Project no. GOCE-036955

LUPIS

Land Use Policies and Sustainable Development in Developing Countries

Specific Targeted Project

Integrating and Strengthening the European Research Area

D1.3: Final Report

Due date of deliverable: March 2011

Actual submission date: 29 August 2011

Start date of project: February 1, 2007 **Duration: 50 months**

Organisation name of lead contractor for this deliverable: LEI

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	X
CO	Confidential, only for members of the consortium (including the Commission Services)	

Authors of this report and contact details:

Name: Irina Bezlepkina — Partner acronym: LEI
Address: PO Box 29703, 2502 LS Den Haag, The Netherlands
E-mail: irina.bezlepkina@wur.nl

Name: Floor Brouwer — Partner acronym: LEI
Address: PO Box 29703, 2502 LS Den Haag, The Netherlands
E-mail: floor.brouwer@wur.nl

Name: Ingrid Nesheim — Partner acronym: UiO
Address: P.O. Box 1116 Blindern, NO-0317 Oslo, Norway
E-mail: ingrid.nesheim@sum.uio.no

Name: René Verburg — Partner acronym: LEI
Address: PO Box 29703, 2502 LS Den Haag, The Netherlands
E-mail: rene.verburg@wur.nl

Name: Huib Silvis — Partner acronym: LEI
Address: PO Box 29703, 2502 LS Den Haag, The Netherlands
E-mail: huib.silvis@wur.nl

With contributions from:

Name: Le Chen — Partner acronym: LEI
Address: PO Box 29703, 2502 LS Den Haag, The Netherlands
E-mail: le.chen@wur.nl

Name: Lindsay Chant — Partner acronym: LEI
Address: PO Box 29703, 2502 LS Den Haag, The Netherlands
E-mail: lindsay.chant@wur.nl

Name: Jacques Imbernon — Partner acronym: CIRAD
Address Campus international de Baillarguet - TA C-91 / F,
34398 Montpellier, Cedex 5, France
E-mail: imbernon@cirad.fr

Name: Muriel Bonin — Partner acronym: CIRAD
Address: Bat F, Bureay 215, 34398 Montpellier CEDEX5, France
E-mail: muriel.bonin@cirad.fr

Name: Vincent Bonnal — Partner acronym: CIRAD
Address: Campus international de Baillarguet - TA C-91 / F,
34398 Montpellier, Cedex 5, France
E-mail: vincent.bonnal@cirad.fr

Name: Jean Philippe Tonneau — Partner acronym: CIRAD
Address Campus international de Baillarguet
TA C-91 / F, 34398 Montpellier, Cedex 5, France,

E-mail: jean-philippe.tonneau@cirad.fr

Name: François Bousquet Partner acronym: CIRAD
Address: Campus international de Baillarguet –
TA C-47 / F (Bât. F, Bur. F110), 34398 Montpellier Cedex 5, France
E-mail: francois.bousquet@cirad.fr;

Name: Desmond McNeill Partner acronym: UiO
Address: P.O.Box 1116 Blindern, NO-0317 Oslo, Norway
E-mail: desmond.mcneill@sum.uio.no

Name: Pytrik Reidsma Partner acronym: WU
Address: P.O.Box 430, NL-6700 AK Wageningen, the Netherlands
E-mail: pytrik.reidsma@wur.nl

Name: Martin van Ittersum Partner acronym: WU
Address: PO Box 430, 6700 AK, Wageningen, The Netherlands
E-mail: martin.vanittersum@wur.nl

Name: Hannes König Partner acronym: ZALF
Address: Eberswalder Strasse 84D, 15374 Müncheberg, Germany
E-mail: hkoenig@zalf.de

Name: Johannes Schuler Partner acronym: ZALF
Address: Eberswalder Strasse 84D, 15374 Müncheberg, Germany
E-mail: jschuler@zalf.de

Name: Stefan Sieber Partner acronym: ZALF
Address: Eberswalder Strasse 84, Germany
E-mail: stefan.sieber@zalf.de

Name: Katharina Helming Partner acronym: ZALF
Address: Eberswalder Strasse 84D, 15374 Müncheberg, Germany
E-mail: helming@zalf.de

Name: Mongi Sghaier Partner acronym: IRA
Address: El Fje, Route Jorf, Km 22, 54119, Médenine Tunisia
E-mail: s.mongi@ira.rnrt.tn

Name: Mohamed Arbi Abdeladhim Partner acronym: IRA
Address: Laboratoire d'Economie et Sociétés Rurales
IRA Médenine, Route de Jorf, Km 22,54119 Médenine, Tunisia,
E-mail: abdeladhim01@yahoo.fr

Name: Nadia Ounalli Partner acronym: IRA
Address: Laboratoire d'Economie et Sociétés Rurales
IRA Médenine, Route de Jorf, Km 22, 54119 Médenine, Tunisia,
E-mail: nihaya_mo@yahoo.fr

Name: Jeder Houcine Partner acronym: IRA
Address: Laboratoire d'Economie et Sociétés Rurales
IRA Médenine, Route de Jorf, Km 22, 54119 Médenine, Tunisia,

E-mail: djederhoucine@yahoo.fr

Name: Riadh Bechir Partner acronym: IRA
Address: Laboratoire d'Economie et Sociétés Rurales
IRA Médenine, Route de Jorf, Km 22, 54119 Médenine, Tunisia,
E-mail: riadh113med@yahoo.fr

