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Social and
Economic Effects of
Multifunctional Land Use
in MERCOSUR Regions
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Objectives:

The major objective of this report is to assess the transferability of generic Impact Assessment tool concepts, architecture design and technical system for a suitable demonstration tool to MERCOSUR conditions.

Specific objectives:

- To describe requirements and alternative solutions of SIAT-TTC to evaluate the sustainability impacts of land use change policies through integrated dynamic models.

- To present SIAT-TTC prototype focused into the assessment of two major policies: (i) expansion of sugarcane crops in Central Brazil and (ii) expansion of planted forest in South of the La Plata River Basin (Argentina, Southern Brazil and Uruguay).

- To report the transferability process potential and constraints in the development of SIAT-TTC programming adaptation and present new approaches with potential of use to improve software flexibility and transferability options.

Activities:

The prototype of SIAT-TTC for Mercosur regions was based on knowledge of the technical procedures implemented in the SIAT-EU, acquired from a dynamic and continued interaction between the EU and Mercosur development teams. This partnership was made possible through official meetings with international visits of the Sensor team to Europe and between Mercosur countries, as well as intensive dialogues by electronic mail.

The development of the SIAT-TTC prototype for Mercosur was carried out as an evolutionary process and involved the following activities:

- Weekly meetings (workshops) of the development team (IT experts, GIS scientists, environmental modellers and post-graduation students)
- Biweekly meetings with SENSOR team of Embrapa and occasionally with other partners, where SIAT-TTC software was presented.
- Assessment of SIAT-EU prototype model domains, source code and architecture, as well as evaluation of the software transferability to Mercosur policies and regional data base characteristics, including country-specific features.
- Elaboration of deliverable 8.4.1 which presented the state-of-the-art of SIAT-TTC Mercosur and regional case studies, a comparative analysis of the conceptual framework, the classification of SIAT-TTC Mercosur and a preliminary description of technical architecture, software design and features.
- Definition and preparation of drivers GIS layers, calculation of drivers using topology and mathematical functions (distance, average, cellular

space functions etc.), preparation of land use map (year 2008), definition and adaptation of the land Use legend, calculation of the demand in the business as usual scenario based on data from CanaSat System (www.inpe.br) to locate sugar cane areas through satellite, and on IBGE statistical data, calculation of probabilities and regression, generation of the dynamic model based on Dyna-CLUE.
- Implementation of a demonstration tool at regional level in MERCOSUR, adapted to local circumstances and allowing cross-country comparative analyses.
- Explanation and decomposition of SIAT-TTC functioning in its sub-tools and functional units (impact identification and evaluation).
- Implementation of specific test-functions, using empirical tests by research expert groups involved in the project for Mercosur.
- Identification of critical success factors through assessment and implementation of test functions and indicators, testing the demonstration SIAT functionality.

Table 1. Meetings for methodology consolidation

Date	Meeting	Location	Participants
August 2007 15-17th	Stefen Sieber visit to Embrapa Soils (kick-off meeting)	Rio de Janeiro, RJ - Brazil	Stefen Sieber, Heloísa (IBGE), Ana Turetta, Heitor Coutinho, Lucietta Martorano, Margareth Meirelles, Milton Jonathan, Joyce Monteiro, Rodrigo Demonte Ferraz
February 2008 25th	End user meeting	Rio de Janeiro, Brazil	Mariano Oyarzabal (UFBA), Sandro Schlindwein (UFSC) and Embrapa team
April 2008 6-9th	Impact assessment of land use change – International Conference (combined with Seamless, Eforwood and Sensor)	Berlin, Germany	Lucietta Martorano, Margareth Meirelles, Ana Turetta.
April 2008 10-11th	Meeting on macro-economical modelling of SENSOR (NEMESIS)	Bath, United Kingdom	Lucietta Martorano, Margareth Meirelles and Ramon Ortiz.
May 2008 12-14th	Integration of M8: WP 8.2, WP 8.3, WP 8.4 and WP M8.6	Florianópolis, SC - Brazil	Sandro Schlindwein, Luiz D´Agostini, Giovana, Heitor Coutinho, Ana Turetta, Joyce Monteiro, Lucietta Martorano. Lílian.
May 2008 15th	SIAT-TTC development WP and Data Base WP teams meeting focused on: How to model land use change related to policy changes using the dynamic model Dyna-CLUE?	Rio de Janeiro, Brazil	Margareth Meirelles, Lucietta Martorano, Rodrigo D. Ferraz, Luiz Ivan Ortiz Valencia and Marysol Schuler

Table 1. Meetings for methodology consolidation

Date	Meeting	Location	Participants
June 2008 9-10th	SENSOR-TTC Meeting at UDELAR	Montevideo, Uruguay	Heitor Coutinho, Margareth Meirelles, Ana Turetta, Santiago Baeza, Alice Altesor
September 2008 9th	SIAT-TTC development team meeting focused on: How to show what information in SIAT?	Rio de Janeiro, Brazil	Lucietta Martorano, Margareth Meirelles, Marysol Schuler, Henrique Tavares.
September 2008 22-25th	Sensor Cluster Meeting	Birmensdorf, Switzerland	Heitor Coutinho, Lucietta Martorano and SIAT-EU team.
Nov. – Dec. 2008	Weekly meetings of WP4 and WP5 to methodological adjustments between the SIAT application, data base and modelling tools.	Rio de Janeiro, Brazil	Lucietta Martorano, Margareth Meirelles, Marysol Schuler, Henrique Tavares, Ivan Ortiz Valencia and Fabio Santos.
Feb. 2009	Two-week hands-on meeting on SIAT-TTC application building and conceptual discussions on SIAT-GUI and meta-modelling system development.	Rio de Janeiro, Brazil	Lucietta Martorano (Embrapa Eastern Amazon), Marysol Schuler and Henrique Tavares.
Feb. – March 2009	Weekly meetings of WP4 and WP5 to methodological adjustments between the SIAT application, data base and modelling tools.	Rio de Janeiro, Brazil	Lucietta Martorano (Embrapa Eastern Amazon), Margareth Meirelles, Marysol Schuler, Henrique Tavares, Ivan Ortiz Valencia and Fabio Santos.
March 2009 5th	Workshop on indicators and SIAT-TTC test How to integrate stakeholder results?	Rio de Janeiro, Brazil	Embrapa team, Mariano Oyarzabal, Sandro and other invited Institutes (IPEA, USP, Embrapa Environment)
Apr-May 2009	Weekly Meetings to discuss the SIAT-TTC prototype development.	Rio de Janeiro, Brazil	WP4 and WP5 teams
May 2009 8-12th	Participatory meeting on final discussions and conclusions of Knowledge Integration and SIAT-TTC prototype development, including review of the deliverable 8.4.2.	Rio de Janeiro, Brazil	Lucietta Martorano (Embrapa Eastern Amazon), Marysol Schuler, Margareth Meirelles, Rodrigo Ferraz and Henrique Tavares.

Executive summary

Sustainability Impact Assessment Tool prototype: Demonstration tool at TTC-level, for MERCOSUR

The Work Package 8.4 aims at the development of a demonstration SIAT-TTC adapted to Mercosur and China. In order to reach this target, TTC-researchers of Mercosur worked on integrating concepts, methodologies, data bases and products of the SENSOR project into the software SIAT-TTC Mercosur.

This deliverable (D 8.4.2b) aims to present the demonstration tool SIAT-TTC prototype for MERCOSUR, describing: i) the software technical features; ii) the major policies focused by SIAT-TTC for sustainability impact assessment (sugarcane and planted forest incentive policies) and how to translate them into SIAT programming functions; and iii) the transformation and implementation of the domain knowledge and data from the SENSOR experts outside of WP8.4 to technically fit into the SIAT-TTC software system adapted to Mercosur conditions.

By the end of 2008, the conceptual model of SIAT-TTC was presented in deliverable 8.4.1, showing the transferability potential and constraints, as well as the similarities and differences between SIAT-EU and SIAT-TTC Mercosur concepts and features. That deliverable explored some alternatives that could be linked to the demonstration tool developed to the La Plata Basin countries. It highlighted the potential introduction of the TerraME system knowledge besides the Dyna-CLUE.

Considering the transferability process to TTC-partners of knowledge previously accumulated within the SIAT-EU prototype I development context, and the gap of time for tool development between the teams of European and TTC-countries, we skipped the step of a wizard like interaction model using dummy data and models and, instead of this first pathway, the group invested efforts to develop the first Mercosur SIAT-prototype based on the SIAT-EU prototype II.

The SIAT-TTC prototype for Mercosur evolved following the same conceptual framework as SIAT-EU. The steps to adapt the tool to assess impacts of the land use related policies in the La Plata Basin are as follows: i) define the policy cases to be assessed and the major instruments for each one of the two chosen policies; ii) evaluate the indicators for the policies impacts, including the availability of data base; iii) integrate in WP8.4 (SIAT-TTC development) all the information from the several WPs of module 8: WP8.2, the Land use scenario, including Driving forces and policies forecast, and indicator based assessment (Monteiro et al. 2008); WP 8.3, Regional sustainability problems, risks and thresholds - targets derived by stakeholder participation and Spatial Regional Reference Framework for Mercosur, (Turetta et al. 2009); WP8.5, Data Base Management System (Meirelles et al., 2009); WP8.6 (Sustainability in sensitive regions of TTC) and finally WP 8.7, End-user participation and institutional analysis in TTC (Vega et al. 2008); iv) insert the policy cases, instruments and

indicators variables into the interface of the original SIAT-EU prototype source code, in such a way to build the SIAT-TTC prototype adapted to Mercosur; v) define policy response functions (relationship between policy variable and land use change variable) and indicator functions and knowledge rules (relationship between land use change and indicator response) to be inserted into SIAT-TTC; vi) assess impact values of different policies and compare the results. The future scenarios are targeted at the year 2025.

In SIAT-EU, system flexibility was expressed in terms of its adaptability to new data/knowledge. Within SENSOR, the EU open standard OpenMI (Open Modelling Interface) is used to describe models related to specific cause-effect relations. For SIAT-TTC prototype development, the OpenMI was used, taking advantage of its power to facilitate the linking of different models by using a standard interface. Within SIAT prototype the models are response functions, indicator rules and aggregation algorithms.

The first part of deliverable, from the Second Chapter to the Fifth one, the SIAT-TTC transferability process is described in terms of "how to" use and adapt the program application to assess impacts of the land use related policies in Mercosur region. The second chapter deals with the general issue of applying Domain Model into the SENSOR conceptual framework to develop a tool able to meet the needs posed by the sustainability impacts assessment within Mercosur policy cases. The third one focuses on the main types of software requirements in this transferability context.

The fourth and fifth chapters present the Architectural aspects and some Software Engineering techniques in test to improve transferability process. It is suggested the use of the Adapted Object-Model Architecture Style, which should allow the introduction of new policy cases, policy instrument settings and other candidate structures to entities in the future without the need of new programming efforts to screen design. This meta-architecture approach makes possible changes in the system at runtime by users' manipulation of Object-Model stored in the database instead of hard-coded programming, and using a domain specific language (DSL).

The objective of enhancing the tool's flexibility was pursued not only by the use of AOM architecture, but also through the implementation of some Engineering Software patterns. The use of both patterns combined would allow the re-use of the SIAT elements in several distinct procedures and simulation models.

The second part of the deliverable, from the sixth to ninth chapter, is dedicated to describe how the SIAT-TTC represents the components of DPSIR framework applied to Mercosur' sustainability impact assessment, and the implementation processes of them, which consist of i) the **Driving forces** related to the policy cases and how the end-user deals with them in the SIAT-TTC application through the Graphical User Interface (GUI), ii) the Pressures acting onto the **States** of land use classes and how the land use change processes are modelled in the policy cases of SIAT-TTC; iii) and the **Impacts** caused by the land use change effects on the system sustainability, which are measured through **indicators** related to the social, environmental and economical dimensions.

Within the framework presented above, the sixth chapter describes the GUI through which the SIAT-TTC end users will be able to choose different settings of policy instruments in a policy case, in order to assess the effects of the policies in Mercosur on the land use change and ultimately on the system sustainability. From the GUI, the end users will access information on the **driving forces** governing the land use changes: a) the exogenous drivers "population growth" and "oil price", as well as b) the policy instruments used to speed up, to discipline or to avoid a certain kind of land use change. The driving forces related to the policy cases and how the different settings of policy instruments may be tested by the end-users are issues explained in the 6th chapter and should be inserted into the SIAT-TTC application using factsheets.

In the assessment of the **Pressures** involved in land use change and how they modify **States** and cause the **impacts**, the Dyna-CLUE model is used to allocate land use classes according to demands given as options of the Policy case in the Graphical User Interface. The seventh chapter describes the first attempts to run the land use model and how its parameters are related to the options wanted to be assessed to evaluate the policy impact on land use change, and consequently on the sustainability. This chapter points out the achieved and main constraints to apply the tool. Next steps include the recommendation to deepen the studies on Dyna-CLUE and test new parameters and approaches to simulate the policy restrictions and land use claims in order to overcome the model domain.

The chapter eight addresses to a range of indicators available in the SIAT-TTC Data Base and capable to be used in the sustainability impact assessment, presenting different methodological approaches to evaluate the social, environmental and economical changes caused by the land use related policies.

The ninth chapter of this report proposes further activities to improve the SIAT-TTC prototype and proposals of new approaches for the knowledge integration within the Sustainability Impact Assessment. Two main approaches are proposed to aggregate indicators from diverse sustainability dimensions into a unique integrated indicator able to show comprehensive information regarding the thresholds and targets of sustainability within Mercosur conditions.

This report concludes with overall considerations on the constraints and potentials that took place during the transferability process, and finally summarize the main points planned to further advancement in sustainability assessment research.

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GLOSSARY

The SIAT-MERCOSUR adopts the same concepts and key-words of SIAT-EU. The glossary below contains definitions presented by Sieber et al. (2008) in del. 4.3.2, in italic font, and introduces specifications for Mercosur.

Glossary from SIAT-EU (Sieber et al. 2008) with additions by SIAT-MERCOSUR adaptation.

AOM architecture	Adaptive Object Model architecture (see chapter 5, item 5.2)
Baseline scenario	*"A scenario which is used as a counterfactual for assessing the impact of policy changes. It contains projections of exogenously assumed developments, on which investigated policies do not have influences. In SENSOR, two types of baseline scenarios are used, namely reference and contrasting scenarios."* Baseline scenarios in SIAT-MERCOSUR considered three drivers: oil price, population growth, and GDP (economic growth).
Fact Sheet	*"Fact sheets summarize specific topics in SIAT. They are implemented to inform the policy maker about the content / background or defined assumptions of all calculation steps, applied methodologies and methods."*
GoF and GoF pattern	GoF is the acronym for "Gang of Four", as the authors of "Design Patterns: Elements of Reusable Object-Oriented Software" (1995) become known. They are: Erich Gamma, Richard Helm, Ralph Johnson, John Vlissides. GoF pattern refers to Software Design Patterns following the classification proposed by the "Gang of Four".
GUI	*Graphical User Interface*
Indicator Function	*"Indicator functions are defined as a mathematical functions and /or a knowledge rule that uses 'land use change' and 'policy variables' (e.g., subsidies) as variables and computes in SIAT indicator values for a specific region."*
LUC	*Land Use Change*
LUF	*"A Land Use Function is an aggregated indicator that is composed of a set of single indicators, which represents one thematic area and indicate at regional level land use-related service such as 'provision of work'.* More detailed definition available in Perez-Soba et al. 2008."
OpenMI	*"OpenMI provides a standard interface, which allows models to exchange data with each other and other modeling tools on a time step basis as they run www.openmi.org"*
Policy case	*"Subject for a set of policy instruments to be applied around a particular theme*". SIAT-MERCOSUR policy cases instances are: Brazilian sugarcane ethanol policy, Afforestation incentive policy, Environmental protection policy." *Within a policy case, different policy variables can be combined, which will be used for defining the policy scenarios. In the case of SENSOR, synonym for "policy scenario", meaning that impacts of different scenarios will be compared."*

Glossary from SIAT-EU (Sieber et al. 2008) with additions by SIAT-MERCOSUR adaptation.

Policy function	*"Policy functions are integrated in a response protocol that is implemented in SIAT. They compute the relation between the 'policy intensity' (e.g., subsidy) and the land use claim of one specific sector (e.g., agriculture) or intermediate variables (e.g., GDP), if land use claims are not needed as an interim step to calculate indicator values for one region."*
Policy instrument	*Delivery mechanisms, individual element/design parameter* *In general: Regulatory watch, Open method of co-ordination, provision of information and guidelines, market-based instruments: taxes or charges, limits to price and/or quantity etc., direct public sector financial interventions, co-regulation, framework directives"* – Examples for the ethanol policy case: Instrument for land use regulation: Agroecological Zoning; Instrument for Natural Areas Protection: CONAMA resolution which prohibits ethanol plants in the Paraguay river Basin.
Policy objective	*"Aim of the policy, understanding of what a policy is supposed to achieve."* An instance from the Brazil sugarcane ethanol policy: • To guarantee regular supplies of sugarcane ethanol while protecting the Brazilian market from extreme oil price fluctuations and asserting the sustainability of the energy sector.
Policy option	"*Set of policy instruments, one of several ways to achieve the objective(s) of a policy*." The policy options considered for the Brazilian sugar cane ethanol policy are listed on Table 1, p.20-21.
Policy scenario	*According to EEA Glossary: the policy scenarios (in the context of environmental studies) depict the future consequences of policy interventions. In other words, they describe the future state of society and the environment under influence of directed environmental policies. Policy scenarios are also known as 'pollution control' or 'mitigation' or 'intervention' scenarios.*
Policy target	*Specification of a policy objective in quantitative terms, accompanied by a point in time at which the target will have to be achieved. In some cases maybe a qualitative target will be necessary (if not quantifiable). In the sugarcane policy case, the target was set as the quantity of land to be occupied the crop.*
Policy variable	*A set of policy instruments within a policy case, expressed monetarily or non-monetarily; The variable is the model-based translation of a policy instrument into a mathematical function.*
Reference scenario	*Scenario against which the impact of policy options will be compared and assessed; continuation of the current policy; other drivers set at continuation of expected trends or most likely trend for the respective target year.*
Response functions	*Meta-model functions derived from a Modelling framework and that summarize the response behaviour of applied model. These functions relate the land use change to the policy variables.*
SIA	Sustainability Impact Assessment
SRRF	Spatial Regional Reference Framework

1 Introduction: A General Overview on Knowledge Integration in the SIAT-TTC development

The main goal of the SENSOR project is the development of a Sustainability Impact Assessment Tool that integrates a set of the concepts, the methodologies and the products developed in the project's modules. This deliverable is focused at describing the SIAT prototype adapted to Mercosur conditions, the so-called SIAT-TTC Mercosur.

The development of the SIAT-TTC initiated from the knowledge on the technical concepts and procedures of SENSOR for the implementation on the Sustainability Impact Assessment Tool SIAT- European Union, in order to allow the software implementation within Mercosur conditions.

1.1 Transferability processes of the meta-modeling tool SIAT into Mercosur

SIAT is designed as a meta-modelling system that aggregates in response protocols a large range of knowledge to assess impacts of land use change caused by policies on sustainability issues, based on integrated qualitative and quantitative indicator analyses (Helming et al. 2007; Sieber et al. 2007).

The process of adapting SIAT-TTC to Mercosur is described in this report under two perspectives. Primarily, four chapters (from the second to the fifth) comprehend the technical concepts and settings of the toolkit itself, consisting of i) the Domain model in, ii) the software requirements, iii) Architectural Aspects, and iv) Software Engineering techniques proposed to the tool adaptation.

In the second analysis perspective, from the user point of view, SIAT-TTC is described in terms of how the Sustainability Impact Assessment was implemented following a logical causal chain concept in a comprehensive way to the end-user.

1.2 Logical analytical chain of SIAT-TTC: the DPSIR framework applied to Mercosur´ land use related policies

The SENSOR logical framework to conduct the sustainability assessment follows the Drivers-Pressures-States-Impacts-Response (DPSIR) framework adopted by the European Environment Agency. In this DPSIR approach to assess and manage environmental problems, "***driving forces*** are the socio-economic and socio-cultural forces driving human activities, which increase or mitigate ***pressures*** on the environment. ***Pressures*** are the stresses that human activities place on the environment. ***State***, or state of the environment, is the condition of the environment. ***Impacts*** are the effects of environmental degradation or amelioration. ***Responses*** refer to the responses by society to the environmental situation. (Source: Global International Waters Assessment (GIWA), 2001; European Environment Agency (EEA); Copenhagen).

In SIAT application, according to Firbank et al. (2007) in Del. 2.3.1, these steps mentioned above are accounted as follows:

- the user selects ***policy options*** that will act as ***drivers***;
- the ***pressures*** are the outcomes of the ***redistribution of land use*** and land management, forecasted in scenario simulation by a land use dynamic model, the Dyna-CLUE;
- the ***states*** are reflected in the *changes to the social, environmental and economic conditions* expressed by ***indicators*** resulting from the land use model estimates applied to the indicator functions;
- the sustainability ***impacts*** are considered by *mapping the* ***indicator changes*** against sustainability *targets*;
- the ***response***, if any, is the *responsibility of the* ***user***. This part is out of scope of SENSOR.

The SENSOR authors considers these steps as providing a pathway of information from the user, through drivers, pressures, states, impacts and back to the user. The Driver-Pressure-State-Impact-Response framework scheme in SIAT is represented in the table 1.

Table 1. Scheme of DPSIR framework of analysis applied to SIAT.

Steps in DPSIR	Action in SIA tool
Driver	Scenario development
Pressure	Multifunctional analysis under scenarios
State	Economic, environmental and social assessment of land use
Impact	Sustainability targets and thresholds
Response	The SIAT user

Source: SENSOR, Del.2.3.1, Firbanks et al (2007).

Following the SENSOR-EU aims and the conceptual design of SIAT, the user is asked to specify settings of a policy case in order to assess the representation of a user-defined policy scenario; these options have been entered in a modeling framework comprehending an economic model (NEMESIS), sector models (CAPRI, EFISCEN) and a land use dynamic model (Dyna-CLUE), which were coupled in order to forecast the land use claims for different classes of use and the land use classes allocation in different sectors based on a cross-sector analysis of activity in an iterative modeling process.

The new land allocations are analyzed by region and together with other outputs of macro-economic and sector models, are used as inputs into the forecast model of changes in social, environmental and economic indicators. The indicator values generated show the impacts of the scenario, per unit of land. These indicators are then interpreted in the context of sustainability thresholds and targets, according to criteria developed in M3 (Firbank et al., 2007).

1.3 Knowledge Integration in the SIAT-TTC

The scope of the present deliverable is to present the development process of a meta-model application tool that allows the user to carry out the sustainability policy assessment in the Mercosur, as well as to describe the knowledge integration which based the modelling framework used in SIAT-TTC.

In order to implement the concept of the Sustainability Impact Assessment Tool SIAT in Mercosur as the integration of a wide scope of knowledge into a meta-modelling application based on response and indicator functions that describe the behaviour of indicators regarding driving-forces and pressures, the solution processes followed the assumptions posed by Sieber et al. 2007 to use a three-stage comprehensive integration which includes: i) Quantitative assessment, ii) Cause-effect chains to qualitative assessment and iii) Multi-scale spatial consistency comprehending data reliability between the participative sector and national approaches.

As a problem- and user-oriented tool, the SIAT-TTC graphical user interface (GUI) needs to be adjusted to meet end user requirements such as a set of policy options to choose; the quick response assessment of sustainability impacts by integrated indicators in different spatial scales; transparency of indicator processing methods and effectiveness of indicator results, in terms of condensed and non-redundancy of information (Sieber et al. 2007).

In the SENSOR-TTC Mercosur, the policy cases evaluated were the Sugar Cane Ethanol Policy and the Afforestation case. Within a policy case, a set of policy instruments are used to obtain a defined objective and pre-defined choices of settings are tested and made available to end-user selection through the Graphical User Interface (GUI). The chapter six shows how the GUI represents the **Driving-forces** of DPSIR framework, which are related to the ***policy instruments*** as well as the ***exogenous drivers***, allowing end user to assess information on drivers concepts and behavior and interact with the policy cases simulations.

The policy cases of Mercosur used different approaches to model the land use change dynamics. The Sugarcane Policy case assessment used the Dyna-CLUE to model the effects of the ethanol demand on the land use change in the Mato Grosso do Sul State. On the other hand, for the Afforestation policy case in the South of the La Plata River Basin, in the areas where forest demand has increased, land use dynamics was evaluated by the Markov-chain model.

In the first SIAT-TTC prototype, the policy case for Sugar Cane Ethanol was elaborated in the GUI to represent a set of policy instruments combinations, to present scenarios of land use derived from previously run simulation of Dyna-CLUE for demand conditions and territorial constraints given by these different combinations of policy instruments, and to forecast the impacts related to the land use changes in each unit of the Spatial Reference Framework.

The seventh chapter presents the steps of the land use dynamic modelling method used to assess the **Pressures,** which are the land use changes due to the political, economical and social driving forces. This chapter describes the settings used in the Dyna-CLUE to represent the different policy instruments proposed in SIAT-TTC to be evaluated regarding their impacts on land use change and sustainability.

In SIAT-EU, the **response functions** were derived by performing a number of simulation experiments within Dyna-CLUE, in which the macroeconomic and sectorial models outcomes of land use claims were used as input parameters. The values of policy variable related to land use demand varied systematically in successive simulation runs, and the results were used ro estimate response function for each unit of Spatial Reference Framework. For Mercosur, the initial results available are not enough to apply the same methodology to obtain the response functions. Other methodological alternatives to model land use change driven by policy changes are presented in chapter 9.

Following the logical DPSIR framework, the **Pressures** (land use changes) will force towards changes in the **States**, which are the environmental, social and economical conditions represented by the **indicators**. This topic should be addressed in the eighth chapter, where the Impact Assessment concept and its implementation potentials and constraints using SIAT tool in Mercosur are discussed.

1.4 Integrated indicators in Sustainability Impact Assessment: Feasibility and Solutions for SIAT-TTC application

The Sustainability Impact Assessment tool SIAT is based on protocol responses which combine quantitative and qualitative integration techniques, allowing *"a maximal number of methodological diverse indicators"* (Sieber 2007).

Following the D-P-S-I-R analytical framework, the policy **Impacts** are measured by mean of **indicator responses** to the land use changes, which represent changes in **States**.

Hence, while the *indicators* are variables that measures the **States** or conditions of the system, the **Impact** is considered by comparing indicator changes against targets or thresholds.

According to Sieber et al. 2008, in the impact assessment of SENSOR, indicator knowledge rules can be quantitative, semi-quantitative or qualitative. While quantitative rules contains mathematical functions, and values are expressed in real units, the semi-quantitative are expressed in class or ranges (risk or relative classes). The qualitative describes decision trees and are expressed in statements of better or worse development.

For the SIAT-TTC Mercosur, a set of variables were pointed out as potential indicators of social, environmental and economical impacts by the WP 8.3 team, based on data availability and expert consultation. The set of variables comprised: Consumption of pesticides, Access to water supply system, Gini Index for the distribution of income, Occupied Persons, GDP per capita and Balance of Trade (Turetta et al. 2009). These variables express mainly social and economical indicators, for which a quantitative analysis is not accessible, once there is no direct mathematical relationship between the indicator and a land use change variable or policy variable. For such kind of indicators, Sieber et al. 2007 points an integration of qualitative knowledge by constructing rules describing cause-effect chains between policies and indicators. This topic is addressed in chapter eight.

On the other hand, considering quantitative assessment, the indicator functions are defined as *simple equations consisting of the variable ´land use change´ driven by the respective policy change (…) that normally drives the result of the indicator"* (Sieber et al. 2008). One indicator proposed in the SIAT-TTC that meets the requirements for a mathematical function relating the land use change and the indicator result is the Water Requirement Satisfaction Index (WRSI) of a given crop. The WRSI is an environmental indicator directly related to the land use class (given crop, e.g., the sugar cane in the Ethanol policy case), besides dependent on topoclimatic conditions.

The chapter eight describes the use of WRSI, as an instance of indicators directly related to the land use change variable in SIAT-TTC. This allowed an effective indicator value simulation from outputs of the land use dynamic model. Another approach presented in this chapter is the causal-chains between policies and indicators, with examples applied in the Ethanol Policy case.

Another remarkable feature of the indicator framework is that the integrated analysis based on the Land Use Multifunctionality approach is not feasible with only few indicators. The integrated assessment through Land Use Functions impacts and thresholds requires a minimum number of indicators to be aggregated in nine Land Use Functions, divided in three dimensions' groups, with a balanced number of functions among the groups.

The SENSOR-TTC team points out some alternative analysis to perform sustainability assessment, still following the general DPSIR framework used in the transferability proocess and aiming at the application of the conceptual guidelines to the regional conditions of Mercosur.

In order to deal with the sustainability impact indicators evaluation in a context of scarce historical data allied to different data frameworks in the Mercosur countries, Turetta et al. (2009) describes in Del. 8.3.3 the Sustainability Barometer, which is a tool proposed by the SENSOR-TTC team as an alternative method to the Land Use Function methodology, that showed not being feasible for Mercosur's studied policy cases.

The chapter 9 presents some proposals of distinguished approaches to be incorporated in future studies on sustainability assessment applied to Mercosur. They include an adaptive object-model architecture for the software application allied to the use of TerraME as a modeling tool coupled to the SIAT-TTC, and the incorporation of integrative approaches in sustainability assessment taking into account the water as mainstreaming component and the use of **signal flags** to indicate sustainability thresholds, exploring the potential of applying an adaptation of the "Ecological Footprint" concept to the sugarcane ethanol production, as the "Agricultural Footprint".

The final considerations of the deliverable address the main aspects on the prototype development and transferability process, reporting the main advancements and constraints. It is also highlighted the fundamental rule of research collaboration within the project SENSOR-TTC between the European Community' and Mercosur' institutions involved, as well as the financial support. The report seeks to show how the knowledge integration succeeded in the transferability process of Sustainability Impact Assessment and the use and development of Tools for Environmental, Social and Economic Effects of Multifunctional Land Use.

2 Applying the Business domain model in SIAT-TTC

2.1 Application of SENSOR concepts of Impact Assessment into SIAT-TTC Mercosur

The efforts to achieve knowledge comprehension of the SENSOR project concepts and procedures involved the Domain Analysis as part of the methodology to design the software architecture used in SIAT-EU. The domain analysis results into a domain model, which is a simplified, abstract image of reality (Verweij et al., 2008).

The analysis describes notions from the domain and the relations between them. At first, for SIAT-TTC development, it was observed how the domain described the assessment of impacts and sustainability risks of EU land use related policies (Verweij et al., 2008), aiming to identify the transferability potential to the Mercosur.

Policy Case, options and instruments

In the context of EU, Sieber et al. 2008 state that an impact assessment tool allows the evaluation of the motivations and the effects of land use related policies, involving a number of questions: "What are the objectives pursued by the policy? What are the main policy options for reaching these objectives? What are the likely economic, social and environmental impacts of those options? What are the advantages and disadvantages of the main options?" [EC 2005].

According to Verweij et al. (2008), a **policy option** concerns a set of quantified/qualified policy instruments, one of several ways to achieve the objective(s) of a policy [EC, 2005]. A **policy instrument** is the tool of power used by policymakers in order to reach defined goals or objectives. In the study case of MERCOSUR called "Sugar-cane ethanol", the main instrument evaluated is the Agro-Ecological Zoning developed in Brazil to orient the expansion of sugar-cane around the country territory. A **policy case** relates to a policy theme and consists of a description of goals, objectives and the used instruments to reach those goals and objectives (Verweij et al. 2008).

The policy options in the SIAT-TTC Mercosur focused on the following questions: "How Mercosur countries could be more competitive in the exports market for sugarcane derived products and forest industry products? How Mercosur countries might be affected by the Brazilian energy matrix changes and by the expansion of industrial forests in the South of Plata River Basin in Argentina, Brazil and Uruguay? What are the proper economic, social and environmental indicators to reflect these land use related policies impacts? Which regions could present evidences of reaching the sustainability and the human development or, in the other hand, of natural resources degradation levels and people impoverishment?

In Mercosur, the SENSOR team proposed to study two policy cases: Sugar Cane Ethanol and Afforestation. Each one of them has its own proper instruments. The software SIAT-TTC was intended to be applied to both situations. Nevertheless, the studies on the policies related to Forestation and historical land use change data showed that the policies applied in different countries, when existent, varied a lot along the last century, sometimes changing to objectives totally opposed to the previous ones. In addition, at present, integrated land use related policy making in the Mercosur is nonexistent, and the group decided to prioritize a policy case of immediate applicability. Hence, the SIAT-TTC prototype is being applied initially to the Sugar Cane Ethanol case. The user interface application has already some features to the development of a prototype directed to the evaluation of Afforestation policy. More studies are recommended to enable the construction of the data base, which includes variables, indicators, response-functions and knowledge rules, required to build future scenarios driven by Afforestation related policies.

The SENSOR reports acknowledge two kinds of **instruments**: i) direct actions of the policymaker; ii) instruments aimed at influencing people behaviour. In this first phase of SIAT- TTC Mercosur, only instruments that involve direct actions are tested, such as the Zoning restrictions or the prohibition of ethanol plants installation in the sensitive area of the Upper Paraguay River Basin, where the wetlands biome *Pantanal* is located.

Baseline Scenarios

The SIAT performs an *ex-ante* impact assessment of policy impacts. In order to evaluate the impact, they are compared to a situation without the policy instrument application, but under a series of exogenous drivers. This situation is called *Baseline Scenario*: a foreseen future under influence of exogenous development, disregarding the policy option (Verweij et al., 2008). In SENSOR-TTC, we used to characterize Baseline Scenario only two drivers which interfere in land use change and sustainability indicators: population growth and oil price. In order to simulate the Baseline Scenario of land use change for the target year 2018, the rate of land use conversion to the sugar cane crop in the last five years was taken as the future rate, considering the business as usual scenario, i.e., no policy change would be applied to cause a variation in ethanol demand.

Indicators

The reports of SENSOR describe **indicators** as the measurement of the progress towards a defined policy objective (Verweij et al., 2008). Indicators "are tools for communication, evaluation and decision making that can take quantitative as well as qualitative form depending on the purpose of the indicator" [Gallopin, 1997]. Six indicators were selected out of a list (described in deliverable 8.3.3, Turetta et al., 2009, manuscript) to be assessed for their viability of being implemented into the SIAT Mercosur prototype.

The cause-effect relations between policy settings and indicator values depend on the policy case, where the instruments are the cause, and the set of indicators are the effect (Verweij et al., 2008).

All these relations should be represented quantitatively in order to be assessed by the Sustainability Impact Assessment Tool (SIAT).

2.2 Policies in the computational domain and the graphical user interface

After understanding the Impact Assessment concepts, it was possible to apply these notions to the SIAT calculation methodology which is performed in computational domain.

