Global Assessment of Biomass and Bioproduct Impacts on Socio-economics and Sustainability

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Tools for identifying the suitability of different land types for sustainable biomass production

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Authors: Rocio A Diaz-Chavez Imperial College London

Contributor: Nils Rettenmaier– IFEU

Editors: Rocio A Diaz-Chavez
Imperial College London Centre for Environmental Policy

Contact: Rocio Diaz-Chavez – Imperial College London Centre for Environmental Policy

E-mail: r.diaz-chavez@imperial.ac.uk, Tel: +44 20 75949338

313 A Mechanical Engineering Bld South Kensington

Sw7 2AZ London, UK

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Abbreviations

EA – Ecosystems Approach

GIS – Geographic Information System

HCV – High Conservation Value Areas

IFES – Integrated Food-Energy System

ILUC – Indirect land use change

LUC – Land use change

MA – Millennium Ecosystem Assessment

RCA – Responsible cultivation areas

Preface

Tools for evaluating land use for biomass purposes are necessary in order to define areas which do not conflict with other uses (e.g. food and fodder production) and values (e.g. High Conservation Value Areas, biodiversity, carbon storage). Depending on the methodology of the tools (e.g. mapping, zoning), their suitability for developing countries is different. This report presents an assessment of selected tools.

The main objective of the EU funded Global-Bio-Pact project is to develop and harmonise global sustainability certification systems for biomass production, conversion systems and trade. For this, the project assess existing and developing sustainability initiatives and certification schemes with focus on social and economic criteria. The review presented in this report aims to look at selected standards that may contribute to this assessment and will link to the environmental impacts.

1 Introduction

Land and the use of land provide a key link between human activity and the natural environment. The use of land is one of the principal drivers of global environmental change, as a consequent environmental change promoting climate change it influences the form communities use land as they have to adapt and mitigate to the effects of a changing climate (Winter and Lobley, 2009).. There is also an increasing pressure on farmers and land managers to act as ‘carbon stewards’ as they have to adapt the land management to minimize carbon losses, and maximize carbon storage and provide substitutes for fossil fuels (Smith, 2009).

At the same time, a series of long-term trends (such as changing global dietary patterns) and shorter-term ‘events’ (such as recent poor harvests and droughts) have led to cons trained global food supply and stimulated pronounced changes **in** global agricultural commodity prices, putting further pressure on agriculture.

Traditionally, land use has been a finite resource from an environmental point of view. The appropriation of the resource has also covered some multi-functionality uses such as food, housing, fibre and fodder. This approach has been changing through time. More recently the discussion over the production of bioenergy crops for either biofuels or for energy generation has put forward a new paradigm in terms on land use and land appropriation. According to Winter and Lobley (2009) land and food are at the forefront of the policy agenda in most parts of the world with climate change playing an important role on land use and ‘Food security’. The new emphasis on agricultural supply-chains and climate change have left the old “environmentalism” with the multifunctional agroenvironments (and their focus on biodiversity and landscapes) behind (Winter and Lobley, 2009).

1.1. What is land and what is land for?

The definitions on land under the debate for bioenergy range from urban, rural, peri-urban, land. Lobley and Winter (2009, page 7) provide the following definitions:

- *Land is a physical resource*
- *Land cover – the biophysical attributes and human structures of the Earth’s surface*
- *Land use –operations or activities carried out on land.*

FAOSTAT (2010) also defines agricultural land as the sum of arable land, permanent crops, and permanent meadows and pastures. Arable land is the sum of temporary crops, temporary meadows and pastures and fallow land. Although marginal land (or `other land' according to the FAO definition) is much more difficult to define: it includes any other land not specifically listed under arable land and land under permanent crops, permanent pastures, forests and woodland, built on areas, roads, barren lands, others. Marginal land is also referred to as ‘unproductive', ‘low productive' or ‘degraded' land (BEE, 2010). The definitions have to be carefully considered especially for bioenergy projects due to the differences in concepts and definitions.

Rettenmaeir et al (2010) categorised the type of biomass according to the origin respect to the type of land and activities (agricultural and forestry) (Table 1).

Table 1. Woody and herbaceous energy crops.

Biomass subcategory	Origin	Type of biomass
Woody and herbaceous energy crops		
Grown on arable land	Arable and permanent cropland incl. SRC	Harvest from arable and permanent cropland incl. annual energy crops and SRC, excl. residues
Grown on grassland	Permanent grassland (meadows and pastures)	Permanent or annual energy crops, excl. residues
Grown on marginal land	Other land (degraded lands, mine dumps...)	Permanent or annual energy crops, excl. residues
Woody and herbaceous agricultural residues		
Primary residues	Agr. cultivation and harvesting activities	Harvesting residues (straw, etc.)
Secondary residues	Processing of agricultural products, e.g. for food	Processing residues (e.g. pits from olive pitting, shells/husks from seed/nut shelling) as well as animal excrements

Source: Rettenmaier et al, 2010.

Eventually, the most important issue regarding energy crops is the assessment of available land. Some models have presented assessments of land availability at global level but at regional scale different methods are needed in order to account for local socio-economic and environmental conditions. Land available for energy crops can be identified with the help of current land use data and statistical databases. Nevertheless, other issues need to be considered such as land conversion costs, social concerns and environmental constraints which may limit the amount of available land for energy crops. Given a set of species suitable for a given area, an optimization problem of the entire energy chain (including cultivation and transport) must be accounted for to determine the amount of land to be dedicated to each specific crop (Angelis-Dimakis et al, 2011).

Most importantly, the review of tools or methodologies should not only approach the availability and characteristics of the land for bionergy selection but also the drivers that influence the selection of land and the land use changes that respond to that selection as well as impacts affecting this selection (e.g. on food).

2 Overview of methodologies for land use assessment for bioenergy

According to Watson and Diaz-Chavez (2010), different factors need to be considered to understand the implications for siting bioenergy projects: (a) likelihood and desirability of converting land to bioenergy feedstocks, (b) appropriateness of contemporary relevant policies, and (c) best choice of feedstocks and production systems. In order to achieve this, a combination of tools and methods, from literature review to geographic information systems and modelling need to be conducted.

As a general overview, the next section presents a non-exhaustive classification of tools to assess land use for bioenergy projects including:

1. Models: spatial and non-spatial models
2. Frameworks: ecosystem services (approach), responsible cultivation, ecosystem approach
3. Planning and zoning: mapping, territorial zoning
4. Statistical analysis and databases

2.1 Spatial and non-spatial models

I) Spatial explicit methods

Local land-use models rely generally on spatial explicit models. The general approach consists in linking **satellite images, aerial photographs, remote sensing data and statistical census data**. Different authors have used different combination of sources.

In spatial explicit models it is difficult to obtain satellite images and define land-use categories on the same area and the same period. Additional issues need to be considered such as atmospheric conditions and satellite orbital frequency which may affect the availability of images. Furthermore, for large areas a significant number of images are required and the quality of the images can vary from one image to another. As a result, land-use changes modelling based on satellite images needs to be supported by additional information. Modelling techniques can be adapted to any location but the application of a specific method depends on the research question to be solved and on the availability of data (Gnansounou and Panichelli, 2008).