Name: Farah Chouikhi Partner acronym: IRA
Address: Laboratoire d'Economie et Sociétés Rurales
IRA Médenine, Route de Jorf, Km 22, 54119 Médenine, Tunisia
E-mail: chouikhi_farah@yahoo.fr

Name: Stella Makokha Partner acronym: KARI
Address: POB 14733, Nairobi, Kenya
E-mail: stellamakokha@yahoo.com

Name: Patrick Gicheru Partner acronym: KARI
Address: PO Box 14733, Nairobi, Kenya
E-mail: cdnarl@iconnect.co.ke

Name: Seema Purushothaman Partner acronym: ATREE
Address: No. 659, 5 th A Main, Hebbal BP 5035, Bangalore 560 024, Karnataka, India
E-mail: seemap@atree.org

Name: Sheetal Somashekar Patil Partner acronym: ATREE
Address: No. 659, 5 th A Main, Hebbal BP 5035, Bangalore 560 024, Karnataka, India
E-mail: sheetal@atree.org

Name: Ierene Francis Partner acronym: ATREE
Address: ATREE, Royal Enclave, Srirampura, Jakkur Post, Bangalore – 560064. India.
E-mail: ierene@atree.org

Name: Shuyi Feng Partner acronym: NJAU
Address: Weigang No. 1, 210095, Jiangsu province, P. R. China
E-mail: shuyi.feng@wur.nl

Name: Futian Qu Partner acronym: NJAU
Address: Weigang No. 1, 210095, Jiangsu province, P. R. China
E-mail: ftqu@njau.edu.cn

Name: Xiaoping Shi Partner acronym: NJAU
Address: Weigang No. 1, 210095, Jiangsu province, P. R. China
E-mail: serena2@njau.edu.cn

Name: Youssouf Cissé Partner acronym: IER
Address: BP 258 - Rue Mohamed V, Bamako - Mali
E-mail: cisse_y@yahoo.com

Name: Nina Novira Partner acronym: GMU
Address: Bulaksumur, Yogyakarta, Indonesia 55281
E-mail: nina.novira@gmail.com

Name: Syarifah Aini Dalimunthe Partner acronym: GMU
Address: Bulaksumur, Yogyakarta, Indonesia 55281
E-mail: syarifah.dalimunthe@gmail.com

Name: Frieta Damayanti Partner acronym: GMU
Address: Bulaksumur, Yogyakarta, Indonesia 55281
E-mail: frietadamayanti@gmail.com

Name: Nur Indah Sari Dewi Partner acronym: GMU
Address: Bulaksumur, Yogyakarta, Indonesia 55281
E-mail: nurindah.dewi@gmail.com

Name: Triana Sefti Rahayu Partner acronym: GMU
Address: Bulaksumur, Yogyakarta, Indonesia 55281
E-mail: trianasefti@gmail.com

Name: Junun Sartohadi Partner acronym: GMU
Address: Bulaksumur, Yogyakarta, Indonesia 55281
E-mail: jsartohadi@gmail.com

Name: Utia Suarma Partner acronym: GMU
Address: Bulaksumur, Yogyakarta 55281, Indonesia
E-mail: lupisindonesia@gmail.com

Name: Saulo Rodrigues-Filho Partner acronym: FUB
Address: CDS-UnB, Universidade de Brasília,
Campus Universitário, Gleba A, Brasília, DF CEP 70910-900, Brazil
E-mail: srodrigues@unb.br

Name: Marcel Bursztyn Partner acronym: FUB
Address: Gleba A, Reitoria Brasília, DF CEP 70910-900, Brazil
E-mail: marcel.cds@gmail.com

Name: Diego Lindoso Partner acronym: FUB
Address: Gleba A, Reitoria Brasília, DF CEP 70910-900, Brazil
E-mail: diegoplindoso@gmail.com

Name: Nathan S. Debortoli Partner acronym: FUB
Address: Gleba A, Reitoria Brasília, DF CEP 70910-900, Brazil
E-mail: nathandebortoli@gmail.com

Table of contents

General part

Objective within the project

This document synthesizes the achievements within the project on the application of methodologies and tools. It follows the research process adopted in the LUPIS project. First, definitions and theoretical framework are presented, followed by an overview of tools, which are applied in the case studies dealing with impact assessments of land use policies. Then, the results of impact assessments are presented, concluded with a presentation of the LUPIS data portal used in the project to document the results of each stage of the impact assessments in a dynamic way.

Executive summary

Problem

Land use changes in developing countries are considered critical to sustainable development; and land use policy is an important tool to control land use conversion. In order to address land use change, it is essential to understand the impact of land use policy on sustainable development. The selection of optimal policies requires a good understanding of the key driving forces in the area, including human activities, such as immigration and agricultural intensification and underlying factors, such as human population dynamics, or economic growth that underpin the proximate causes and either operate at the local level or have an indirect impact from the national or global level. The institutional context determines whether the selected polices can be effectively and successfully implemented. To understand this complexity of interacting factors, an integrated approach is required, drawing on various disciplines and assessing the combined effects of socio-economic, environmental and institutional factors. Meeting the challenges facing sustainable development in developing countries requires a proper understanding of the linkages between rural development, poverty reduction, (particularly food security and enhancing livelihood quality) and environmental management.