The Baseline Scenario defines the range of values or default for the policy variables related to the instruments (Verweij et al., 2008). The settings are defined by the user who can evaluate different situations of policy cases. It is important to mention that all the possible combination of policy settings and their respective response-functions, indicator function and output variables (land use and indicator variables) should be previously stored in a Data Base. In SIAT-TTC Mercosur, the data base will be stored in a SQL server.

In SIAT-TTC studies, the policy cases were chosen considering the impact of Sugar-cane expansion related to bio-energy policies as well as the continuous growth of afforestation areas for industry. One can observe the policy cases in the user interface screen: Sugar Cane Ethanol and Industrial Forests.

These features and user options are designed in the Graphical Interface using the Adobe Flex. The buttons in the screen, though, are not sufficient to allow full interaction with the end-user. The definition of variables and of the calculations that will be fostered is also required and achieved by the selection of one option or combination of options by the user. In other words, a formal relationship is necessary between the screen control buttons and the software procedures programmed in ActionScript 3.0.

As described by Verweij et al. (2008), the SIAT calculates indicator values which express the impacts of the user defined policy settings. The calculations are performed by models or meta-models.

The simulation models in SIAT are executed previously and a range of policy variable values and the corresponding results are used to define the response-functions (land use change and policy relationship) available in the Data Base system. This data (response-functions) will feed the SIAT-TTC system according to the input of user defined policy options. Each possible user-defined policy setting has its impacts calculated for a preset list of indicators.

The cause-effect relations between policies, land use changes and indicators are established previously through studies carried out by experts and the knowledge is then integrated into SIAT. In the case of SIAT-TTC, as data sets are restrict and several studies are under development, it is important to have an approach that allow a continuous improvement of information and data available in the Data base System as well as of the SIAT-TTC itself. For that, a software engineering approach presented in chapter 5 is proposed to increase the scalability of the SIAT-TTC system and provide the desired improvement of the tool.

In SIAT-EU, a simulation has all the information required to run the models: policy case, policy settings and baseline scenarios, as well as the results previously stored in a SQL-server Data Base System (Verweij et al., 2008). In its first prototype, the SIAT-TTC followed the same approach of SIAT-EU. However, problems in the modelling process using Dyna-CLUE caused gaps in the needed output. Current plans for SIAT-TTC team include further tests of Dyna-CLUE, as well as other modelling alternatives, such as the use of TerraME to simulate the land use dynamics.

The adaptation of SIAT-TTC in Mercosur requested the analysis of the architecture used in SIAT-EU, its advantages and constraints for transferability process and the proposal of new approaches to be tested in order to meet the technical and functional requirements of this region.

3 System requirements

In the SIAT-EU prototype description, requirements were defined as "documented needs of what a particular product should be or do", and described as three types of system requirements: technical, qualitative or functional. The same requirements of SIAT-EU were focused in SIAT-TTC.

3.1 Technical requirements

As the SIAT-EU, the software SIAT-TTC is a web-server application built to run in a browser with the Adobe Flash installed, connected by internet to a SQL server database that will feed the meta-model calculations. Some members of the team had experienced TerraME (www.inpe) and tested the potential of land use dynamic modeling, indicating the possibility of future integration with SIAT-TTC application in order to allow model calculations to be performed by the server as it receives new input of policy settings by the users. Surely this should require the use of a powerful server to enable fast simulations, and alternatives to keep a short response time must be considered as high priority to be tested and implemented.

3.2 Qualitative requirements

Regarding the qualitative requirements, SIAT-TTC aims at the main points focused in SIAT-EU (Verweij et al., 2008): i) achieving a good range of response time; ii) providing scalability to allow enlargement of hardware or software to handle a high demand of processor work due to the increment of users or model calculations complexity; iii) improving flexibility to easily adapt to different situations.

Flexibility: a relevant requirement for transferability

Following the guidelines of SIAT-EU (Verweij et al, 2008), flexibility is defined in terms of easily adding, removing, or changing:

- Regionalization (e.g. cluster regions, countries, states, provinces, micro-regions, departments, censitary regions and counties);
- Policy cases (policy case determines available regionalization);
- Policy case specific policy instruments;
- Indicators (in terms of land use classes, impact indicators and land use functions);
- Symbolizations (e.g. colours in maps for a certain indicator);
- Factsheets (can be associated with any policy case, region, indicator, menu topic);
- Models (translating policy to indicators. Currently response models, and others)

In SIAT-TTC, to expand the flexibility and facilitates the transferability process, a new approach in Software Engineering is proposed.

3.3 Functional requirements

SIAT-EU developed an inventory of functional requirements to describe "what and how one can do with this system", for which some questions were used such as: "i) what type of assessment would you like to do? ii) how do you want to present the results? or iii) how to make assessments transparent; (…)" (Verweij et al., 2008).

For SIAT-TTC, in this first prototype, it was not possible to make such inventory. The team of SIAT-TTC development worked with the current functional requirements, but identified some other requirements to meet the Mercosur institutions needs, such as:

- Possibility of introducing new policy cases, options and functions into the SIAT tool with a minimum need of programming. This requirement should be met by the implementation of the **Adaptive Object- Model Architecture Style**, which will be focused in items 4.2 and 5.2.

- Perform new options of modeling during the processing time. This can be implemented by using the TerraME Modeling Environment. Once triggered by the SIAT-TTC prototype, TerraME should access a SQL server Data Base to run the land use dynamic model with user-defined policy settings, and provide new outputs to the graphical user interface. The interaction between SIAT and TerraME would be possible through the use of OpenMI. This functionality was not tested yet, but it is part of the proposal for further advancements (chapter 9).

Another proposal to meet the requirements of stakeholders for assessing the Mercosur policy cases is by providing a tab with a question form in the SIAT-TTC, a so-called "User Consultation Form", to be filled by users. The SIAT-TTC team should evaluate the requests relevance and rank the most requested functional requirements to be implemented in a priority order.

4 System architecture

The system architecture is the logical construct that defines and controls the interfaces and the integration of system elements (Zachman, 1987, according to Verweij et al., 2008). The SIAT software architecture facilitates the development and maintenance of elements separately, with characteristics such as a loose coupling that increases reusability enhancing the transferability process.

4.1 Layered architecture

The SIAT system uses the enterprise layered architecture, where the user interface, functional process logic, data storage and data access are developed and maintained as independent modules or layers (Verweij, 2008).

This architecture allows the SIAT flexibility which is focused at three main points: i) Data driven; ii) 'plug and play' models; iii) loose coupling of user interface.

The SIAT-TTC team took advantage of the software flexibility which allows easily changes in response functions, indicators and introduction of new data. However, the flexibility is limited for changes in the policy cases, which demands the work of a programmer. To improve the flexibility characteristic of SIAT allowing a larger number of new policy cases, the SIAT-TTC proposes a different approach in Software Engineering, by using the Adaptive Model-Object Architecture Style.

4.2 Architectural elements and proposals for SIAT-TTC

The SIAT system is divided into several elements to be able to reuse isolated functionality and to support the organizational structure of the Sensor project in which different engineering groups are responsible for development and/or maintenance of different software parts. Each element has its own functional responsibilities. The elements of SIAT system are: (1)*SiatGUI* – Graphical User Interface; (2) *Simulation services* – access to the policy cases, land use and indicator functions; (3) *SiatLinkables* – specific model implementation as policy and indicatos functions; (4) *Map Services* – interactive mapping; (5) *SLD services* – symbolization; and (6) *3D landscape images visualization services* (Verweij et al. 2008).

In SIAT-TTC most of the architectural elements were used as in SIAT-EU, except for the two last elements presented, which were not applied in SIAT-TTC, once the phase of prototype development achieved did not required yet the use of the elements responsible for the symbolization per spatial entity and the 3D landscape visualization.

Regarding the other architectural elements, some of their functionalities were adapted using tools as the Adobe BlazeDS and applying the Adaptive Object-Model Architecture Style. Before describing these changes, it is worth to define in general terms these approaches.

Adaptive Object-Model Architecture Style

The Adaptive Object-Model Architecture Style is an alternative to conventional object–oriented design, with the major advantage of easily change the system. Adaptive Object-Model Architecture is considered useful when the system requires constant changes, or if it is desirable to allow users to dynamically configure their system (Yoder & Johnson, 2002). These authors classify this architecture style as one type of "meta-architecture", which is designed to adapt applications to new requirements at runtime by retrieving descriptive information interpreted also at runtime.

An Adaptive Object-Model represents classes, attributes, relationships and behaviour as *metadata*. When willing to reproduce changes in domain, users change the *metadata* (object model) and alter the system's behaviour. This is possible once the Object Model is stored in a data base instead of hard-coded, and the system interprets it. Whenever the object-model has its descriptive information modified, the system behaviour reflects those changes (Yoder & Johnson, 2002).

Adobe BlazeDS

The *Adobe BlazeDS* is an Open Source product (License LGPL v3), correspondent to JAVA server-side technology, which support FlexMessaging and FlexRemoting, with object exchanges between JAVA and ActionScript, Flex and Flash programming tools. These exchanges incorporate data transmission by publishing the methods signature.

BlazeDS makes possible to generate several types of connection channels, highlighting **Data-push** service, implementation similar to the **Observer Pattern** (GoF[1]), performed by the mechanism *Module Loader*, where modules .SWF are carried as one request is done from the *client layer*, for instance, with a click in a menu button.

The module .SWF of Adobe Flex technology has a similar behaviour to a Sun Java Applet technology .JAR module. They use the technique "Code-on-Demand", where executable modules are downloaded from *server layer* to the *client layer* according to the running requirement identified by SIAT-TTC.

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[1] GoF: Software Architecture Pattern GoF, from "Gang of Four", as the authors of "Design Patterns: Elements of Reusable Object-Oriented Software" (1995) become known. They are Erich Gamma, Richard Helm, Ralph Johnson and John Vlissides.

In the BlazeDS philosophy, each class Domain Model class implemented in Java should correspond to an equivalent class implemented in *ActionScript*. This characteristic allows the direct communication between Java and *ActionScript* objects and aggregates the data transmission and the behavior (computational execution) to the client layer.

Due to the increasing demand for creation of new Domain Model classes, the duplication of *ActionScript* classes derived from Java classes becomes more repetitive and time-consuming. To solve this problem, a possible alternative is the use of the *Granite Data Services* library.

The functionality *Granite Data Services Remoting* supports Domain Model classes' serialization. GraniteDS has the tool Gas3 able to generate automatically the ActionScript classes from equivalent Domain model Java classes. The new version 1.1 improves the process by the use of a *plugin* to IDE Eclipse, which generates *on the fly* needed classes in ActionScript whenever the entities of JPA (Java Persistence API) are created or modified in the Eclipse's project. It is necessary only a JPA data model and the *ActionScript* classes created in the *Flex UI layer* are automatically used.

Architectural elements in SIAT-TTC

Taking into account the concepts and tools presented in the last paragraphs, some adaptations of SIAT-TTC are under test within the transferability process linked to the architectural elements:

- *SiatGUI* – Graphical User Interface. Both presentation and application layers of the system had the same development approach used by SIAT-EU. It was required to re-build the SiatGUI to meet the requirements of Mercosur policy cases and data base;
- Simulation services – for this element able to access the Domain Model, the BlazeDS is used in SIAT-TTC to promote a high performance in binary data transmission between client layer and Server layer. The transmission velocity is noticebly higher than textual protocols velocity, such as SOAP or XML.
- SiatLinkables – this element refers to specific model implementations (e.g. response functions). SiatLinkables are candidates to the ***refactoring*** application, aiming to achieve the Adaptive Object-Model Architecture Style to allow new mathematical models to feed the SIAT-TTC through the user interface Flex UI, as well as to meet new functional requirements, such as the introduction *on the fly* of new Policy Cases, Policy Instrument Settings, and Baseline Scenarios, this means, these variations would be put on work in the SIAT-TTC application during its normal functioning, without the need of rebuilding or recompiling the functional modules of SIAT-TTC.

Regarding the element Map Services, it was used by SIAT-TTC with the same purpose as in SIAT-EU: to access the geo-referenced images representing maps, by the use of Web Mapping Service (WMS). By the moment, no structural modification has been proposed to it.

Despite the possibility of each element be located at a different location, for the moment, while the prototype is under development and testing, the systems elements are located in a unique location (SiatGUI, SimulationSevices and SiatLinkables), while the SQL server Data Base is at another one, for organizational and security reasons.

4.3 Element autonomy

The elements characteristic of autonomy allows separated development, maintenance and testing. This is possible because in SIAT, each element has a well defined interface and behaviour.

The elements autonomy facilitates the transferability process, once it makes easier the adaptation of the prototype by the programmer who can change and test each element separately, according to the desired functionality.

4.4 Data persistency

The SIAT-TTC, homologous to SIAT-EU, uses different types of data, which are stored and persisted within different elements using its own optimal solution.

For the implementation of the proposed Adaptive Object-Model Architecture in SIAT-TTC, one of the primary issues is the storage and representation of the model in a database, on other words, how to make models persistent. According to Yoder and Johnson (2002), AOM exposes *metadata* as regular objects, what means that the *metamodel* can be stored in databases following conventional techniques. These authors pointed out Object-Oriented databases as the easiest way to manage object persistence, but consider possible to manage the model persistence using relational database (which is used in SIAT-TTC) or other ways (XML, XMI). They note that no matter how the metadata is stored, the system has to be able to read it and to populate the AOM with the correct configuration of instances.

5 Software Engineering applied to SIAT-TTC

The Software Engineering was applied to SIAT-TTC development in order to enhance the transferability assessment process based on the level of components insulation achieved by the M-V-C pattern (Model – View – Control). The MVC pattern imposes the logical separation of i) the **Model** components, where the Business Rules are located; ii) the **View** components, which are expressed through the GUI (Graphical User Interface), and iii) the **Control** component, which harmonizes the application functioning, as it serves as a mediator between the other components.

The GUI developed in Adobe Flex assumed the format RIA (Rich Internet Application), a software design format which prefers the use of Web Browsers as the structure to express the View component of MVC pattern. This makes the software SIAT-TTC to behave as a Desktop application.

The task of aggregating behaviour to the components designed on the screens and establishing communication to the server where the SIAT Core is hosted is attributed to the ActionScript 3.0 modules.

In order to insert the policy cases chosen in Mercosur to sustainability assessment (Sugar Cane Ethanol and Industrial Forests), the graphical user interface (SiatGUI) was rebuilt by the SIAT-TTC development team within the same conceptual framework of SIAT-EU, presented in the figure 1 (SENSOR, 2008) with the simulation process and required information.

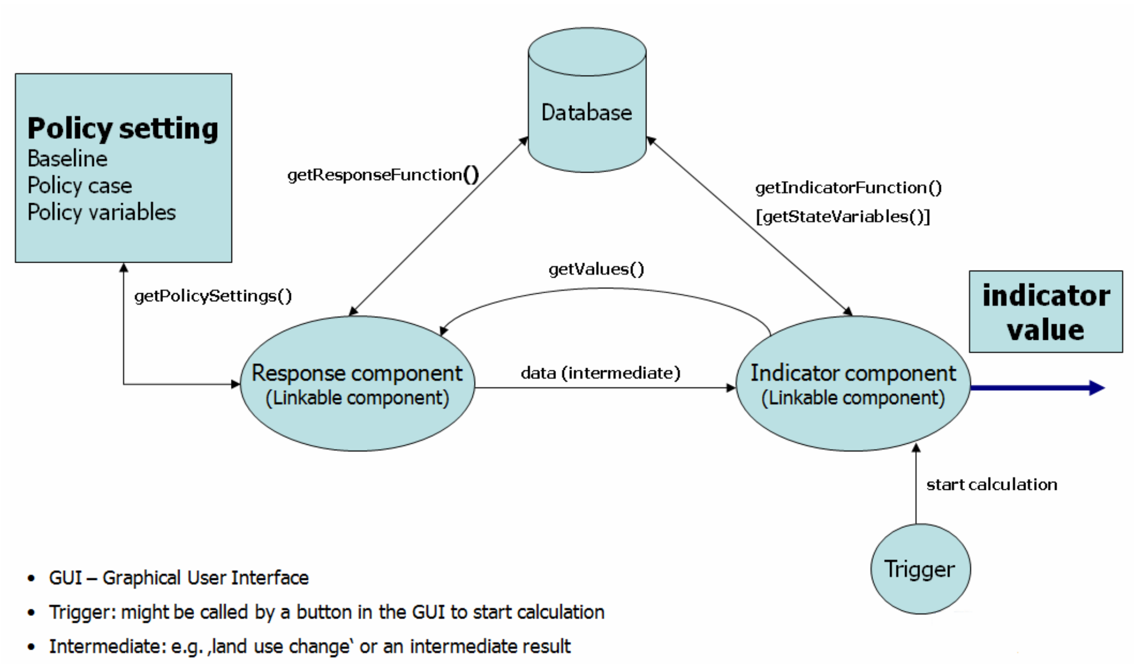


Figure 1– Diagram of SIAT OpenMI mechanism. Source: SENSOR, 2008.

The scenario simulation process to sustainability assessment by end-user in SIAT includes the following steps:

1. The user chooses the Base Line Scenario and the Policy Case among several options listed in the screen. To make possible the SIAT-TTC functioning, it is necessary previous establishment of the relationships between the Policy variables, Land use change and Indicators behaviour. Only after these relationships have been setup, the scenarios simulation will be possible.
2. The user chooses one indicator among the several listed on screen and press the button to trigger the simulation process.
3. The indicator needs intermediate results to calculate the final variables. The intermediate results are obtained from the Response Functions established by region to correlate the policy variable to a defined land use change variable. The response functions for the several regions were previously calculated from the results of Dyna-CLUE multiple runs using a range of policy variable values for all possible combinations of policy options. All response functions should be stored in a Data Base table.
4. Once identified the Response Function that meets a certain combination "region" x "indicator", the simulation is setup with a Baseline ID (Identifier), a Policy Case ID (1- Sugar Cane, 2- Forests) and the values of policy variables from the GUI (Graphical User Interface), in order to calculate the intermediate values that will be the input to the Indicator Function obtained from DataBase through the Indicator ID chosen by the user.

The former paragraph exposed the interaction between the end-user and the SIAT simulations and impact analysis via the Graphical Interface. To accomplish the SIAT-TTC transferability it was necessary rebuilding the user graphical interface aiming at a participatory approach, in order to meet the Policy Cases requirements in different regions, presented by a range of stakeholders. The use of GUI also to promote a participatory assessment of the prototype will be done by mean of the "User Consultation Form" of SIAT-Mercosur GUI to receive contributions to the prototype amelioration (users requirements related to new policy cases and instruments, visualization pattern, different methods of indicator analysis, for instance). In the future, other ways of participation may be implemented besides the "User Consultation Form". To achieve an effective tool to provide to decision makers a useful information on sustainability impacts of land use related- policy, the group intend to reach a good level of stake-holders participation. It is important to integrate within the SIAT-TTC prototype evolving process the contributions of the usual and consolidated research partnerships, but also of other acknowledged stakeholders from all Mercosur countries, such as scientific institutions, farmers associations, societal organizations, local level governments as well as state and national level decision makers. This will be an important step in the transferability process.

The following item describes some technical approaches to improve the transferability process in SIAT-TTC Mercosur.

5.1 Proposals of technical solutions for SIAT-TTC implementation

The current state of SIAT-EU allowed testing the transferability based on the reuse of application core through the libraries of JEP (Java Math Expression Parser) and OpenMI (Open Modelling Interface and Environment).

The meta-model Open-MI was used to facilitate the re-use of the mathematical models, the data structure and the business rules, as well as to make possible the dynamic creation of chains linking Indicator functions and response functions suitable to simulate impact scenarios in each region of study. These chains were created by the *LinkableComponent* Interface (OpenMI). The *IndicatorComponent* and *ResponseComponent* are implementations of the *LinkableComponent*. In SIAT, one Indicator function gives different responses for different spatial regions due to the significance of the variables within the varied Response Functions.

The library JEP (Java Mathematical Expressions Parser) avoided the need of creating different JAVA programs for new sets of Response Functions or Indicator Functions that might be inserted to represent new policy cases and options. These functions are added to SIAT-TTC using JEP which is a Parser to Mathematical expressions that implements features from the *Interpreter Pattern* and *Flyweight Pattern* (both are GoF), aiming to build an Abstract Syntax Tree.

An abstract syntax tree (AST) is defined as a tree representation of the abstract (simplified) syntactic structure of the source code written in a certain programming language. Each node of the tree represents a construct occurring in the source code. The syntax is called abstract because it does not represent every detail apparent in the real syntax.

The "abstract syntax tree" (AST) captures the essential structure of the input in a tree form, while omitting unnecessary syntactic details [1].

JEP: Java Math Expression Parser

JEP library evaluates a mathematical expression, or string, in a two step process: *Parsing* and *Evaluation*, as shown in the figure 2.

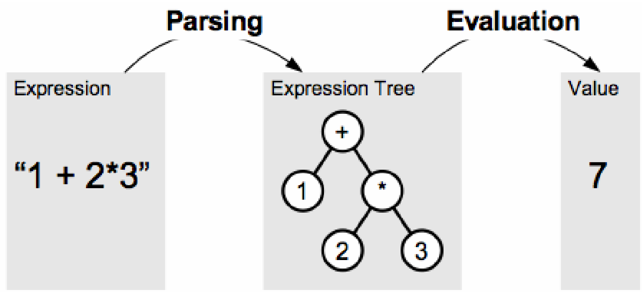


Figure 2 – Singular Systems.

Only after this 2-step process (Parsing+Evaluation) the expression (string) can be activated.

Parsing

The Parsing step aims to read the *string* whose mathematical expression was retrieved from a data base table.

The mathematical *Parser* JEP has the features of an AST (Abstract Syntax Tree), what is confirmed by JEP documentation that describes the objects identification process.

The input to the *Parsing* is a mathematical text with operands and operators, in which the operands may be variables, functions or constants while the output is a tree representation of the expression. This tree representation allows a fast evaluation in the next step.

For instance, the mathematical expression "3+4" written in Infix notation can be translated to Prefix notation, or Polish notation, what turns it to "+ 3 4", what is adherent to a tree organization, according to the figure 3.

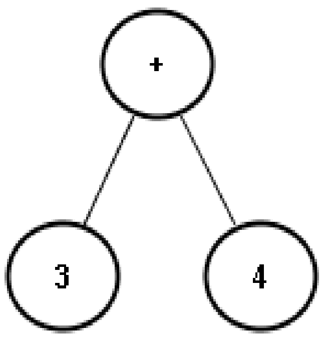


Figure 3 – Polish Notation written within a tree.

Similarly, an Indicator Function may be represented by a mathematical expression, as the following instances: a) (ETc/ETo), used to calculate the indicator variable WRSI in the SIAT-TTC Mercosur, or b) the expression "1-(DEMPTOT/ LABFOR)" used as indicator variable in SIAT-EU (Figure 4):

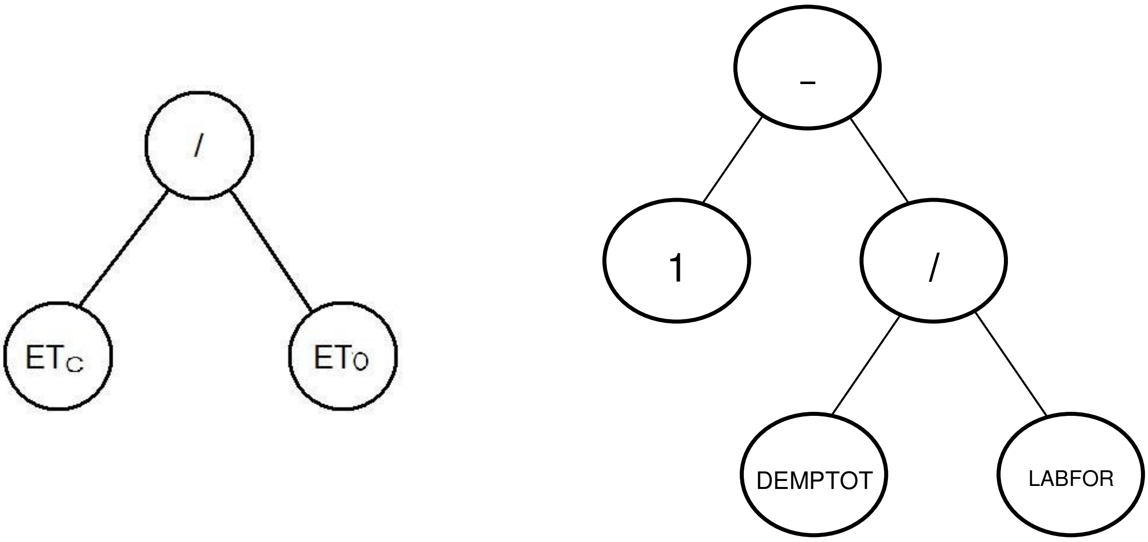


Figure 4 – Polish Notation written within a tree.

The *Parsing* interprets the characters associated to the objects of JEP Parser to make them available in the memory and to allow any processing with these objects.

The *Evaluation* step gives the value of the expression from a tree representation.

Evaluation

After the first step (Parsing), the mathematical expression is represented in the memory as a tree, formed by the objects obtained through the interpreter applied onto the string which is stored in the data base tables. To build the tree in the memory, the "Composite Design Pattern" (GoF) is used.

Once the memory is organized, these objects will be used to evaluate the expression and to obtain the result in such a way that the values are dynamically taken to the tree through special *Nodes* called *Variables*. In order to allow this dynamic transfer of values to the syntax tree, the tree should be built from expressions using *Variables* as the operands.

The format of one mathematical expression that uses Variables as operands is similar to the expression "1-(DEMPTOT/ LABFOR)". The expression is an indicator function where DEMPTOT and LABFOR are two variables whose values are attributed according to the context of use. Within the SENSOR project, these context concerns to the Regions, once there are specific values of variables used as operands in the mathematical expressions corresponding to the functions used in the SIAT simulation process: response-functions or indicator-functions.

These functions are *strings* stored into data base tables that use variable operands and are activated by the SIAT-TTC through the mathematical parser JEP, which applies the parsing and evaluation processes to the strings. The advantage of this approach lays on the fact that is not necessary to rewrite the SIAT-TTC application for every change. The task of activating these functions is on charge of the mathematical parser JEP.

In the SIAT prototype, the data base tables named SENS_RESPONSE_FUNCTION and SENS_INDICATOR_FUNCTION contains, respectively, (i) the policy response functions for each policy option and region in a given policy case, and (ii) the indicator functions in each policy case. In summary, these tables store strings related to the SIAT impact analysis and scenarios simulation.

Module Project

The Software Engineering works to reach new techniques aiming at constant improvement of the software building process, and also concerns on how to maintain the software working properly, given the maintenance requirements of its components.

Page Jones (1988) proposes levels of the cohesion and coupling within the System Structured Project. The System Structured Project consists of transforming the user requirements given by the Analysis process into a "Plan of implementation" through the electronic automation. In this phase, differently form the Analysis, the hardware and software are taken into account, besides their constraints. According to Jones (1988), every implementation aims at the module organization with a low coupling level in order to reduce the chain effect when a module is changed. This avoids the damage of fundamental properties of a module and is important to guarantee software resiliency. The low coupling diminishes the interdependency between modules, which gives them greater functional power, i.e., makes them self-sufficient modules. This is related to the module characteristic of cohesion.

Eric Evans (2004) presents the concept of Domain-Driven Design applied to the comprehension of the domain, where technicians are able to talk to domain experts. The Domain-Driven Design, concerns to the complexity of the Domain where the Model is an abstraction system which describes selected aspects of a Domain and can be used to solve problems using a so-called *Ubiquitous Language*.

The *Ubiquitous Language* is a structured language within the Domain Model, and is used by all team members to improve the communication, an omnipresent language. It is a type of jargon, a set of specific terms used among people that share or develop the same Project. There is a notion that the language is present everywhere in the Project, and it propagates through several media: the source-code, the data base, the textual documentation, or the high semantic level UML diagram-based documentation.

The use of a Ubiquitous Language raises some essential aspects:

- Creative collaboration between Domain experts and software experts;
- Exploration and experimentation, where bad ideas may rise, though the domain exploration is important to the comprehension of the problem Domain;
- Emerging models to elaborate and re-elaborate an *Ubiquitous Language*;
- Explicit context layers;
- Focus on the Core Domain.

Martin Fowler and Eric Evans presented a *Design Pattern* known as *Specification Pattern* [2], represented by figure 5. The greater contribution of this *Pattern* is to promote the Boolean logic insulation applied to the software functioning. This Pattern, combined to other *Design Patterns,* allows the application to be executed according to the logical recorded in the persistent layer, e.g., a data base. In this sense, the Specification Pattern offers some techniques of using Project patterns that facilitates even more the transferability process. For instance, the possibility of building screens in Adobe Flex with automatic tools, allowing the SIAT transfer to other places and application to different policy cases, without hiring new programmers. The strategy facilitates the inclusion of new policy options and policy cases by the model experts, through the storage of new tables in the data base. This procedure is also used to add new functions into the tables SENS_RESPONSE_FUNCTION and SENS_INDICATOR_FUNCTION which store the strings that feed the application as the basis of the simulation process.

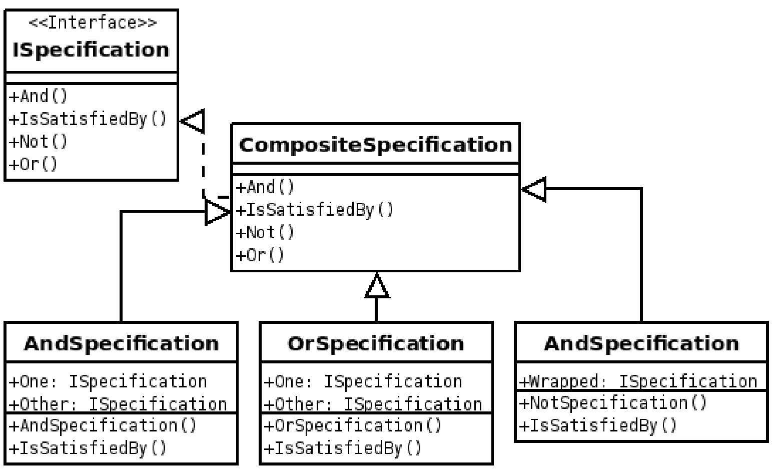


Figure 5 – Diagram of Specification Pattern.

The diagram presented in figure 5 is implemented by the program ***public interface*** `Specification` presented in Appendix A as program A1.

Another instance of the *Specification Pattern* implementation to the SIAT-TTC application is showed by the JAVA hard-coded program A2 called *SuggarCaneEthanolSpecification sugarcane.*

The diagram of figure 6 represents the implemented classes in the solution proposal of the SIAT-TTC.

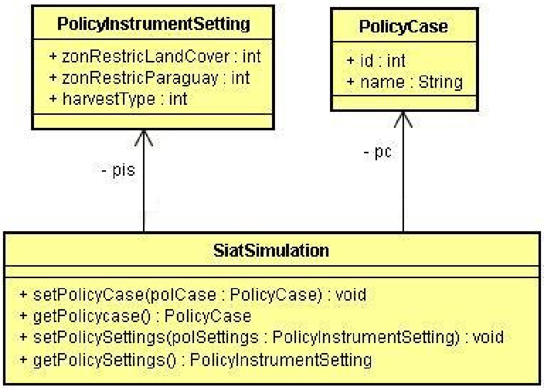


Figure 6 – Diagram of classes in SIAT-TTC prototype.

In a new simulation, two objects are attributed to it. The first one concerns to the *Policy Case* that will be simulated. Currently, two possibilities are pointed out in SIAT-TTC as types of policy case: *Sugar Cane Ethanol* or *Industrial Forest*. The second object concerns to the settings applied to the chosen *Policy Case*. In the example of Sugar Cane, they can be related to the following possible settings:

1) *Expansion Support Level;*
2) *Zoning Restrictions to Land Cover before conversion to Sugar Cane;*
3) *Zoning Restrictions to Paraguay River Basin;*
4) *Harvest Type*

Not all of these settings have already been modeled by the land use dynamic model Dyna-CLUE, but they should be implemented in the future steps of the project. The Chapter 6 describes the input data and parameters used in Dyna-CLUE to model the different options of the policy case Sugar Cane.

In figure 7, the diagram of classes shows the representation of objects and their relationships for the current policy cases and options of the SIAT-TTC prototype. This diagram uses the *Specification Pattern*.

With the Specification Pattern implementation, it is necessary to create a new class always that a new domain is specified, in order to evaluate new policy cases. This makes the transferability more difficult and expensive, once more work is necessary to be done by the programmer.

Another proposal more effective is to combine the Specification Pattern to the Domain Model Pattern.

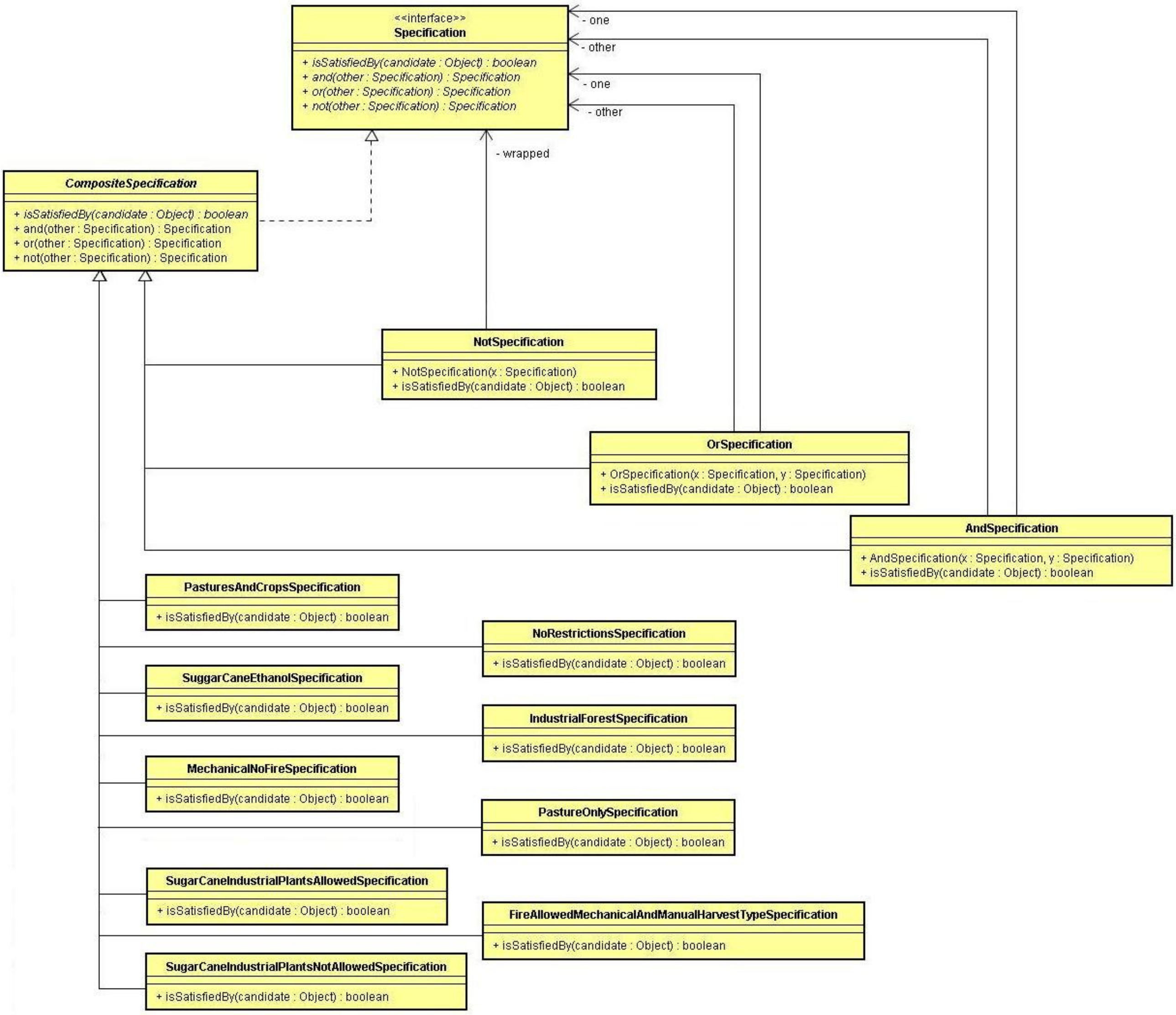


Figure 7 – Diagram of Specification Classes in SIAT-TTC.