Among the spatial explicit models the following have been identified by Gnansounou and Panichelli (2008) used for different applications related to bioenergy projects, especially for selection of areas and for assessing land use change:

a) Geo-statistical techniques allow integrating spatial data with statistical analysis and can be used to find correlations between biophysical and socioeconomic spatial variables and land-use change. The method is useful to determine transition probabilities in land-use dynamic approaches.

b) Cellular automata is a technique used to analyse land-use changes at the local/regional level. They are dynamic models based on a set of probabilistic or deterministic rules that determine the state of a discrete cell in space and time characterized by local interactions. Some authors studied the relation between social, biophysical and geographical driving forces of land-use dynamics. Gnansounou and Panichelli (2008) reported that the CLUE (Land-use Change and its Effects) is a cellular automata georeferenced model for the analysis of LUC. The model allows making a spatially explicit, multi-scale, quantitative description of land-use changes through the determination and quantification of the important drivers of agricultural land-use on the basis of the actual land-use structure. Results of this analysis are incorporated into a dynamic model, which describes area changes of the different land-use types. Apart from tracking historical LUC, the model explores possible land-use changes in the near future under different development scenarios, having a time horizon of about 20 years. Current applications concern bio-energy allocation simulation and Brazilian case study development. The model has also been used, among other applications, to study pasture expansion into forest based on location and contextual factors.

c) Agent-base models are dynamic models based on heterogeneous agents with bounded rationality and imperfect information that are able to learn and adapt their behavior in function of their expectations and the interaction with other agents in a common environment. ABM allows modelling the system dynamics and accounting for spatial features of the system. . Its application is namely, according policy analysis and planning, participatory modelling, explaining spatial, patterns of land use or settlement, testing social and science concepts, and explaining land use functions. According to Gnansounou and Panichelli (2008) no agent-based model has been yet applied to explain land-use patterns due to biofuels production.

d) The **MODIS** data classifies the biophysical condition of the land based in a current year, not the land cover or land use change. It is possible to link Landsat images, deforestation data, with vegetation phenomenology information with field studies on location of deforested areas, cropland and pastureland. To produce yearly maps, all images collected during the year need to be considered. For example, if area in 2001 is classified as grassland this means that the ground conditions observed from the satellite images for larger part of the year is herbaceous vegetation with <10% shrub cover, if the same area was classified in

2005 as wetlands, this means that in 2005 these area had characteristics of lands as mixture of water and herbaceous vegetation for larger part of the year (Petrova, 2011 pers com).

II) Non-spatial methods

Non-spatial models mainly focus on explaining driving forces of LUC based on **statistical analysis and regression models.** Several techniques exist to aggregate/group or reduce the number of variables (factor analysis, principal components, canonical correlation, cluster analysis). Different regression techniques exist, including linear, logistic, multinomial, ordered logit, tobit and simultaneous regressions. Logistic regression is the most commonly used in land-use change modelling. Regression analysis should be complemented with other statistical tests in order to evaluate causality patterns (Gnansounou and Panichelli, 2008).

According to the review by Gnansounou and Panichelli (2008) other authors have used a statistical approach to assess correlations between land cover changes and local socio-economic variables in a rural landscape in Germany. Variables giving high correlations can be used as socio-economic indicators of land cover changes.

III) Additional models and databases

Different families of models were reviewed by Smith et al. (2009). Some models are top down, such as the general equilibrium macro-economic model, EPPA, which projects the effects of economic growth on five land **types, including bioenergy cropland, at 5 year intervals**. This model assumes that conversion of land back to a ‘natural state’ has no cost, an assumption that overlooks the need to assess counterfactual conditions (Davis et al, 2011).

Two other models that categorize bioenergy as a unique land use, IMAGE and MiniCAM, are both integrated assessment models. IMAGE includes clear geographically delineated land-use categories, but must be coupled with a separate economic model to simulate dynamics of LUC over time while MiniCAM simulates the feedbacks between profitability margins and land allocation to different categories (Davis et al, 2011).

A different approach for estimating energy crops potential is the economic modelling of the entire agricultural sector. Economic models account for biomass production for the internal market, exports and imports, and detailed costs and benefits of the major farming goods. The Polysis model, developed for the USA estimates biomass production on the basis of the net profits compared with those derived from conventional crops. This model relies on many assumptions that range from farming practices to macro-economic variables of the agricultural sector (Angelis-Dimakis et al, 2011).

Geographic Information Systems (GIS) based applications allow considering spatial patterns of biomass distribution. There are models developed at regional scale GIS based modelling system for evaluating potential biomass production and costs from energy crops (Angelis-Dimakis et al, 2011).

Interactions of biomass supply and demand have also been a major subject of research. Masera et al. (2006) have assessed the wood fuels resources in Mexico, Slovenia and Senegal using the Woodfuel Integrated Supply/Demand Overview Mapping model (WISDOM). The model is a **GIS** based tool aiming to analyse firewood demand and supply spatial patterns highlighting areas in which several criteria of interest coincide.

According to Angelis-Dimakis et al (2011), satellite images have been widely used to assess spatial patterns of biomass production. Methods account for the integration of forest inventories with satellite imagery such as the use of LIDAR remote sensing data, teledetection applications and normalized difference vegetation index (NDVI) data processing.

Regarding agricultural projections, the most widely used models are those of FAO and IFPRI. IFPRI uses the IMPACT model as the basis of its projections. The methods underlying the FAO projections are more diverse, using both models and expert consultations. Both studies consider mostly agricultural markets, and thus do not fully cover land-use projections (Smith et al, 2010).

There is considerable uncertainty over projections of competition for land in the future and the regional distribution of this competition. This means that models used for land-use assessment need to incorporate a wide range of drivers, from macro-economic indicators to local policy specifications.

2.2 Frameworks: Ecosystem services (approach); Landscape ecology

a) Ecosystem services (approach)

Ecosystem services are the benefits people obtain from ecosystems. Biofuels can provide ecosystem services (e.g. food, freshwater services) and biodiversity which are of paramount value for human well-being. However, knowledge about the effect of biofuels on ecosystem services and biodiversity is fragmented and in some cases is still only emerging. Moreover, the effect depends on several interconnected factors.

Figure 1 shows the Millenium Ecosystem Assessment (MA, 2010) framework for ecosystem services. This framework is useful to select areas for bioenergy production that do not interfere with these services and that on the contrary may enhance them. Ecosystem services are the benefits people obtain from ecosystems. These include provisioning, regulating, and cultural services that directly affect people and supporting services needed to maintain the other services. Changes in these services affect human well-being through impacts on security, the necessary material for a good life, health, and social and cultural relations (MA, 2005)

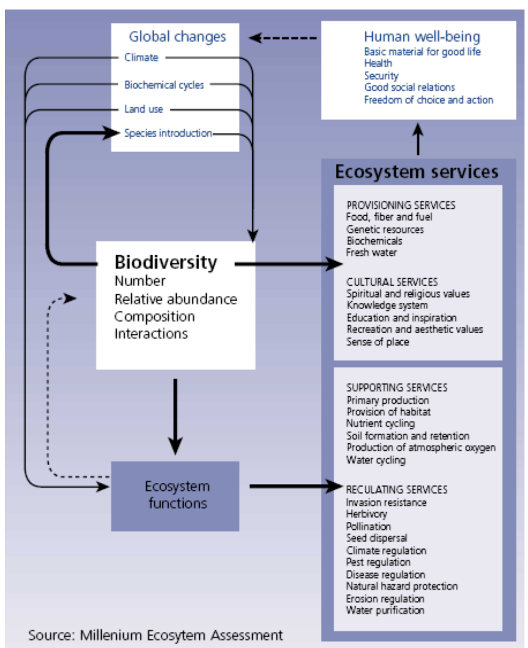

Fig.1. Ecosystem services and human well-being. (MA, 2005)

According to Stromberg et al (2010) some biofuel practices can be net energy suppliers, environmentally friendly, and socioeconomically beneficial. Nevertheless, there is also significant evidence that biofuels not only provide a number of ecosystem services but that they also compromise other ecosystem services such as food and freshwater service. Furthermore, biofuel production can sometimes deprive livelihood options for the poorer strata of society (Cotula, et al., 2008). However, this knowledge is fragmented and data is still rudimentary largely due to the fact that most existing biofuel programs are still only in their infancy.

The UNU-IAS report produced a diagram to exemplify the links of ecosystems services and biofuel production (Stromberg et al, 2010). This figure (Fig 2.) shows the issues needed to consider for instance for biofuel expansion (e.g. access to food), hence affecting both security and basic materials supporting livelihoods. Lastly, strategies and interventions such as land use planning can enhance the ecosystem and social benefits resulting from the linkages shown in Figure 1.