For the ex-ante analysis of land use policies for sustainable development in developing countries assessment procedures are provided. These make use of a generic and flexible analytical framework that enables understanding of the effect of different land use policies on sustainable development. This analytical framework covers all the necessary steps in an ex-ante impact assessment - from problem identification to communication of assessment results. It has been applied in seven case study countries in Africa, Asia and Latin America, differing considerably with regard to the economic, environmental and social dimensions.

Case studies

In seven case studies the sustainable development problem is put in its environmental, economic and social dimensions. The interrelated causes of the situation are analysed by identifying key drivers, and selected land use policies of particular relevance. Indicators are selected for the assessment of land use policies. Prioritized land use policies are discussed in relation to its potential impact.

The case study in Tunisia concerns the complex interaction between socio-economic development and environmental degradation. Increasing human needs and agricultural development have led to very high pressures on the fragile natural resources of the basin. Land degradation is becoming increasingly serious due to increased sedentarization, land fragmentation and growth of the agricultural sector. The case study focuses primarily on two environmental policies: ‘Water and soil conservation strategies’, and the ‘Policy of saving water and incentives to irrigation’.

The case study in Kenya is concerned with an increasing population leading to uneconomic land fragmentation and land degradation. Poor growth in the agricultural sector has been attributed to land degradation, increased droughts and floods, inadequate markets and marketing infrastructure. The main policy assessed is that concerning land tenure, whereby private land rights are distributed at the expense of the customary land tenure holders.

The case study in India covers selected districts in Northern Karnataka and illustrates how the social, or poverty, dimension of sustainable development interacts with the economic and environmental. India has experienced rapid economic growth in recent years, and like many other parts of the country Karnataka has witnessed a commercialization of agriculture in terms of input application, choice of crops and marketing of products. The inherent risks involved in inputs for intensive commercial crops are high, especially for small-scale farmers.

The case study on Taihu Lake in China exemplifies the conflict between two dimensions of sustainable development: economic development and conservation of the environment. Since the 1980s, the water in the major rivers running into Lake Taihu, and in the lake itself, has become seriously polluted, and the nitrogen and phosphorus eutrophication of water have become major environmental problems. This case study focuses especially on the agricultural sector, and policies to improve water quality in the lake and sustainable development more broadly.

The case study in Mali concerns the irrigation scheme, the ‘Office du Niger’, an irrigation scheme created for rice production. Droughts in the Sahel area and particularly in Mali have caused people to migrate to the Office du Niger. The increasing population has led to competition over land, deforestation and water pollution. Extension policies and privatization of land have been implemented by the government with the aim of enhancing food security. Policies to be assessed are related to the scarce natural resources and the coexistence of pastoralists and farmers in the area.

The main problem in the case study of Indonesia addresses uncontrolled land-use change from agriculture to non-agricultural use in the province of Yogyakarta special region (D.I.Y.). The rapid urbanization and migration into the area have become threats to both the environmental and the social dimensions of sustainable development. The case study discusses the feedback mechanisms behind this change in land use and addresses several related policies: planning policies, development policies and agricultural policies.

The Brazilian case study concerns deforestation in the Amazon region related to the paving of the full length of the 1,780 km federal highway BR-163 that crosses part of the states of Mato Grosso and Pará. The motivation for this investment is to promote economic development in rural areas, but it has major side effects on biodiversity loss and CO_2 emissions. The demand for commodities as a driver of this development is discussed, along with the impact of weak governance in relation to conservation and sustainable use policies; colonization and land reform programmes; and infrastructure projects.

Tools applied in case studies

Table1 indicates a variety of tools being applied in seven case studies during impact assessments of selected policies. The variety of tools applied along the execution of impact assessments does differ per case study. This is mainly explained by the scale of assessment (field, farm, region, country), data availability and composition of research teams.

Table 1: Tools used for impact assessment in 7 case studies of LUPIS

Case study	Field level	Farm level	Regional level	Country level	Evaluation method
Tunisia	CropSys	FSSIM	CGE	IMPACT	MCA, FoPIA
Kenya			FoPIA	IMPACT	FoPIA
India	TechnoGIN	Multiple regression	Upscaling	IMPACT	MCA, FoPIA
China	TechnoGIN	FSSIM	Upscaling	IMPACT	MCA
Mali			CORMAS	IMPACT	
Indonesia			IDRISI, Pro-Vision	IMPACT	MCA, FoPIA
Brazil			LUSMAPA	IMPACT	MCA

DPSIR (Driver, Pressure, State, Impact, Response) is a framework to establish causalities. The framework is used in the first stage in the analysis of the case studies. This presents the trade-offs that exist between the three dimensions of SD: in many cases economic development on one side and environment and social equity on the other. These trade-offs, related to the potential or actual conflict between development and the environment, also appear as trade-offs between the interests of present and future generations.

FoPIA (Framework of Participatory Impact Assessment) is a tool for impact assessments of alternative land use scenarios, which draws on the knowledge and expertise of stakeholders. The implementation of this approach at case study level follows three main steps: i) scenario development, ii) specification of the sustainability context, and iii) impact assessment. Stakeholder participation is at the core of this method and considered in each assessment step.