Domain Model Pattern

Domain models are used to insulate the business aiming to facilitate the task of dealing with complex rules. This pattern makes the software able to work hardly based in the ***Domain-Driven Design***. The typical approach of the Domain Objects is showed in the diagram of figure 8.

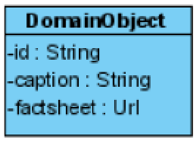


Figure 8 – DomainObject diagram. Source: Verweij et al., 2006.

Verweij (2006) suggests the use of Domain Model Pattern to create subclasses from the DomainObject class, according to the need of new semantics from different Domains (Figure 9):

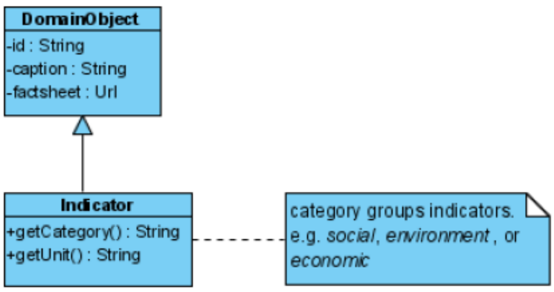


Figure 9 – In this diagram, Indicator is a Domain Object, within the functional logics of SIAT. Source: Verweij et al., 2006.

Following this rationale, the candidates to the Domain Objects in SIAT-TTC are:

- PolicyCase
- PolicyInstrumentSettings
- SiatSimulation
- Indicator
- Region
- Regions

The new semantics into a defined work context is expressed through the Object-Oriented inheritance[2]. Hence, the attributes Id: String, caption: String and factsheet: URL, are inherited by the new classes or derived classes, created to meet new demands of development.

[2] In object-oriented programming, **inheritance** is a way to form new classes (instances of which are called objects) using classes that have already been defined. The inheritance concept was invented in 1967 for the programming language Simula.[1] 1 How Object-Oriented Programming Started – By Dahl and Nygaard

For instance, a new demand for semantic composition is represented by the relationship between a Region and several Regions that should be carried out through the use of Object-Oriented composition mechanism. This example of composition is shown in the diagram of figure 10.

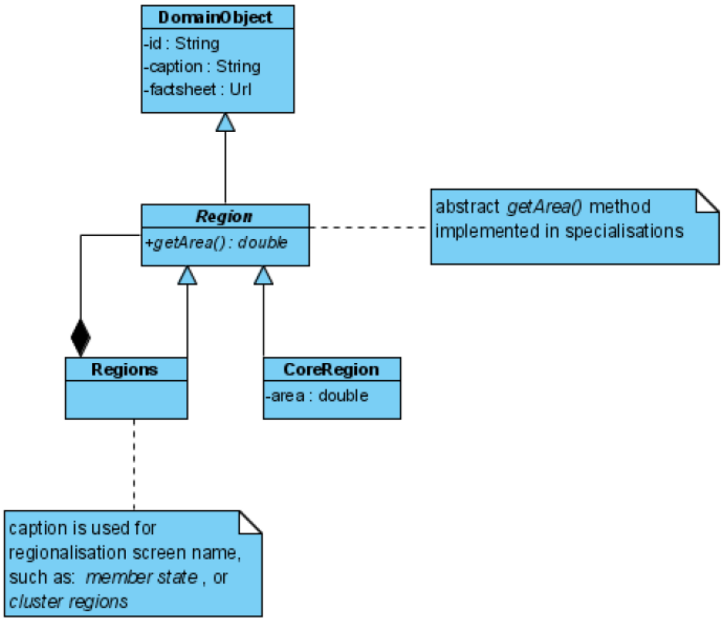


Figure 10 – In this diagram, Region, Regions and CoreRegion are Domain Objects, within the functional logics of SIAT. Source: Verweij et al., 2006.

An effective proposal is the adjustment of Specifications by combining Specification Pattern and Domain Model Pattern, applying ***refactoring*** onto their classes to create a Meta-Specification and a Meta-DomainObject.

Refactoring applied to Specification and DomainObject Patterns

From the former examples of *Specification* and *Domain Model* Patterns implementation, it was identified the need of new classes to derive the objects responsible for the dynamic aspect of SIAT application. For instance, to use current semantics in a *Region*, one should derive a class which inherits from the *DomainObject* class and represents this semantic expression.

Another instance is the need of using *Specification* variations which characterize all logical conditions of the application. One of these conditions is the policy option called *Pastures and Crops Only*, within the possible options to Previous land use to sugarcane crop. It is possible to express this condition only through the creation of a subclass from the Specification class, using the Specification Pattern strategy. This subclass called *PasturesAndCropsSpecification* would make possible the creation of objects which express dynamically its purpose, i.e., the purpose of provide the application state settings to simulate the scenario resulted from the user's choice "pasture and agriculture" to the Policy Instrument Settings. Any other subclasses of *Specification* work like this.

The class *SugarCaneEthanolSpecification* inherits from *CompositeSpecification* and capsulates the logical condition of Sugar Cane Ethanol Policy Cane in the following way:

```
class SugarCaneEthanolSpecification extends CompositeSpecification{
      //(polCase.id == 1) : it means Sugar Cane Ethanol Policy Case
      @Override
      public boolean isSatisfiedBy(Object candidate) {
            PolicyCase polCase = (PolicyCase) candidate ;
            return (polCase.id == 1);
      }
}
```

The need of implementation through the method *isSatisfiedBy( )*, abstract in the superclass *CompositeSpecification*, will return a "true" value if PolCase.id is equal to 1.0 (unit), and "false" if polCase.id is different to 1.0 (unit). By convention, this value was attributed to Sugar Cane Policy Case. Following this guidelines, other *Specifications* obey the *Specification Pattern*, with a new class to each new *Specification*.
The following diagrams of classes in figures 11 and 12 represent programs which are texts created by *Specification* pattern to different classes (*IndustrialForestSpecification* and *PastureOnlySpecification*), showed respectively in programs A3 and A4 of Appendix A.

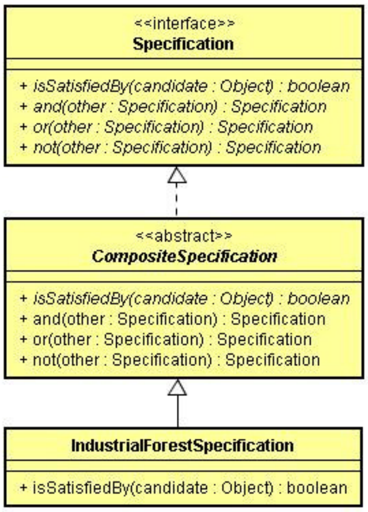


Figure 11 – Diagram representing implementation of the IndustrialForestSpecification.

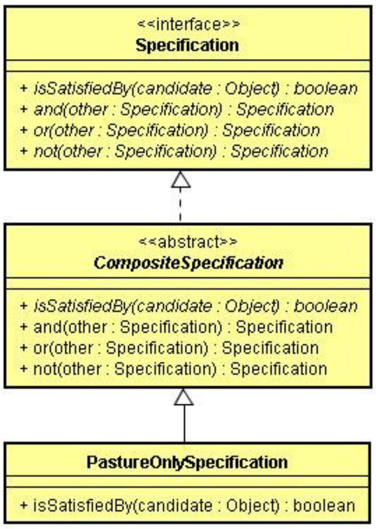


Figure 12 – Diagram representing implementation of the *PastureOnlySpecification*.

In order to consider the utility to SIAT-TTC of the ***refactoring*** process applied to subclasses of *Specification* and *DomainObject*, it should be based on the transfer of responsibilities from the classes dimension to the objects dimension, which collaborate among themselves. In this way, the scalability is not lead by the need of new subclasses creation, condition that suggests an increment of static components, but is lead by the creation pf new classes from the metaclasses. This makes feasible the creation of new *Types* (Interfaces) with the application *on the fly* (during execution), and favor a dynamic approach on the definition of the classes format, of which objects instantiated will enter in execution.

Metaclasses in the Context of SIAT-TTC

A re-adaptation of the Specification class after refactoring creates a new format of building the objects through the following builder:

```
public Specification(   String name,
                        SpecificationUnitPart oneOperand,
                        SpecificationUnitPart otherOperand,
                        String comparator  ) {…}
```

Figure 13 represents refactoring process applied to Specification Pattern and Domain Object Pattern, according to the builder above.

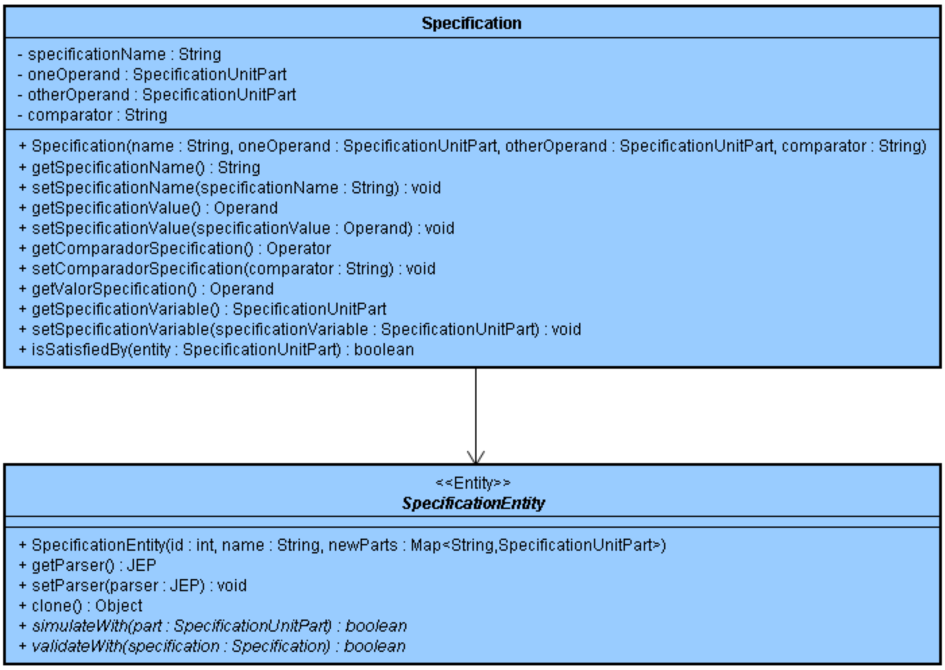


Figure 13 – Refactoring applied to Specification Pattern and Domain Object Pattern.

Supported on this new organization of classes based on the ***refactoring*** of the *Specification Pattern* and the *Domain Object Pattern*, it is possible to build any combinations of Entities and business rules through simple combination of instantiated objects of two classes: Specification and SpecificationEntity. One hard-coded example of this new way of programming is showed in Program A5 of Appendix A, as `Policy Case Specifications`.

In the extract of Java programming text mentioned above, two *Specifications* were created from two distinct variables, each one originated from its own Entity:

```
SpecificationVariable variable1;
Specification conditionOfSugarCaneEthanol;


SpecificationVariable variable2;
Specification conditionOfIndustrialForest;
```

Another possible setting could be two Specifications sharing one unique variable derived from one Entity. This situation occurs for instance, in the entity of one *InstrumentSetting*, presented in program A6 of Appendix A. In this class the objects are always created from the same classes *Specification* and *SpecificationEntity*.

Inclusion of the *Specifications* into the *Parsing* process

The class `PostfixMathCommand` of the mathematical parser JEP offers the opportunity of describing new functions from the creation of subclasses that process the values given to the method **`public void`** `run (Stack`

`inStack) throws ParseException` through parameters pilled in the argument inStack.
The variable called numberOfParameters, defined in the class PostfixMathCommand, establishes the maximum quantity of parameters allowed to pilling and processing.

When a new subclass of **`PostfixMathCommand`** is created, called **`SpecificationFunction`**, it is possible to override (replace) the method **`void`** `run(Stack inStack)`, what allows making the method able to execute the conditional tests of a determined Specification (Figure 14). This causes that objects instantiated through the **`SpecificationFunction`** are identified by the parser JEP as they were new functions to be executed based on the acknowledgement of strings recorded into the Data Base and used by the application SIAT-TTC in the proper moment.

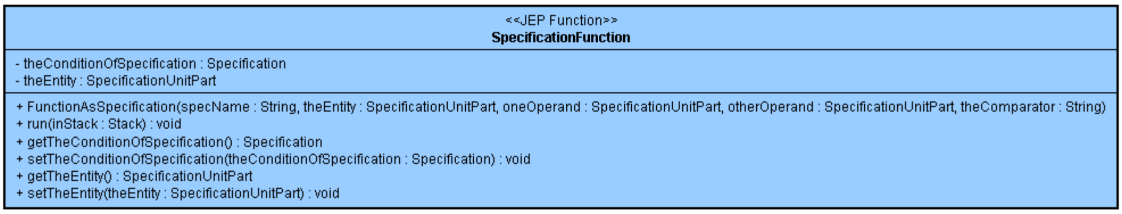


Figure 14 – Example of new subclass of PostfixMathCommand, the Specification Function.

Through a programming text in SIAT-TTC, a new function is made available to the mathematical parser JEP, according to the program A7 of Appendix A called as Factory Specification EntityFactory.getFactory.

This new approach allows overriding the Response Functions with the growing semantics to the functioning of cause-effect structure present in the decision support tool.

Through the manifestation of one Specification Function, which is the Response Function condition encapsulated, it is possible to record the causes in separated table of data base, disregarding the effects (responses) propagated to each region.

According to this rationale, the example of *Response Function* is shown below:

```
if ((FIN_MSUP==1)&&(FIN_RND==1),
   2551.365912+(-44.562396)*FIN_DSUP+FIN_DSUP*(1.511714)*FIN_DSUP,
   0
)+ if(
        (FIN_MSUP==2)&&(FIN_RND==1),
        2566.158514+(-44.666928)*FIN_DSUP+FIN_DSUP*(1.256867)*FIN_DSUP,
        0
)+ if(
        (FIN_MSUP==1)&&(FIN_RND==2),
```

```
        2508.777219+(-0.787763)*FIN_DSUP+FIN_DSUP*(0.932925)*FIN_DSUP,
        0
)+ if(
        (FIN_MSUP==2)&&(FIN_RND==2),
        2520.788297+(0.787715)*FIN_DSUP+FIN_DSUP*(-0.759845)*FIN_DSUP,
        0
)
```

SIEBER et al. (2008) points out that (FIN_MSUP==1)&&(FIN_RND==1) represents one of the several possible combinations and options for selection in the SIAT screen, which varies between:
(a) direct support and market support 'off' / R&D 'off'
(b) direct support and market support 'on' / R&D 'on'
(c) direct support and market support 'off' / R&D 'on'
(d) direct support and market support 'on' / R&D 'off'

When a new `SpecificationFunction`–type object is available to use through the parser JEP, it is possible to override the Response Function above as follows:

```
if (    MarketSupportAs(PolicyInstrumentSetting) &&
        ReinvestmentResearchDevelopmentAs(PolicyInstrumentSetting),
        2551.365912+(-44.562396)*FIN_DSUP+FIN_DSUP*(1.511714)*FIN_DSUP,
        0
)+ if(
        NoMarketSupportAs(PolicyInstrumentSetting) &&
        ReinvestmentResearchDevelopmentAs(PolicyInstrumentSetting),
        2566.158514+(-44.666928)*FIN_DSUP+FIN_DSUP*(1.256867)*FIN_DSUP,
        0
)+ if(
        MarketSupportAs(PolicyInstrumentSetting) &&
        NoReinvestmentResearchDevelopmentAs(PolicyInstrumentSetting),
        2508.777219+(-0.787763)*FIN_DSUP+FIN_DSUP*(0.932925)*FIN_DSUP,
        0
)+ if(
        NoMarketSupportAs(PolicyInstrumentSetting) &&
        NoReinvestmentResearchDevelopmentAs(PolicyInstrumentSetting),
        2520.788297+(0.787715)*FIN_DSUP+FIN_DSUP*(-0.759845)*FIN_DSUP,
        0
)
```

The format above aggregates semantics to the creation of *Response Functions* as the use of *Specification Pattern* shows clearly the conditions which define the response value. However, this format makes difficult future updates of *Response Functions* which accumulate in only one string all combinations of options available for selection in the SIAT-TTC interface.

The example shows four combinations:
(FIN_MSUP==1)&&(FIN_RND==1),
(FIN_MSUP==1)&&(FIN_RND==2),
(FIN_MSUP==2)&&(FIN_RND==1),
(FIN_MSUP==2)&&(FIN_RND==2).

These combinations are strongly dependent on the ternary operator "IF" of the mathematical parser JEP, where the first parameter presents the conditional test done, the second presents returned value if the conditional test results as "true" and the third parameter presents returned value if the conditional test results as "false".

The current organization of Response Functions suggests the only one of the conditional tests can be approved, making the others fail and return a value equal to null (0), where its sum to the response of the approved conditional test does not change the final result in the Response Function processing.

A proposal to improve the format of the *Response Functions* structures is the decoupling of the options' combinations. This is made possible by the normalization applied to the following tables:
- SENS_RESPONSE_FUNCTION,
- SENS_PARAMETER,
- SENS_DEFAULT_PARAMETER_VALUE,
- SENS_PARAMETER_OPTION, and
- SENS_VARIABLEXTYPE.

The current scheme of tables describing the parameters used by a *Policy Case* is shown in the figure 15.

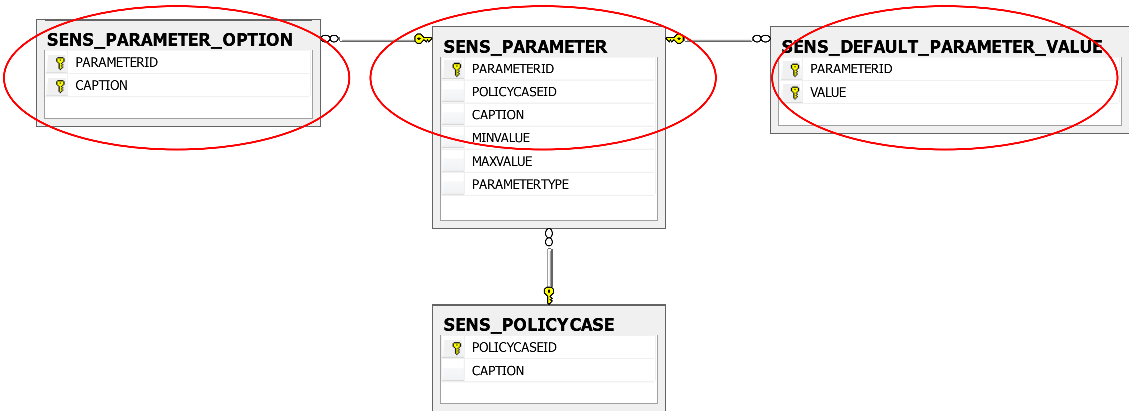


Figure 15 – Scheme of parameter tables for the Policy Cases in current SIAT prototype II.

After re-structuring the SENS_VARIABLEXTYPE table with the new fields variable_type_id and variable_type_description, new records can be created. The table 2 shows contents for the SENS_VARIABLEXTYPE table, which includes identification and description.

Table 2. SENS_VARIABLEXTYPE: identification and description of variable types.

variable_type_id	variable_type_description
1	Intermediate
2	indicator01
3	Parameter

The variable_type_id with value equal to "3" represents a "parameter" variable, which allows using the table SENS_VARIABLE to store also the parameters as variables. This causes the elimination of the other tables currently in use: SENS_PARAMETER, SENS_DEFAULT_PARAMETER_VALUE and SENS_PARAMETER_OPTION, which information turns redundant.

As a conclusion, in the same way the *Response Functions* and *Indicator Functions* are recorded as ***strings*** into data base tables, the *Specifications* of SIAT-TTC application are elements feasible to be recorded into a Data Base and to be recognized by the parser JEP from the consults to the new tables called as SENS_SPECIFICATIONS, SENS_RESPONSE_REGIONXSPECIFICATION, SENS_ENTITY, SENS_ENTITY_BUILDER e SENS_SPECIFICATION_BUILDER.

In this way, each possible combination of options (*Specification*) into the SIAT-TTC screen is stored in a new table called SENS_SPECIFICATIONS and has a SPECIFICATION_ID which represents as showed in the figure 16.

	SPECIFICATION_ID	POLICYCASE_ID	VARIABLE_ID	ENTITY_...	SPECIFICATION_BUILDER_ID	VALIDATION_VALUE	COMPARATOR	DESCRIPTION
1	1	SUG_CANE	ZonRestLC	1	1	1	==	PasturesOnlyAs(PolicyInstrumentSetting)
2	2	SUG_CANE	ZonRestLC	1	1	2	==	PasturesAndCropsOnlyAs(PolicyInstrumentSetting)
3	3	POL_FIN	FIN_RND	1	1	1	==	ReinvestmentResearchDevelopmentAs(PolicyInstrumen...
4	4	POL_FIN	FIN_RND	1	1	2	==	NoReinvestmentResearchDevelopmentAs(PolicyInstru...
5	5	POL_FIN	FIN_RND	1	1	1	==	MarketSupportAs(PolicyInstrumentSetting)
6	6	POL_FIN	FIN_RND	1	1	2	==	NoMarketSupportAs(PolicyInstrumentSetting)

Figure 16 – Structure of the new table SENS_SPECIFICATIONS with description of possible combinations of Policy Options in SIAT-TTC.

Noticeably, the variable ZonRestLC (*variable_id_field*) when compared (*comparator field*) to a value equal to "one" *(validation_value field*) turns to have the significance of *PastureOnlyAs* (***PolicyInstrumentSetting***) (*description field*). This results from the selection of the equivalent option in the SIAT-TTC screen.

The results to a defined Response Function, which varies according to the region, are stored in the field *response_of_function* within the table SENS_RESPONSE_REGIONXSPECIFICATION, as it is showed in the figure 17.

	regionid	specificationid	response_of_function
1	1	1	2551.365912+(-44.562396)*FIN_DSUP+FIN_DSUP*(1.511714)*FIN_DSUP
2	2	1	2520.788297+(0.787715)*FIN_DSUP+FIN_DSUP*(-0.759845)*FIN_DSUP
3	3	1	2566.158514+(-44.666928)*FIN_DSUP+FIN_DSUP*(1.256867)*FIN_DSUP
4	4	1	2508.777219+(-0.787763)*FIN_DSUP+FIN_DSUP*(0.932925)*FIN_DSUP

Figure 17 – Structure of the table SENS_RESPONSE_REGIONXSPECIFICATION, which contains response functions for all possible Policy Options and regions in SIAT-TTC Mercosur.

The new scheme of Data Base tables within SIAT-TTC is synthetically showed in the figure 18.

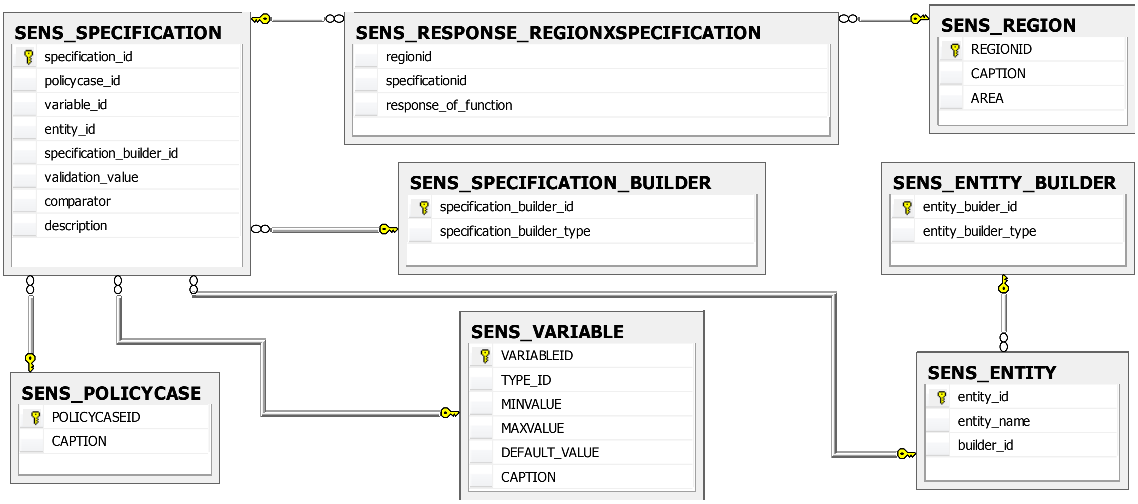


Figure 18 – Scheme of Data base tables in the proposal of SIAT-TTC.

5.2 Adaptive Object-Model Architectural Style

The Adaptive Object-Model [3] is an Architectural Style which keeps the business rules or the Domain Model in the Persistency Layer separated from the source-code. In this style, the application code serves as a “glue” to join different parts of the Domain Model, and brings it to an executable format. The Domain Model is stored in an external Data Base or into XML files. *Adaptive Object Model* can be seen as a type of Domain-Specific Language [4], [5] that relies on the dependency injection [6] to reconcile the application code and the externally represented Domain Model.

The reason for using an *Adaptive Object-Model Architectural Style* [7] is based firstly on the goal of achieving higher resiliency aggregated to the SIAT-TTC application, as well as improving the scalability for the inclusion of new *Policy Instrument Settings*, without loose semantic focus which is very active in the *Domain-Driven Design*. Besides, by transferring this characteristic to the Persistency Layer, it is possible that the inclusion of new *InstrumentSettings* will not require re-adaptation of the GUIs (*Graphical User Interfaces*) in each new transferability process attempt.

TypeObject

The *TypeObject pattern* establishes a way to define dynamically new entities of business in a system (Yoder, 2002). The *TypeObject pattern* is used to separate the Entity from its Type, using a semantic composition between what would be a pair of superclass and subclass, i.s., it should abandon the inheritance mechanism of Object-Orientated Programming.
The figures 19 and 20 present two comparative classes’ diagrams using respectively the *DomainObject pattern* and the *TypeObject pattern*.

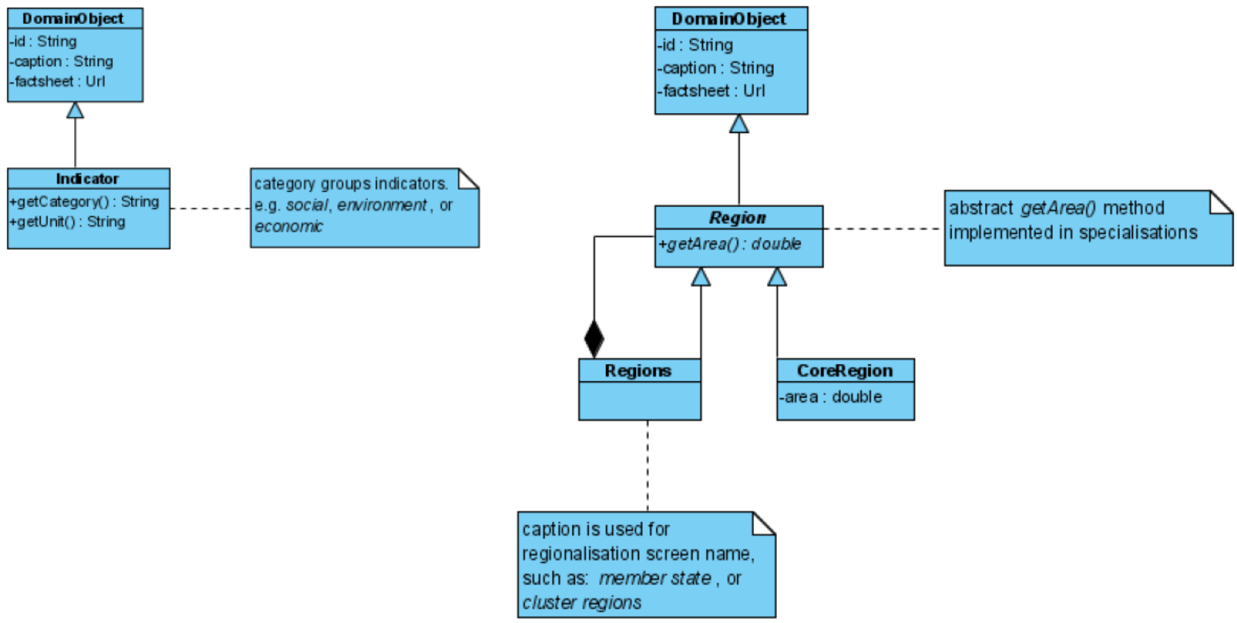


Figure 19 – Diagram of Classes with *DomainObject Pattern* Architecture Scheme.

The use of *DemandObject Pattern*, required the use of five classes only for the current demand of SIAT. With the implementation of *TypeObject Pattern*, only two classes were needed to any demand of new variables, functions or options.

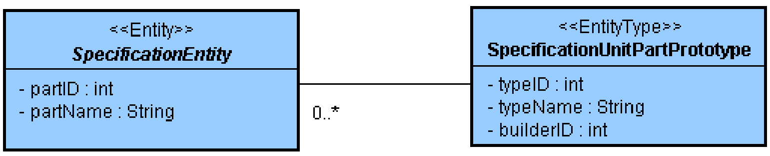


Figure 20 – Diagram of Classes with *TypeObject Pattern* Architecture Scheme.

Due to the need of manipulate composite entities, it was applied the *Composite Pattern* (GoF) to allow simple entities as well as composite entities have a standard treatment with transparency in the SIAT-TTC.

The classes *SpecificationUnitPart, SpecificationVariable*, *SpecificationEntity*, *SpecificationEntityLeaf* e *SpecificationEntityComposite* , when joined, allow their instantiated objects form a tree based on the combination of various entities, able to validate the values of variables, as well as to apply the necessary simulations (Figure 21).

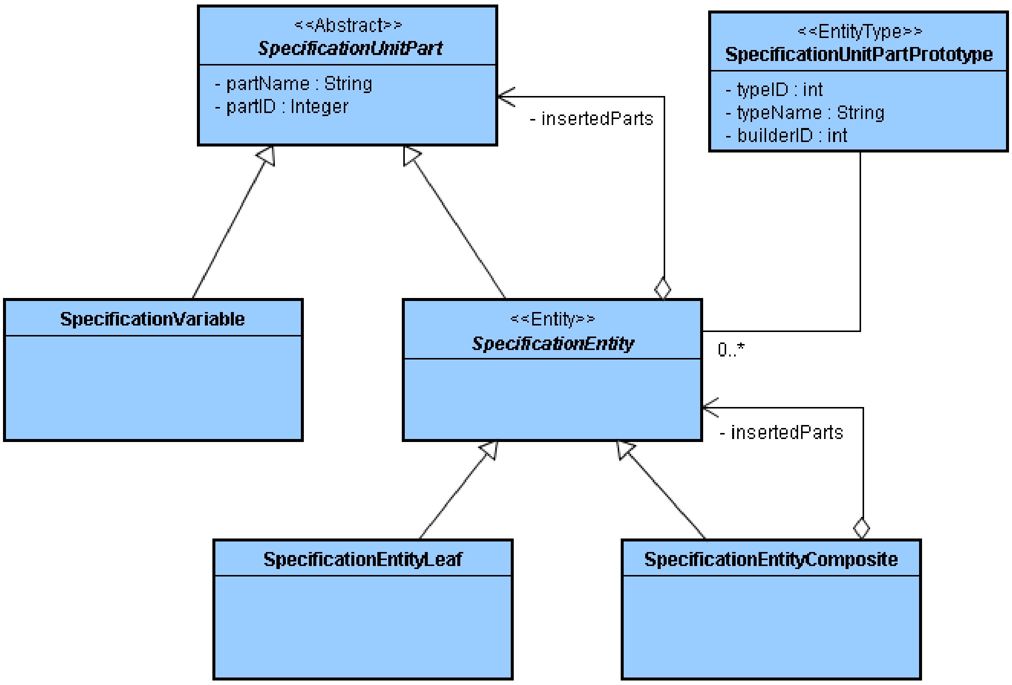


Figure 21 – Use of the Composite Pattern (GoF) to manipulate the combinations between entities.

In the opposite direction of dynamic languages or dynamic types as Python [8] and Ruby [9], Java is considered a static language or static type-based language, where is necessary to establish the *Types (Interfaces)* before the compilation and the execution of application. Then, the *Prototype Pattern* (GoF) is used in Java to mimic the functioning of a *metaclass* mechanism, present in dynamic languages, where the first object instantiated from a class is considered a prototype of the objects created later on.

The following objects are clone from this first instantiated object that makes possible a considerable increment of application performance, because the cloning of objects occurs in the memory. The method used to the objects cloning is the method `clone()`, inherited from the superclass *Object* and overridden in the subclasses of *SpecificationUnitPart* (Figure 22).

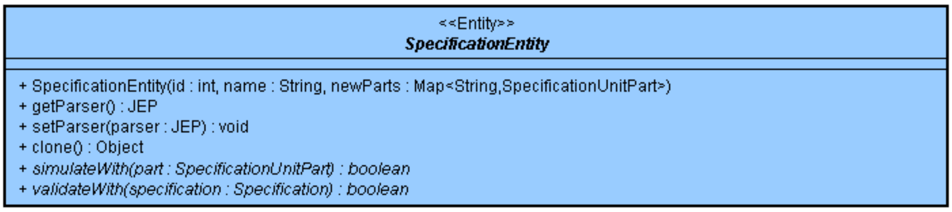


Figure 22 – Overriding of Method `clone()` inherited from the superclass *Object*.