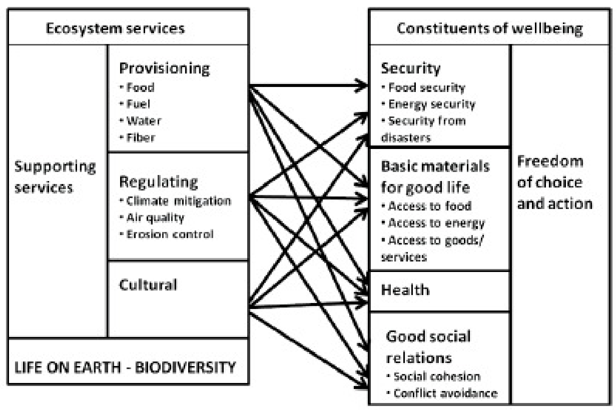

Fig.2. Links between ecosystem services and biofuel production. (Stromberg et al, 2010)

A careful assessment of land use allocation options and major restructuring of the agricultural management system may be required for biofuel expansion to proceed with little or no environmental costs. From an ecosystems services perspective, there is an added urgency to also work on immediate solutions to minimise the loss of threatened ecosystem services due to biofuel expansion. According to Stromborg et al (2010) there are response options that can be further developed to enhance the long-term sustainability of biofuels by minimising their impact on ecosystem services and biodiversity. The key responses include the use of degraded land for the production of biofuel feedstock, the adoption of improved management practices, the development of designer landscapes, and the adoption of innovative schemes such as Payment for Ecosystem Services (PES), Reduction of Emissions from Deforestation and Degradation (REDD), and biofuel certification.

b) Responsible Cultivation Areas

The products of the first goal of the Responsible Cultivation Areas (RCA) concept, a practical methodology to identify concrete areas and/or production models that can be used for environmentally and socially responsible additional energy crop production without causing unwanted indirect effects, are primarily focussed on companies and land-use planners (Ecofys, 2010).

This is not intended as a certification scheme, but rather as a practical tool for parties that want to identify areas for sustainable feedstock production, taking into account both direct and indirect effects. This methodology, if applied properly, may (1) take into account the majority of the sustainability requirements with respect to land-use change of policies such as the EU Renewable Energy Directive (RED) or those of voluntary schemes such as the Roundtable on Sustainable Biofuels (RSB), and (2) take into account criteria for bioenergy with a low risk of indirect effects.

The methodology includes both direct and indirect effects. For example, clearing primary forest for energy crop plantations may have a small risk of indirect effects if the land is not used by humans, but clearly the direct effects such as the loss of biodiversity and carbon stocks would not be considered sustainable. The direct effects that are taken into account in the site identification module are not a reinvention of the wheel but are built upon the sustainability criteria of today's key sustainability initiatives for biofuels including: the Roundtable on Sustainable Biofuels, the EU Renewable Energy Directive (RED) and the UK Renewable Transport Fuel Obligation (RTFO). The information required and used for RCA site selection can later be used to demonstrate compliance with the criteria of the before mentioned policies and voluntary schemes (Ecofys, 2010).

According to Ecofys (2010), the RCA concept is focussed on identifying areas that can be used for environmentally and socially responsible energy crop cultivation without causing unwanted indirect effects. The RCA site identification module is not intended to guide parties in designing their actual plantation once the site has been selected. The RCA concept stops where site selection stops and where detailed planning and design on the selected site starts.

In the RCA concept, an area is considered suitable for "environmentally and socially responsible" cultivation if its conversion does not cause unwanted direct effects and has a low risk of unwanted indirect effects. For this purpose a set of sustainability criteria on the direct effects of the conversion of an area have been defined. These sustainability criteria for the direct effects are based on the criteria of the following biofuel sustainability initiatives:

- EU Renewable Energy Directive (RED)
- UK Renewable Transport Fuel Obligation (RTFO)
- Roundtable on Sustainable Biofuels (RSB)

The five principles considered in RCA are:

1. Establishment of energy crop plantations maintains or increases High Conservation Values[1]
2. Establishment of energy crop plantations does not lead to significant reductions in carbon stocks
3. Establishment of energy crop plantations respects the legal land status and customary land rights
4. Establishment of energy crop plantations does not cause unwanted indirect effects
5. Intensification does not cause adverse environmental or social effects.

The classification of High Conservation Value areas is presented in Box 1.

[1] The High Conservation Values mentioned in principle 1 refer to the six values identified by the High Conservation Network. For the 4 categories review the Proforest 2008 document. According to ProForest (2008), a high conservation value is a biological, ecological, social or cultural value which is considered to be of outstanding significance or critical importance at the national, regional or global scale. HCV areas are critical areas in a landscape which must be managed to maintain or enhance HCVs.

Box 1. HCV classification

HCV 1 Areas containing globally, regionally or nationally significant concentrations of biodiversity values (e.g. endemism, endangered species, refugia).
HCV 2 Globally, regionally or nationally significant large landscape-level areas where viable populations of most if not all naturally occurring species exist in natural patterns of distribution and abundance.
HCV 3 Areas that are in or contain rare, threatened or endangered ecosystems.
HCV 4 Areas that provide basic ecosystem services in critical situations (e.g. watershed protection, erosion control).
HCV 5 Areas fundamental to meeting basic needs of local communities (e.g. subsistence, health).
HCV 6 Areas critical to local communities' traditional cultural identity (areas of cultural, ecological, economic or religious significance identified in cooperation with such local communities).

Source: Proforest, 2008

c) The Ecosystem Approach

The Ecosystem Approach is defined as a strategy for the management of land, water and living resources that promotes conservation and sustainable use in an equitable way. While similar to a number of other holistic approaches to conservation, development and natural resource management, it has some key distinguishing features, i.e.:

- it is designed to balance the three CBD objectives (conservation, sustainable use and equitable benefit sharing of genetic resources);
- it puts people at the centre of biodiversity management;
- it extends biodiversity management beyond protected areas while recognizing that they are also vital for delivering CBD objectives; and
- it engages the widest range of sectoral interests.

The key principles of the Ecosystem Approach are presented in Box 2 (Bogdanski et al, 2011).

Although all the principles marked in Box 2 are useful for land use assessment, the main principles for this purpose are Principles 1, 3, 5, 7 and 10. Nevertheless, to date there are no clear examples on the use of this approach for the selection of suitable land for bioenergy production.

Box 2. Ecosystem Approach principles

Principle 1.	The objectives of management of land, water and living resources are a matter of societal choice.
Principle 2.	Management should be decentralized to the lowest appropriate level.
Principle 3.	Ecosystem managers should consider the effects (actual or potential) of their activities on adjacent and other ecosystems.
Principle 4.	Recognizing potential gains from management, there is usually a need to understand and manage the ecosystem in an economic context. Any such ecosystem-management programme should: a) reduce those market distortions that adversely affect biological diversity; b) align incentives to promote biodiversity conservation and sustainable use; and c) internalize costs and benefits in the given ecosystem to the extent feasible.
Principle 5.	Conservation of ecosystem structure and functioning, in order to maintain ecosystem services, should be a priority target of the ecosystem approach.
Principle 6.	Ecosystems must be managed within the limits of their functioning.
Principle 7.	The ecosystem approach should be undertaken at the appropriate spatial and temporal scales.
Principle 8.	Recognizing the varying temporal scales and lag-effects that characterize ecosystem processes, objectives for ecosystem management should be set for the long term.
Principle 9.	Management must recognize that change is inevitable.
Principle 10.	The ecosystem approach should seek the appropriate balance between, and integration of, conservation and use of biological diversity.
Principle 11.	The ecosystem approach should consider all forms of relevant information, including scientific and indigenous and local knowledge, innovations & practices.
Principle 12.	The ecosystem approach should involve all relevant sectors of society and scientific disciplines.

Source: Smith and Maltsby, 2003

2.3 Planning and zoning: Mapping; Territorial zoning

Geographic Information System (GIS) helps to analyse data and also to provide graphic information to any reviewer. Figure 3 shows the flow chart of use of the GIS for the analysis and mapping indicators using, as an example, the indicator of working population in rural areas. The main advantage of using a GIS is more its organizing principle than its being a set of technologies (Diaz-Chavez, 2004, 2006). The use of a GIS helps in the following respects:

- analysis of land use changes
- integration of different databases
- analysis of selected indicators in the area
- a fast, reliable and useful visual aid.