FSSIM (Farming Systems Simulator) is a generic bio-economic farm model. It has been applied in combination with higher level models to assess farm level impact of future policy scenarios for different farm types in different regions. It is an optimization model which maximizes a farm's total gross margin subject to a set of resource and policy constraints.

CropSyst (Crop Systems Simulator) was used to address agro-ecological relationships. It is a bio-physical model that can be combined with FSSIM. In the Tunisian case study the model was used to calculate the externality "soil erosion".

TechnoGIN (Technical Coefficient Generator**)** was used to calculate technical coefficients (like yields, fertiliser requirement, nutrient losses and balance, biocide use and index, water requirement (monthly), labour use (monthly), fuel machine, animal and seed use, costs per input and profits) for cropping systems

CGE (Computable General Equilibrium) model is a modelling tool for the regional level. Computable General Equilibrium models were used to assess the impacts of exogenous shocks and policy changes transmitted through different markets..

IMPACT (International Model for Policy Analysis of Agricultural Commodities and Trade) is a model of international agricultural trade, developed by IFPRI (International Food Policy Research Institute). It examines the links between food production and consumption and food security at the national level.

MCA (Multi-criteria analysis) is applied for the evaluation of different alternatives (i.e. scenarios, policy options). It shows the contribution of criteria to the alternatives, based on the weights (preferences) that are given.

IRA-Dataportal – IRA (lead partner for the case study Tunisia) has integrated the LUPIS DATA PORTAL in its information system. The administration of IRA-Data Portal is ensured by IRA (Center of Information and communication), the users are all researchers from IRA, national, regional and local stakeholders.

CORMAS (Common-pool Resources and Multi-Agent Systems) is a multi-agent simulation platform specially designed for renewable resource management. The framework was adopted in the case study in Mali.

IDRISI is an integrated geographic information system (GIS) and remote sensing software developed for the analysis and display of digital geospatial information.

LUSMAPA (land Use Simulator Mato-Grosso Para) is a tailor made land use simulation model developed for the case study in Brazil. The model uses input data on price developments of various commodities (beef, soya) and demographic patterns. Through a user interface the effectiveness of conservation policies (Forest Code and Conservation Units) can be simulated.

LUPIS data portal

The LUPIS Data Portal (http://lupis.cirad.fr) aims at providing access to data and results from the LUPIS project, giving users a gateway to selected information. Its online database holds a large number of data: local (case studies), national and global statistics, geospatial data sets (maps) covering various themes or public policies documents.

Through this information, the LUPIS data portal provides on-line documentation and understanding on the impacts of land use policies on sustainable development. It is also used for dissemination of project findings.

Lessons

Although the case studies are very varied, some general conclusions emerge regarding the design and use of tools to assess the impacts of land use policies.

To ensure local knowledge and anchoring, stakeholders should be consulted. Such consultation includes regular interaction between policy makers and the researchers involved. Such interaction increases both the quality and the policy relevance of the research. It is essential to design and implement policies that are forward looking, taking into account the challenges that are often felt at regional level between economic development, with its claims on the physical and natural environment, and the broader social context. In many poor countries existing research currently underestimates the importance of the ecological and social dimensions that shape, and are shaped by, economic development. To overcome such constraints, research capacity to perform impact assessments is urgently needed.

Participatory approaches provide a source of new ideas for policy options. Such participatory approaches require a careful selection of participants. If this is not done in a proper manner, the impact assessments would at best result in biased outcomes, and could even provide incorrect claims about the links between land use policies with sustainable development. Focus groups, for example, are suitable to analyse the policies for implementation by the actors. As part of such focus groups, factors critical to the successful implementation of policies could be identified as well as strategies to cope with them in real-world situations.

A prerequisite for an integrated impact assessment is a multidisciplinary approach. It is necessary to draw on a range of disciplines, from both natural and social sciences. It is important that researchers work together over an extended period of time, in order to clarify and resolve differences in perspective, and even terminology, as a basis for undertaking a coherent and integrated study which is accessible to policy-makers.

Major data constraints are often faced when preparing an integrated assessment. Serious limitations in data availability should not prevent researchers from understanding the issues at stake and exploring the room for policy intervention; expert knowledge can often be used in place of statistics. Regular interaction between researchers and policy makers is indispensible to explore promising intervention strategies.

The impacts of policies are felt at different scales. While the impact of measures are felt mainly by individual actors, in the case of economic and social domains, pressures on the environment (and the impact of measures to reduce them) are often observed at regional level. Policy measures need to be taken that cope with such pressures across the different spatial levels.

In selecting policy options, and in assessing their impact, it is important to be realistic about the willingness and ability of government to implement them, and to build this into the assessment methodology.