Facing these several ways of building entities, which may vary between simple entities and composite entities, the opportunity of using Builder Pattern (GoF), makes possible to build Entities Objects in a standard way (Figure 23), independently on the composition degree, through the use of the polymorphic methods:

- buildScale(id : int, name : String) : void
    - Defines if a *Leaf* or a *Composite* will be built
- buildChildren(newParts : ArrayList<SpecificationUnitPart>) : void
    - Builds the parts of a *SpecificationUnitPart*. For a Simple Entity, the built parts are variable. In the case of a Composite Entity, the built parts are other Entities, either Simple ones or Composite ones, recursively until complete the bulding of a tree with various *SpecificationUnitParts.*
- getResult() : SpecificationUnitPart
    - Obtains the result from the sequential execution of both previously cited methods, of which format describe a tree with various *SpecificationUnitPart.*

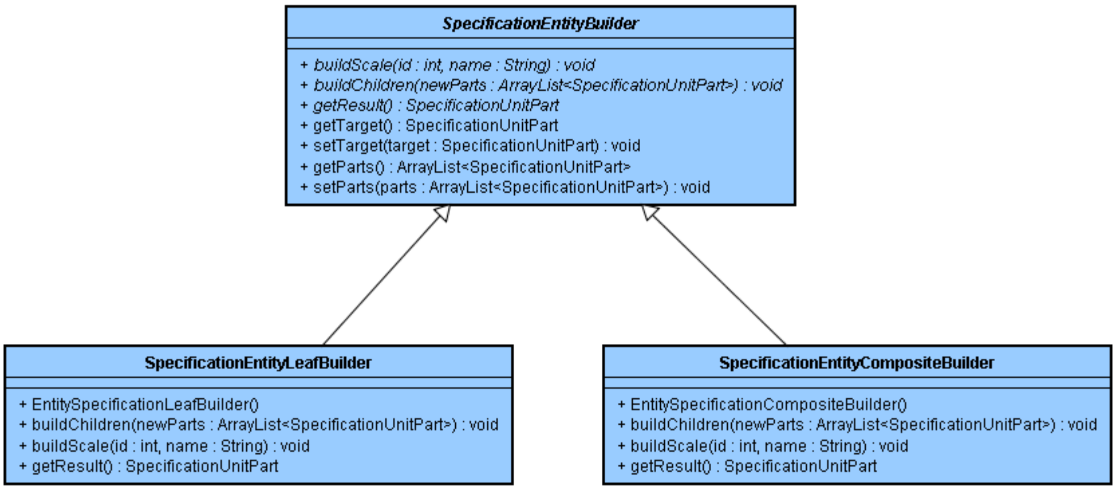


Figure 23 – Diagram of classes in a scheme using the *Builder Pattern.*

6 SIAT-TTC Graphical User Interface: end user interaction with policy settings and scenarios

The Graphical User Interface (GUI) is the media through which the end user interacts with the SIAT system to assess the impacts of land use related policies on sustainability. As a user-oriented tool, the application GUI is designed to allow the user understanding and manipulating a defined group of Drivers, i.e., the settings of policy instruments evaluated by the SIAT-TTC scenarios simulation system.

There are two possible policy cases to choose in the SIAT-TTC prototype (Sugar Cane Ethanol and Industrial Forest). This chapter shows the GUI screenshots and describes how it represents the policy case "Sugar cane" chosen for scenarios simulation in this first SIAT-TTC version and the way by which the user interacts with the application to select policy options. The Industrial Forest policy case is under development.

Despite the non-existence of a common land use policy applied to all Mercosur' countries, facing the growing demand for biofuel and the need of alternative energy sources, the South American nations governments have been discussing in regional forums some common goals as well as evolving national policies, as to promote the development of biofuel production, considering Latin America's potential as a great supplier of this kind of energy (Masiero and Lopes, 2008). Box 6.1 offers an overview on Biofuel and Ethanol policies in Mercosur.

6.1 The Ethanol Sugar Cane Policy Case: policy instruments and options

The possible policy settings available to the end users to simulate scenarios in the Sugar Cane Ethanol policy case derive from the combination of options related to different policy instruments. The objectives and target-groups vary according to the kind of instrument and the policy objective chosen.

It is important to highlight that the Brazilian National Plan of Agroenergy (2006) intends to promote the sugarcane expansion guided by paradigm of the sustainable development (see Box 6.2). Hence, the application of the instruments presented bellow should support both objectives, or meet the purposes of one objective without be a barrier to the other's achievement.


Box 6.1. Energy policies in Mercosur to develop a Biofuel Market: advantages and constraints.

Latin-American nations are seeking to build regulatory and financial infrastructure to the emerging biofuel industry. Brazil has signed partnership agreements with some of these countries aiming at technology transfer and cooperation in biofuel production and trading. Argentina has a great expectation on expanding biofuel production and aims to diversify the energy matrix, and has invested in technology generation and inner market formation for mixed fuels. Paraguay's agrarian economy makes the country a candidate to develop biofuel industry. The mixture of 24% ethanol in the petrol is compulsory and there are 15 new projects developed by the government to produce biofuel. Uruguay's energetic policy is highly integrated to the other Merocsur' countries, an the government has promoted the industry through the National Comission of Biofuel and the National Programa of Bio-ethanol (Pronabio-E). The agricultural capacity, the need of oil-dependency reduction and the generation of rural employment are factors that incentive the biofuel industry development in Uruguay.

The configuration of a global Biofuel market shows that the main producers should be the Latin-American countries, while the Asian nations tend to be the great biofuel consumer market.

Examining this Biofuel Market in formation, governments and internationals banks hail the advantages of biofuel market to the developing countries, such as the improvement of rural life quality where technologically advanced industries are installed and the reduction of energy vulnerability in small economies, which are totally oil dependent, there are also a list of criticism regarding the negative impacts of biofuel expansion policies.

The major critics highlight the environmental issues, such as deforestation, the Food Security and work exploration in extense monocultive areas. Also, they throw light to the low contribution of biofuel to diversify energy matrix.

The actual bioenergy potential can be used with sustainability by making an important change in current policies: priority should be given to research not only in technology development, but also to input costs and availability. Nowadays, the biofuel cannot compete with oil without subsidies. The land required to biofuel crops is a limited resource in most of countries, and can compete with food supply and reduce water supply, which is an increasingly scarce resource around the planet.

Source: Masiero & Lopes, 2008.

In the policy case of Sugarcane Ethanol, based on the fundaments of National Program for Agro-energy (PNA, 2006; Monteiro et al. 2009), summarized in the Box 6.2, two main policy objectives are aimed by the application of policy instruments assessed in the study:

- ✓ the **expansion of Sugarcane Ethanol production**, related to the Brazilian Policy of Biofuel Production;

the **conservation of environmental services and multifunctional land use**, related to the Environmental Policies which comprise a range of environmental conservation regulatory laws, based on Federal Constitution, the Forest Code, the Water Resources Policy Law, and regulatory decrees.

The policy scenarios available in SIAT-TTC are simulated to the target-year 2018. This was conditioned by the Government goals and projections to the Sugar Cane Ethanol Sector expansion given to this same period (PNA, 2006).

Box 6.2. Brazilian National Program for Agroenergy

The National Program for Agroenergy Production is oriented to achieve the following general goals:

- ✓ Supporting the renewable energy production increment in the Energetic Matrix.
- ✓ Inducing the regional development, based on agriculture expansion and the value aggregation of productive chains.
- ✓ Fostering the employment expansion and the agribusiness income increment.
- ✓ Providing Food Security and Energy Security to the communities.
- ✓ Optimizing the use of human-modified and degraded areas.
- ✓ Coping with the Environmental Law, being integrated to the sustainable development goal;
- ✓ Reducing oil imports and increasing the biofuel exportation rates.

Source: National Plan of Agroenergy (PNA, 2006). Available at: http://www.agricultura.gov.br/pls/portal/docs/PAGE/MAPA/PLANOS/PNA_2006_2011/PLANO NACIONAL DE AGROENERGIA 2006 - 2011-INGLES.PDF

In order to achieve the goals of National Plan for Agroenergy, a group of policy instruments were designed and some of them were selected to be assessed in the SIAT-TTC. These instruments presented in the SIAT-TTC GUI have options or variables related to the objective perceived, as well as defined target-groups. For land use change modeling purpose, these instruments can be divided in two groups, according to their scope and form of representation in the model system.

The first group refers to spatial restrictions, and comprises the application of the Agroecological Zoning and other regulatory means based on areas exclusion. The second group of options is linked to the application of constraints in previous land use class for conversion. The chapter seven explains how each instrument is represented by the model. Another kind of instrument is related to variables that affect the level of land use claims, such as the financial support to ethanol plants. This variable was not tested yet in the land use change modeling application within SIAT Mercosur.

The following items describe the instruments available in SIAT-TTC GUI, pointing their objectives, target-groups and reasoning.

a) Sugarcane Agroecological Zoning

This is an orientation instrument, which should support both objectives (sugar cane expansion and environmental conservation). The agro-ecological zoning should point the priority areas for sugarcane cropping and sensitive areas that must be protected. This instrument aims different target-groups:
i. the farmers, which will use the Zoning to make decisions on the crops;
ii. the ethanol sector, that should follow the results of Zoning to allocate new industrial plants or expand the current ones;
iii. the Governmental Financial Sector, that should guide the Credit Support to ethanol industrial plants and to the farmers according to the Zoning, locating the investments in the more suitable areas.

b) Banning the pre-harvest burning

This is a possible repairing instrument, related to the environmental conservation, but also to the sustainable development of the Sugar Cane Ethanol Sector aimed within the Biofuel Expansion Policy. Despite this is not implemented yet, there are discussions of the importance for maintenance of the air quality, human health and natural ecosystem conservation due to the risk of fires. In the Cerrado region, during the drier period of the winter (usually from July to August), the burning is usually forbidden to avoid fires in wildlife areas.

The pre-harvest burning is related to the manual sugar cane harvest done in areas where the mechanical harvest is not possible. It should be highlighted the heavy social impact of pre-harvest burning, due to the hard seasonal work of sugar cane manual harvest, besides the harmful smoke damage to the human health and the greenhouse gas emissions.

The Agroecological Zoning provides an indicative to the sugar cane crop being cultivated only in areas suitable to mechanization, i.e., areas with slopes lower than 12%, where the burning is not needed. This could eliminate the pre-harvest burning of the manual process, by mean of an orientation instrument, the Agroecological Zoning, which considers areas with low slopes more suitable to the sugarcane cropping, and consequently able to receive financial support to sugarcane industrial plants.

The target-groups of these policy instruments (burning prohibition and agro-ecological zoning limiting suitable areas to less than 12% slope zones) are:
i. the sugarcane cropping farmers who should change their harvest system;
ii. the ethanol industrial sector, that should locate the ethanol plants close to areas considered suitable to the harvest mechanization.

c) Protection of sensitive areas by banning the presence of ethanol industrial plants: the case of Upper Paraguay River Basin

This policy instrument has clearly the main objective of environmental conservation, but is also related to the sustainable development of a given region. The prohibition of sugar cane ethanol plants within the area of The Upper Paraguay River Basin was an important decision in the 90's to avoid the rapid agriculture growth to be a thread to the Pantanal region, which is a fragile ecosystem of wetlands.

The policy instrument currently in use, a CONAMA regulatory decision, has a fragile permanence and may be changed depending on the forces relation between the environmentalists and the rural producers, which play traditionally antagonist rules in the political scene.

The Agroecological Zoning is a valuable tool to help identifying sensitive areas where the sugarcane cropping or the Ethanol plants should be prohibited, within or out of the Upper Paraguay River Basin.

The target-groups of this kind of policy instrument are:
i. the farmers, who should select their crops based on this limitation;
ii. the ethanol industrial sector, that should locate the ethanol plants out of the sensitive areas.

d) Allowance of sugarcane crops according to the previous land use

This instrument is only a possibility related to the perspective of discipline the sugar cane cropping to maintain the multifunctionality of land use. The purpose is linked not only to environmental conservation, but also to the sustainability of ethanol production and food security.

Although there are no current policy instrument related to this purpose in the State of Mato Grosso do Sul, there are areas where the conversion of natural vegetation to pasture or agriculture is fully prohibited. This is the case in the Atlantic Forest Biome, due to the great devastation it has been submitted for centuries.

In this policy case, the options presented for this instrument are: a) previous use of only pasture; b) pasture and agriculture as previous use; and c) no restriction of previous land use.

This instrument would force the target-groups to take into account the current land use before decision making regarding:
i) the establishment of a new sugar cane crop area by the farmers;
ii) the investment on installing a new plant by the ethanol industrial sector.

e) Financial support to sugarcane ethanol plants

The financial support can be considered an awarding instrument to promote the expansion of ethanol production, and the target-group is clearly the Ethanol Industrial Sector.

The amount of investment from the government to the industrial ethanol sector is a policy variable that affects the land use claims for sugar cane cropping, in the SIAT-TTC. Hence, the sugar cane crop area demand estimates were based on the targets of investment into the ethanol sector planned by the Brazilian Government. The policy instrument called Expansion support express the level of financial support to the Ethanol Industrial Plants that affects the total land use demand for sugarcane crop.

The combination of options related to the instruments above is done by the end user through the SIAT-TTC Mercosur GUI. The item 6.2 describes how the users will select their choices navigating through the screenshots.

6.2 SIAT-TTC Graphical User Interface: interacting with policies via screens

The use of the Sustainability Impact Assessment Tool SIAT-TTC initiates with the definition of the policy to be evaluated by the end user.

The policy cases are represented in the screenshot of SIAT-TTC GUI showed in figure 24. The choice of the policy case is the first step of policy definition procedure by the end-user.

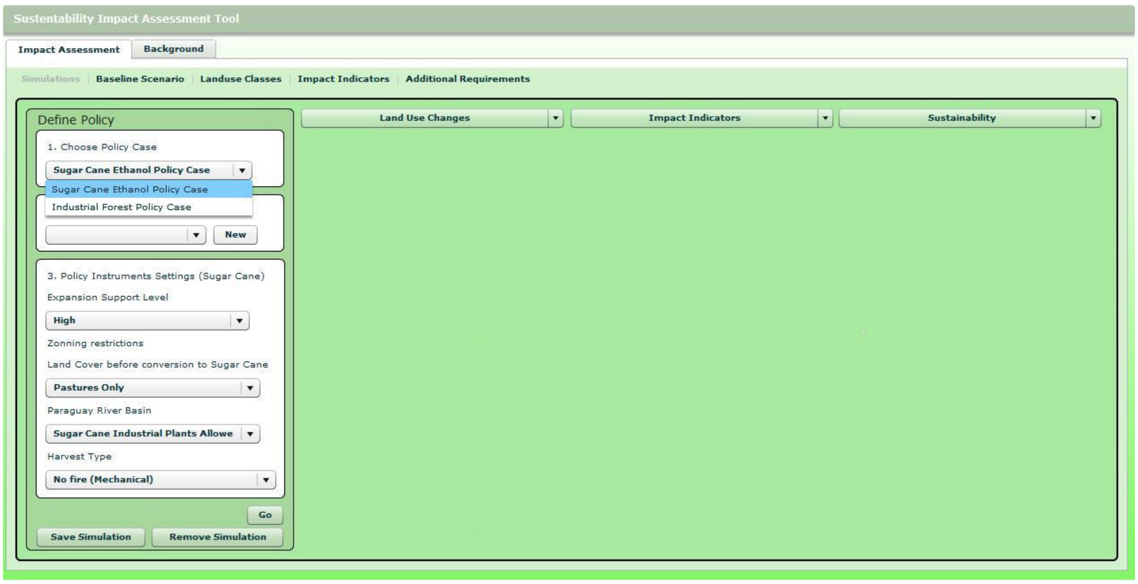


Figure 24 – Screenshot of SIAT-TTC prototype: first step in the policy case definition.

The graphical interface consists of two main tags labeled as "Impact assessment" and "Background". By accessing the first one, the user is able to choose some previously designed policy settings to assess its effects on the land use changes, the impact indicators in multiple scales and integrated responses on sustainability. The "Background" tag is under construction and contains synthetic descriptions of the knowledge integration and analysis methodologies applied in the transferability process of SENSOR project via the SIAT-TTC development. The "Impact assessment" tag has a set of sub-tags. The first one, "Simulations", is where the user interacts with the tool to define the policy settings and to assess diverse policy impacts. The user should be able to visualize the Land Use changes and the impact indicators behavior in the units of the Spatial Reference Framework, as well as an integrated sustainability indicator analysis associated to thresholds in the Mercosur' context. The last methodological approach is under construction and the basic concepts and assumptions are referred in the chapter 8.

There are also sub-tags where summary reports should be inserted as information or fact sheets, in order to ensure transparency and traceability, as highlighted by Sieber et al. 2008. The information sheets of Impact Assessment tag contain descriptions of: i) Baseline Scenario; ii) Land use Classes and iii) Impact Indicators. One other tag is available with a form with multiple choice questions regarding "Additional Requirements", which can be filled by the users and provide information to continuous improvement of the tool.

The screenshot showed in figure 25 highlights the possibility of choosing different levels of financial support to the Ethanol Industrial Plants, what will influence the and land use claims for the sugar cane cropping. The option of no support refers to the baseline condition, i.e., the business as usual growth rate of sugar cane cropping area, with no Governmental financial investment to support Ethanol Industrial Sector.

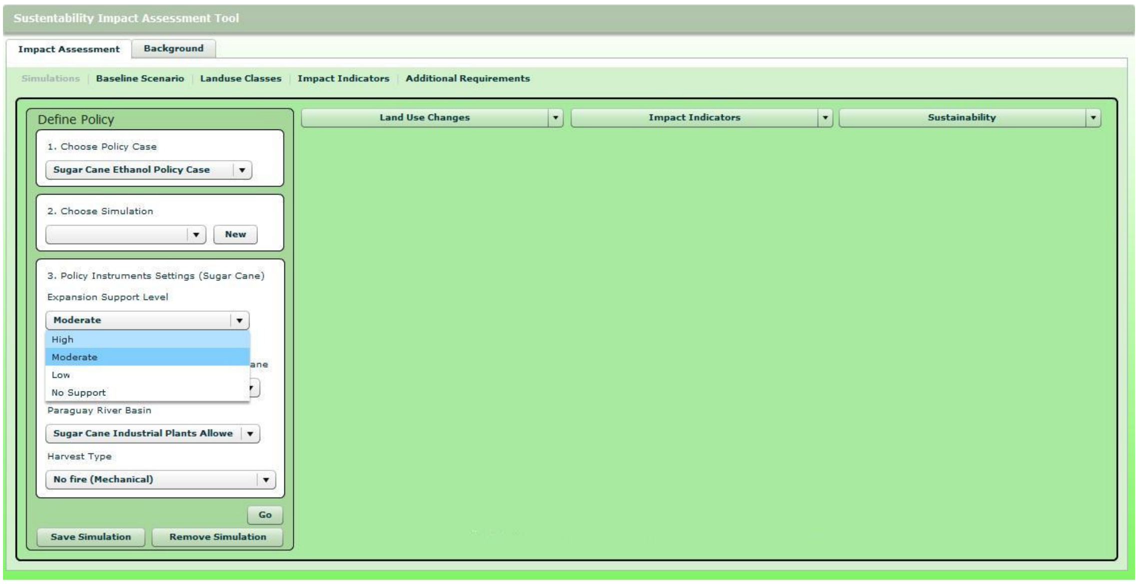


Figure 25 – Screenshot of the Sugar Cane policy case: Levels of Financial Support to the Ethanol Sector expansion.

The screenshot in figure 26 refers to the different possibilities of previous land use class. The user may choose to evaluate the land use change impacts if sugar cane cropping is financed in three different situations: i) only on previously pasture-covered areas; ii) only on previously cropping- and pasture-covered areas; and iii) with no restrictions related to the previous use.

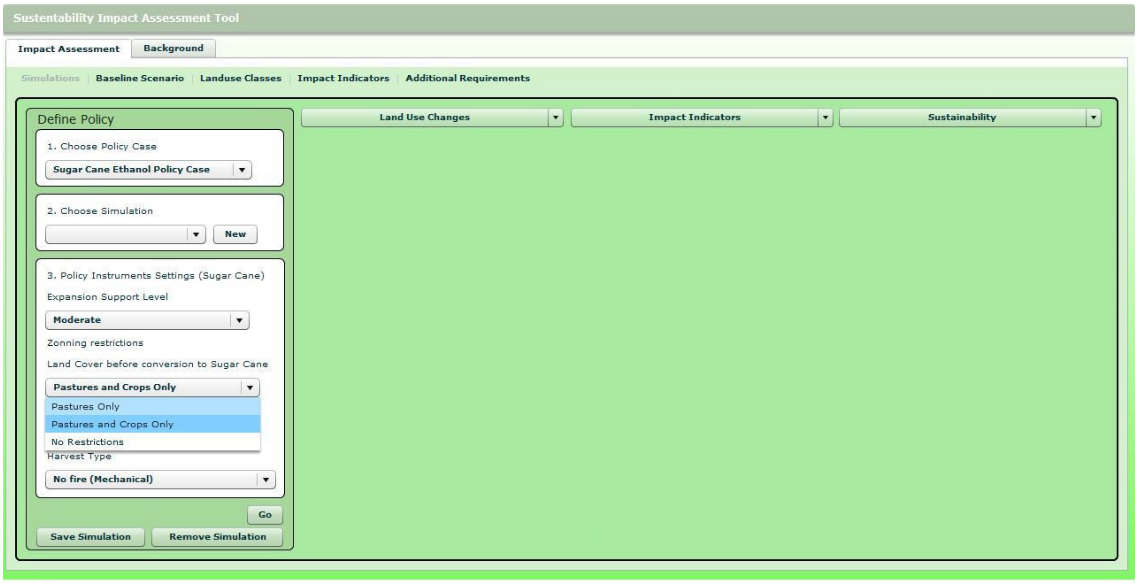


Figure 26 – Screenshot of the Sugar Cane policy case: Agroecological Zoning restrictions related to the previous use.

Another option for the end user choice is related to the maintenance of the Upper Paraguay River Basin as an area free of Sugar Cane Ethanol Plants, once their installations are prohibited in the basin to avoid damages into the fragile ecosystem called Pantanal (Figure 27).

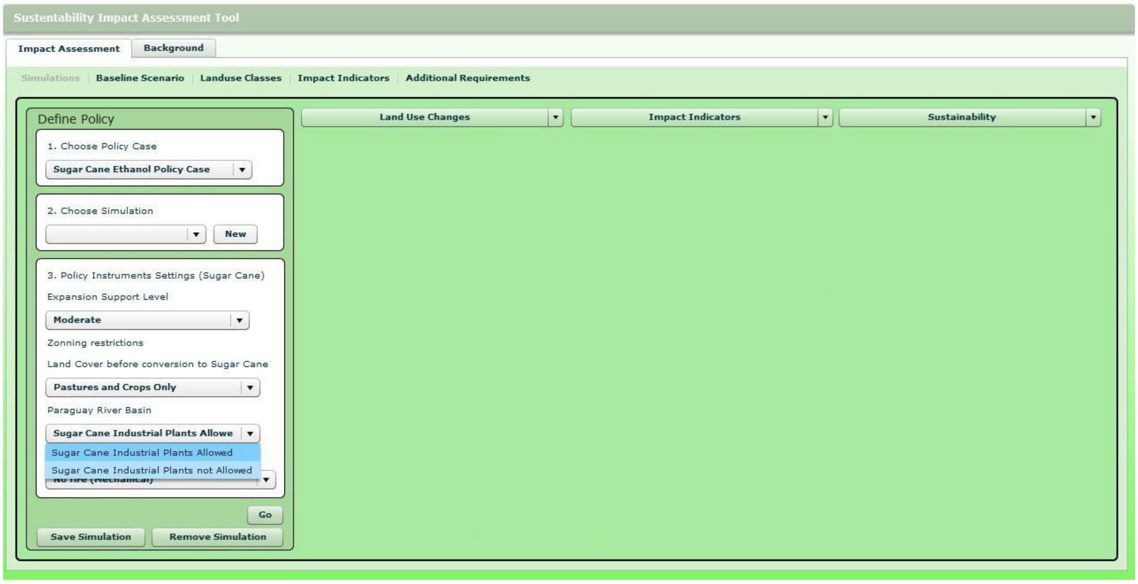


Figure 27 – Screenshot of the Sugar Cane policy case: maintenance of the prohibition of Sugar Cane Plants in the Paraguay River Basin area.

The screenshot of figure 28 shows the options of harvest type that is linked to the use of burning before manual harvest. Only areas with slopes lower than 12%, which allow agricultural machinery, are considered to be used for the sugar cane cropping expansion in the first choice available in the screen, what is mandatory if the pre-harvest burning is prohibited by environmental laws. Currently, the pre-harvest burning is permitted, with exception for a very dry period of the year, usually around three months, according to the weather conditions. Social and environmental pressures to prohibit the burning are growing, due to the severe effects on the atmospheric pollution, besides the fire risk.

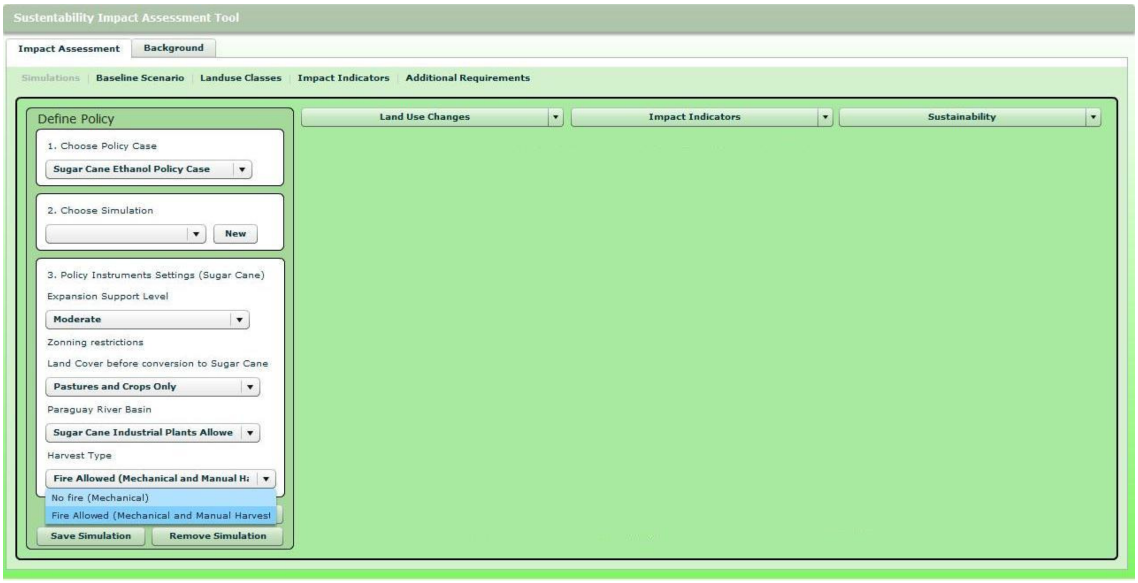


Figure 28 – Screenshot of the Sugar Cane policy case: Pre-harvest burning prohibition in the state of Mato Grosso do Sul.

There is a button labeled as "GO" in the low part of the left side of the screenshot. After choosing the settings for the policy to be analyzed, the user will trigger the SIAT simulation process by pressing the button "GO". In this moment, the meta-model SIAT-TTC initiates the procedures of retrieving data from Data Base System to run the calculations.

Options to visualize scenarios simulation

Then, the user should choose the visualization mode of the simulation results to the year 2018. The first part of scenario simulation is related to the land use changes driven by the policy options and calculated using of Dyna-CLUE model. The basic parameters and procedures used are described in the chapter seven, as well as examples of simulation outputs.

a) Land use change

This step of the impact assessment by the user, related to the land use change modeling, is showed in the screenshot of the figure 29. In order to evaluate the land use change model results, the user should select: i) the way one wants to see the impacts, if by graph, map or table; ii) the spatial scale (Microrregion and Ecorregion, under construction); iii) the regions where one wish visualize the impact results; iv) the variables related to land use (the land use classes).

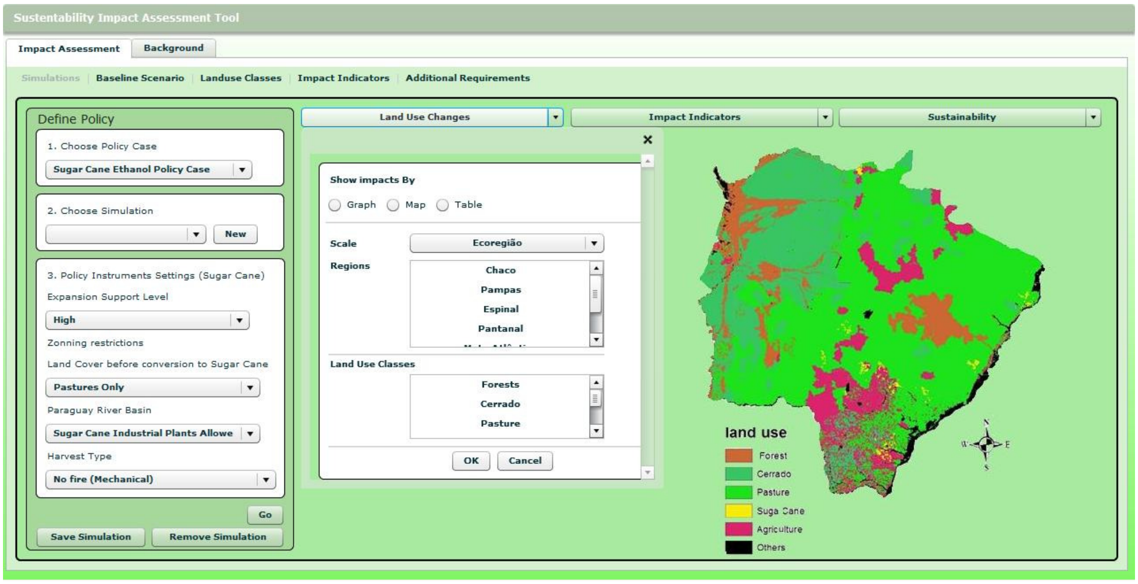


Figure 29 – Screenshot of the Sugar Cane policy case: Land Use Change analysis.

Regarding to the land use variables considered in Sugar Cane policy case, their dynamics and the modeling approach are presented in more detail in chapter seven (Land Use change model Dyna-CLUE applied to SIAT-TTC). It is worth to highlight that six classes were considered in the preliminary executions of Dyna-CLUE to generate land use responses to the SIAT-TTC system:

1. Forest: this class takes into account natural forests and afforestation regions, but in the next steps of land use dynamics modeling, they should be considered separately.
2. Cerrado: it is the natural vegetation of the predominantly Morphoclimatic Domain of the Mid-West region of Brazil, characterized by the presence of sparse trees, bushes and herbs (see Box 8.1, in chapter 8).
3. Pasture: the major land use of the state territory, it is formed by natural pastures (one typology of Cerrado Domain) and planted pastures.
4. Sugarcane: it was considered as a land use class type separately from the other crops, once is the land use class focused on the Ethanol policy case.
5. Agriculture: this class presented the higher land use change rate in the last decade, due to the grain crops expansion. The state of Mato Grosso do Sul is among the major grain crops producer states in Brazil, in the Mid-West region.

6. Others: this class refers to urban areas, water bodies, roads, and features that do not fit the previous land use classes.

b) Impact Indicator

The figure 30 refers to the user preferences to visualize Impact indicators: the visulatization mode; the region selected; and the chosen indicator. In the workshop of Indicators (SENSOR-TTC Mercosur), the following variables were pointed out as potential indicators to the impacts of sugar cane and forestation expansion policies, such as: WRSI, water consumption, greenhouse gas emissions, rural labor force demand, pesticide consumption and the gross domestic product (GDP). The indicator analysis approach and its application potential are discussed in the chapter eight. The implementation in the SIAT-TTC GUI is feasible in a prototype II.

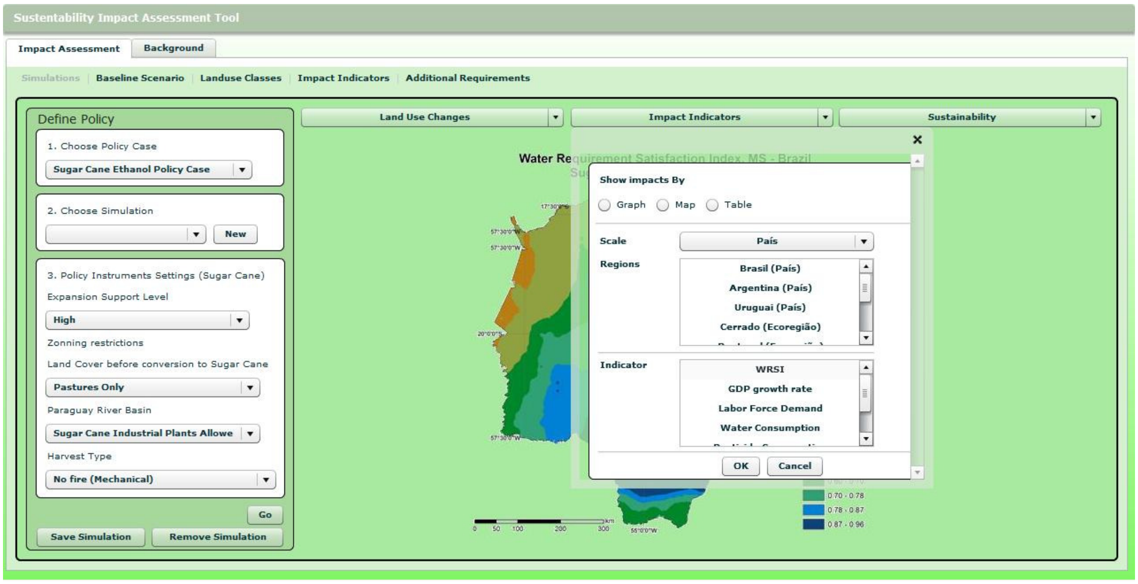


Figure 30 – Screenshot of the Sugar Cane policy case: Impact Indicators choices in the SIAT-TTC.

c) Integrated Sustainability Indicator

The SIAT-TTC Graphical Interface should also provide comprehensive information based on the integration of multi-dimensional indicators of sustainability. An integrated indicator composed by the aggregation of diverse variables representing different sustainability dimensions has the purpose of point the sustainability level of a region, usually by comparison to thresholds and targets.

The SENSOR-EU team proposed the use of Land Use Functions (LUF) methodological approach, which applies the spider-web graph as the visual mode to represent the sustainability of a region related to the land use multi-functionality and its thresholds and targets. In the SIAT-TTC, other integrated indicators are discussed as possible methods, due to the constraints related to data availability in the fulfillment of the transferability process using the LUF approach.

The last screenshot (Figure 31) presents the user options for the integrated Sustainability analysis of the impact indicators linked to the land use changes: i) visualization mode (graph, map, table); ii) scale; iii) regions; iv) integrated indicator analysis methods. The possible methods are presented in the ninth chapter. The first approach mentioned is the Barometer of Sustainability, used in the Del. 8.3.3 (Tureta et al. 2009). Another possible methodological proposal included is the "Agricultural Footprint", focused on the water consumption demand by the land use change, for instance, due to sugarcane and forestation expansion.