GIS are the modern form to organise different datasets and maps layers for different purposes but specially for planning and zoning. Watson (2007) reported the use of GIS data sets that categorise spatial and temporal variations in Africa's physiographic parameters, vegetation cover, land use. As a precaution against detrimental impacts on biodiversity, all categories of protected areas, closed canopy forests and wetlands were designated as **unavailable** for bioenergy crop production and filtered out from the regions depicted in the base map. UNEP et al. (2006) was used to delineate the International Protected Areas, National Protected Areas (Categories I-VI), and National Protected Areas (Uncategorized), Watson (2007)presented case studies in Africa with different bioenergy initiatives. A second set of maps used the semi-arid and arid regions as a template on which available and suitable areas for bioenergy crop production, roads, railroads, rivers and populated places are sequentially shown and variously labelled. BWG's (2007) data on roads, railroads and rivers, and ESRI's (2006) data on populated places were employed. The specific habitat requirements of various bioenergy crops needs to be evaluated in order to identify the best potential candidates in different parts of each country.

2.4 Statistical analysis and databases

Biomass can be supplied from dedicated agricultural crops of arboreous and herbaceous species: short rotation forestry (SRF, e.g. poplars, willows, eucalyptus), annual crops (e.g. corn, soy, sugar cane, sorghum) and perennial grasses (e.g. switchgrass, miscanthus). Several models have been developed to support the decision over which species to grow and where. For this different considerations need to be assessed including local climate, morphology, soil characteristics, water and nutrients. For example, potential biomass productivity of tree species can be assessed on the basis of the FAO/IIASA **Agro Ecological Zones approach**, while some information for herbaceous species can be found in the **ECOCROP database** (ecocrop.fao.org/) (Angelis-Dimakis et al, 2011).

Different databases have been used to apply with GIS. This provides geographical information data for certain aspects such as water, soil, conservation areas, agriculture land, forests, arid lands, among others. Watson (2007) described the methodology of combining the use of datasets with GIS. ESRI and the ECJRC's (2003) GLC database were used to delineate countries and forests (closed deciduous, evergreen lowland, montane and submontane) as well as wetlands (mangroves, swamp bush) and grassland.

The GLC database was also used to delineate areas where (i) crops cover more than half the surface, (ii) croplands occur within a matrix of open woody vegetation, (iii) irrigated crops predominate, and (iv) tree crops predominate. In order to avoid food security concerns these areas were also designated as **unavailable** for bioenergy crop production and filtered out from the arid and semi arid regions. Watson also reported that this database was used to delineate the following areas considered **unsuitable** for bioenergy crop production: cities, bare rock, sandy desert and dunes, stoney desert, and water bodies.

3 Links between land use assessment methodologies and socio-economic issues

Most of the methods and tools used for the assessment of land for bioenergy purposes focuses on land availability, the suitability for the feedstocks considering physical local conditions (e.g. water, soil, geomorphology) and after these considerations the main following one is the economic aspect.

Once that the available potential of biomass is assessed, the system is optimized based on cost minimization of biomass production and utilization in energy conversion facilities. Therefore, one of the main issues is the distance of the conversion plant from the needed feedstock and the capacity of the plant itself. Given a certain biomass availability and regional distribution, at the increase of size, in fact, collecting distances increases and thus also the biomass supply costs. Many models have evaluated these issues, among them the Biomass Resources Assessment Version One (BRAVO) system in a computer based DSS to assist the Tennessee Valley Authority in estimating the supply cost for wood fuel as a function of the hauling distances. In this type of analysis, spatial information is needed in order to know where to collect the biomass from and where to deliver it (Angelis-Dimakis et al, 2011).

The further links with social and economic issues at the community level are most of the time overseen and until recently considered due to the influence of policies and the need of standards to access the desirable market (e.g. Europe).

In particular the use of indicators associated with datasets and GIS provided a good source of information to assess land use for different purposes including bioenergy production (see Watson, 2008).

Figure 3 shows the type of information that is possible to incorporate for land use assessment for different purposes but useful for bionergy production land use (Diaz-Chavez, 2003).

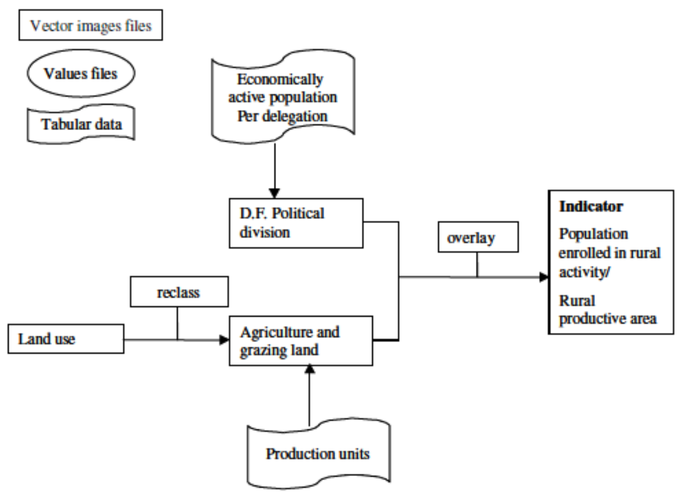

Fig.3. Use of the GIS for integrating indicators (Diaz-Chavez, 2003)

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3.1 Overview of the different methodologies and their link to socio-economic issues

Table 2 summarises the different methodologies and tools explored in chapter 2 and their link with some social and economic issues regarding the assessment for bioenergy production.

There is not one single technique to assess suitability of land for bioenergy purpose. As it can be seen from the analysis of the different methodologies, frameworks and tools, a combination of them represents an advantage to incorporate different type of information and review the links among them.

The additional information that needs to be incorporated are the driving forces that promote this assessment such as policies, programmes and regulations. Figure 4 shows the integration of the different information that needs to be considered in order to assess land use.

Table 2. Summary and application of different methodologies, frameworks and tools (P: partial).

Methodology	**Global/Regional**	**environmental**	**social**	**economic**
Models				
Spatial	G/R	√		
Non-Spatial	G/R	√	√ P	√
Ecosystem services	R	√	√	√ P
RCA	R	√	√P	
Mapping	G/R	√	√P	
Databases	G/R	√	√	√

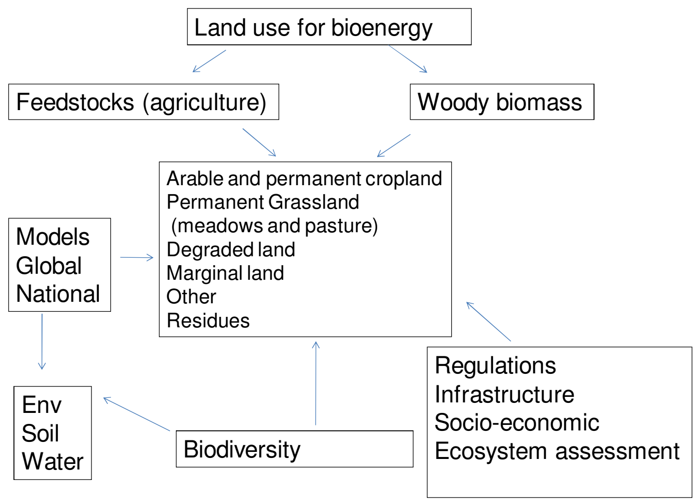


Figure 4. Integration of different information for land use assessment

4 Application for the Global-Bio-Pact case studies

The examples of the case studies of the Global-Bio-Pact project are referenced here regarding the type of information used for the land use assessment.

1. Argentina

Argentina uses the USA soil classification databse (USDA-SCS). The country has a framework that regulates and promotes the production and use of biofuels since 2007. The National Institute of Agriculture Technology (INTA) has been working on the construction of a GIS where different crops were placed. The purpose of this mapping was to identify critical information, to raise a methodology to obtain accurate and up-to date thematic maps using satellite images, to feed a GIS and to integrate the different layers to estimate biomass potentials for energy supply in Argentina, assessing potential land availability for biofuel crops or plantations to be produced with ecological, economic and social sustainability bases (Carballo et al, 2008).

