development of a multiple criteria analysis for the definition of biomass for energy penetration strategies. The model requires the determination of the objectives at the regional level as well as the identification of their consequences and illustration of possible contradictions. For instance, objectives may be, the minimisation of the energy cost, the increase of agricultural income, and also the environmental sustainability.

Decision making in biomass planning also involves the consideration of a number of goals that can not be aggregated into a single criterion to be used as a performance measure for ranking alternatives. Usually models may have to run several times in order to identify the best or even acceptable solution. Many options need to be examined to generate the information required for these decisions. This entails the use of multiple criteria optimisation techniques. It also requires the interaction of the various stakeholders in the elaboration of DSS in order to ensure the relevance and applicability of the systems and also to facilitate their dissemination, acceptance and use.
This model is fed by the results of the particular models previously developed, i.e. GHG emissions reduction, socio-economic benefits, and economic parameters.

3 OUTLOOK

The integrated tool is able to evaluate different alternatives for energy crops on the basis of a multiple criteria analysis. It helps decision makers to introduce energy crop into a regional energy system under current conditions of Common Agriculture Policy, National Energy Policies and Regional Framework and adopting relative measures to improve their competitiveness.

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