Specific part

1 Part I: Introduction and overview of the LUPIS project

1.1 Background

In the frame of the joint European and developing country project (LUPIS - Land Use Policies and Sustainable Development in Developing Countries, February 2007 – March 2011), seven case studies have been selected in seven developing countries (China, India, Indonesia, Brazil, Tunisia, Kenya, Mali) for performing ex-ante impact assessments of land use policies (McNeill *et al.*, 2011). Each case study has its own specific land use problem, and each problem requires targeted land use policies. In order to assess these consistently, a methodological framework for sustainability impact assessment (SIA) has been developed that allows ex-ante assessments including (i) multiple land use sectors, (ii) multiple dimensions of sustainability, and (iii) multiple scales (Reidsma *et al.*, 2008a; Reidsma *et al.*, 2011). The framework is meant to be generic and flexible, so that it can be applied across a range of issues and countries. It builds upon two complementary methodologies (SEAMLESS and SENSOR), developed in the European context, but has been enhanced and adapted to the context of developing countries. SENSOR (Sustainability Impact Assessment: Tools for Environmental, Social and Economic Effects of Multifunctional Land Use in European Regions) (Helming *et al.*, 2008a) developed ex-ante impact assessment tools at regional scale for EU policies related to land use, with a focus on cross-sectoral trade-offs and sustainability side-effects. SEAMLESS (System for Environmental and Agricultural Modelling: Linking European Science and Society) (Van Ittersum *et al.*, 2008b) concentrated on the agricultural sector and targeted at assessing agricultural and environmental policies and technological innovations at multiple scales. Using these two methodologies as building blocks, allows addressing a wide variety of land use problems, with a focus on agriculture, which is at the core of sustainable development in developing countries.

1.2 Placing LUPIS within the area of integrated ex-ante impact assessment research

This section is based on (Reidsma *et al.*, 2011) and (Bezlepkina et al., 2011).

Sustainability of agricultural systems and land use is widely discussed in international literature and is essential for achieving global sustainable development. In the so called Brundtland approach (UNWCED, 1987), and since then mainstreamed in sustainability thinking (UN, 2003), the three-pillar-approach to sustainable development is based on the understanding that all three dimensions are crucial, interconnected, and urgent. According to (Binder *et al.*, 2010), research on sustainability assessment in agriculture has so far poorly addressed multi-functionality in agriculture, has favored the ecological aspect of sustainability instead of aiming at a balance between the ecological, economic and social dimensions of sustainability, and neglected the knowledge of utilizing the results of assessments to achieve their implementation. Irrespective of sustainability definitions, integrated assessment (IA) is seen as a powerful tool for scientific support to the implementation of sustainable development in agricultural policy making (Abaza, 2004). IA provides structured knowledge of human-environment interactions that can be used for decision making in light of sustainable development (Schößer *et al.*, 2010). The importance of this approach is acknowledged by the international research, resulting in a steep increase in the number of publications in the area of 'integrated assessment' (and synonymous terms) and 'agriculture' in agricultural, environmental or social sciences since the mid 90's (see Figure 1).

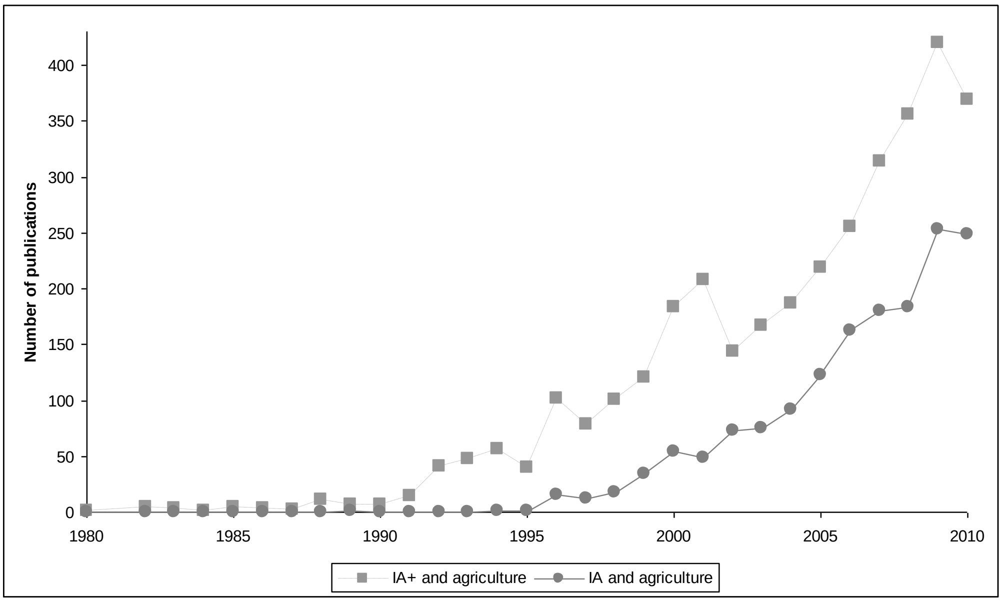


Figure 1:. Number of publications as cited in Scopus (www.scopus.com). The 'IA+ and agriculture' line mirrors the number of publications using key words similar to IA such as 'impact assessment', 'sustainability assessment', 'future assessment', 'ex-ante assessment' 'integrated tool', 'decision support', 'integrative approach', 'integrated analysis', 'integrated framework' and 'model-based framework'

The abbreviation 'IA' is not to be confused with the often used term for Impact Assessment, which was introduced by the European Commission in 2003 and since 2005 it is a formal procedure of European policy making to be mandatorily applied to all policy process within the European Commission (EC, 2009). Building on Rotmans's (1998) definition of Integrated Assessment that is 'a structured process of dealing with complex issues, using knowledge from various scientific disciplines and/or stakeholders, such that integrated insights are made available to decision makers', this Special Issue focuses on four integrative elements of IA: sustainability dimensions, scales, models and stakeholders. By illustrating the types of data and models used, we indicate what disciplinary knowledge has been involved and by specifying examples of indicators – what sustainability dimensions are covered. Such setting allows for comparison of studies as well as reflecting on the main methodological challenges of IA as presented in (Rotmans, 1998) concurred in recent publications (Van Ittersum and Brouwer, 2009; Sieber *et al.*, 2010; Fürst *et al.*, in press; Sieber and Pérez Domínguez, in press): (i) aggregation versus disaggregation, (ii) treatment of uncertainty, (iii) blending qualitative and quantitative knowledge, (iv) building up scientific and political credibility of IA models, and (v) developing comprehensive and transparent scenarios in a participatory way.