The methodology used by INTA combined the use of an economic ecological and social criteria with modern techniques used in the construction of a geographic information system (GIS). After a selection of the principal crops with potential to be grown at the maximum expansion, the bioclimatic requirements were assessed for the Argentine territory. The different climatic requirements were identified including frost resistance according to the international and national literature. With this information bioclimatic index were developed for each crop considering their potential growth, development, danger of loss. In this work the assistance of the University of Buenos Aires Agronomy Faculty was crucial coordinated by Eng. Murphy.

Using the national meteorology databases 1971-2000, the boundaries over the territory were defined classifying the regions into four categories according to crop aptitude to different weather characteristics: high, medium, low and marginal aptitude. The maps were integrated into a GIS. The second stage input the soil characteristics and requirements to generate zones with different aptitude for each crop, using the digital soil map of INTA (scale 1:500.000). The maps were adjusted with satellite photography in each region. The final review was done over LANDSAT images (1986-2007). The eight classes of soil capacity criteria of the US soil conservation system were used to assess the potential of the different crops. Four categories were selected for the selected crops.

In a multi criteria approach to define four levels of aptitude and using ArcView the socioeconomic analysis was integrating considering processing plants, roads, railways and hydro ways in the GIS. In a second stage of the program the residue generation by the principal agro industries were added in order to obtain the potential use of this product in bioenergy generation.

As a result, thirteen crops were identified and mapped. Carballo et al (2008) presented a case on soybean (Fig. 5). The authors concluded that GIS system is a very important tool used by governments, research community and investors in order to study the viability of feedstock's production in the very different regions. The system is in permanent development adding new data and enlarging the database with the rapid changes.

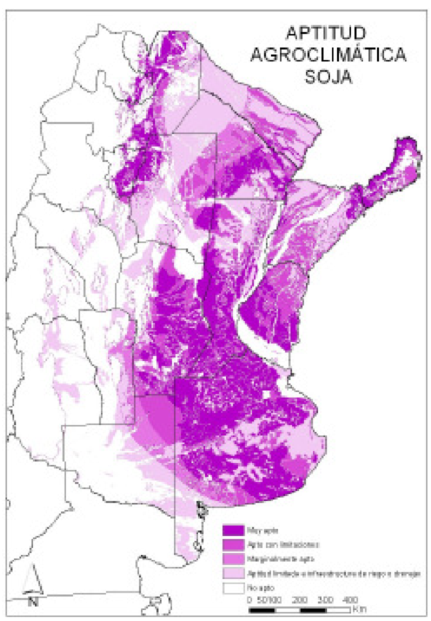
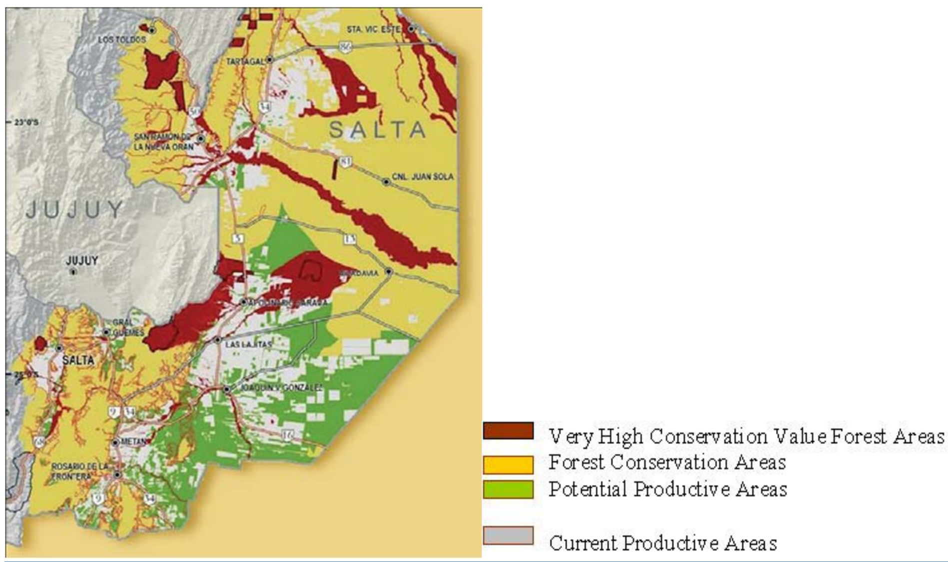


Fig. 5. Example of final output map for soybean with the four capacity areas (Carballo et al, 2008).

Further work from INTA has tried to contribute to the definitions of agro-ecological potentialities for any zone in Argentina for the diffusion of different crops or plantations adapted to the area that could be derived to bioenergy, and to know the possibilities for electrical energy production using the local biomass potential considering criteria of environmental, economic and social viability. The geo spacialized information allows to optimise the location and sizing of the electrical generation plants using renewable resources (Carballo, 2009). Regarding soil use in the country a very important law was enforced in 2009 **Ley de Presupuestos Mínimos de Protección Ambiental de los Bosques Nativos**; it establishes the minimum requirements for defining the different uses of land by the provinces. Each province as responsible for its territory has to define the different regions and uses according to the agroecological and social particularities. Most of the main provinces have already established the different areas within their boundaries. This will put an end to an unplanned agricultural expansion invading conservation areas.

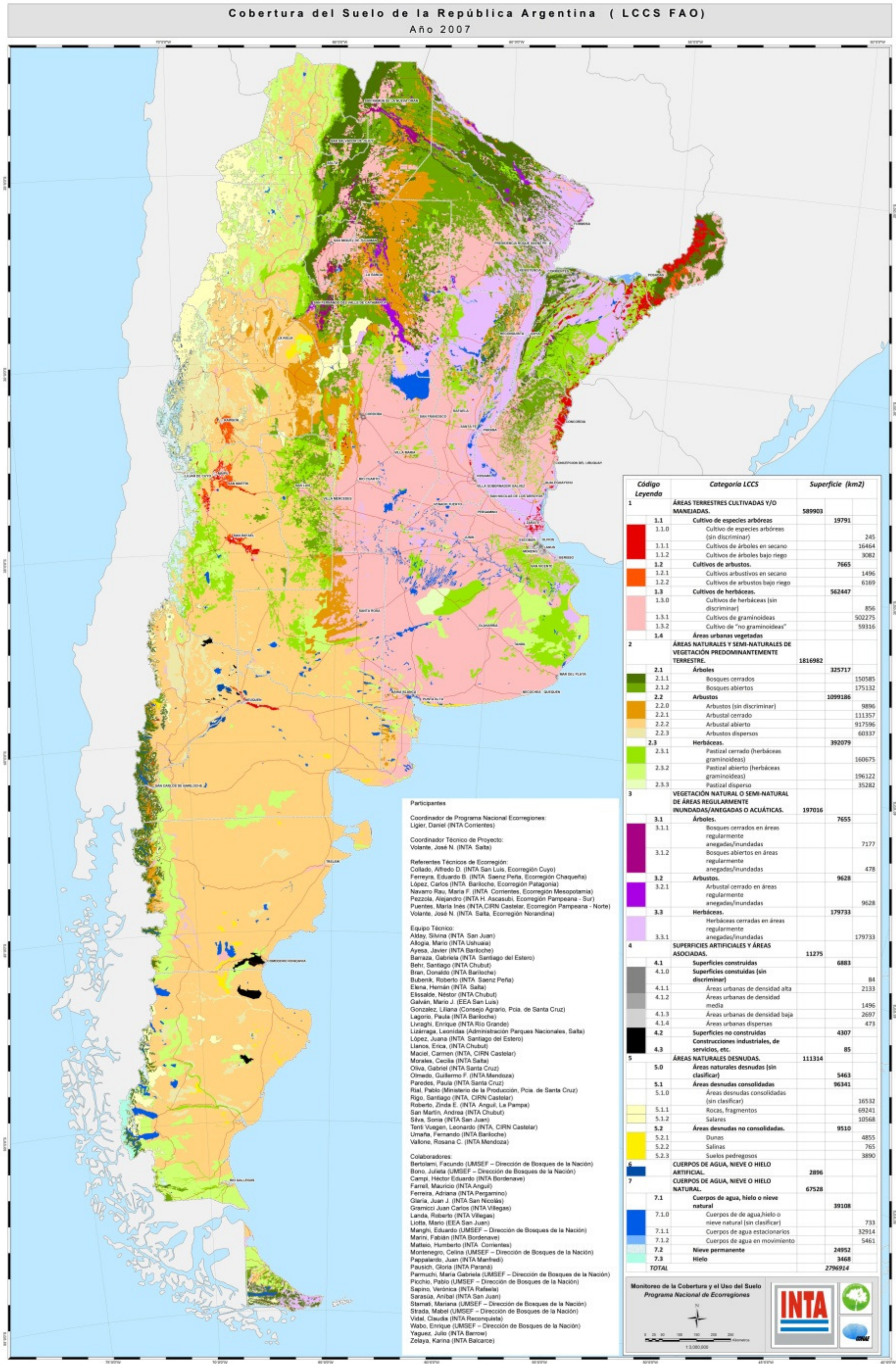
An example of this approach is Salta land classification one of the Northwest provinces with native forest areas and an expansive agriculture