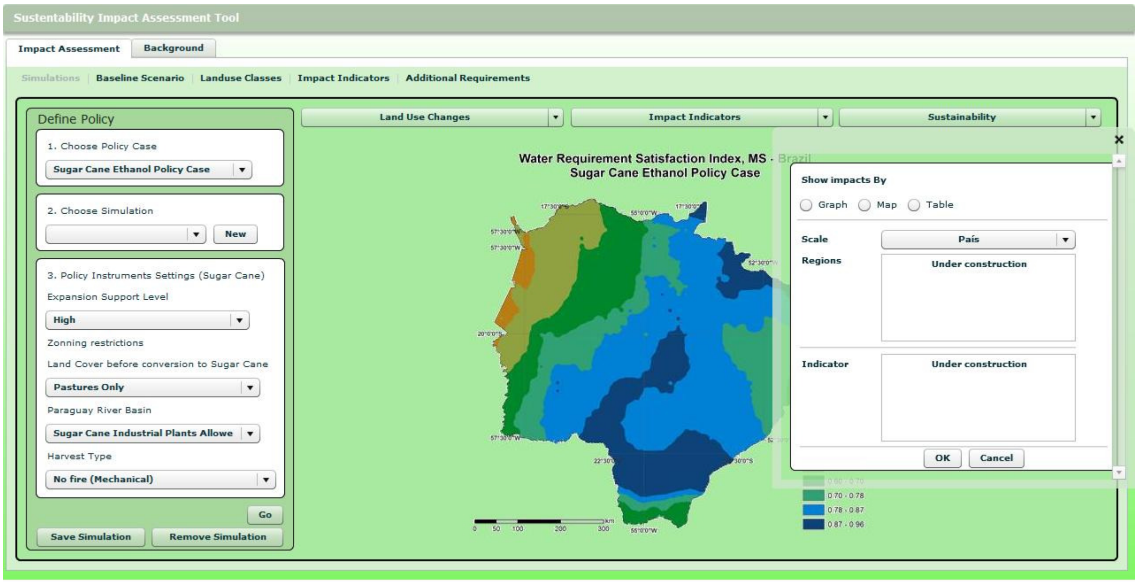


Figure 31 – Screenshot of the Sugar Cane policy case: Sustainability Assessment and Integrated Impact Indicators choices in the SIAT-TTC.

It is important to highlight that fact sheets are under construction focused on comprehensive information regarding each step of Sustainability Impact Assessment methods and conceptual guidelines used in the SIAT-TTC transferability process.

7 Land Use change model Dyna-CLUE applied to the SIAT-TTC

The modelling of land use is a central to SENSOR, which adopts a cross-sector approach to land use, according to Jansson et al. 2007. The land use change (LUC) is an intermediate variable of SIAT system that reflects the ***impacts*** of policies. The LUC is the policy response variable by which impacts are driven to change indicators related to the social, economic and environmental dimensions of sustainability. In the DPSIR framework of sustainability assessment, the Land Use Changes are related to the ***pressures*** upon the states of social, economical and environmental dimensions.

In SENSOR, a complex modelling framework is used to quantify the effects of a set of policies (driving forces) on land use (pressures), which consists of i) a macro-econometric model NEMESIS, ii) sector models such as CAPRI for agriculture, EFISCEN for forestry, SICK for urban, B&B for tourism and TIM for transport structure; iii) a land cover model DYNA-CLUE which disaggregates the land use on state level down to 1 km^2 grid units, and allocate the sectors' land use demand.

In SENSOR-TTC, there was not an available macroeconomic model to estimate land use claims in Mercosur. To obtain the forecasts for two policy cases of SIAT-TTC the following modeling approaches were used:

1) Sugar Cane expansion: LUC is modeled by Dyna-CLUE (Conversion of Land Use and its Effects), a dynamic model to simulate the spatial allocation of land use changes (Verburg et al. 2002, Verburg et al, 2007), used by SENSOR modeling framework. As there was not a macro-economic model available to derive the land claims like NEMESIS, the input land use demand into Dyna-CLUE was estimated for two different situations: i) business as usual scenario, considering for the next ten years (up to 2018) a sugar cane demand growth following the same trend observed during the last five years; ii) Ethanol expansion policy scenario, which considers the Governmental targets of ethanol production for the financial support of Ethanol Industrial Plants (Monteiro et al. 2009). At the current stage, only the business as usual scenario has been simulated in Dyna-CLUE.

2) Afforestation expansion: the modeling approach used was the Markov chain, which is based on the historical behavior of the land use transitions (Peña et al. 2008). The afforestation policies in the three countries are presented by Oyarzabal et al. (2009) and Manfroi et al. (2009) in Del. 8.2.1. (Monteiro et al. 2009).

The Dyna-CLUE modeling in SENSOR was essential to generate input functions to the SIAT meta-modeling framework. In SIAT-EU, the **response functions** were derived by performing a number of simulation experiments within Dyna-

CLUE, in which the macroeconomic and sectorial models outcomes of land use claims were used as input parameters. The values of policy variable related to land use demand varied systematically in successive simulation runs, and the results were used ro estimate response function for each unit of Spatial Reference Framework.

The spatial dynamic simulation in Dyna-CLUE represents the space as a cell matrix and the mathematical functions are applied to each one of the cells simultaneously (Pedrosa; Câmara, 2007; Lisboa, 2008; Valencia, 2008).

To simulate the land use change, Dyna-CLUE uses empirical relationships between the land use class and its driving forces in a dynamic modeling process (Veldkamp, Fresco 1996; Verburg et al., 1999).

The Dyna-CLUE model has a spatial and a non-spatial components and a series of parameters and input data which represent the aggregated demand at regional level (non-spatial component), as well as decision knowledge rules formulated by specialists for estimating allocation in a local level using a matrix (spatial component).

Policy options scenarios to be estimated and how they are represented in Dyna-CLUE for Sugar Cane Ethanol policy case are the issue of item 7.1. The parameters and input data of Dyna-CLUE are described in item 7.2 and how they relate to the policy options.

7.1 Policy options and scenarios of Sugar Cane in Dyna-CLUE

The policy case "Sugar Cane Ethanol Expansion" is reported in the chapter 6, item 6.1, where the policy instruments and options are presented in the SIAT-TTC GUI screens in order to allow the end-user selection of previously designed settings. The representation of policy options settings within the land use allocation model Dyna-CLUE consisted on the spatial restrictions and the transition settings. The spatial restrictions were represented by different information plans (IP), while the transitions settings are done by a transition matrix. The IPs and the transition matrix used in the Dyna-CLUE to the Sugar Cane policy case are described in this chapter.

As it was explained in the Chapter six, the possible policy settings are the combinations derived from the set of policy options by the end users. The four groups of policy options available may be divided in two kinds of restriction policies (spatial component and transition rules) and one demand incentive policy (non-spatial component):

- ✓ Spatial restrictions to sugarcane cultivation
  1. No restriction
  2. Agroecological Zoning restriction

3. Inclusion or Exclusion of Ethanol Plants in Upper Paraguay River Basin (currently this area is not allowed to ethanol plants installation)
4. Inhibit pre-harvest burning, limiting sugar cane cropping to areas with slopes lower than 12% (where mechanized harvest is feasible) or not (when manual harvest is used in higher slopes with pre-harvest burning).

✓ Restrictions of land use class previous to sugarcane
1. Any previous use;
2. Only pastures;
3. Pastures and crops allowed.

✓ Demand Incentive by Different Financial Support level
1. No support (business as usual)
2. High Level of Support
3. Intermediate Level of Support
4. Low Level of Support

The **spatial restrictions** are represented in the Dyna-CLUE model by **plans of information**, which contains spatial restriction areas data in raster format as ASCII files (see item7.2). In the first attempt of Dyna-CLUE execution, the plan of information used was the "Agroecological Zoning restriction".

The **transition matrix** is used to represent the **previous land use class** in Dyna-CLUE model, in order to test options such as only areas opened to pasture and agriculture allowed to receive sugarcane crop production credit incentives. The prohibition of any natural area of Cerrado and forest to be opened to Agriculture in the region is still very unlikely, but is worth to test a possible prohibition to measure the possible benefits of limiting measures, which are actually laws in other areas and states, where most of the Atlantic Forest have been degraded to open areas for pasture and agriculture. In the first simulation attempts, the choice of transition was ***any previous use to sugarcane***.

The **land use claims** for different land use classes are represented by a ***matrix of land use area demand***, in which the total land area claims for sugar cane is driven by a policy option scenario of Ethanol Sector Financial Support. Hence, one matrix of demand should be estimated for each level of ethanol demand correspondent to the level of Support.

In this first simulation, the scenario chosen was the business as usual, i.e., no financial support. This is the **Baseline scenario** of land use change, which considers that ethanol demand will keep the current trend of growth rate, i.e., no Financial Support policy would be applied to cause a variation in sugar cane demand growth rate. It is worth to highlight that the monitoring of the Land Use Change can be supported by an automated system for Land Use Dynamics monitoring based on MODIS data as described in Jonathan et al. 2008.

In order to simulate the Baseline Scenario of land use change for the target year **2018**, the rate of land use conversion to the sugar cane crop in the last five years was taken as the future rate and total area demanded estimated to each land use class using Census data.

7.2 Parameters and input data of Dyna-CLUE model

According to Verburg et al. 2007, Dyna-CLUE is *"classified as a spatial dynamic, hybrid land use change model based on pixel-level simulation*", and can be configured in different ways by the user *to address specific scenarios or policy cases depending on the study area*.

This item presents the parameters and input data to configure Dyna-CLUE model in order to estimate the land use change allocation in the State of Mato Grosso do Sul, Brazil, for Sugar Cane policy case scenarios.

The input data are linked to the policy options available for the end user choice. The policy options were presented in the chapter six regarding the SIAT-GUI interaction while the former item (7.1) described how they are represented in Dyna-CLUE, or what entities simulate these options in the model (plans of spatial information as raster data; transition matrix and land use demand matrix). The input and parameter data presented in the following paragraphs refer to the numerical content of these entities representing policy restrictions and general input data such as initial conditions and location drivers for land use change.

General input data

The characteristics of the ***Cell Plan*** used to represent the studied areas are the following ones:

Area per pixel	*1 km^2 or 100 ha*
Number of pixels	*359 388*
Total Area	35 938 800 *hectares*

Dyna-CLUE is based on dynamic simulation of competition and interactions between land use types (Verburg et al. 2007). According to these authors, "*the actual allocation is based on a set of constraints and preferences that reflect the characteristics of the land use type, location and processes and constraints assumed as relevant to the scenario. Given the competitive advantage of a land use type (…), each location is used for the land use type with the highest suitability at that location. The suitability is the sum of values that reflects the determinants to the total suitability. The main determinant is the current location preference in response to location characteristics, such as soil, slope, climate and accessibility of markets"* (Verburg et al. 2007).

The necessary data and parameters used to calculate the suitability of a location for a specific land use are presented in the following paragraphs.

Land Use Classes

The source of land use classification was the PROBIO project, which uses specific classes per each biome: Cerrado, Atlantic forest and Pantanal (wetlands ecosystem). The land use classes of PROBIO were grouped and reclassified in the following types: Agriculture, Pasture, Forest, Cerrado and Other (Urban areas, water bodies, e.g.).

Data from CANASAT (INPE, 2008) was used as the mapping source of sugarcane crops areas in the State of Mato Grosso do Sul. The combination of both sources (PROBIO and CANASAT 2008) generated the distribution of land areas presented in table 3 and the codes associated to each one the land use classes and the map of land use (Figure 32).

Table 3. Land use classes in the State of Mato Grosso do Sul, respective areas (in hectares) and codes used in Dyna-CLUE land use modeling system.

Classes	Area (ha)	Land Use Codes
Agriculture	3 902 300	4
Sugar Cane	236 600	3
Cerrado	8 672 100	1
Pasture	18 652 100	2
Forest (natural and planted)	3 547 100	0
Others	928 600	5
Total	35 938 800	

It should be noted that the Forest class included the forestations as well as the natural forests, as they are not the focused interest of the "Sugar cane" policy case. However, it was suggested the separation of these two land use classes in the next steps, once the land use claims tend to be different for each one of them.

Another class type containing different categories is agriculture, which do not distinguish the annual crops from the perennial crops. As the focus was the sugarcane copping in the present policy case, only this cropping was separated from the total area of agriculture land use.

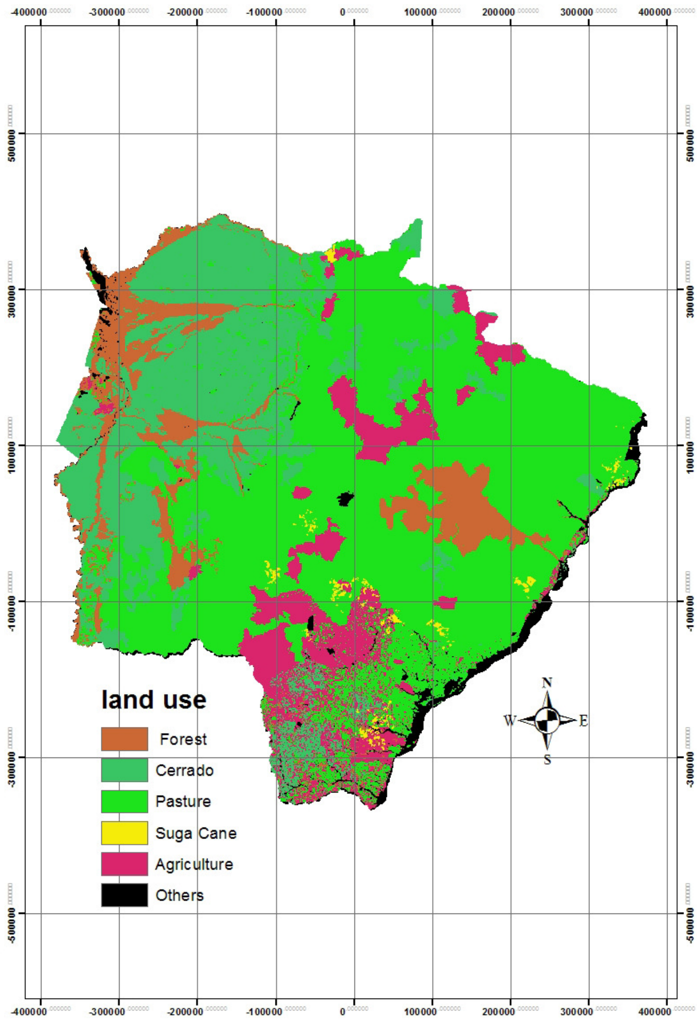


Figure 32 - Land use classes of the State of Mato Grosso do Sul, in 2008, prepared based on PROBIO (www.mma.br) and CANASAT (www.inpe.br) data sets.

Files of information

To run Dyna-CLUE model, different data files are requested containing information on the suitability of a land use type at each location. The description of input files is summarized in Table 4.

Table 4: Description of Dyna-CLUE input files and information.

Files	Options	File name	Type of file
Parameters	Main Parameters	main.1	txt
	Regression results	alloc1.reg	txt
	Change matrix	allow.txt	txt
Input Spatial Base	Land use at initial year	cov_all.0	ASCII raster
	Change Drivers	sc1gr#.fil	ASCII raster
	Spatial restriction areas	regi*.fil	ASCII raster

Parameters Files

There are three types of files containing information of parameters. They are text files and are presented as follows.

a) Main parameters

The main parameters are described in the file **main.1** as it follows.

Line 1	Number of land use classes	6
Line 2	Number of regions	1
Line 3	Max. number of independent variable (Regr.Eq.)	7
Line 4	Total Number of driving factors	7
Line 5	Number of rows	765
Line 6	Number of columns	758
Line 7	Cell area in hectares	100
Line 8	x coordinate	-383000
Line 9	y coordinate	-368000
Line 10	Land Use codes	0 1 2 3 4 5
Line 11	Elasticity Codes	0.2 0.1 0.1 0.9 0.5 1
Line 12	Iteration variable	1 20 100
Line 13	Initial and final year of simulation	2008 2018
Line 14	Number of dynamic driving factors	0
Line 15	Output type: ArcGis	1
Line 16	Region specific regression	0
Line 17	Initialization of land use history	1 5
Line 18	Using neighborhood function	0
Line 19	Variable for location specific preference	0

Elasticity (0,1)

The parameter elasticity is related to the stability presented by a land use class to be converted or to maintain the same state. Elasticity determine the resistance of a land use type to change location. This value varies from 0 to 1, and as the value tends to 0, the probability of change is higher (low resistance to change). As it tends to 1.0, the probability of the class to maintain the state is higher (high resistance to change).

Table 5: Land Use Classes and Land use change elasticity.

Land Use Classes	*Elasticity value*
Forest	0.2
Cerrado	0.1
Pasture	0.1
Sugar cane	0.9
Agriculture	0.5
Others	1

The land use class "Others" represents a group of land cover that must not change to any land use class. It represents the urban areas, the water bodies, roads, for instance. Then, the elasticity value is 1.0, which means no change in the pixels assigned with this class (code value 5).

b) Files of Change Matrix or Transition matrix

In the Dyna-CLUE modeling the transition matrix are related to the end user settings of the policy options. Three transition matrices correspond to different optional settings related to the possible land use classes previously to the sugarcane introduction in a given land area.

In the Graphical User Interface, the policy options regarded to the "Previous land use to sugarcane crop" are:

a) Any previous land use
b) Only pasture allowed
c) Pasture and agriculture land allowed to conversion

The transition matrix is stored in the file **allow.txt**. In this text file, the values describe the allowance or not allowance for all the possible transitions from a previous land use class to a new land use class. Each matrix point corresponds to a specific combination of a previous land use class and a final one.

The values of the transition matrix are:

1 – if transition is allowed.
0 – if no change occurs through this transition type.

The following tables describe the transitions allowed in three possible policy settings of previous land use: any previous class allowed (table 6); conversion allowed only in previous pasture (table 7); conversion allowed only in previous pasture and agriculture (table 8). Note that the differences rely on transitions to sugarcane.

Transition matrices for alternative previous land use to sugar cane crop conversion.

Table 6: "Any previous land use to sugar cane crop".

		Final Use					
		Forests[1]	Cerrado	Pasture	Cane	Agriculture	Others
Initial Use	Forests[1]	1	0	1	1	1	0
	Cerrado	0	1	1	1	1	0
	Pasture	0	0	1	1	1	0
	Sugar cane	0	0	0	1	0	0
	Agriculture	0	0	0	1	1	0
	Others	0	0	0	0	0	0

[1] This class includes natural forests and forestations.

Table 7. "Sugar cane allowed only in previous pastures".

		Final Use					
		Forests[1]	Cerrado	Pasture	Cane	Agriculture	Others
Initial Use	Forests[1]	1	0	1	0	1	0
	Cerrado	0	1	1	0	1	0
	Pasture	0	0	1	1	1	0
	Sugar cane	0	0	0	1	0	0
	Agriculture	0	0	0	0	1	0
	Others	0	0	0	0	0	0

[1] This class includes natural forests and forestations.

Table 8. "Sugar cane allowed in previous pastures and crops".

		Final Use					
		Forests[1]	Cerrado	Pasture	Cane	Agriculture	Others
Initial Use	Forests[1]	1	0	1	0	1	0
	Cerrado	0	1	1	0	1	0
	Pasture	0	0	1	1	1	0
	Sugar cane	0	0	0	1	0	0
	Agriculture	0	0	0	1	1	0
	Others	0	0	0	0	0	0

[1] This class includes natural forests and forestations.

The matrices show that any land use class may be converted to the class "Others", and the pixels assigned to "Others" will not change also. This is based on the assumption that these areas will not increase or decrease during all the assessment period. Although this is not truth, the change in urban areas from 2008 to 2018 is considered small enough to be ignored in the present study, aimed at the agricultural land use sugar cane. The transition matrix presented in table 6 was used in the first simulation of Dyna-CLUE, representing conversion to sugarcane allowed in any previous land use class, except "others" (urban areas, water bodies, etc.).

One instance of the file allow.txt with the transition matrix associated to "no restriction of previous use for sugar cane conversion" is available at the appendix B (file B1).

Input Spatial Base Files

This section presents the different types of spatial base files:

a) Land use at initial year 2008

The initial file **uso_cod.asc** is an ASCII file that contains a spatial matrix where each point is represented by the code number of the prevalent land use class in the correspondent pixel. This ASCII file is used to generate another ASCII file in Dyna-CLUE: cov_all.0.

b) Stable change drivers

The Dyna-CLUE model the preferential allocation of a given set of land use claims based in a range of variables candidates to driving-forces. These variables are of two types:

1. Continuum variables (distances):
- Minimum distance to river (meters)
- Minimum distance to ethanol plant (meters)
- Distance to municipality core (meters)
- Minimum distance to road (meters)

2. Indicator variables related to the Suitability zoning:
- Low suitability zone;
- Intermediate suitability zone;
- High suitability zone.

The land use change driving forces related to a continuum variables, such as the minimum distance to an ethanol plant, were transformed into categories of distance ("greater than" or "lower than").
- Minimum distance to river < 10 km
- Minimum distance to ethanol plant < 50 km
- Distance to municipality core < 50 km

The codes and files related to each variable candidate to be a driver in the regression model are in the table 9.

Table 9. Drivers' codes in Dyna-CLUE model applied to Sugar Cane Policy Case (MS)

Land Use Change Drivers	Name	Type	Code	File
Distance to the ethanol plants up to 50km	dmin_usi_cat	Indicator	0	sc1gr0.fil
Distance to river up to 10km	dmin_hid_cat	Indicator	1	sc1gr1.fil
Distance to the municipality core up to 50km	dmin_sed_cat	Indicator	2	sc1gr2.fil
Low Suitability Zone	zone_cod_1	Indicator	3	sc1gr3.fil
Intermediate Suitability Zone	zone_cod_2	Indicator	4	sc1gr4.fil
High Suitability Zone	zone_cod_3	Indicator	5	sc1gr5.fil

The spatial distribution of these data within the State of Mato Grosso do Sul is shown by the maps of figures 33 to 39.

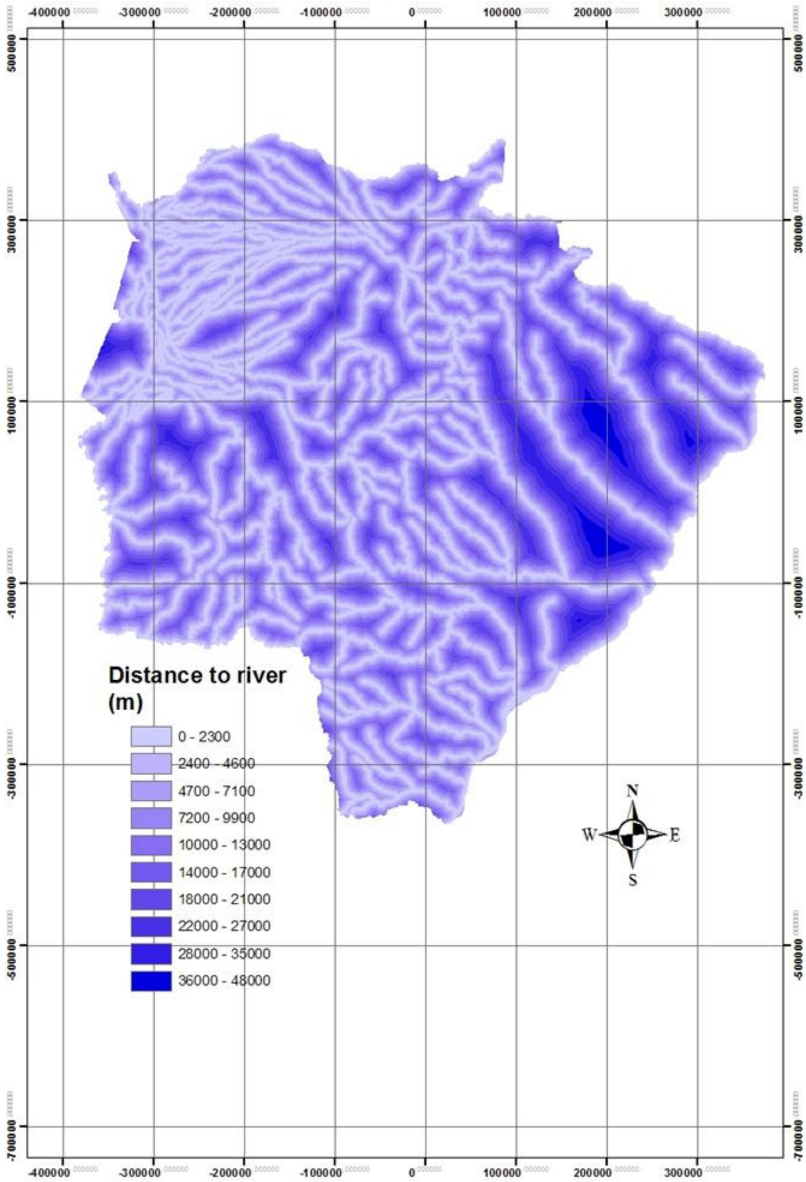


Figure 33 – Variable influence of distance to river less than 50km (meters) assigned to the pixels of 1km^2 area within the cell plan representing the State of Mato Grosso do Sul.

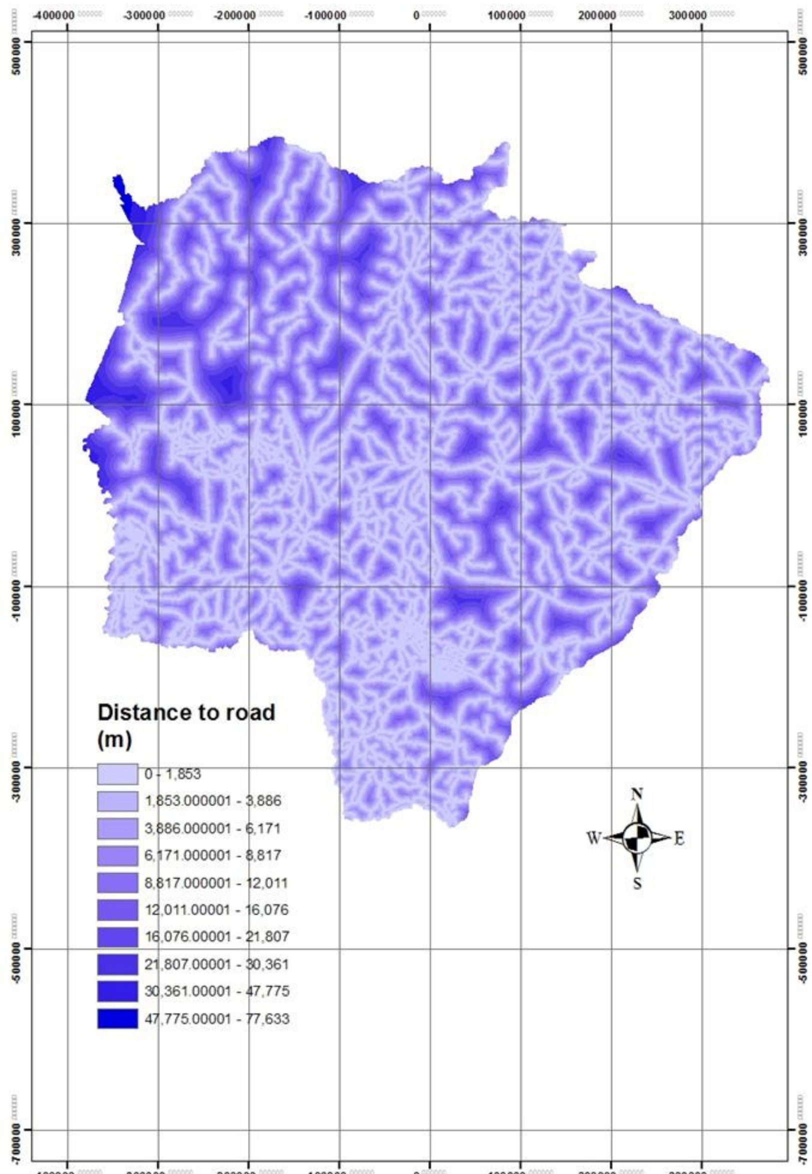


Figure 34 - Map of the variable "minimum distance to road" (meters) assigned to the pixels of 1km^2 area within the cell plan of the State of Mato Grosso do Sul.

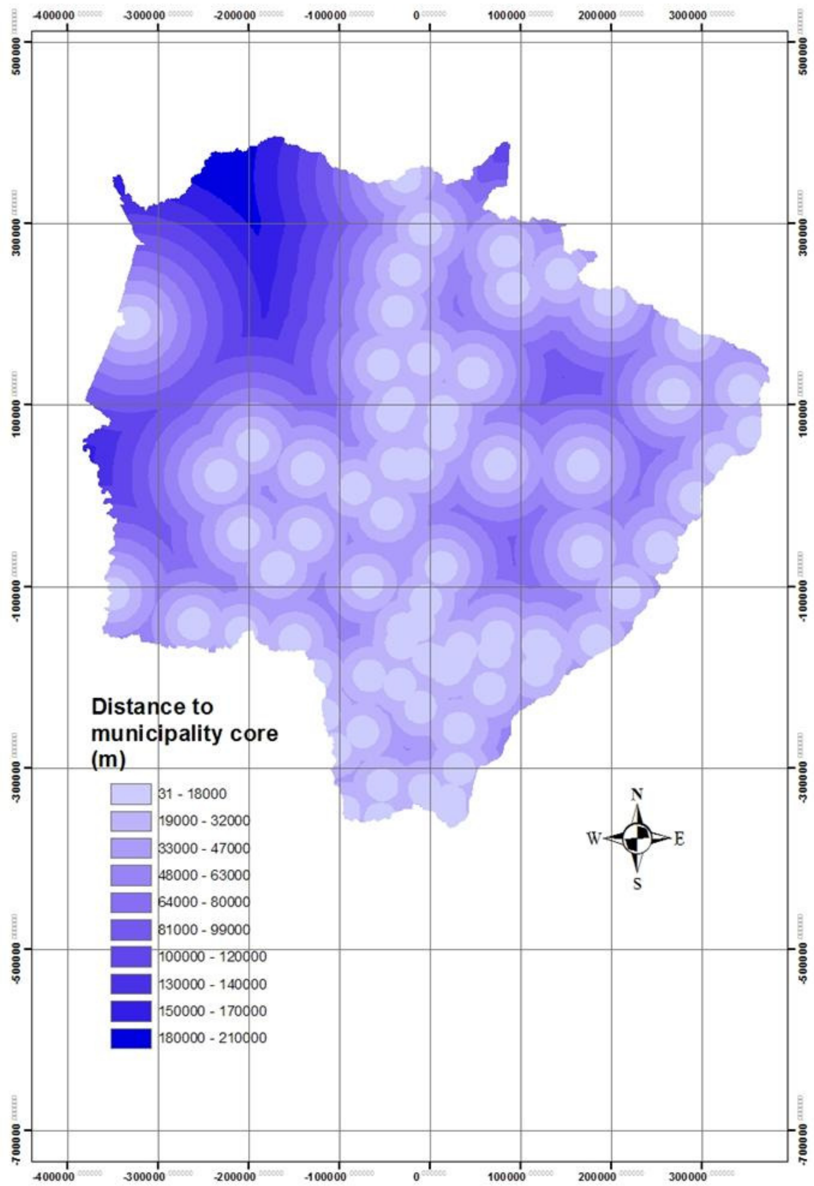


Figure 35 - Map of the variable "minimum distance to municipality core" (meters) assigned to the pixels of 1km^2 area within the cell plan of the State of Mato Grosso do Sul.

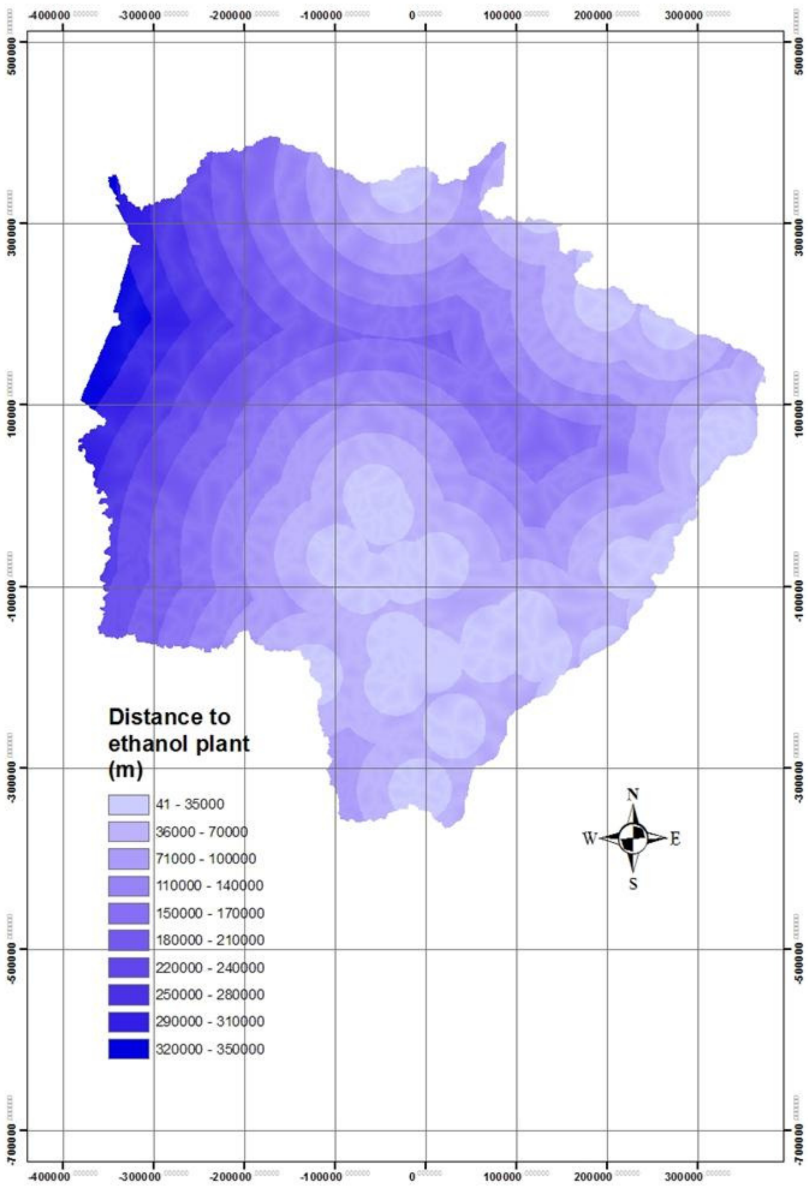


Figure 36 - Map of the variable "minimum distance to ethanol plants" (meters) assigned to the pixels of 1km^2 area within the cell plan of the State of Mato Grosso do Sul.