In Europe, the introduction of the European Commission Impact Assessment Guidelines created research funding opportunities for integrated projects and additionally have resulted in spin-off collaborative research efforts commissioned within e.g. the 6th Framework Program (FP6) for research (2002-2006). This program is one of the largest research programs in the world having allocated about 2120 million euro in the area of Sustainable development, Global change and Ecosystems (12.1% of the total FP6 budget). About 55 million euro of the FP6 funds enabled launching a family of research initiatives listed below to build science-based methods and support tools for sustainability impact assessment. They include large research projects like EFORWOOD for the forestry wood chain (Lindner *et al.*, 2010), SEAMLESS for agriculture (Van Ittersum *et al.*, 2008b), SENSOR for multifunctional land use (Helming *et al.*, 2008a), PLUREL for rural–urban linkages of land use (Nilsson *et al.*, 2009), MATISSE for Methods and Tools for Integrated Sustainability Assessment (Ness *et al.*, 2010).

LUPIS is a smaller project aiming at sustainable land use in developing countries (Reidsma *et al.*, 2011), joining the group of projects like MEA-Scope for multifunctional agriculture (Piorr *et al.*, 2009), Sustainability A-test for a general review of tools for sustainability assessment (Kasperczyk and Knickel, 2006), Advanced-EVAL for evaluation methods of rural development programs (Advanced-EVAL, 2010), EVIA for procedures and practices of impact assessments in the EU (Jacob *et al.*, 2008), INDI-LINK for sustainable development indicators (INDI-LINK, 2010), and ATLAS for training in the area of land use and sustainability impact assessment (ATLAS, 2010).

The integrative type of research brings different communities of researchers together and in many cases results in special issues, which primarily reflect on European experiences. Such examples are special issues in International Journal of Geographical Information Science (Verburg and Veldkamp, 2005), in Land Use Policy (Kok *et al.*, 2007), and in Landscape Ecology (Houet *et al.*, 2010) reconfirm through the years the need for more integration in research area of land use changes. A collection of papers in Agriculture, Ecosystems and Environment (Verburg *et al.*, 2006) reflect on research methods and tools used in studies of land use and agriculture done mainly in two projects at the European scale (ATEAM (Schröter *et al.*, 2005) and EURURALIS (Verburg *et al.*, 2008a)). These and following the list issues present novel approaches and methods of linking models, indicators, data and society: in Environmental Science and Policy (Dilly and Pannell, 2009), two issues in Ecological Indicators on assessment methods (Mander and Uuemaa), 2010) and on assessment indicators (Petit and Frederiksen, 2010), an issue in Ecological Modelling (Sieber *et al.*, 2010) on modeling approaches and in Ecology and Society (Helming and Perez-Soba, in press) on scenarios for multifunctional landscapes. A special issue in Environmental Science and Policy (Van Ittersum and Brouwer, 2009), a special issue in Journal of Policy Modelling (Sieber and Pérez Domínguez, 2010) adds to the discussion on tools and methods for assessment of agrifood policies in an integrative way, but again from European perspective. Tools, methods and applications of modeling land use change for spatial planning support are presented in the special issue of Annals of Regional Science (Koomen *et al.*, 2008). Lastly, the latest special issue in Environmental Management (Fürst *et al.*, in press) presents examples covering a broad variety of integrated land-use management support tools on different scales.

Whether it is the topic, underlying methodology or research project that initiates publications under the keywords “integrated assessment” and “agriculture”, an increasing number of publications also indicate that in demand for integrated type of research a new type of integrative scientists seems to emerge. These scientists are willing to invest into a collaborative type of work which requires commitment in learning about the work of adjoining disciplines to seek for possible linkages (interdisciplinary interaction) and to invest into getting equipped with participatory methods facilitating the implementation of results (transdisciplinary interaction). In about 90 publications that are part of the 12 special issues listed above, the relevance of integrated assessment is presented in various formats emphasising e.g. integrated frameworks and on linkages between data, models, indicators and stakeholders. It is however the role of editorials to bring these views under an over-arching theme and to streamline the research terminology such that these research findings through the use of commonly understood language are recognised by a wider research community.