Land use regarding soybean expansion has been analysed by INTA were the different forces that rules agricultural expansion and intensification are treated. Between the principal drivers of land use change the following were detected:

- National agricultural policy with special importance of the export duties over the principal crops being planted.
- Technology improvements extensive uso of MGO, presition agriculture, no tillage
- Active role of farmertechnical associations
- Innovative forms of land ownership and rent systems
- International commodity prices
- Trasnport infrastructure and costs
- Incentives to biofuel use in the external and internal markets

INTA has in place a national program of ecoregions and territories that is focused with a holistic approach of territorial development in different parts of the country http://www.inta.gov.ar/invest/ecorregiones.asp Under this program the project INTA PNECO1643 has ended the digital cover at regional level (E 1:500.000) using LCCS of FAO Di Gregorio et al (1998) available at http://www.inta.gov.ar/prorenoa/info/pneco/lccs.htm. This is an integrated study for the different regions of the country with participation of multiple actors.



2. Costa Rica

In 2008 Raub reported that despite the National Biofuel Program's October implementation deadline, Costa Rica lack sufficient natural resources to produce biofuel. At the time most of the country's ethanol and African palm oil, which can be used to produce bio combustibles, was sold internationally for a much higher profit than keeping it here at home.

At the time two Costa Rican businesses (Ingenio Taboga and Central Azucarera Tempisque (Catsa) produced sugar cane alcohol. Both firms exported their product to Europe, tax-free, making them a solid profit. Taboga, for example, was producing approximately 300,000 liters (almost 80,000 gallons) yearly, while of Catsa's 23 million-liter (6+ million gallons) yearly production, only 10 percent stays within the country.

African palm oil is in a similar situation, as much of its production is exported to Mexico and the rest of Central America. According to Emileth Barrantes, representative for the National Chamber of Palm Producers (Canapalma), if all Costa Rican palm oil production were directed at the country's biofuel program, Costa Rica's diesel consumption could be reduced by 15 percent, or 1.2 billion liters. Unfortunately, international prices for African palm oil are very high, having increased by more than $1000 per metric ton in the last 3 years, making palm oil a very expensive green alternative (Raub, 2008).

African palm oil and ethanol are not the only sources of bio fuel ingredients, though, and Costa Rica could use sorghum, industrial yucca, jatropha, or higuerilla to produce green fuel. None of these methods have taken off yet, however, which already poses a large problem for Costa Rica's biofuel program. Under the current plan, regular and super gasoline will contain 7.5 percent alcohol and diesel will be made up of 5 percent biodiesel by next year. Without marked changes in biofuel production, neither of these goals will be met (Raub, 2008).

Industrial yucca, also known as bitter yucca, and higuerilla are Costa Rica's best bet for further biofuel ingredients. Like sugar cane, yucca is processed to produce ethanol, and 5,400 liters can be produced from a one-hectare planting – that's 578 gallons per acre. Guanacaste provides the perfect agricultural conditions for yucca cultivation, and there are currently 52,000 cultivated hectares. If properly utilized, Costa Rica could produce more than 280 million liters (75 million gallons) of yucca-based ethanol. Higuerilla, like African palm oil, is used to create biodiesel, and each cultivated hectare can produce 1,800 liters (476 gallons) of biodiesel. With current biofuel sources too expensive for national use, and no companies interested in beginning yucca or higuerilla biofuel production, Costa Rica must consider importing biofuels. Of course, the process of importing and transporting those products contradicts and even cancels out many of biofuel's positive aspects, so the National Refinery (Recope) expected it to be a temporary solution (Raub, 2008).

The National Biofuels Programme in Costa Rica (MINAE, 2008) based the definitions of the Programme on the results of the Commission created in 2006 where feedstocks for bioethanol and biodiesel were proposed. The National programme indicated the work to prioritise production zones, feedstocks, available and dedicated land as well as the incentives (e.g. taxes and fares) to promote the market. The Programme considered three different models for the organisation of the biofuels industry:

a) Agro-environmental model: This one considers the environmental issues associated to a a sustainable agricultural conditions including issues on soil, hydrology, good agricultural practices and use of agrochemicals, energy and air emissions, environmental and social management. The main focus here is the use of land dedicated to agriculture to avoid use of conservation areas and areas dedicated for food production.

b) Agro-industrial model: This model considers social and industrial issues to promote rural development. This model links social and economic issues with the production of biofuels and is also related to the different types of feedstocks.

c) Market model: this model is more focused on the economic benefits of the final product considering issues such as taxes, distribution, final prices for the consumer, and prices for the international market. It considers the basis the agriculture and industrial development in the country. This look to prioritise agricultural zones, type of feedstocks, amount of hectares for production, sustainable production, competitive prices and taxes according to the market.

Figure 6 presents the integration of the different issues considered for the development and research of the National Programme.

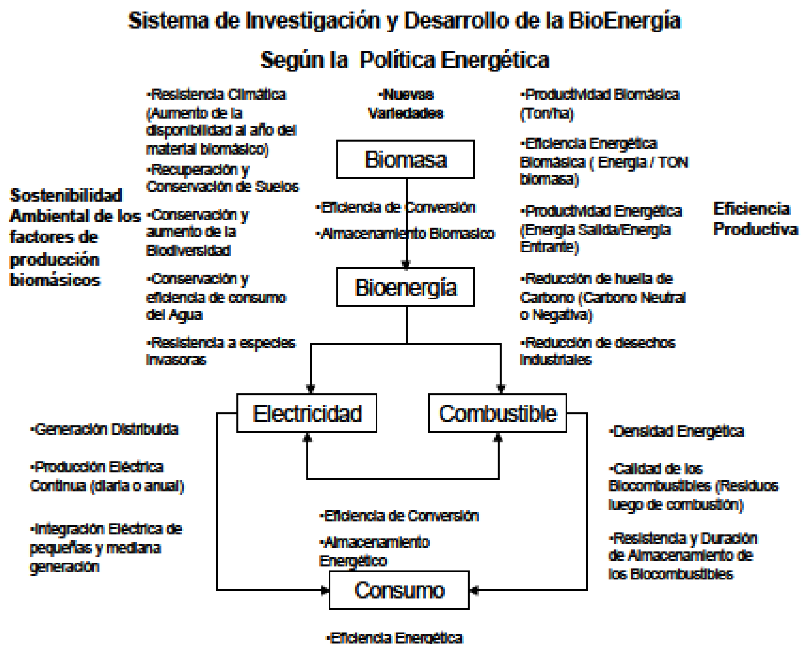


Fig.6. Model for development and research of Bioenergy (Julio César Matamoros – Viceministro, MINAE, 2008).

The use of land in Costa Rica (not only for the case of the Biofuels National Programme) is based on the Land Use Map of Costa Rica which is part of the Agrozoning Programme of Costa Rica (Acon,1991).

This map was developed considering different characteristics:

- Edaphology (type of soils)
- Amount of land
- Distribution of soils
- Geomorphology

The classification of soils was based on the capacity of the soil according to its use and is based on the Manual 210 for Soil Conservation of USA (Klingebiel y Montgomery, 1961), with adaptations to local conditions. This system uses three categories: class, subclass and units. The amount and detail of information is deeper at unit level. Figure 7 shows the classes used in Costa Rica.