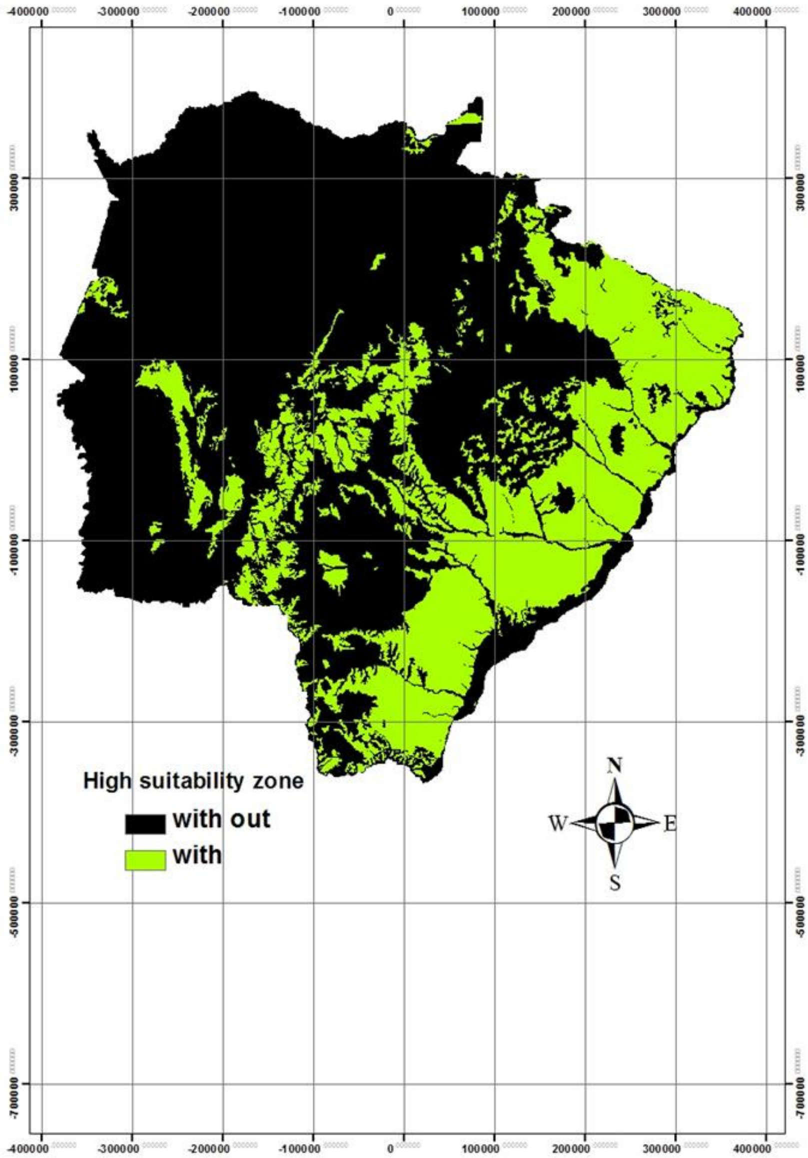


Figure 37 - Map of the variable "High suitability zone" (binary variable) assigned to the pixels of $1km^2$ area within the cell plan of the State of Mato Grosso do Sul.

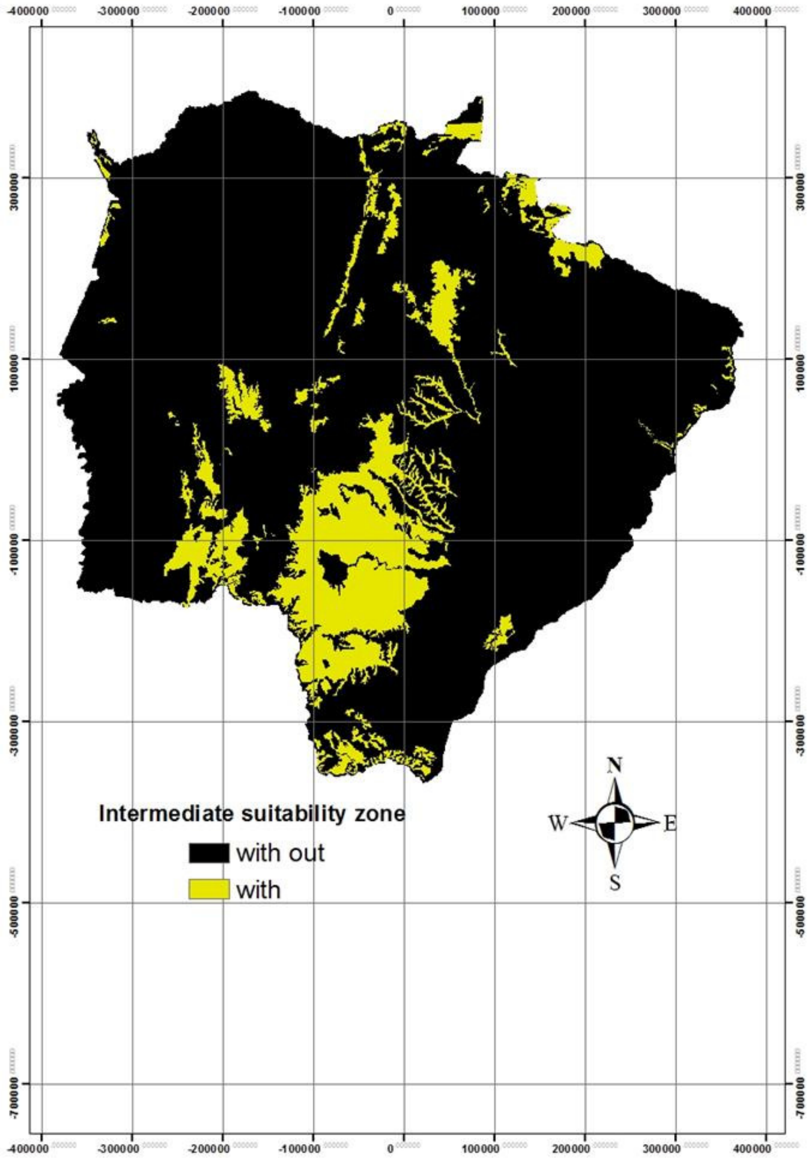


Figure 38 - Map of the variable "Intermediate suitability zone" (binary variable) assigned to the pixels of 1km^2 area within the cell plan of the State of Mato Grosso do Sul.

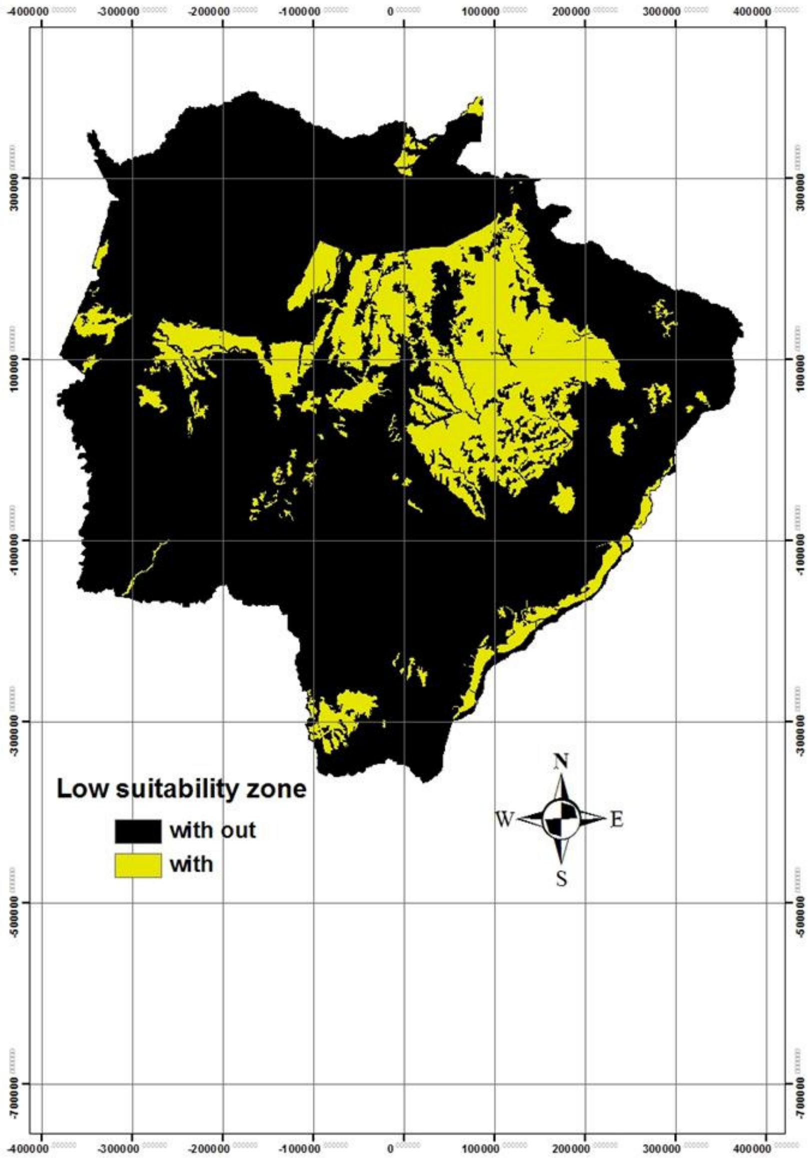


Figure 39 - Map of the variable "Low suitability zone" (binary variable) assigned to the pixels of 1km^2 area within the cell plan of the State of Mato Grosso do Sul.

c) Spatial Restrictions

Three types of spatial restrictions options for sugarcane land use were used:

- No restriction;
- Agroecological Zoning restrictions;
- Agroecological Zoning restrictions, excluded the Upper Paraguay River Basin (UPRB).

In order to represent these spatial restrictions, a plan of information was created for each one of them. The table 10 presents the name of the original data file in ASCII format (input data in Dyna-CLUE) and the name of file generated in Dyna-CLUE.

Table 10. Spatial Restriction and respective information files.

Spatial Restriction	Input file (asc)	Output file (Dyna-CLUE)
No restriction	restri_0.asc	No restriction.fil
Agroecological Zoning	restri_1.asc	
Agroecological Zon. except the Upper Paraguay Basin	restri_2.asc	

In these preliminary executions of Dyna-CLUE, only the Agroecological Zoning option was evaluated, which consider three levels of Agro-ecological suitability (High, Intermediate and Low) represented by the cell grids demonstrated in the map of figures 37, 38 and 39. It should be mentioned that Agroecological Zoning considers areas with slopes higher than 12% as no able to receive Ethanol Industry support, once the mechanized harvest is not possible.

Land Use Claims to Sugar Cane

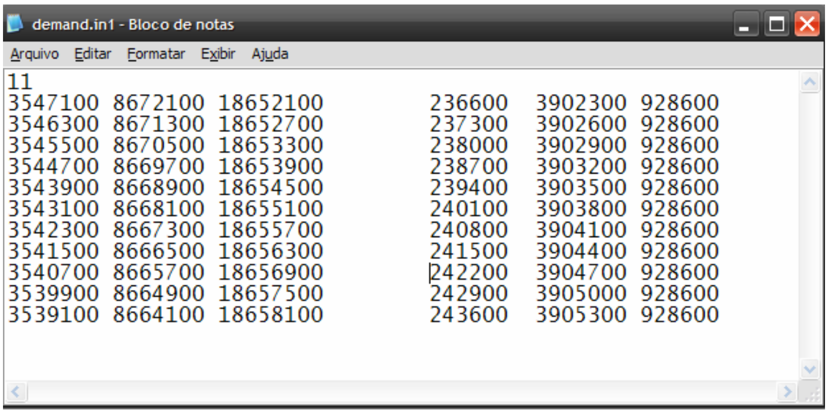
The evolution of the land use claim through the options available in the SIAT-GUI considers different levels of Financial Support Ethanol plants, from *business as usual* scenario (no support policy), to *high level of Financial Support* planned to Ethanol Expansion Financial Support by the Government, what means 100% of the production growth targeted to 2018 (see chapter 6).

In order to simulate the Baseline Scenario of land use change for the target year 2018, the rate of land use conversion to the sugar cane crop in the last five years was taken as the future rate, considering the business as usual scenario, i.e., no policy change would be applied to cause a variation in ethanol demand different from the demand growth observed in the recent years. The results presented in this deliverable refer only to the Baseline scenario.

The land use claims to sugar cane cropping were then estimated from historical data of CANASAT project (INPE, National Institute of Spatial Research), while the land use claims to other classes such us pasture and agriculture, were calculated from Rural Cense data (IBGE). The analysis of the CANASAT project data on the area planted with sugar cane showed that the total growth rate of Sugar Cane in the state of Mato Grosso do Sul for the last 3 harvest-years was 19%. In the appendix B, tables B1 and B2 show, respectively, available data from CANASAT (area to sugar cane harvest in the State of Mato Grosso do Sul in 2008/2009) and from IBGE (historical data of total pasture and forest areas within rural properties from 1975 to 2006).

LAND USE CLAIMS from 2008 to 2018 input data to Dyna-CLUE

The aggregated sugarcane demand table contains the land use claims for each land use class type in the state level. This file is used by Dyna-CLUE to simulate the land use change dynamic. The aggregated land use demand file called demand.in1 is showed figure 40, and the table sheets used to generate the demand file are presented in the appendix B, item 4.


demand.in1 - Bloco de notas
Arquivo Editar Formatar Exibir Ajuda

```
11
3547100 8672100 18652100        236600   3902300 928600
3546300 8671300 18652700        237300   3902600 928600
3545500 8670500 18653300        238000   3902900 928600
3544700 8669700 18653900        238700   3903200 928600
3543900 8668900 18654500        239400   3903500 928600
3543100 8668100 18655100        240100   3903800 928600
3542300 8667300 18655700        240800   3904100 928600
3541500 8666500 18656300        241500   3904400 928600
3540700 8665700 18656900        242200   3904700 928600
3539900 8664900 18657500        242900   3905000 928600
3539100 8664100 18658100        243600   3905300 928600
```

Figure 40 – Aggregated Land Use Demand (demand.in1): file with the demand table of for each land use change for "business as usual" scenario. Demands are estimated based on the rate of increasing or decreasing of each land use change during the last ten years.

One major constraint in the simulation of land use change and allocation by Dyna-CLUE was related to the difficulty for achieve convergence of the model using the high growth rates of sugarcane crop demand. This could be probably due to problems in the regression process and the identification of the main drivers. The occurrence of a major land use class, such as the pasture, in areas that would fit to the sugar cane conversion in the future, probably makes difficult the simulation of a fast land use conversion rate. Although the team has acquired a good knowledge in Land Use Change Modeling, there is still a way to run in order to obtain a reliable land use change scenario.

Logistical Regression

Besides the described parameters, the Dyna-CLUE model uses logistical regressions calculated from the matrix data of the land use locations and the matrices of driving-forces variables (minimal distance to ethanol plants; minimal distance to rivers; minimal distance to roads; minimal distance to municipality cores and levels of suitability to sugar cane (high, intermediate and low). The regressions provide a probability estimator for each land use change.

The results of Logistic regression are presented in the appendix B.

Probabilities for Land use classes

The following maps represent the probability of occurrence of a given land use class (Figures 41 to 45). The probability map results from the logistical regression, which are based on the relationship between each land use class type (dependent variable) and the independent variables that are potential drivers (distance from ethanol plant; distance from river; etc.)

The simulated scenarios of land use change showed to be basically oriented by the regression results, instead of by parameters such as the elasticity and the aggregated land use demand. The regression results showed that the Ethanol Plants are the main drivers to the presence of sugarcane. The simulation procedure had some constraints, such as the need of defining separately the location of ethanol industrial plants currently in operation and of those planned to the next few years, and how to deal with this information in the modeling process.

Probability maps for land use types in the State of Mato Grosso do Sul, Brazil.

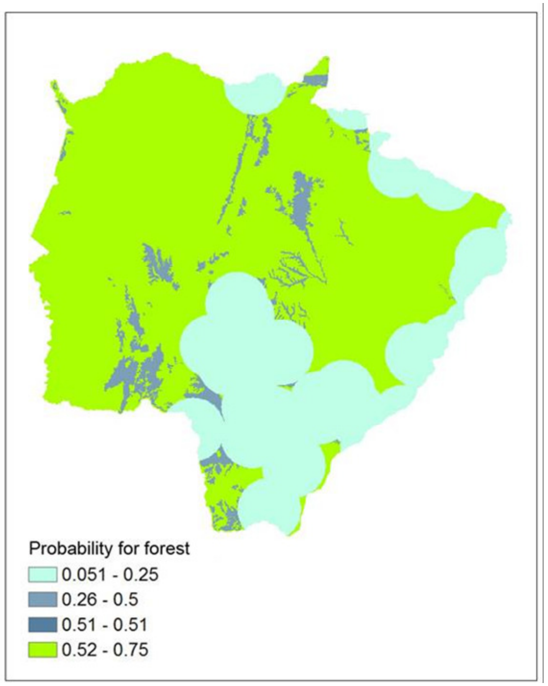


Figure 41 – Probability map for Forest.

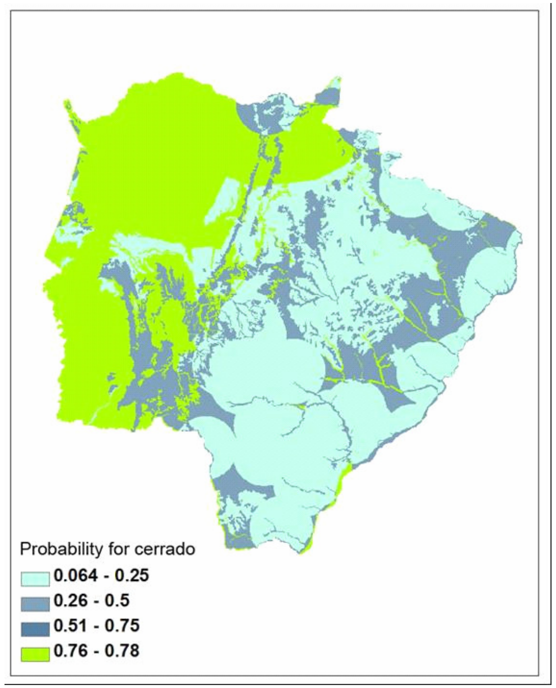


Figure 42 – Probability map for Cerrado.

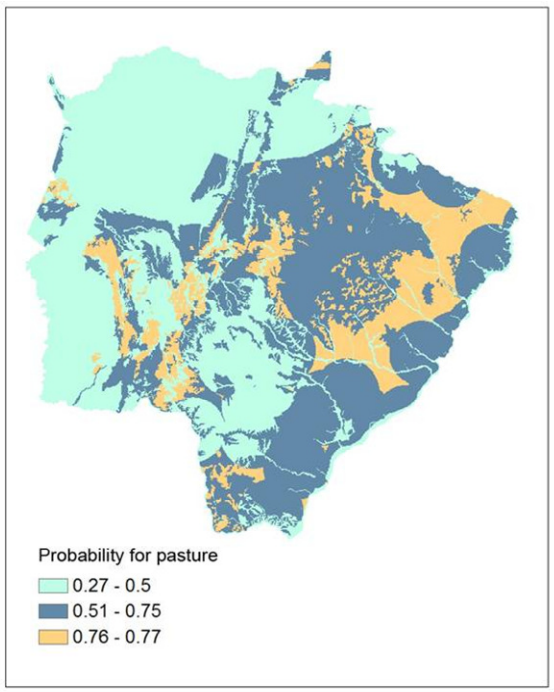


Figure 43 – Probability map for Pasture.

Probability maps for land use types in the State of Mato Grosso do Sul, Brazil. (2nd. part)

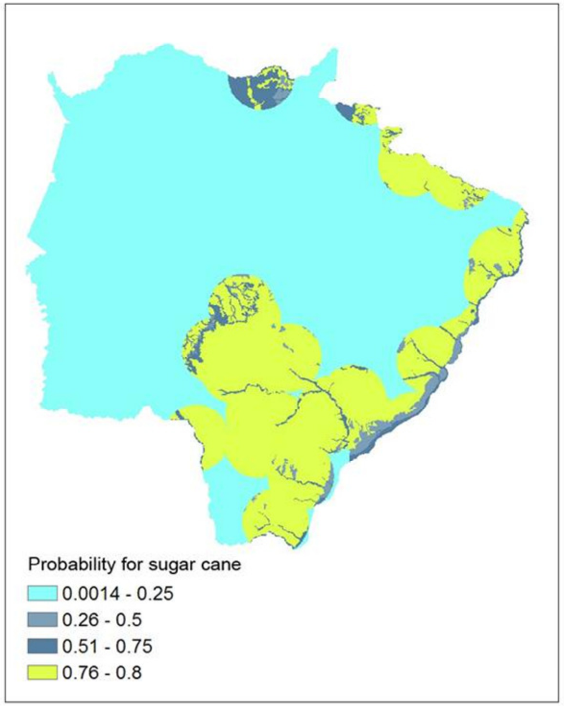


Figure 44 – Probability map for Sugar cane.

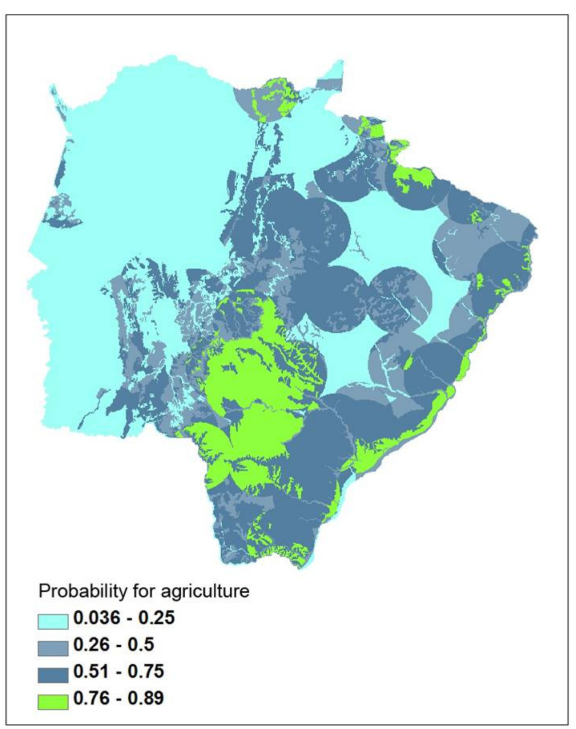


Figure 45 – Probability map for Agriculture.

Land Use Change: the results of Simulation

The Dyna-CLUE modeling using "no restrictions" option of spatial restriction and a demand table based on "business as usual" generated baseline scenario simulation of land use in 2018. In order to show the impact of sugar cane cropping increment along the different microrregions of Mato Grosso do Sul, the figure 46 e 47 represent the land use variable "sugar cane area (hectares) per microrregion", with colors representing classes of areas (from 0 to 100.000 ha, with class intervals of 20.000 ha), in the year 2008 and 2018, respectively.

It is observed that two microregions showed an expressive increment to change the class of sugar cane cropping area, one located in the North of state and other in the South.

For the next steps, it should be simulated the expansion of sugarcane considering the demand of alcohol expansion foreseen in the Governmental Plan of Biofuel, which has designed an increment in ethanol production much higher than the business as usual production growth rate observed in the last 5 or 10 years.

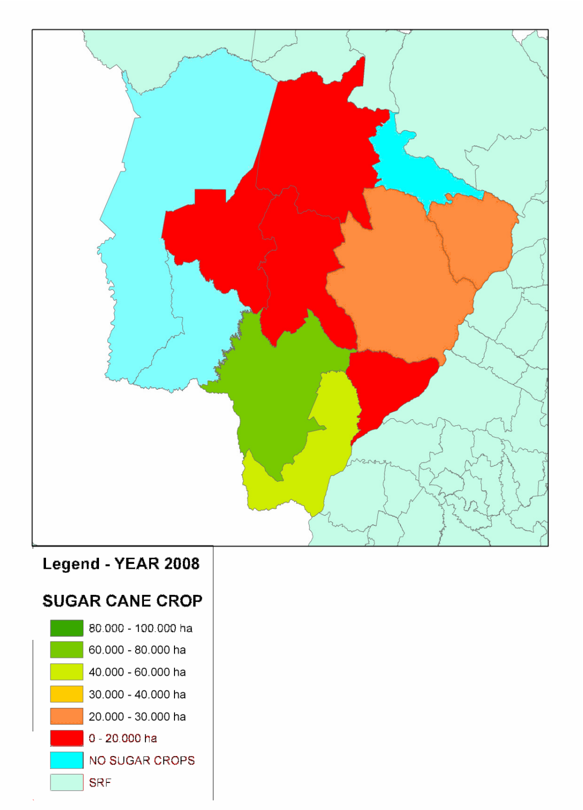


Figure 46 – Distribution of Sugar cane cropping areas classes per microrregion in the State of Mato Grosso do Sul, Brazil, in the year 2008.

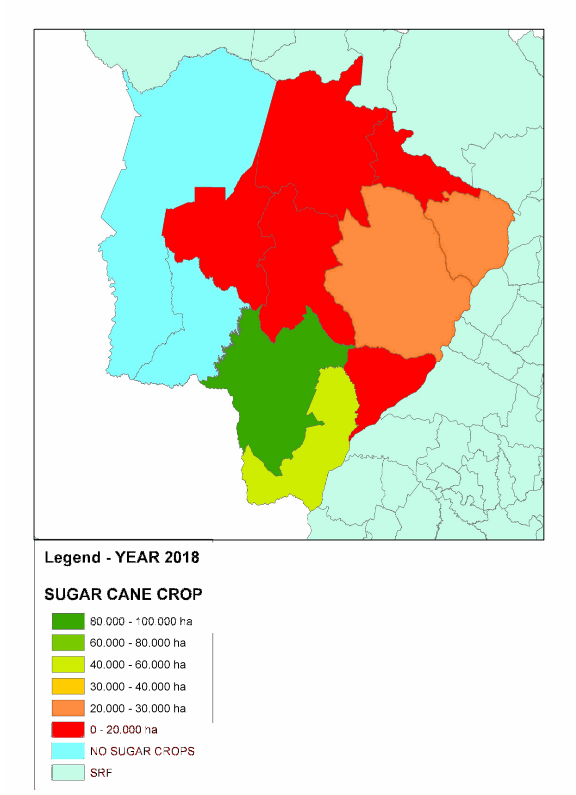


Figure 47 - Distribution of Sugar cane cropping areas classes per microrregion in the State of Mato Grosso do Sul, Brazil: Scenario in the year 2018.

8 Sustainability Impact Indicator in SIAT: how to represent relationship between land use related policies and changes in the System States

In the SIAT system, indicator functions were generated and integrated into the response protocols. Sieben et al. (2008) outlined that *each indicator function needs as input exogenous sets of variables on: (a) land use change types, (b) states (e.g., soil types) and (c) specific intermediate variables, provided by the response protocol. The endogenous variable are indicator values of indicator function, (...) which use (a), (b) and (c) as input for calculations. These input variables are mathematical funtions.*

In other words, to simulate the policy changes and indicators relationships, a set of models should be used to calculate the values derived from the cause-effect chain from the policy to the indicators, passing through intermediate variables such us land use. Torbjörn Jansson (2007) describes the strategy followed in SENSOR to capture the reactions of key model results, required for indicator computations, to the changes in a selected set of policies by *response functions*. The outcomes of the *response functions* are used within SIAT instead of the true models as inputs in the indicator computations. The author suggested that the reactions of model results to policy changes could be abstracted in the form of response functions, and defined protocols required for communication of numerical results. In SIAT-EU these protocols were used. In SIAT-TTC, it was not possible to use such kind of protocol for the impact analysis for a series of lacking constraints.

These lackings are related to the poor historical data series of indicators as well as to the absence of a clear relationship between selected indicators and the land use change impacts.

The indicator functions requirement were not fulfilled due to the lack of regional studies and experts to correlate indicators to the land use change. In this regard, some topics were identified by the team as primary needs of research on impact indicators for sustainability assessment, which are referred in the item 8.2.

According to the conceptual basis presented by Sieber et al. 2008 in the deliverable 4.3.2 on Knowledge Integration, the impact assessment of SENSOR uses different types of indicator knowledge rules to establish the respose protocols: quantitative, semi-quantitative or qualitative.
a) Quantitative: When quantitative data are available, it is possible to obtain response functions derived from a model framework. These mathematical functions are used as the quantitative indicator knowledge rules, and values are expressed in real units.
b) The semi-quantitative knowledge rules are expressed in class or ranges (risk or relative classes).

c) The qualitative knowledge rules: describes decision trees and are expressed in statements of better or worse development.

In the following items, a brief description of the quatitative and qualitative indicators assessment are described, as well as one example application for each type of indicator.

8.1 Quantitative assessment of indicators

In the SENSOR, the quantitative assessment is described as *the systematic scientific investigation on forecasting land use policies related to quantitative properties and phenomena via a set of connected models* (Sieber et al. 2007). The modelling framework used in SIAT comprised a macroeconomic model, five sector models and Dyna-CLUE (Land Use Change Dynamic model) to forecast scenarios across land use sectors, based on macroeconomical drivers, and to allocate changes in land use, running these coupled models in an iterative way, reaching the pricing equilibrium. These models outputs form an implicit function representing the sectors response to policy changes.

According to Sieber et al. (2008) , this implicit function may be represented as

$$f : A \rightarrow B$$

a function from A to B which defines a simple correlation between A, the space of possible policies, to B, the space of possible model results. Considering C as the space of possible indicator results, each indicator is represented by a equation or function g_i from A and B to C, with subscript I representing the individual indicators. This results in:

$$f : A \rightarrow B, \text{ and } g : A \times B \rightarrow C$$

The function $g = (g_1, g_2, \ldots, g_i, \ldots, g_n)$ is the vector of indicator functions. The indicator can be computed as a funtion of policy.

In summary, each quantitative indicator consist of a direct model output, which is fed by land use change or another model's output. These functions provide a set of numerical "response protocols" at regional level.

The problem of lacking quantitative data made the SIAT-TTC noticed the importance of identifying indicators directly correlated to the land use change impacts driven by the chosen policies.
This direct relationship between land use and indicator is more easily noted in environment conditions. One instance of quantitative indicator related to land use change is the WRSI (Water Requirement Satisfaction Index), that is described in the following paragraphs. It is an indicator that results from the interaction between climate conditions and land use class.

***WRSI**: attempt to identify thresholds for water sustainability*

In order to measure the impact of sugar cane alcohol sector expansion on the water resources, it was calculated the WRSI, as it explained in the following item, and the values were mapped and classified according to the potential water availability for sugarcane production.

The areas where the index values were in the range 0.6<WRSI<0.8 were classified as favorable to sugarcane cropping in terms of water availability. In the areas where WRSI> 0.8, water excess could be a constraint for sugar cane cropping. Areas where WRSI<0.4, considered unfavorable to sugar cane, the thresholds of water sustainability is considered low, either to the sugar cane production as to other uses, such as drinking water for populations.

As a first attempt to evaluate the potential of using WRSI as a spatially distributed indicator of water sustainability that strongly related to the land use change, the Water Requirement Satisfaction Index values in the State of Mato Grosso do Sul were calculated according to the method demonstrated in the next item and presented as a map of WRSI classes. The calculations were carried out within the TerraME platform.

Concepts and estimates of WRSI– Water Requirement Satisfaction Index

The purpose of such index is to detect water deficit risks during crop growth and to investigate water requirement satisfaction in different critical periods. In order to determine suitable areas for crops, the agroclimate zoning uses WRSI, which evaluate the interactions between water availability and crop growth and yield. Studies on index application point out that water availability fluctuation is the major limiting factor for reaching near potential yields and the main cause of variability within observed yields yearly in different Brazilian agricultural regions.

In the SIAT-TTC, WRSI was chosen as an indicator once it demonstrates the climate impact on economic agricultural production in a region as well as it shows water use capacity of crops. It is related to environmental and economical impacts of land use changes.

This index can be used to classify land regions according to water availability indicating the potential impact of land use change on water consumption that is related to environmental Land use function such as provision of abiotic resources, support and provision biotic resources and maintenance ecosystem processes.

Methodology / Data acquisition:

A water balance model is used to estimate the climatic risks due to crops water deficit. The data sets used to obtain the environmental indicator WRSI in SIAT

–TTC are originated in the following sources: Climatic Risk Zoning of Sugarcane in Brazil (EMBRAPA and Governmental Consortium for Sugarcane Agro-Environmental Zoning); Water balance calculated from Climate data from http://www.iwmi.org; GIS (Geographic Information System) containing georreferenced altitude and slope data maps generated from SRTM (Shuttle Radar Topography Mission) in http://seamless.usgs.gov, in order to provide spatial distribution of WRSI values; sequential water balance calculated using historical time series of daily meteorological data (INMET); Water balance considers local climate interaction with soil physical properties, sowing season and crop growth to estimate WRSI, that is the ratio (equation 1) of seasonal actual crop evapotranspiration (*ETa*) to the seasonal crop water requirement, which is the same as the crop evapotranspiration (*ETc*).

$$WRSI = \frac{\sum ETa}{\sum ETc} \times 100 \qquad (1)$$

where *ETc* denotes crop evapotranspiration after an adjustment of the potential evapotranspiration (ETo) by the use of appropriate crop coefficients (Kc). Kc values define the water use pattern of a crop which varies with the phonological stages of the crop. When there is not local Kc determined to a specific crop published values can be used.

It is important to investigate where the areas with low, medium and high climatic risks are located, what should be done with support of spatially distributed data sets available in Geographic Information System. Spatial distribution of water availability is shown using classes of WRSI values: favorable, intermediate and unfavorable.

The primary aim of WRSI in SIAT-TTC is to identify and to characterize the effect of water availability on land use claims according to potential fulfillment of crop water needs. The indexes that express the water condition in different phases of the crop development are the best estimators of yield losses and consequently may be used to model land use claims.

Precipitation conditions and WRSI

As mentioned in previous item, the WRSI is dependent on climate conditions, mainly on precipitation totals and distributions, as it results from the water balance calculated in a given area for a given crop.

Hence, the annual average precipitation was previously estimated for several locations of the State of Mato Grosso do Sul and its spatial distribution presented in the map of figure 48, showing that areas with the highest annual precipitation values (identified as green), from 1400 to 1700 mm, are located in the North-South central axe of the state, mainly in the extremes. The lowest values (950 to 1000 mm) are observed in the West region of Mato Grosso do Sul state.

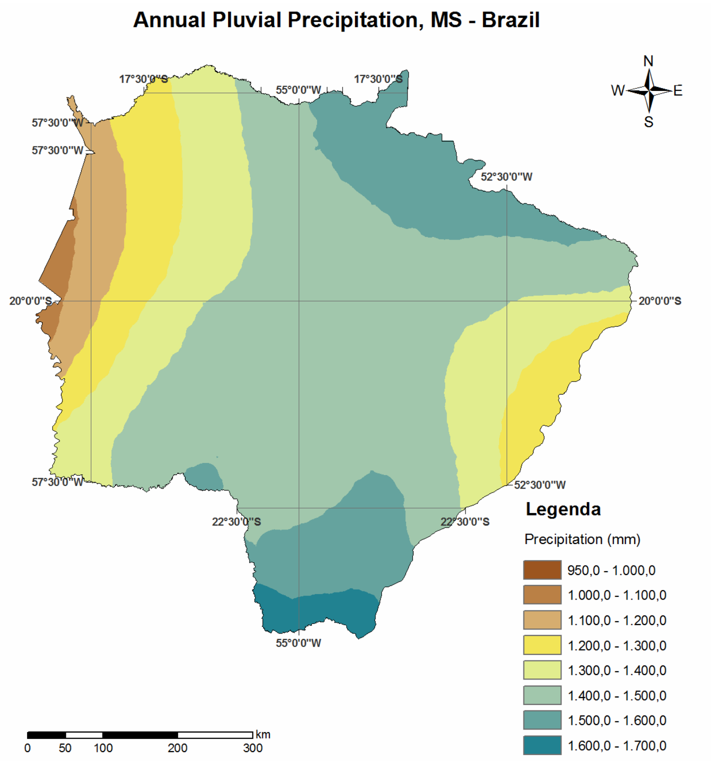


Figure 48 – Annual Average Precipitation in the State of Mato Grosso do Sul.