Nevertheless, there is hardly any systematic experience to perform ex-ante assessment approaches that link land use policies with their potential contribution towards sustainable development in *developing countries* (Reidsma *et al.*, 2011). Thorough theoretical and empirical research into the effects of land use policies on the sustainable development of developing countries is still very much needed if we are to ensure the achievement of the Millennium Development Goals. Land use policies are especially critical in the poorest countries in their efforts to achieve poverty reduction, and there are few cross country assessments to learn from. Such understanding from assessments is vital to explore notions that, for example, the importance of trade is often underestimated (e.g. (Dawe, 2001)), agricultural intensification can both lead to and increase and loss in biodiversity and ecosystem service provision (Mooney *et al.*, 2005) (Reidsma *et al.*, 2006) (Glendining *et al.*, 2009), intensification leads to soil mining (Panayotou, 1994) (Pagiola, 1996), and although intensification is considered as an ideal for farmers, this remains an utopian for the majority of farmers due to biophysical limitations (Tittonell *et al.*, 2009).

As Kates et al. ((Kates *et al.*, 2001)) argue, there is an information gap between developed and developing countries. The affluence in developed countries are the main causes of global problems, and research often focuses on higher level problems with a more theoretical approach. The poverty in developing countries leads to a focus on local problems and action-driven research, including traditional knowledge. This leads to knowledge differences, which should be bridged by collaborations including developed and developing countries to discuss key questions, appropriate methodologies and institutional needs. Sharing knowledge is vital for developing countries to address sustainability issues in an integrated way. Numerous studies have shown that investments in research and development typically rank first or second in terms of returns to growth and poverty reduction, along with investments in infrastructure and education (von Braun *et al.*, 2008). Besides collaboration between developed and developing countries, other requirements to improve sustainability science (Kates *et al.*, 2001) are to connect to the policy agenda, and focus on nature-society interactions and the pathways that lead to sustainability considering these interactions.

1.3 Outline of the report

The report consists of eight parts. Part I introduces the report. Part II covers general understanding of land use policies and Part III of sustainable development adopted in the project. One of the project objectives is to test the applicability of tools developed in the European context within these EU projects. The challenges of adapting the tools from SEAMLESS and SENSOR to such varied case studies have led to the tools as being viewed as a set of available methodologies and not tools *per se* to be used in the non-EU context (Chant *et al.*, 2009). The use of a common methodological framework therefore provides the link between individual case studies rather than necessarily the use of common models from SEAMLESS and SENSOR. This framework is described in Part IV. Part V provides an overview of impact assessment methods and tools applied in LUPIS. These do not exclusively come from SENSOR or SEAMLESS but have been enrolled into impact assessments as the project evolved. The motivation of choices made in favour of modelling techniques or qualitative methods is partly supported in D6.1 (review of existing literature, (Chant *et al.*, 2009). Part VI of the report each refer to a particular case study. Further details and motivation of choices per case study have been reported in country reports D7.2-D13.2 (Chen *et al.*, 2011; Cissé *et al.*, 2011; Feng *et al.*, 2011; Novira *et al.*, 2011; Purushothaman *et al.*, 2011; Rodrigues Filho *et al.*, 2011; Sghaier *et al.*, 2011). Part VII presents LUPIS data portal that has been built in the spirit of computerised tools that have been practised in SEAMLESS and SENSOR. Part VIII ends the report with General discussion and conclusions.

2 Part II: Land Use Policies

2.1 Introduction

This section is based on (Bonin *et al.*, forthcoming).

According to Vinck (1983), land use "expresses the management of ecosystems by man in order to achieve some of his needs". Land use policies thus include not only "land administration" (Barnes, 2003; Steudler *et al.*, 2004), "cadastral systems" (Rajabifard *et al.*, 2007) that correspond to the implementation of state control over land, and "land planning" which introduces the idea of a strategy in planning infrastructures (roads, dams, etc) to orient the occupation and use that will be made of the land. Land use, and therefore also land use policies, are also concerned with "resources" associated with the land; and with user practices to mobilize these resources, through extractive or production systems (Landais *et al.*, 1988). A study of land use policies, by contrast with classical land planning, thus focuses more on local resources and practices; it involves a variety of stakeholders and opens for consideration of wide-ranging governance issues. Land use policies present particular challenges in developing countries, for at least three reasons: because natural resources are particularly vulnerable under the very varying climatic conditions found in the South; because governance is often characterized by weak states, confronted by powerful international organizations and difficult decentralization processes; and because the use of land and natural resources is a subsistence issue for the majority of the population, so that traditional rights of ownership are especially important. Land use policies have the potential to influence who can use the natural resources, and also the manner and extent of this exploitation. Underlying power relations will be "crystallized" in the land use policy that emerges, for they will influence the orientation of the policy (the focus), the governance of the policy (its implementation), and the way it considers land. In what follows, therefore, we reflect on the links between these three issues - orientation, governance and relation to land – which together will strongly influence the impact of land use policies on sustainable development.

2.2 Specificity of land use policies in relation to other policies

The specificity of land use policies is manifested in the combination of the following three elements:

- **resources and practices:** land is considered in terms of the resources that are localized on it, and resources are considered locally (Callaghan, 1996). This draws attention to one of the central issues of sustainability (Haberl *et al.*, 2004): that resources existing locally must be preserved for future use (McCracken and Bignal, 1998) breaking the productive paradigm which sometimes considered that when resources were depleted, one could move on to another localization (ex: agricultural frontiers). Practices are central: they influence the way resources are mobilized.
- **governance:** governance introduces a wide variety of actors, with different (and sometimes conflicting) interests. This raises questions of how to take into account the different stakeholders. This is revealed through methodological development, such as the increasing interest in participatory methods for land use policies (Antunes *et al.*, 2006; Renn, 2006; Stirling, 2006), or conflict resolution methods to resolve stakeholder disagreements in order to select an optimal land use plan (Prato, 2007). Exploratory land use studies can accompany the formulation of strategic policy objectives (Van Ittersum *et al.*, 1998).
- **an appropriated space:** space is not just physical, it becomes cultural, an identity emerges, often through the definition of territories, giving a uniqueness to the place regarded (Roca and Oliveira-

Roca, 2007). Land rights and discrepancies between areas of action and problem areas condition the implementation of land use policies.