The classes have different groups of lands similar regarding the uso limited to agricultural use or with risk of deployment when in use. It also shows the location, distribution and aptitude. The two main groups included here are:

a) Land adequate for crop production and

b) Land adequate only for permanent vegetation (forest and grassland).

They are subdivided in four classes and they are subdivided according to the type of use. Therefore classes I, II and III are land used for regular cropping and IV for land with risk of deterioration. Classes V, VI and VII are not adequate for agriculture and are proper for grassland and forests. Class VIII is only for recreational use.

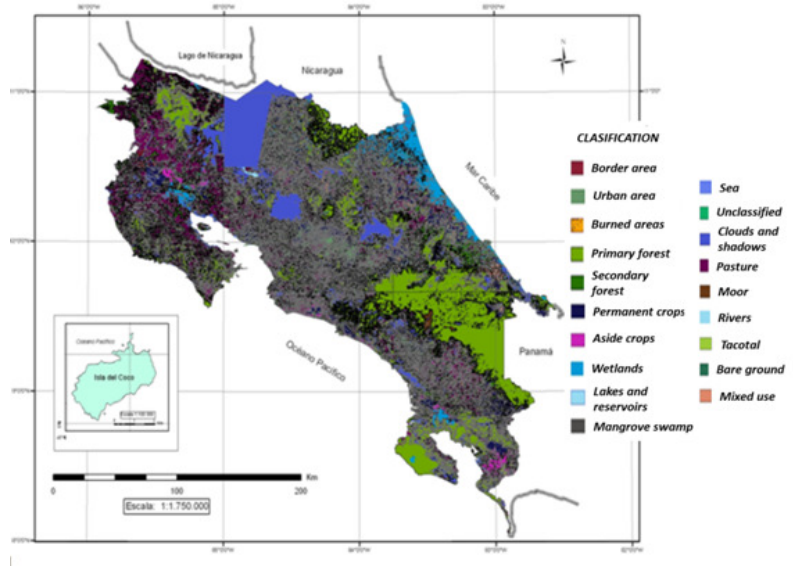


Fig. 7. Land use in Costa Rica. The map that is considered as a baseline for the bioenergy production. Source: PNUD- IMN-MINAET 2009

3. Indonesia

The basic law(s) governing land use and land use changes that require Environmental Impact assessments (EIAs) have been recently re-established in the Environmental management law No. 32 of 2009. This is overseen by the Ministry of the Environment and provincial environmental assessment agencies (BPLHD). Indonesia is party to all of the major international environment treaties/conventions/protocols generally seen as a good indicator of environmental awareness and activity. The Fourth Report to the Convention on Biological Diversity was prepared by the Ministry of the Environment in 2009. This can provide good up-to-date baseline information on the status of biodiversity conservation in the country, the perceived threats to its conservation, and lists of on-going and planned activities that attempt to address these threats. In addition the country has a National Environmental Action Plan, the Agenda 21, developed in 1997/98. This plan, although by now becoming out of date, helped to shape thinking and national and regional priorities important to current activities and plans (Soeparno, 2010)

Land use maps that can be used for baseline information and monitoring tools have been prepared and may be available through the Ministry of Public Works and ground-truthed by the Ministry of Forestry, at least for the forested areas of Indonesia. These maps should also identify the location of Indonesia's protected areas which now officially cover slightly more than ten percent of the nation (ten percent is viewed internationally as a good target figure for a nation). It is unclear from our survey how many of these PAs have active and viable management plans – an important fact to determine in their effectiveness and their contribution to local communities and economic development (Soeparno, 2010).

Additional areas with High Conservation Value (HCV) have also been determined into the development of the palm oil industry and forest concessions. HCV areas have not been officially delineated or published; these HCV areas should definitely be an important factor to monitor for biofuels development and future data collection. There are numerous institutions (WWF, CI, Forest Stewardship Council, SmartWood, Ministry of Forestry) concerned with this fact that can be consulted (Soeparno, 2010).

A number of "state of the environment" reports, biodiversity assessments, wetland inventories and other reports have been published in the period 2007 to 2010 that can provide important details and discussion regarding Indonesia's ecosystems and habitats. Many of these have been "third-party" efforts funded by bi-lateral and multi-lateral donors, as well as international NGOs. Habitat and species lists, which are good indicators of the health and status of flora and fauna resources have been periodically published and updated for Indonesia. Officially, the Ministry of Forestry and the Indonesia Institute of Science (LIPI) are the main repositories for this information. The Ministry of Agriculture is responsible for regular monitoring of invasive species (Soeparno, 2010).

Additionally, in Indonesia there have been other considerations to engage on land use and access issues with central and local government, NGOs, farmer and adat groups, academics and business interests. The Department of Forestry established the Tenure Working Group in November 2001 to develop a discourse on forest management that is more just and sustainable. The Working Group aims to develop mechanisms for resolving conflicts and building understanding among multiple stakeholders about land use conflicts (as mandated by a legislative decree in 2001) (WB, 2006)

More recently, a new policy to develop oil palm on degraded land was seen as a new form of protection. In May 2010, Indonesian President Susilo Bambang Yudhoyono declared a policy to develop oil palm plantations on “degraded land” instead of forest or peatland. As part of the national REDD+ strategy to be developed, this policy has the potential to allow the palm oil industry to continue to expand generating profits, government revenues, and jobs while reducing greenhouse gas emissions from deforestation and forest degradation (Gingold, 2010).

Whether the expansion of oil palm plantations on degraded land is sustainable will depend largely on how important details such as the meaning of “degraded”, are addressed during implementation. Such degraded lands, for example, could be areas that were cleared of forests long ago and that now contain low carbon stocks and low levels of biodiversity, such as *alang alang* grasslands.

Under Project POTICO, WRI and Indonesian partner Sekala have developed a working methodology for identifying degraded land that is acceptable for sustainable oil palm plantation expansion. According to this methodology, information on environmental, economic, social and legal is needed (Figure 8).

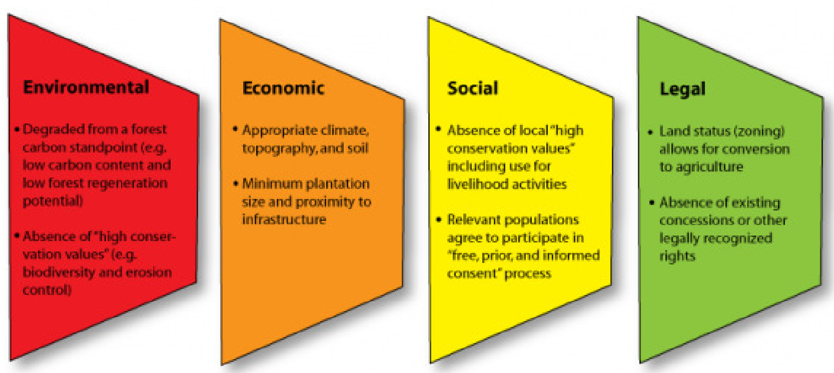


Fig. 8. Screening Criteria for Identifying Acceptable Areas for Sustainable Oil Palm Expansion (Project Potico, WRI, 2010)

These screening criteria are applied in a multi-step process consisting of a desktop analysis followed by field visits to assess individual sites (Figure 1). The desktop analysis uses relevant spatial data based on satellite information, aerial imagery, and other sources to assess factors that can be measured and mapped objectively—such as carbon content. Field work is required to verify the results of the desktop analysis and assess factors that can only be determined on a site level, especially those related to social acceptability (Gingold, 2010).

According to Gingold (2010), if defined and designed effectively, the proposed "degraded land database" will help Indonesia achieve its low carbon and agricultural development goals through sustainable oil palm expansion on degraded land.