Besides the distribution of annual average precipitation, the duration of rainy season and its beginning month are important variables to be identified and spatially mapped, once this is directly related to monthly water balance and to the behavior of Water Requirement Satisfaction Index (WRSI).

The importance of precipitation behavior knowledge was verified by Arvor et al. (2008a), who mapped the variability of the rainy regimes in the state of Mato Grosso (north to the state of Mato Grosso do Sul). Their study showed that rainy season duration variability is specially related to the onset variability in Mato Grosso. The variation of rainy season onset explained the various agricultural calendars for soybean in the region and the farmer´s vulnerability, which is caused by the effects of delayed and short rainy seasons on Water Requirement Satisfaction Index.

Their conclusion is confirmed in other studies, remote sensing imagery data (EVI/MODIS) were used to assess the soybean crops dynamics in no-tillage system and observed a delay in soybean sowing in the Southeast region of Mato Grosso state, where the rainy onset is late (Arvor et al. 2008b; Arvor et al. 2007). This leads to higher risks of the production and less opportunities to other crops by the end of rainy season, what limited the no-tillage rotational system, adopted largely in areas with early rainy season. Thus, it can be infered that limitations in WRSI may be a major constraint not only to the land use class subjected to the farmers choice, but also to their decision on soil management and conservation practices adoption.

WRSI and the agro-climatic suitability classes

The importance of WRSI resides on the definite value to the economical feasibility of a crop, in such a way that WRSI is used to define the classes of agroclimatic potential in the Zoning. The table 12 describes the conditioners for the classes of suitability adopted in the Brazilian Agroclimatic Zoning of Sugar Cane crop.

Table 12. Classes of Suitability for sugar cane crop and respective conditioners.

Suitability Class	Conditioner Features
A	Higher agroclimatic potential • Annual Mean Temperature > 19°C • Frost occurrence < 20% • Annual Mean Water Deficit < 200 mm • WRSI > 0,6
B	Intermediate agroclimatic potential, Irrigation needed • Annual Mean Temperature > 19°C • Frost occurrence < 20% • Annual Mean Water Deficit: 200-400 mm • WRSI > 0,6
C	Temperature limitation to sugar cane crop • Annual Mean Temperature < 19°C • Frost occurrence > 20% • Annual Mean Water Deficit: 200-400 mm • WRSI > 0,6
D	Low Water Availability restriction to sugar cane crop • Annual Mean Water Deficit > 400 mm • WRSI < 0,6
E	High Water Availability Restriction (losses in maturation and harvest) • Areas with High Water excess • Dry season < 3 months

Source: Embrapa, 2008. Metadata of the "Sugar cane Zoning in Brazil".

The distribution map of Water Requirement Satisfaction Index values for Sugar Cane crop in this state of Mato Grosso do Sul is presented in the figure 49, showing that a major part of the state has a high potential of agro-climatic suitability to sugar cane cropping, with WRSI values greater than 0.6.

Though the WRSI of 0.6 is considered in Table 12 as the threshold value (contour condition) to the zones with higher potential to sugarcane cropping, the range of Water Requirement Satisfaction Index in Mato Grosso do Sul was divided in levels to show the evidence of different water availability in the state. The water availability is a key element to be assessed in the evaluation of the impacts and changes in states. It should be further explored in the potential use of the "Agricultural Footprint" as an integrated indicator of sustainability in the region, proposed in the chapter 9.

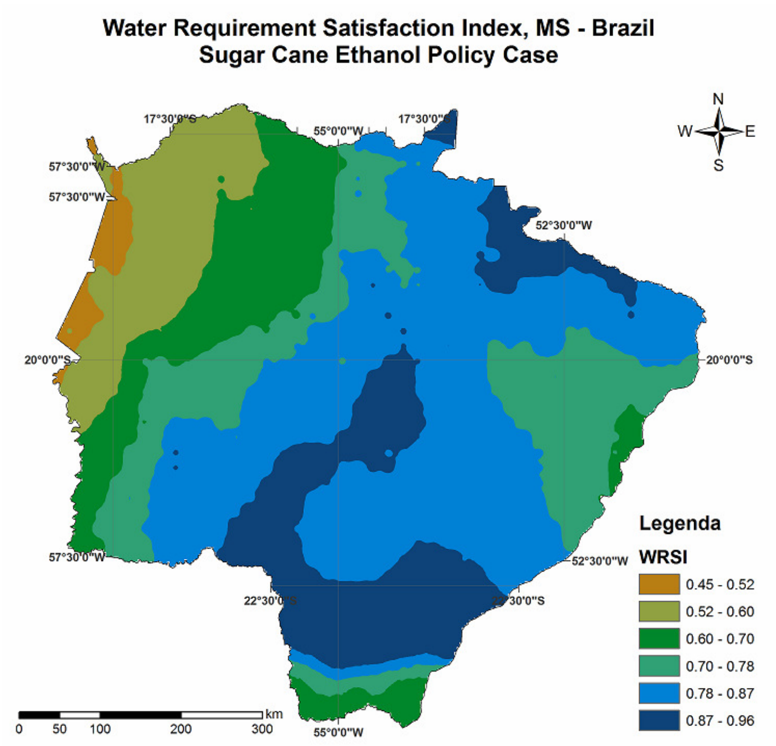


Figure 49 – Map of Water Requirement Satisfaction Index distribution in the State of Mato Grosso do Sul.

Climate, soil and vegetation domains of Mato Grosso do Sul State: natural features and the land use policy interaction

The state of Mato Grosso do Sul is located in the Mid-Western region of Brazil, the largest producer of grains and cattle, with climatic conditions characterized by a pluvial seasonality, with dry winter and rainy summer typical of the Morphoclimatic Domain "Cerrado". The vegetation types of the region, of which the characteristics are related to rainfall seasonality, are shown in the description of Box 8.1.

The climatic conditions, added to the soil physical properties responsible for the good drainage observed in Cerrado soils, together with a predominantly plain relief, propitiated the agriculture expansion in the last 30 years, despite of the very low nutrient contents and high toxicity caused by iron- and aluminum-concentrations observed in the soils.

The grain crop expansion in the Cerrado Domain was made possible by the intensive use of fertilizers and other management technologies based on the agricultural mechanization along the Cerrado region flat territories. However, the management system adopted, without conservationist practices, allied to the soil and climatic conditions and the break of the environmental laws, brought drastic consequences to the region. The water erosion process is a chronic and severe problem, especially in the Upper Taquari Basin (UTB), located in the north of Mato Grosso do Sul (Martorano et al. 2002; Jonathan et al. 2008) and connected to the Pantanal "wetlands" downstream. The rainfall regime, duration of rainy season and the events' intensities and durations are directly linked to the erosion process (Lisboa 2008; Galdino et al. 2006; Galdino et al. 2003a; Galdino et al. 2003b).

Box 8.1. CERRADO: the Morphoclimatic Domain

Brazilian territory is divided in six morphoclimatic domains (Ab' Saber, 1970), according to specific climatic, bothanical, pedological, hydrological and phytogeographic characteristics. The morphoclimatic domain "*Cerrado*", also known as Biome, comprehends 45 millions of hectares and has the second largest territorial extension of Brazilian domains.

The Cerrado is characterized by sparse tortuous trees and bushes, having a thick bark, hairy leaves and very deep roots. The dry aspect of vegetation is due not only to the seasonal precipitation, but mainly to the soil chemical composition, with high aluminum contents and low nutrient concentrations.

The Biome Cerrado is one of the richest of all tropical savanna regions and has high levels of endemism among plant species, according to the Conservation International (http://www.biodiversityhotspots.org).

The region is home to an estimate of 10,000 plant species, of which about 4,400 are endemic.

Figure 50 – Vegetation typology kinds in Cerrado Biome and River Taquari. Pictures: L. Martorano, S. Galdino and C. Costa. Source: Project SOS Taquari, coordinated by H.Coutinho.

Another activity of the state, the cattle ranch, which represents the main land use class in area (pasture), have gained large areas of the state, followed by the grain crops agriculture. The rapid expansion of these both activities had great incentive by the governmental policies during the last 30 to 40 years, leading to the deforestation of large areas in the Cerrado Domain, the most threatened ecosystem of Brazil.

The effects of the land use-related policies during the twentieth century (fourties' and fifties' interior development policy and the National Integration policy in the seventies), as well as the current sugarcane expansion in the region show the importance of choosing a sensitive area in this morphodomain to sustainability impact assessment within SENSOR-TTC and the proposal of evaluating the "Agricultural Footprint" related to sugarcane advance in the region.

8.2 Qualitative assessment of indicators

When quantitative data analysis is not accessible, qualitative information may generate knowledge rules depending on logical reasoning of cause and effect relationship behind diverse aspects of indicator behaviour.

In order to meet the requirements of the SIAT response protocols of SIAT, analytical causal chains can be constructed to represent the cause-effect link between policies and qualitative indicators. They are implemented by describing the factors that promote the impact on the sustainability.

For the Mercosur conditions, a set of variables were pointed out as potential indicators of social, environmental and economical impacts by the WP 8.3 team, based on data availability and expert consultation. The set of variables comprised: Consumption of pesticides, Access to water supply system, Gini Index for the distribution of income, Occupied Persons, GDP per capita and Balance of Trade (Turetta et al. 2009).

These variables express mainly social and economical indicators, for which a quantitative analysis is not accessible, once there is no direct mathematical relationship between the indicator and the land use change variable or policy variable.

Taking into account the Analytical causal chain concept for imapct Assessment in SENSOR presented by Helming et al. 2007, and applying this concept as Sieber et al. 2007 suggested to integrate qualitative knowledge into SIAT, the procedure recommended to obtain the response protocols is by constructing rules describing cause-effect chains between policies and indicators.

An example of causal chain for a qualitative indicator within the Sugar Cane Ethanol policy case is described as follow (Figure 51).

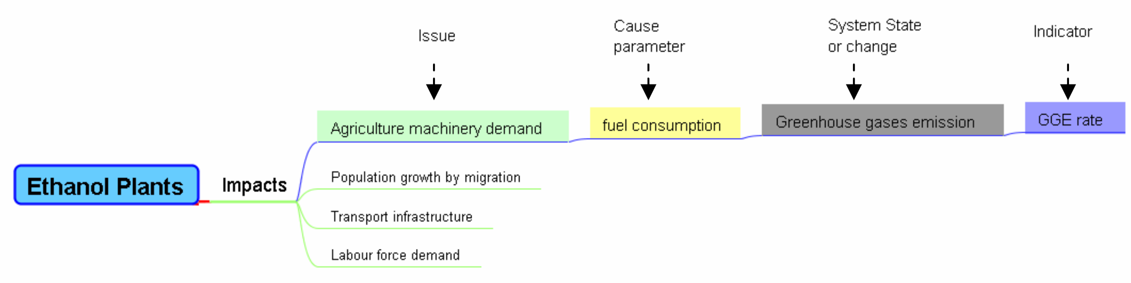


Figure 51 – Requirement qualitative in the State of Mato Grosso do Sul.

The first step consisted of identifying a number of possible issues that receive direct pressures from ethanol industry expansion on social and economical conditions. A number of Issues were listed, such as the agriculture machinery demand, transport inrfaestructure, labor force demand, migration causing population growth, and others.

The next procedure was identifying the causal parameter for one issue taken as example. As the growth of machinery demand was chosen as an issue, the parameter considered as representing the cause of impact was the fuel consumption. The system state or system change was the Greenhouse Gas emission (GGE). As indicator, the rate of GGE is adequate to represent the impact.

This causal chain was not implemented yet in SIAT-TTC, but it should be applied as well as other causal chains once there is information available on the machinery demand, fuel consumption and GGE per hectare of sugarcane.

9 Further advancements: Challenges of the SIA tools in the transboundary basin of the La Plata River

Hence, the objective of these proposals is not only facilitate the user interaction with the SIAT-TTC software but increase the possibility of apply and test a range of new options, variables, response functions and models in different policy cases.

9.1 Integration of Knowledge and Multiple Methodological Approaches in Sustainability Assessment

Besides the transferability analysis primarily used in the adaptive development of SIAT-TTC, within the Sustainability Assessment through the DPSIR framework applied in the Mercosur' policy cases, a variety of methodological approaches were used by SENSOR and some of them were evaluated regarding the potential of use in the transferability process, such as the indicator framework process, the driving forces storylines, the land use change modeling the SENSOR-TTC team, the indicator analytical causal chains and the Land Use Function integrated impact analysis. Nevertheless, the SENSOR-TTC team has also tracked different pathways to investigate the impact of the land use related policies on sustainability.

In the evaluation of the changes in the ***states*** as responses to the ***pressures***, we should highlight the methodologies tested in the following studies:
i) Land use change to Forestation in the South Region of the La Plata River Basin, carried by the FAUBA team using the **Markov Chain model** (Peña et al, 2008)**;**
ii) Application of TerraME (Modelling Environment) in a sensitive basin of Mato Grosso do Sul, the Upper Taquari River Basin (Lisboa, 2008).
More information on these studies was presented in the delivery 8.4.1 of the WorkPackage 8.4 (SIAT-TTC development).

Another example of these methodological attempts aiming to overcome the data and information constraints as well as the lack of the models used in the SENSOR-EU, is the Barometer of Sustainability pointed out in del. 8.3.3 by Turetta et al. (2009), Work Package 8.3. This method focuses on the measurement of the ***impacts*** component of the conceptual framework DPSIR by a set of indicators, and it was described in the above mentioned deliverable.

Considering the challenge of the sustainable development in a economically, socially and environmentally diverse region located in a highly populated trans-boundary basin such as the La Plata Basin, where different approaches of the territory analysis and management are abundant, it is very important: a) to evaluate available data, information and accumulated knowledge in the region;

b) to identify the main gaps of research and data, and c) to design strategic objectives to be pursued in integrative analysis of sustainability.

Based on the range of results of this collaborative project SENSOR-TTC, as well as on previous studies and knowledge acquired within different institutions that develop research in the region, a proposal for an integrative and adaptive approach of sustainability assessment has been evolved as an initial seed for future and wider collaboration.

This initial proposal includes the use of multiple methodologies of modeling and analysis, many times integrates, but also as alternative approaches for comparative reasons. Up to the moment, three approaches are pointed out as of high potential for application. The advantages of them were realized during the studies carried out by the SIAT-TTC team. They are as follow:

1. The use of the SIAT-TTC as an adaptive software application able to couple different modeling tools related different knowledge domains.
2. The application of dynamic models within the platform TerraME (Modelling Environment), coupling the land use change modeling to other environmental models as well as social and economical models, considering spatial and temporal behavior of the variables under interest.
3. The use of indicator analysis approaches more suited to the current state of data sets, information and knowledge available in Mercosur, within the logical of strategic analysis and using ***integrative indicators*** that could play the role of a *signal-flag for sustainability* thresholds. Two possible methodologies are the *Barometer of Sustainability* and the *Agricultural Footprint*.

9.2 Advantages of implementing AOM architecture style and TerraME Modeling Environment

The first approach and its main advantages were extensively explored in the chapters 3, 4 and 5 of this deliverable, which highlighted the flexibility and scalability characteristics of the AOM Architecture Style, besides the benefits of other Software Engineering tools.

The application of TerraME Modelling Environment has been mentioned in the Deliverable 8.4.1, which presented some instances of the environmental data analysis results in the sensitive area of Upper Taquari, generating mainly maps related to climate behaviour. It is worth to remember that TerraME is not limited to the Land Use dynamics modelling, but it is framework developed by Carneiro (2006) using the assumptions of *Nested Cell Automata* (CA) and multi-agent models, to deal with the multi-scale modelling suited into a computational support (Lisboa, 2008).

The use of TerraME in SIAT-TTC is highly supported by the understanding that the Adaptive Object-Model Architectural Style applied to SIAT will allow a range of format options to be used in SIAT, as well as changes to be performed in the Object-Model SIAT at runtime. Ideally, SIAT-TTC would be able not only to assess response-protocols, but also to trigger models built in TerraME platform that would receive from the data base server the necessary input information to run a new simulation. A great advantage is that this input might not be modeled previously.

Then, not only policy settings could be changed by the end-user, but also a large group of model experts would be able to test a range of possible policy options and constraints by introducing and modifying parameters, functions and variables in tables of the database, that could be interpreted by the SIAT as by the modeling system TerraME. Of course, the persistency layer should be set to allow and not to allow different types of data.

As numerous tests would be performed on the fly, a dynamic building of the SIAT would facilitate its continuous improvement, in terms of: i) making possible models coupling and experts analysis, ii) increasing the user interaction to the proposed simulations via GUI and iii) enhancing the sustainability assessment.

9.3 Integrated Approaches for Sustainability Impact Assessment: Conceptual Basis for a Signal Flag

Within the integrated approaches for Sustainability Assessment, a number of composite indicators have been developed which differ in several aspects, although they usually present some general characteristics, such as:

- Multidimensional analysis, integrating social, economical and environmental variables, to meet the three pillars of Sustainability concept;
- Aggregation of several index derived from state variables to make up a composite integrative indicator;
- Ability to provide comprehensive information, what means the ability to meet the requirement of condensed, non-redundant and effective information.

These characteristics are similar to those mentioned by Sieber et al. 2007, and Pérez-Soba et al. (2007) regarding the SIAT requirements or LUF advantages. They are also mentioned by Lorenco (manuscript) as present in different indicators evaluated by the author, the Barometer of Sustainability, the Dash Board of Sustainability and the Ecological Footprint.

Recognizing the need of research to overcome the gap of information to feed complex impact indicator analysis systems, such as the proposed by the LUF approach, this chapter presents preliminary proposals aimed at the application of Sustainability ***Signal Flags*** related to the land use change impacts caused by Sugarcane expansion policy onto sensitive areas selected within the La Plata River basin.

The first methodological approach presented by SENSOR-TTC in Mercosur for integrative indicator analysis is the Barometer of Sustainability, presented by Turetta et al. 2009, in the Deliverable 8.3.3. The Barometer of Sustainability was developed by The World Conservation Unit (IUCN) and The International Development Research Centre (IDRC) to aid governmental and non-governmental agencies, decision makers and individuals in the sustainable development at national and regional level (PRESCOTT-ALLEN 1997). This tool is based on the aggregation of indicators using a lot of data and combining them into indices. The authors deal with the problem of different units by using a performance scale to combine indices of one same dimension. A description of the Barometer of Sustainability applied to the SENSOR-TTC policy case of Sugar Cane Ethanol is provided by Turetta et al. 2009.

The second approach pointed out as potentially useful to the Mercosur policy cases is the "Agricultural Footprint". This item reports the basic concepts to embed the application of the Ecological Footprint adapted to the Agricultural Sector, more precisely to the Sugar Cane Ethanol case.

In order to evaluate the overall impact of the agricultural advance caused by the Bioenergy Policy incentive to Ethanol, which promotes the sugar cane cropping expansion, and due to the lack of data for Land Use Function Methodology application, the SIAT-TTC team suggests an approach based on the "Ecological Footprint" methodology, as well as taking into account the central role of water for the human development and environment health, and considering it, besides the land use, as a major component of the sustainability impact assessment.

An approach of sustainability assessment is presented by Louette (2008), who points out some studies that compare the Ecological Footprint (ha/ hab) against the HDI (Human Development Index) values, whose baseline value is defined as 0,8 by United Nations. This comparative analysis aims to identify sustainable development levels. Louette (2008) reports a matrix of assessment for sustainable development, where the ecological durability is achieved as the Ecological Footprint relies between 0 and 2, and HDI overcomes 0,8 and approximates to 1,0. The Ecological Footprint indicates the ratio between the biologic productive area and the population size, which measures the area needed to produce the resources for the population of a region.

Several reasons support the idea of considering water as a major component, or even as mainstreaming, in Sustainability Assessment approaches. This is particularly true when dealing with such a region like the La Plata River Basin. Three motivations deserve to be mentioned, as they have been just highlighted in the recent 5th WWF Thematic Reports, on March 2009:

1. Water is an actual cross-sector component of human development. Water is directly or indirectly linked to most of challenges posed by the Millennium Development Goals: Climate Change, ecosystem degradation, the food crisis, the energy crisis and the economic crisis. Water "*provides the basic drivers of human development – drinking water, sanitation, energy, food and transport"*.
2. River basin cross political boundaries and its management is posed a key challenge and opportunity for sustainable management "*focused on hydrosolidarity as a means* to improve trans-boundary cooperation."
3. The development of *indicators able to monitor and assess the quality of cooperation at any level of basin management* (e.g., local, national, trans-boundary) *is extremely important for the range of stakeholder to assess progress.* They stress that "*creating a sense of ownership among stakeholders is a key to the success of a project on the ground". (5th WWF, 2009)*.

On the other hand, the proposal of using an approach based on the **Ecological Footprint**, the "Agricultural Footprint" of the sugar cane production, being water mainstreaming, is still on formulation and deserves to be justified.

The *Ecological Footprint* methodology consists into the accountability of matter and energy fluxes and their conversion in area of bio-productive land needed to the maintenance of this fluxes. It was developed by WWF (World Wildlife Foundation) aiming at mobilization and awareness by sharing information on the unsustainable production fed by high levels of consumption.

Increasingly, the sustainability depends on changes in the consumption pattern, not only at local or national level, but also at global level. Within the promotion of policies suitable to a sustainable development model, the governments, allied to the economical sector and the civil society may contribute to the adoption of goods and services efficiently produced, what means, with a low level of energy and matter consumption.

The establishment of policies focused at a sustainable development means that the human activities s be planned and managed to meet human wellbeing requirements as well as to keep impacts under the support capacity limits of a given region, in order to maintain its ability to perpetuate itself and to provide goods and services to the future generations.

The Ecological Footprint, as an indicator of the consumption impact on the bioproductive land use, in terms of area per inhabitant, when coupled to the use of an environmental impact indicator, such as the water availability in a region impacted by sugarcane crop, allow evaluating how much the impact is related to the local consumption and how much is caused by activities that feed external demands in a global web of economical, social and environmental relationships.

The use of water related indicators to signalize the water availability and quality, as well as the implications of ethanol productions to the boundaries regions is a promising attempt.

Taking into account that: i) the Sugar Cane Alcohol Production Sector promotes a set of social and economical activities which demand matter and energy; ii) one of the main environmental resource used is water, and the water availability to the crop besides water quality play a major role in the regional sustainability, the following approach should be developed:

- The establishment of a sustainability **signal flag** using the "Agricultural Footprint" of the sugarcane and alcohol sector impact onto water availability, to assess the thresholds to sustainability.

An integrated indicator that may be considered as a signal of water sustainability, for instance, should take into account the WRSI (Water Requirements Satisfaction Index (WRSI) related to sugar cane, and try to relate the SugarCane Ethanol "Agricultural Footprint" to the water availability. It worthwhile to mention that World Wildlife Foundation has a project focused at developing Water Footprint of Cattle for the Pantanal region, a sensitive area within the La Plata River Basin.

10 Final Considerations

The studies carried out by the Work-Packages 8.4 and 8.5 were conducted in close partnership, particularly in the final phase, aiming at the development of SIAT-TTC and scenarios simulation modeling. The integration of the results of the Work Packages of Module 8 pursued the conditions to build a reliable tool for sustainability assessment of land use-related policies.

Some points of constraints and successes of the transferability process were identified on the SIAT-TTC prototype adaptation for the Mercosur conditions. Some constraints of transferability have already been mentioned in former deliverables, according to the adaptation processes experienced in each Work Package. The development of SIAT-TTC has overcome the constraints and explored the advantages related in the following paragraphs. The successful advancements and the main proposals are pointed out in the final statements of this chapter.

Constraints

In the SIAT-TTC transferability process, the WP 8.4 team faced a series of constraints:

- ✓ The time requirements to the SIAT-TTC development process are beyond the team availability and size. It should be noticed that the formation of the WP 8.4 group were delayed in relation to the project SENSOR-TTC starting point, due to problems as the exit of one of the members;
- ✓ The lack of IT knowledge in the SENSOR-TTC team, once the researcher of this area left Embrapa Soils staff in February 2008. From October to May, one technical professional (M. Sc. student) was hired to be responsible for the SIAT-TTC prototype programming within WP 8.4;
- ✓ Difficulties in achieving the integration of all WPs of the project SENSOR-TTC Mercosur. This integration is very important once each work-package (WP) team is involved into the SIAT-TTC prototype development through the knowledge construction on the different issues and methodological analysis of Sustainability Impact Assessment focused by the WPs. One possible reason for this constraint was the difference of domain languages due to varied scientific formation of members, and small experience with complex system modeling by several participants of the project;
- ✓ Difficulties in the construction of the analytical causal chains by identifying the factors that describe the cause-effect relations between the external pressures and indicators.
- ✓ Data availability limitation to develop the meta-modeling system based on the response protocols;
- ✓ Lack of aggregated information from the indicators pointed by experts to be used in Mercosur. This information conditioned the meta-model

development and, as a consequence, some features of the graphical interface SIAT- TTC GUI implementation process.

Advantages

Aiming at overwhelming these limitations the WP4 team (SIAT-TTC development) took advantages of the following successful procedures and potentials:

- ✓ Good integration of the WP4 team through frequent hands-on meetings of the group;
- ✓ Intensive communication with the personnel responsible by the SIAT-EU development;
- ✓ Intensive communication work with the people from the other WPs and;
- ✓ The hiring of two IT personnel (the first one involved into the SIAT-TTC prototype programming, taking part of the WP 8.4 team, and the other collaborating with the Data Base Management System design and construction, under the WP 8.5 responsibility), and the hiring of a M.Sc. student responsible to the application of the Land Use Change model Dyna-CLUE;
- ✓ Frequent meetings for discussions on the SENSOR reports and publications by the WP 8.4: the input from SIAT-EU conceptual guidelines was a fundamental contribution to the SIAT-TTC transferability process, besides the input from the several WP of the SENSOR-EU project team presented in the deliverables and the book "Sustainability Impact Assessment of Land Use Changes"
- ✓ The varied scientific formation of the members was taken as an advantage for offering diverse points of view regarding the project process. The insight provided from the several WPs deliverables were very important to the knowledge integration into the SIAT-TTC;

The major advancements achieved during the SIAT-TTC development are:

a) The transferability process of the Sustainability Impact Assessment Tool SIAT-TTC demonstrated to be effective regarding the following results:

✓ The comprehension of the meta-modeling approach applied to the DPSIR framework used in SENSOR Impact Assessment was obtained and allowed the design of an adapted SIAT-TTC prototype (first version in development available at http://siatttc.cnps.embrapa.br/);

✓ Preliminary results of Land Use Change scenarios were obtained for the Ethanol policy case in the state of Mato Grosso do Sul by mean of the dynamic modeling system Dyna-CLUE. The model parameters of conversion and transition were set to simulate the driving effects of the policy instruments based on spatial restrictions and land use class restrictions to conversion;

b) Although the SENSOR-EU modeling framework of Sustainability Impact Assessment based on macroeconomical model NEMESIS integrated to five sector models and Dyna-CLUE was not fully applied in Mercosur conditions due to limitations such as the lack of data and the small staff number, the SIAT-TTC team achieved the **understanding** of **how to design a policy case assessment** based on its land use change effects and impacts on the social, economical and environmental conditions, and **how to apply Land Use Change (LUC) Modeling System results** to generate mathematical functions used as factors of **response protocols** linking policy effects on land used change to sustainability indicators in a meta-modelling approach.

c) The building of **response protocols** was constrained by: i) the limited quantitative data to relate LUC and quantitative variable indicators, using indicator functions; and ii) the lack of established knowledge-rules regarding qualitative indicators in Mercosur conditions. Nevertheless, in the transferability of SIAT modeling framework, the application of **Analytical Causal Chain concept** provided a method to translate the policy pressures, given as land use changes, into an impact indicator related to social, economical or environmental dimension. This approach, based on identifying the factors that describe the cause-effect relations between the external pressures and indicators, was exemplified in the chapter 8 and has a high potential of future application.

d) In the last step of Sustainability Impact Assessment, the Multi-functionality of land use is taken into account with SENSOR adoption of the LUF (**Land Use Functions**) concept to evaluate changes in sustainability considering: i) the three dimensions (economic, social and environmental) of the sustainability within the goods and services offered by the multiple use of the land; ii) the need of an aggregated impact indicator able to provide comprehensive information on the sustainability level; and iii) in comparison to thresholds and targets designed according to the community/ stakeholders/ decision makers goals. The lack of available indicator variables enough to the LUF analysis application avoid it to be used in the SIAT-TTC Mercosur. However, following these three basic principles (multi-dimension approach, provision of useful and reliable information on sustainability and design of thresholds and targets), the team presented alternative proposals for future research advancements on integrative indicators (ninth chapter): the application of the Barometer of Sustainability and the Agricultural Footprint based on the "Ecological Footprint" concept.

The proposals for future studies aimed at the development of Sustainability Assessment tools and methodological research are:

- ✓ The improvement of SIAT-TTC Mercosur by the implementation of Adaptive Object-Model architecture style, to obtain a more flexible system, with an increment of end user interaction and greater autonomy for modelers test changes into the system parameters, without the need of a programmer to modify the hard-code;

- ✓ The integration of SIAT-TTC software to the modeling tool TerraME, in order to provide a larger range of possibilities for complex systems modeling, such as environmental models or sustainability scenarios models;
- ✓ The inclusion of Water as a major component in Sustainability Assessment, particularly in areas where the central role of water resources in human development is impacted by situations such as scarcity, conflicting purposes and trans-boundary context.

In summary, through an intensive process of internal integration work and a high level interaction with the SENSOR-EU project partners, the SIAT-TTC team in Mercosur achieved a degree of training that allowed: i) the knowledge integration into the SIA tool to be applied to Mercosur conditions, although constrained by mentioned problems, and ii) the construction of possible technical solutions to implement the SIAT-TTC prototype and to adopt the SIA framework DPSIR, with needed adaptations.

11 References

[1] Abstract Syntax Tree (2009, March 10), In Wikipedia, the free encyclopedia. Retrieved March 10, 2009 from http://en.wikipedia.org/wiki/Abstract_syntax_tree

[2] Specification Pattern(2009, March 10), In Wikipedia, the free encyclopedia. Retrieved March 10, 2009 from http://martinfowler.com/apsupp/spec.pdf

[3]http://www.adaptiveobjectmodel.com/WICSA3/ArchitectureOfAOMsWICSA3.pdf

[4] http://www.martinfowler.com/articles/languageWorkbench.html

[5] http://www.infoq.com/presentations/domain-specific-languages

[6] (http://www.martinfowler.com/articles/injection.html)

[7]http://www.adaptiveobjectmodel.com/WICSA3/ArchitectureOfAOMsWICSA3.pdf

[8] http://www.python.org/

[9] http://www.ruby-lang.org/

[10] Conservation International. Biodiveristy Hotspots. (Accessed in May/2009). http://www.biodiversityhotspots.org/xp/Hotspots/cerrado/Pages/default.aspx

Arvor, D., Sant'Anna Neto J. L., Dubreuil, V., Almeida, I. R., Meirelles, M. S. P. 2007. Análise dos perfis temporais de EVI/MODIS para o monitoramento da cultura da soja no Estado do Mato Grosso, Brasil In: XIII Simpósio Brasileiro de Sensoriamento Remoto, Florianópolis, SC, 21-26 de abril de 2007. Anais do XIII Simpósio Brasileiro de Sensoriamento Remoto.

Arvor, D., V. Dubreuil, M. S. P. Meirelles. 2008a. Variabilité spatio-temporelle du début de la saison des pluies au Mato Grosso (Brésil). In: 'Actes du XXème colloque de l'Association Internationale de Climatologie'. pp. 87-92. http://www.uhb.fr/sc_sociales/Costel/costel-mt.html

Arvor, D., M. S. P. Meirelles, L. G. Martorano, M. Jonathan, V. Dubreuil, I. Herlin, J.-P. Berroir. 2008b. Séries temporais de EVI/MODIS na identificação da dinâmica da soja em sistema plantio direto no Mato

Grosso, Brasil. XVII RBMCSA, 10-15 de agosto de 2008, Rio de Janeiro, Brasil.

Ab'Sáber, A.N. 1970. Províncias geológicas e domínios morfoclimáticos no Brasil. Geomorfologia, n.20.

Carneiro, T. Nested-CA: a foundation for multi-scale modeling of land use and land change. 2006. 116f. Tese (Doutorado em Ciência da Computação) - National Institute of Space Research, São José dos Campos, Brazil, 2006.

Domain model (2009, March 10). In Wikipedia, the free encyclopedia. Retrieved March 10, 2009 from http://en.wikipedia.org/wiki/Domain_model

Evans, E. 2004. "Domain-Driven Design: Tackling Complexity in Software," Addison-Wesley.

Firbank, Les, Norbert Kohlheb, Tom Kuhlman, Louise Reid, Tim Taylor, Hans Verkerk. 2007. Review of studies linking social, environmental and economic sustainability and land use land use. SENSOR, Deliverable 2.3.1, 21p.

Galdino, S.; Vieira, L.M.; Pellegrin, L.A. 2006. Impactos ambientais e socioeconômicos na Bacia do Rio Taquari. Corumbá: Embrapa Pantanal. 356 p.

Galdino et al. Perdas de solo na Bacia do Alto Taquari. Corumbá: Embrapa Pantanal. Boletim de Pesquisa e Desenvolvimento, n.44, 2003.

Galdino, S., Vieira L.M., Soriano, B.M.A. Erosão na Bacia do Alto Taquari. Documentos 52. 2003. Corumbá, MS. Available online: www.cpap.embrapa.br/publicacoes/online/DOC52.pdf

Gamma, E., Helm, R., Johnson R. and Vlissides J. 1994. Design Patterns: elements of reusable object-oriented software.

Helming K., Tscherning, K., Koning, B., Sieber, S.,Wigering, H., Kuhlman, T., Wascher, D., Perez-Soba, M., Smeets, P., Tabbush, P., Dilly, O., Huttl, R., Bach, H. 2008. Ex ante impact assessment of land use changes in European regions – the SENSOR approach. In: K. Helming, P. Tabbush and M. Perez-Soba (Editors), Sustainability impact assessment of land use changes. Springer, pp. 77-105.

Jansson, T. M Bakker, B Boitier, Afougeyrollas, J Helming, H van Mejil, PJ Verkerk. 2007. Cross sector land use modelling framework. In: K. Helming, P. Tabbush and M. Perez-Soba (Editors), Sustainability impact assessment of land use changes. Springer, pp.159-180.