4. Brazil.

The main aim of the Sugar Cane agroecological zoning in Brazil is to supply subsidies for the formulation of policies considering the expansion of the crop and its sustainablde development in Brazil. Some of the specific objectives to promote this zoning included:
• selection of potential lands for culture expansion
• technical subsidies for policymaking
• offer sustainable economic alternatives to producers;
• create a database for planning
• sustainable cultivation, respecting legislation and preserving biodiversity
• integrated energy matrix
• rural development focal areas
• policy follow-up
• reduced competition for land
• protection of biomes and other sensitive areas

The methodology for this zoning included the use of digital images From 2002, to assess the potential of the land for the culture of sugar cane in an area without irrigation, considering:
• sugarcane requirements (soils dephts, types, water)
• based on soils (physical-chemical, mineralogic), climate (rainfall, temperature, frosting, heat waves), yield potentials, legislation
• indicated areas for agricultural land
  – intensive and semi-intensive production
  – perennial and annual crops
  – pastures
• 3 Classes of potentials and three types of use:
  – High/Medium/Low potentials
  – Agriculture / Cattle raising / Both uses

The zoning also considered the current environmental legislation.

According to EMBRAPA (2008), some areas were excluded from the study
–Biomes Amazon (rainforest) and Pantanal (grasslands, wetlands)
- States in the South Centre
– slopes > 12% (non-mechanisable lands, without harvest burning);
– remaining forests, native vegetation; environmental protection areas
– traditional indigenous people areas
– sand dunes, mangroves, cliffs and rock formations
– reforested areas
– urban and mining areas, quarries

The result of the zoning showed that Brazil does not need to deforest and/or to affect food production in order to expand the sugarcane production area. It showed that the country has 64.7 million ha available for cane (19.3 Mha "High potential"; 41.2 Mha "Medium"; 4.3 Mha "Low") with a potential to convert available 37.2 Mha of pasture lands (as per 2002).

Figure 9 shows the maps of the aptitude of soils for all the areas considered for the zoning.

Map a. Areas with agricultural aptitude for sugar cane production

Map b Classification of soil aptitude for sugar cane production (high, medium low).

For the case of Sao Paulo the zoning was set in 2008 in an agreement between the Environmental and the Agriculture Secretaries of the State. The main aim is to organise and order the expansion and use of land for the sugar cane sector and at the same time provide the subsidies for the policies.

For the zoning map different issues were considered including:
- soil aptitude
- restrictions to mechanization (slopes)
- availability of superficial waters
- vulnerability of underground waters
- importance to biodiversity protection
- environmental protection areas
- integral conservation units
- priority to biological connectivity
- air quality (saturated / under saturation areas

As a result, for areas were classified according to the different degrees of agro-environmental aptitude as shown in Table 3. Figure 10 shows the map with the zoning of agro-environmental areas for the State of Sao Paulo with aptitude for the sugar cane - ethanol production (Governo Estado de Sao Paulo, 2008).

Table 3. Classification of areas for sugar cane production in the State of Sao Paulo

Area	% of the total area	Characteristics for the production of sugar cane
Adequate	26	Favourable soil and climatic conditions for sugar cane and with no restrictions
Adequate with environmental limitations	45	Favourable soil and climatic conditions for sugar cane and some Protected Areas (APA); areas of medium priority for interconnection of a biodiversity programme (BIOTA-FAPESP); hydrological basins considered critical.
Adequate with environmental	28	Favourable soil and climatic conditions with zome buffer areas from the Integrated Protected Areas (UCPI); high

restrictions		priority areas of the biodiversity project BIOTA-FAPESP; high vulnerable areas of groudnwater
Inadequate	1	These are the Integrated Protected Units; some areas classified of extreme importance for conservation; Areas of wildlife from the Environmental Protected Areas with restricted soil and climatic conditions for sugar cane.

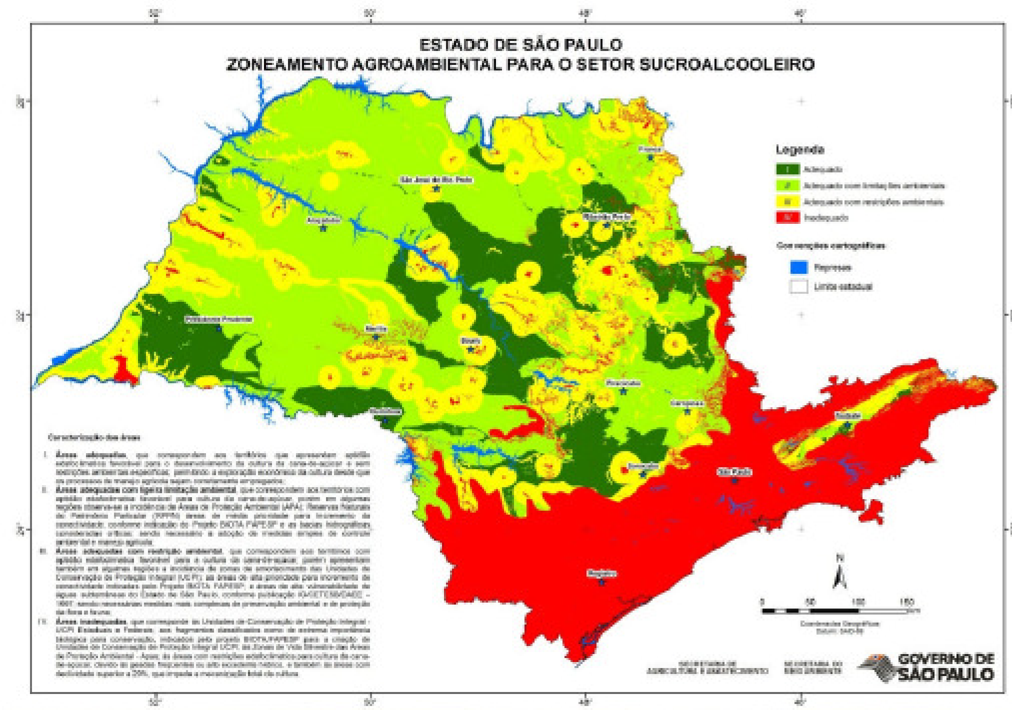


Fig 10. Map of areas with aptitude for sugar cane and ethanol production in Sao Paulo State.

This zoning resulted in the Environmental Secretary of the Sao Paulo State's resolution 88/2008 which defines parameters and guidelines for environmental permits (land use and for agro-industrial processes installations and expansions) according to the different areas.

5 Conclusions

This report presented different methodologies, frameworks and tools for assessing land use for bioenergy production. Although they are not exclusively used for these goals, they have been applied or used at some stage to assess the suitability of land.

The modelling tools have already been developed and are subject to ongoing critique within specialized disciplines that define each of these model classes. The combined results of multidisciplinary state-of-the-art models should be informative for assessing LUC outcomes. These models should ideally subscribe to similar criteria in all regions, relying on data sources analogous to a global unified database and ground-truth verifications of projections (through data collection and monitoring) of fuel-related LUC (Davis et al, 2011).

The assessment done by Davis et al (2011) also demonstrated that feedbacks to ecosystem services are the least represented (relative to effects on production and economics) in integrated assessment models like Mini-CAM, and are more often modelled regionally without considering interactions with the global market. Connections between regional responses of ecosystem services, including greenhouse gas mitigation and carbon sequestration, and LUC must be made in order to assess global scenarios. Davis et al (2011) suggested that a wide variety of existing tools must be used in aggregate to assess LUC. A combination of productivity, biogeochemistry, economics, environmental impact and social impact models must be employed to clarify the potential consequences of bioenergy in different regions of the world.

Furthermore, model inputs depend on land cover information (agriculture/ forestry/ grassland). This information is available from various products at different resolutions. Products are improving with satellite technology, but there are still differences among datasets that are partly due to classification (e.g. per cent coverage of trees that classifies land as a forest can vary from 20% to 60%) (see Watson, 2007). This has to be considered when using a global comprehensive model of LUC. Standardization of land-use categories would increase the relevance of LUC models for global analysis, and should be inclusive of subdivisions with varied management practices that are employed throughout the world (Davis et al, 2011).

The case studies clearly demonstrated that an integration of the different tools is necessary in order to assess the land use. Furthermore, the information also contributes and responds to policy making process in different parts of the world.

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