Jonathan, Milton, Meirelles M. S. P., Coutinho H. L. C. 2008. Supporting Land Use Change Modeling with Automated Monitoring of Land Use Dynamics in the La Plata River Basin" – Impact Assessment of Land Use Changes In: International Conference, Berlin, April 6th-9th, 2008, Berlin.

Lisboa, Leila Sheila. 2008. Cenários de mudanças climáticas com modelagem dinâmica na Bacia do Alto Taquari. M.Sc. Dissertation, Rio de Janeiro: UERJ, State University of Rio de Janeiro, 88pp.

Louette, Anne. 2007. Compêndio para a Sustentabilidade. Ferramentas de Gestão de Responsabilidade Socioambiental Uma Contribuição para o Desenvolvimento Sustentável. 184p.

Manfroi, O. J., G. O. Fistarol, S. L. Schlindwein, L. R. D'Agostini, A. C. Fantini, S. R. Martins, K. Medvedovsky. 2009. Policy Instruments Related to Afforestation in Brazil. (Ch. 5.2) In: Monteiro, J. M.G., Coutinho, H. L.C., Veiga, L.B.E. et al. 2009. Driving force and policy scenario forecasts for land use changes in MERCOSUR case study areas. SENSOR-TTC Mercosur Del. 8.2.1b, 79pp.

Martorano, L. G., Galdino S., D´Agostini L.R., Ponce S. A., Hernani L.C., Cupertino J.L., Costa C. A. da, Vieira L. M., Rosso J., Costa A.R.C., Ramalho Filho A., Coutinho H. L. da C. 2002. Índice de desempenho ambiental na Bacia do Alto Taquari, MS: aspectos metodológicos. Rio de Janeiro: Embrapa – Embrapa Solos, Documentos, 34. 30 p.

Masiero, Gilmar and Lopes, Heloisa. Etanol e biodiesel como recursos energéticos alternativos: perspectivas da América Latina e da Ásia. Rev. Bras. Polít. Int. [online]. 2008, vol.51, n.2, pp. 60-79. ISSN 0034-7329.

Meirelles, M. S. P., Martorano L. G., Schuler A. E., Teixeira F. A., Santos F., Turetta A.P., Tavares H., Coutinho H., Ferraz R.D., Palma F., Schlindwein S., Fistarol G., Sieber S., Mülle K., Pohler D., Verweij P., Van Eupen M., Perez-Soba M., Verburg P., Oyarzabal M., Vega E., Jobbagy E., Baeza S., Altesor A. 2009. Operational GIS based data management which will be integrated into the SENSOR data management system. SENSOR, Del. 8.5.1, 21p.,

Monteiro, J. M.G., H. L.C. Coutinho, L.B.E. Veiga et al. 2008. Driving force and policy scenario forecasts for land use changes in MERCOSUR case study areas. SENSOR-TTC Mercosur Del. 8.2.1b, 79p.

Ortiz-Valencia, L. I. 2008. Enfoque da estatística espacial em modelos dinâmicos de mudança do uso do solo. M.Sc. Dissertation, Rio de Janeiro: UERJ, State University of Rio de Janeiro, 82pp.

Oyarzabal, Mariano, E. V. Vega Peña, G. Piñero y E. Jobbagy. 2009. Policy Instruments Related to Afforestation in Argentina (Ch. 5.3) and Policy Instruments Related to Afforestation in Uruguay. (Ch. 5.4) In: Monteiro, J. M.G., Coutinho, H. L.C., Veiga, L.B.E. et al. 2009. Driving force and policy scenario forecasts for land use changes in MERCOSUR case study areas. SENSOR-TTC Mercosur Del. 8.2.1b, 79pp.

Page-Jones, Meillir. Projeto Estruturado de Sistemas. São Paulo: Mcgraw-hill, 1988

Peña E.V.V., Oyarzabal M., Jobaggy E., and Paruelo J. Cambios en el uso del suelo en la cuenca del Rio de la Plata: Caracterización de los câmbios ocurridos y generación de escenarios futuros mediante modelos. SENSOR-TTC MERCOSUR. Manuscripts for Del. 8.2.1b and 8.4.1b. 2008.

Pedrosa, M.B.; Camara, G. Modelagem Dinâmica e Sistemas de Informações Geográficas. "In": Meirelles, M.S.P.; Camara, G.; Almeida, C.,M.

Geomática: Modelos e Aplicações Ambientais. Ed. Brasília, DF: Embrapa Informação Tecnológica. p. 237-280. 2007.

Pérez-soba, M., Petit, S., Jones, L., Bertrand, N., Briquel, V., Omodei-Zorini, L., Contini, C., Helming, K., Farrington, J., Mossello, M.T., Wascher, D., Kienast, F. and Groot, R.d., 2008. Land use functions — a multifunctionality approach to assess the impact of land use changes on land use sustainability In: K. Helming, P. Tabbush and M. Perez-Soba (Editors), Sustainability impact assessment of land use changes. Springer, pp. 375-404.

Plano Nacional de Agroenergia 2006-2011. Ministério da Agricultura, Pecuária e Abastecimento, Secretaria de Produção e Agroenergia. 2. ed. rev. - Brasília, DF : Embrapa InformaçãoTecnológica, 2006. 110 p. Available at: http://www.agricultura.gov.br/pls/portal/docs/PAGE/MAPA/PLANOS/PNA_2006_2011/PLANO NACIONAL DE AGROENERGIA 2006 - 2011-INGLES.PDF

Sieber, Stefan, Katharina Fricke, Dirk Pohle, Klaus Müller. Knowledge integration: Implementation of response functions and fact sheets into the Sustainability Impact Assessment Tools SIAT. SENSOR Deliverable 4.3.2, 2008.

Sieber, S., Klaus Müller, Verweij, P., Hördur Haraldsson, KAtharina Fricke, Cesare Pacini, Tscherning, K., Helming K., Jansson, T. 2007. Transfer into decision support: The Sustainability Impact Assessment Tool (SIAT) In: K. Helming, P. Tabbush and M. Perez-Soba (Editors), Sustainability impact assessment of land use changes. Springer, pp. 107-128.

Torbjörn Jansson (2007) Protocols for integration of model and indicator outputs into SIAT. Del. 2.3.5

Turetta, A.P.; Guimarães, L.T.; Perez-Soba,M.; Monteiro, J.; Veiga, L. B. E.; Martorano, L.G.; Schuler, A.E.; Coutinho, H.L.C.; Fistarol, G.; Schlindwein, S. TTC input maps for SIAT-TTC providing indicator assessment results and thresholds making reference to Land Use Functions. SENSOR Deliverable 8.3.3. 2008.

Vega, Ernesto; M. Oyarzabal, E. Jobbágy, G. Piñeiro, A. Altesor, S. Baeza, G. O Fistarol, H. L. C. Coutinho. 2008. Reports on institutional analysis of the use of SIAT-TTC and definition of requirements for successful participatory implementation into institutional environment. SENSOR Deliverable 8.7.1b. 41p.

Veldkamp, T.; Fresco, L.O. 1996. *Dyna-CLUE-CR*: an integrated multi-scale model to simulate land use change scenarios in Costa Rica. Ecological Modelling. v. 91. p. 231-248.

Verburg, P.; Veldkamp, T.; Fresco, L.O. 1999. *Simulation of changes in the spatial pattern of land use in China*. Applied Geography. v. 19, p. 211–233.

Verburg, P., M. Bakker, K.P. Overmars, I. Staritsky. 2007 Landscape level simulation of land use change. In: K. Helming, P. Tabbush and M. Perez-

Soba (Editors), Sustainability impact assessment of land use changes. Springer, pp.211-230.

Verweij Peter J.F.M., Johnny Te Roller, Bas Vanmeulebrouk, Rob Knapen, Yke Van Randen, Wim De Winter, Peter Van De Koppel SENSOR (2008), SIAT design and architecture, Sustainability Impact Assessment Tool prototype II. In: SENSOR, 2008. Deliverable 4.3.1. 68 p.

Verweij P. J.F.M., Knapen M.J.R., Wien J.J.F. 2007. The use of OpenMI in model based integrated assessments, Modsim2007, Christchurch, New Zealand, 2007.

Verweij, P., Sieber, S., Wien, J. and Müller, K. SIAT, a sustainable impact assessment tool for understanding the drivers in integrated impact assessment, International Congress on Environmental Modelling and Software. iEMSs, 2006, Burlington (Vermont), USA.

5th World Water Forum. Thematic Report. Theme 1: Global Changes and Risk Management. Coord.: Schaick, Henk va (CPWC), Avinash Tyagi (WHO) and Tim Kasten (UNEP). Bridging Divides for Water. Istambul, March 16th-22nd, 2009. 15p.

5th WWF. Thematic Report. Theme 2: Advancing Human development and the Milennium Development Goals. Coord.: Pasquale Steduto (UN Water/ FAO). Bridging Divides for Water. Istambul, March 16th-22nd, 2009. 10p.

5th WWF. Thematic Report. Theme 3: Managing and Protecting Water Resources and their Supply Systems to Meet Human and environmental Needs. Coord.: Reid, Ken (AWRA), Hasan Özlü (DSI) and Karin Krchnak (TNC). Bridging Divides for Water. Istambul, March 16th-22nd, 2009. 13p.

Yoder, Joseph W.; Ralph Johnson, The Adaptive Object-Model Architectural Style. 2002. Retrieved March 10, 2009 from http://www.adaptiveobjectmodel.com/WICSA3/ArchitectureOfAOMsWICSA3.pdf

APPENDIX A

Programs of Chapter 5:

Software Engineering applied to SIAT-TTC

a) Program A1: **public interface** Specification.

```
public interface Specification{
    boolean isSatisfiedBy(Object candidate);
    Specification and(Specification other);
    Specification or(Specification other);
    Specification not(Specification other);
}

public abstract class CompositeSpecification implements Specification{

    public abstract boolean isSatisfiedBy(Object candidate);

    public Specification and(Specification other) {
        return new AndSpecification(this, other);
    }
    public Specification or(Specification other) {
        return new OrSpecification(this, other);
    }
    public Specification not(Specification other) {
       return new NotSpecification(this);
    }
}

class AndSpecification extends CompositeSpecification
{
    private Specification one;
    private Specification other;

    public AndSpecification(Specification x, Specification y){
        one = x;
        other = y;
    }
    public boolean isSatisfiedBy(Object candidate) {
        return             one.isSatisfiedBy(candidate)             &&
            other.isSatisfiedBy(candidate);
    }
}

class OrSpecification extends CompositeSpecification{
    private Specification one;
    private Specification other;

    public OrSpecification(Specification x, Specification y){
        one = x;
        other = y;
    }

    public boolean isSatisfiedBy(Object candidate){
        return             one.isSatisfiedBy(candidate)             ||
             other.isSatisfiedBy(candidate);
    }
}

class NotSpecification extends CompositeSpecification{
    private Specification wrapped;

    public NotSpecification(Specification x) {
        wrapped = x;
    }
```

```
    public boolean isSatisfiedBy(Object candidate)
    {
        return !wrapped.isSatisfiedBy(candidate);
    }
}
```

b) Program A2: *SuggarCaneEthanolSpecification sugarcane*.

```
SuggarCaneEthanolSpecification sugarCane;
sugarCane = new SuggarCaneEthanolSpecification();

IndustrialForestSpecification industrialForest;
industrialForest = new IndustrialForestSpecification();

PastureOnlySpecification pastureOnly;
pastureOnly = new PastureOnlySpecification();

PasturesAndCropsSpecification pastureAndCropsOnly;
pastureAndCropsOnly = new PasturesAndCropsSpecification();

NoRestrictionsSpecification noRestrictions;
noRestrictions = new NoRestrictionsSpecification();

SugarCaneIndustrialPlantsAllowedSpecification industrialPlantsAllowed;
industrialPlantsAllowed                      =                     new
SugarCaneIndustrialPlantsAllowedSpecification();

SugarCaneIndustrialPlantsNotAllowedSpecification
industrialPlantsNotAllowed;
industrialPlantsNotAllowed                    =                    new
SugarCaneIndustrialPlantsNotAllowedSpecification();

FireAllowedMechanicalAndManualHarvestTypeSpecification
mechanicalAndManualHarvestType;
mechanicalAndManualHarvestType                 =                   new
FireAllowedMechanicalAndManualHarvestTypeSpecification();

MechanicalNoFireSpecification mechanicalHarvestType;
mechanicalHarvestType = new MechanicalNoFireSpecification();

PolicyCase polCase1 = new PolicyCase();
PolicyCase polCase2 = new PolicyCase();

PolicyInstrumentSetting polSettings1 = new PolicyInstrumentSetting();
PolicyInstrumentSetting polSettings2 = new PolicyInstrumentSetting();
PolicyInstrumentSetting polSettings3 = new PolicyInstrumentSetting();

polCase1.id = 1;
polCase1.name = "Sugar Cane Ethanol";

polCase2.id = 2;
polCase2.name = "Industrial Forest";

// zonRestricLandCover == 2 ... "Pastures and Crops Only"
polSettings1.zonRestricLandCover = 2;
// zonRestricParaguay == 2 ... "S. Cane Industrial Plants Not Allowed"
polSettings1.zonRestricParaguay = 2;
```

```
// harvestType == 1  ... "No fire (Mechanical)"
polSettings1.harvestType = 1;

SiatSimulation simulation1 = new SiatSimulation();
simulation1.setPolicyCase(polCase1);
simulation1.setPolicySettings(polSettings1);
```

c) Program A3: *IndustrialForestSpecification*

```
class IndustrialForestSpecification extends CompositeSpecification {
      /*
       * (polCase.id == 2) : it means Industrial Forest Policy Case
       */
      @Override
      public boolean isSatisfiedBy(Object candidate) {
            PolicyCase polCase = (PolicyCase) candidate ;
            return (polCase.id == 2);
      }

}
```

d) Program A4: *PastureOnlySpecification*.

```
class PastureOnlySpecification extends CompositeSpecification {
      /*
       * (polInstrumentSetting.zonRestricLandCover == 1) :
       *    it's a type of restriction of zoning to the covering
       *    of the land before the conversion to sugar cane
       */
      @Override
      Public boolean isSatisfiedBy(Object candidate) {
            PolicyInstrumentSetting               polInstrumentSetting;
            polInstrumentSetting = (PolicyInstrumentSetting) candidate;
            return (polInstrumentSetting.zonRestricLandCover == 1);
      }
}
```

e) Program A5: `Policy Case Specifications`.

```
/*
 * Policy Case Specifications
 */
// (policyCaseID == 1): it means Sugar Cane Ethanol Policy Case
SpecificationEntityFactory theFactory;
SpecificationEntity scPolCase;
SpecificationVariable variable1;
Specification conditionOfSugarCaneEthanol;

theFactory = SpecificationEntityFactory.getFactory();
scPolCase = theFactory.createEntityFrom("PolicyCasePROTOTYPE");
scPolCase.setPartName("Suggar Cane Ethanol Policy Case");
variable1 = scPolCase.getPart(scPolCase.getPartID(), "policyCaseID");

conditionOfSugarCaneEthanol =
            new Specification("Suggar Cane Ethanol Specification",
                              variable1,
```

```
                              "1",
                              "==");

// (policyCaseID == 2): it means Industrial Forest Policy Case
SpecificationEntity indForPolCase;
SpecificationVariable variable2;
Specification conditionOfIndustrialForest;

indForPolCase = theFactory.createEntityFrom("PolicyCasePROTOTYPE");
indForPolCase.setPartName("Industrial Forest Policy Case");
variable2                                                         =
indForPolCase.getPart(indForPolCase.getPartID(),"policyCaseID");

conditionOfIndustrialForest =
            new Specification("Industrial Forest Specification",
                              variable2,
                              "2",
                              "==");
```

f) Program A6: *InstrumentSetting*.

```
/*
 * (varZonRestricLandCover == 1) :
 *    it's one option of restriction of zoning to the covering
*     of land before the conversion to sugar cane
 */
SpecificationEntity policyInstrumentSetting;
SpecificationVariable varZonRestricLandCover;

policyInstrumentSetting =
      theFactory.createEntityFrom("PolicyInstrumentSettingPROTOTYPE");
policyInstrumentSetting.setPartName("Instrument Setting");
varZonRestricLandCover                                            =
policyInstrumentSetting.getPart(policyInstrumentSetting.getPartID(),
                                          "zonRestricLandCover");
Specification conditionOfPastureOnly =
            new Specification("Pastures Only Specification" ,
                              varZonRestricLandCover,
                              "1",
                              "==");


/*
 * (varZonRestricLandCover == 2) :
 *    it's another option of restriction of zoning to the covering
 *    of land before conversion to sugar cane using the same
 *    varZonRestricLandCover variable.
 */
Specification conditionOfPasturesAndCrops =
            new Specification("Pastures and Crops Only Specification",
                              varZonRestricLandCover,
                              "2",
                              "==");
```

g) Program A7: `Factory Specification EntityFactory.getFactory`

```
factory = SpecificationEntityFactory.getFactory();
parser = new JEP();
```

```
entity = factory.createEntityFrom("PolicyInstrumentSettingPROTOTYPE");
variable =
      oneEntity.getPart(oneEntity.getPartID(), "zonRestricLandCover");

//configurate an entity as new variable into JEP.
parser.addVariable("PolicyInstrumentSetting", entity);

function = "conditionOfPastureOnlyINTO(PolicyInstrumentSetting)"

//configurate new function into JEP.
parser.addFunction(
                  function,
                  new SpecificationFunction(
                                    "Pastures Only Specification",
                                    entity,
                                    oneVariable,
                                    "1",
                                    "=="
                                          )
);

// Parse the expression
n = (ASTFunNode) parser.parse(function);
// Get the result
result = parser.evaluate(n);
```

APPENDIX B

Additional Tables of Chapter 7:

Land Use change model Dyna-CLUE applied to the SIAT-TTC

1. Transition Matrix Files to Dyna-CLUE model applied to Sugar cane Policy case in Mato Grosso do Sul State

Example of transition matrix file allow.txt applied to Sugar cane policy case, for the first option settings tested in Dyna-CLUE for previous land use to sugar cane conversion: any previous use allowed.

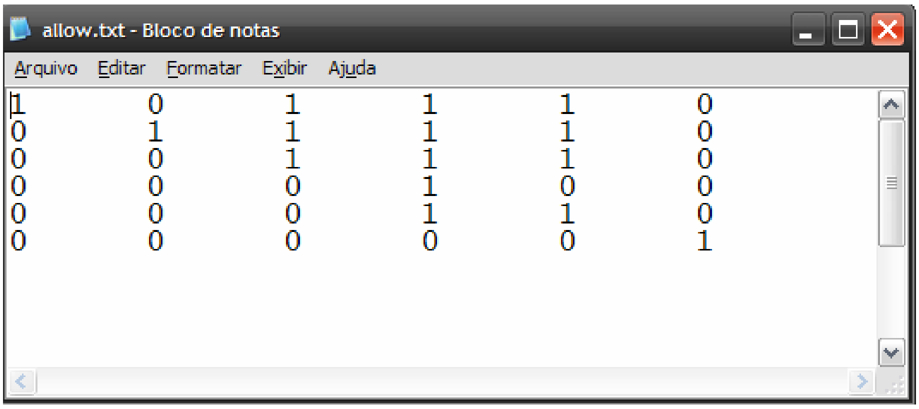


Figure B1 – Example of file allow.txt with transition matrix associated to "no restriction" of previous use for sugar cane conversion.

2. Logistical regressions

The logistical regressions relate the matrix data of land use locations and the matrices of candidate variables to drivers. The regressions results indicate the main drivers for each land use class.

Forest: Logistic regression results

Classification Table[a]

	Observed		Predicted		
			Uso vegetacao natural		Percentage Correct
			sem	com	
Step 1	Uso vegetacao natural	sem	13351	22522	37.2
		com	2379	36950	94.0
	Overall Percentage				66.9

a. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95.0% C.I.for EXP(B) Lower	95.0% C.I.for EXP(B) Upper
Step 1[a]	dmin_usi_cat(1)	-2.125	.031	4775.730	1	.000	.119	.112	.127
	dmin_hid_cat(1)	.119	.018	43.064	1	.000	1.126	1.087	1.166
	zone_cod_2(1)	-1.270	.036	1231.683	1	.000	.281	.262	.301
	zone_cod_3(1)	-.305	.021	220.816	1	.000	.737	.708	.767
	Constant	.464	.017	771.905	1	.000	1.590		

a. Variable(s) entered on step 1: dmin_usi_cat, dmin_hid_cat, zone_cod_2, zone_cod_3.

Cerrado: Logistic regression results

Classification Table[a]

Observed			Predicted: Uso cerrado sem	Predicted: Uso cerrado com	Percentage Correct
Step 1	Uso cerrado	sem	69149	17851	79.5
		com	21235	65486	75.5
	Overall Percentage				77.5

a. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95.0% C.I.for EXP(B) Lower	95.0% C.I.for EXP(B) Upper
Step 1[a]	dmin_usi_cat(1)	-1.327	.019	5101.763	1	.000	.265	.256	.275
	dmin_hid_cat(1)	.159	.014	135.162	1	.000	1.172	1.141	1.204
	zone_cod_3(1)	-2.469	.018	19639.212	1	.000	.085	.082	.088
	zone_cod_2(1)	-1.893	.021	8304.539	1	.000	.151	.145	.157
	zone_cod_1(1)	-1.727	.015	13284.245	1	.000	.178	.173	.183
	Constant	1.113	.014	6562.233	1	.000	3.045		

a. Variable(s) entered on step 1: dmin_usi_cat, dmin_hid_cat, zone_cod_3, zone_cod_2, zone_cod_1.

Pasture: Logistic regression results

Classification Table[a]

Observed			Predicted: Uso pastagem sem	Predicted: Uso pastagem com	Percentage Correct
Step 1	Uso pastagem	sem	111474	61393	64.5
		com	52524	133997	71.8
	Overall Percentage				68.3

a. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95.0% C.I.for EXP(B) Lower	95.0% C.I.for EXP(B) Upper
Step 1[a]	zone_cod_1(1)	1.158	.010	13923.009	1	.000	3.183	3.123	3.245
	zone_cod_2(1)	.871	.012	5430.120	1	.000	2.390	2.335	2.446
	dmin_usi_cat(1)	-.187	.009	395.066	1	.000	.829	.814	.845
	zone_cod_3(1)	2.028	.010	39232.457	1	.000	7.601	7.450	7.755
	Constant	-.803	.006	17965.396	1	.000	.448		

a. Variable(s) entered on step 1: zone_cod_1, zone_cod_2, dmin_usi_cat, zone_cod_3.

Sugar Cane: Logistic regression results

Classification Table[a]

Observed			Predicted: Uso cana acucar sem	Predicted: Uso cana acucar com	Percentage Correct
Step 1	Uso cana acucar	sem	1735	631	73.3
		com	40	2326	98.3
	Overall Percentage				85.8

a. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95.0% C.I.for EXP(B) Lower	95.0% C.I.for EXP(B) Upper
Step 1[a]	dmin_usi_cat(1)	6.510	.416	245.373	1	.000	671.878	297.532	1517.216
	zone_cod_1(1)	-.851	.277	9.429	1	.002	.427	.248	.735
	zone_cod_2(1)	.546	.164	11.069	1	.001	1.727	1.252	2.383
	zone_cod_3(1)	.533	.154	12.052	1	.001	1.704	1.261	2.303
	Constant	-5.695	.418	186.070	1	.000	.003		

a. Variable(s) entered on step 1: dmin_usi_cat, zone_cod_1, zone_cod_2, zone_cod_3.

Agriculture: Logistic regression results

Classification Table[a]

Observed			Predicted: Uso agrocultura sem	Predicted: Uso agrocultura com	Percentage Correct
Step 1	Uso agrocultura	sem	25308	13715	64.9
		com	6013	33010	84.6
	Overall Percentage				74.7

a. The cut value is .500

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95.0% C.I.for EXP(B) Lower	Upper
Step 1[a]	dmin_usi_cat(1)	1.336	.021	4005.163	1	.000	3.803	3.648	3.963
	zone_cod_1(1)	2.040	.032	4003.916	1	.000	7.688	7.217	8.189
	zone_cod_2(1)	2.753	.032	7280.467	1	.000	15.692	14.731	16.717
	zone_cod_3(1)	1.291	.030	1842.309	1	.000	3.638	3.430	3.859
	dmin_sed_cat(1)	1.273	.029	1908.962	1	.000	3.573	3.374	3.783
	Constant	-3.294	.034	9223.180	1	.000	.037		

a. Variable(s) entered on step 1: dmin_usi_cat, zone_cod_1, zone_cod_2, zone_cod_3, dmin_sed_cat.

3. Land use change historical trends

a) Sugarcane: Data from CANASAT 2008/2009 (www.inpe.br)

Table B1. Available area to sugar cane harvest and reform in the State of Mato Grosso do Sul - Season 2008/2009

CODE IBGE	Counties	Available area to harvest (ha)				Current Reform[d] (ha)	Total Area[e] (ha)
		Planted [a]	Reformed[b]	Expansion[c]	Total[a+b+c]		
5000203	Água Clara	0	0	0	0	0	0
5000252	Alcinópolis	0	0	0	0	0	0
5000609	Amambaí	0	0	0	0	0	0
5000708	Anastácio	0	0	0	0	0	0
5000807	Anaurilândia	0	0	546	546	0	546
5000856	Angélica	3,669	0	8,570	12,239	0	12,239
5000906	Antônio João	0	0	0	0	0	0
5001003	Aparecida do Taboado	18,640	630	5,137	24,407	2,264	26,671
5001102	Aquidauana	0	0	0	0	0	0
5001243	Aral Moreira	0	0	0	0	0	0
5001508	Bandeirantes	0	0	0	0	0	0
5001904	Bataguassu	0	0	0	0	0	0
5002001	Batayporã	0	0	1,583	1,583	0	1,583
5002100	Bela Vista	0	0	0	0	0	0
5002159	Bodoquena	0	0	0	0	0	0
5002209	Bonito	0	0	0	0	0	0
5002308	Brasilândia	8,250	462	0	8,712	0	8,712
5002407	Caarapó	0	0	890	890	0	890
5002605	Camapuã	0	0	0	0	0	0
5002704	Campo Grande	0	0	0	0	0	0
5002803	Caracol	0	0	0	0	0	0
5002902	Cassilândia	0	0	0	0	0	0
5002951	Chapadão do Sul	0	0	897	897	0	897
5003108	Corguinho	0	0	0	0	0	0

Table B1. Available area to sugar cane harvest and reform in the State of Mato Grosso do Sul - Season 2008/2009

CODE IBGE	Counties	Available area to harvest (ha)				Current Reform[(d)] (ha)	Total Area[(e)] (ha)
		Planted [(a)]	Reformed[(b)]	Expansion[(c)]	Total[(a+b+c)]		
5003157	Coronel Sapucaia	0	0	0	0	0	0
5003207	Corumbá	0	0	0	0	0	0
5003256	Costa Rica	0	0	464	464	0	464
5003306	Coxim	0	0	0	0	0	0
5003454	Deodápolis	410	0	335	745	0	745
5003488	Dois Irmãos do Buriti	640	569	0	1,209	484	1,693
5003504	Douradina	0	0	0	0	0	0
5003702	Dourados	1,186	0	3,851	5,037	14	5,051
5003751	Eldorado	90	0	2,734	2,824	0	2,824
5003801	Fátima do Sul	0	0	79	79	0	79
5003900	Figueirão	0	0	0	0	0	0
5004007	Glória de Dourados	0	0	31	31	0	31
5004106	Guia Lopes da Laguna	0	0	0	0	0	0
5004304	Iguatemi	4,907	0	3,215	8,122	0	8,122
5004403	Inocência	0	0	0	0	0	0
5004502	Itaporã	2,866	0	1,554	4,420	0	4,420
5004601	Itaquiraí	14,139	1,596	857	16,592	2,067	18,659
5004700	Ivinhema	30	0	1,953	1,983	0	1,983
5004809	Japorã	0	0	0	0	0	0
5004908	Jaraguari	0	0	0	0	0	0
5005004	Jardim	0	0	0	0	0	0
5005103	Jateí	0	0	788	788	0	788
5005152	Juti	716	64	196	976	0	976
5005202	Ladário	0	0	0	0	0	0
5005251	Laguna Carapã	0	0	0	0	0	0
5005400	Maracaju	16,887	1,190	6,185	24,262	830	25,092
5005608	Miranda	0	0	0	0	0	0

Table B1. Available area to sugar cane harvest and reform in the State of Mato Grosso do Sul - Season 2008/2009

CODE IBGE	Counties	Available area to harvest (ha)				Current Reform[(d)] (ha)	Total Area[(e)] (ha)
		Planted [(a)]	Reformed[(b)]	Expansion[(c)]	Total[(a+b+c)]		
5005681	Mundo Novo	0	0	0	0	0	0
5005707	Naviraí	15,110	1,052	2,992	19,154	2,567	21,721
5005806	Nioaque	0	0	0	0	0	0
5006002	Nova Alvorada do Sul	18,777	457	2,530	21,764	568	22,332
5006200	Nova Andradina	13,851	1,623	2,459	17,933	4,660	22,593
5006259	Novo Horizonte do Sul	0	0	0	0	0	0
5006309	Paranaíba	1,856	0	5,090	6,946	0	6,946
5006358	Paranhos	0	0	0	0	0	0
5006408	Pedro Gomes	0	0	0	0	0	0
5006606	Ponta Porã	0	0	1,346	1,346	0	1,346
5006903	Porto Murtinho	0	0	0	0	0	0
5007109	Ribas do Rio Pardo	0	0	0	0	0	0
5007208	Rio Brilhante	35,919	800	22,657	59,376	77	59,453
5007307	Rio Negro	0	0	0	0	0	0
5007406	Rio Verde de Mato Grosso	0	0	0	0	0	0
5007505	Rochedo	0	0	0	0	0	0
5007554	Santa Rita do Pardo	10,035	1,468	1,907	13,410	612	14,022
5007695	São Gabriel do Oeste	0	0	0	0	0	0
5007802	Selvíria	1,149	0	230	1,379	0	1,379
5007703	Sete Quedas	0	0	0	0	0	0
5007901	Sidrolândia	8,627	1,370	4,723	14,720	1,060	15,780
5007935	Sonora	10,938	1,028	1,876	13,842	3,414	17,256
5007950	Tacuru	0	0	0	0	0	0
5007976	Taquarussu	34	0	110	144	0	144
5008008	Terenos	1,636	726	191	2,553	1,103	3,656
5008305	Três Lagoas	0	0	0	0	0	0
5008404	Vicentina	160	0	1,458	1,618	0	1,618

Table B1. Available area to sugar cane harvest and reform in the State of Mato Grosso do Sul - Season 2008/2009

CODE IBGE	Counties	Available area to harvest (ha)				Current Reform[(d)] (ha)	Total Area[(e)] (ha)
		Planted [(a)]	Reformed[(b)]	Expansion[(c)]	Total[(a+b+c)]		
Total		**190,522**	**13,035**	**87,434**	**290,991**	**19,720**	**310,711**

(a) "Soca" is the sugar cane crop which has suffered more than one cutting, i.s., refers to the sugarcane sprouts. This class includes also one-year-old sugar cane crops reformed.

(b) "Reformed" is the sugar cane crop class where crops that is one year and a half, reformed in the previous year and ready to the harvest.

(c) "Expansion" is the sugar cane crop available to harvest at first time. Sugar cane crops converted to another land use during 2 or more harvest seasons and were cultivated with sugar cane again.

(d) "Reform" is the sugar cane crop class that will not be harvested due to reform with one year-and-a half plant-cane or destined to another use. When the 1.5 year-sugarcane crop in the "reforming" class is reformed, the area changes to the class "Reformed" in the next year harvest.

(e) "Total cultivated" involves all the classes (a+b+c+d), but it does not include new sugar cane crops, which will be harvested in the next year. For instance, a sugar cane crop cultivated in february 2008 will be available to harvest in 2009/2010 and is not included in the class "Total cultivated" of the harvest 2008/2009.

b) Pasture and Forest – Rural Cense (IBGE – Brazilian Institute of Geography and Statistics)

Table B. 2. Structural data results from Agricultural Cense
Mato Grosso do Sul - 1970/2006

	Censes				
Structural Data	1975	1980	1985	1995	2006
Number of Properties	**57 853**	**47 943**	**54 631**	**49 423**	**65 619**
Total area (ha)	**28 692 584**	**30 743 738**	**31 108 813**	**30 942 772**	**26 449 105**
Land use area (ha)					
Pasture	20 793 497	21 334 938	21 802 753	**21 810 708**	**18 421 427**
Forests	4 139 900	4 651 260	4 624 848	**5 877 739**	**4 951 044**

4. Aggregated Land Use Demand

Land Use demands are estimated based on the rate of increasing or decreasing of each land use change during the last ten years (business as usual scenario). These table sheets show the process used to calculate the land use claims for each land use type. The first table sheet presents the vvalues in hectares, and the second one in number of pixels.

pixels	35471	86721	186521	2366	39023	9286	359388
ha	3547100	8672100	18652100	236600	3902300	928600	
codigo clue	0	1	2	3	4	5	
taxa em pixels	-8	-8	6	7	3	0	0
taxa em hectares	-800	-800	600	700	300		
	(-)	(-)	(-)	(+)	(+)	(=)	
	VN	CE	PA	CA	AG	OU	Total
2008	3547100	8672100	18652100	236600	3902300	928600	35938800
2009	3546300	8671300	18652700	237300	3902600	928600	35938800
2010	3545500	8670500	18653300	238000	3902900	928600	35938800
2011	3544700	8669700	18653900	238700	3903200	928600	35938800
2012	3543900	8668900	18654500	239400	3903500	928600	35938800
2013	3543100	8668100	18655100	240100	3903800	928600	35938800
2014	3542300	8667300	18655700	240800	3904100	928600	35938800
2015	3541500	8666500	18656300	241500	3904400	928600	35938800
2016	3540700	8665700	18656900	242200	3904700	928600	35938800
2017	3539900	8664900	18657500	242900	3905000	928600	35938800
2018	3539100	8664100	18658100	243600	3905300	928600	35938800
1 pixel	100	ha					

Figure B2 – File with the aggregated demand (ha) for each land use change for "business as usual" scenario.

ano	pixels					
	VN	CE	PA	CA	AG	OU
	35471	86721	186521	2366	39023	9286
1	35463	86713	186527	2373	39026	9286
2	35455	86705	186533	2380	39029	9286
3	35447	86697	186539	2387	39032	9286
4	35439	86689	186545	2394	39035	9286
5	35431	86681	186551	2401	39038	9286
6	35423	86673	186557	2408	39041	9286
7	35415	86665	186563	2415	39044	9286
8	35407	86657	186569	2422	39047	9286
9	35399	86649	186575	2429	39050	9286
10	35391	86641	186581	2436	39053	9286
acrescimo total	-72	-72	54	63	27	0

Figure B3 – File with the aggregated demand (pixels) for each land use change for "business as usual" scenario.