In developing countries, particular challenges cast new light on these specificities of land use policies. Regarding **resources and practices**, particularities are mostly geophysical: severe climate episodes in tropical zones have a strong influence on the land, through severe droughts which weaken the soil structure, or through torrential rains which leach the soils. Developing countries are also characterized by a rich diversity of ecological conditions which favour great biodiversity (in tropical forest for example). All these issues are often exacerbated by global climate change, as climate episodes become more violent. In fact, developing countries are confronted by an extreme vulnerability to environmental change, which challenges their capacity to adapt in the face of these changes.

Another particularity concerning resources is due to the geopolitical position of developing countries. Since a great part of their agriculture is focused on export towards developed countries, local resources (such as scarce water) being used for export products cannot be used by local populations.

Concerning **governance**, developing countries often have to face difficulties in land administration. As suggested by Pugh (1996), although land use policy and land management vary widely from one country to another, what is common is that land administration is often inadequate, with incomplete registration systems, uncertainty of legal titles, and ineffective cadastral systems, leading to high transactions costs, and even corrupt practices.

International institutions, such as the World Bank, have a strong involvement in the definition of land use policies. On the one hand, there has been a process of liberalization, and on the other hand, international institutions or conventions must be taken into account, such as the Rio agenda (Wood and Lenne, 2005), the biodiversity convention, the WTO agenda, etc. Understanding the influence of international agendas is fundamental to analyze the evolution of land use policies, and the introduction of land use issues.

Another particularity is the emergence of local governance which involves civil society, local and regional governments, state institutions, NGOs, trade unions, firms, chambers of commerce, etc. However, administrations do not always manage to give life to this institutional decentralization, revealing a serious need for capacity building (Barnes, 2003).

As for appropriation of space, particularities depend on land rights and strong cultural features. A large proportion of land development is “informal”, not corresponding to legal rules but to de facto social recognition. Different types of property rights are often overlapping and inconsistent, deriving from customary indigenous culture, from colonial inheritance and from post-colonial reform.

2.3 An analytical framework to understand the diversity of land use policies

Land use policies mainly deal with programmes and operations of public authorities to influence land use in a way which is considered desirable; in the case of LUPIS, in a way which contributes to sustainable development. As discussed above, an instructive way to characterize a land use policy is to analyze how it aims at influencing resource use and practices (its orientation), how it will involve various stakeholders (governance), and how it features the relation to land (appropriation). These elements form the basis of our analytical framework.

2.4 Elements characterizing the orientation of a land use policy

Land use policies generally focus on controlling the impact of practices on resources (water, land, fauna, flora); but they may be based on very different perspectives. Different conceptions of sustainable development will lead to different orientations in the land use policies. Policies can be characterized according to the priority given to each objective (economic, social, environmental). Four main orientations can generally be distinguished:

- **Policies aiming at resource management and conservation**: Obviously, the first way to influence the use of resources is through policies dealing directly with resources, such as land, water, biodiversity (fauna, flora). These can be conservation policies (for example, establishing a nature reserve), or segmented policies, which aim at correcting specific problems (for example pollution). However, these resources are impacted because of other activities, and it is therefore fundamental to understand the effects of other types of policies.
- **Policies focused on production systems**: These are often sectoral policies, defining specific measures focused on one sector: agriculture, forestry, tourism, transport, energy infrastructure and extractive industries. These activities have strong impacts on resources through the use they make of the resources or through externalities of production (negative, such as pollution, or positive, such as maintaining agricultural landscapes). Therefore, these policies can encourage different usages of land and try to control their impacts.
- **Policies dealing with social aspects**. These are often differential policies, aimed at specific populations (poor, rural, etc) and are aimed at correcting existing inequalities (in level of development, access to services, access to employment, etc.), through positive discrimination for example. They can influence the way land is used (for example, if a population is too poor, it will tend to migrate to the city, abandoning land), but the effects are generally indirect.
- **Policies which focus on a region, in a development perspective**: Based on actor proximity and decentralization, they enhance territory as an integrating area, mainly through planning and governance measures (for example: integrated river basin management). These policies often affect production capacity by acting on productive and social infrastructure, thus influencing the whole range of productive, economic and social aspects of a territory.

The orientation of a policy reflects its intention, the goals that it aims at. However, it is important to realize that a policy will also have side-effects: an assessment, ex ante or ex post, must therefore consider all intentional and non-intentional impacts, in every dimension of sustainable development (economic, social, environmental) to truly understand how a policy influences the use of land and resources.

2.5 Elements characterizing the governance and instruments of the policy

Governance specifies what actors, objects, rules, and instruments seem relevant at a given moment to orient and implement the policy. Land use policies are increasingly implemented within contexts of shared decision taking. They depend on a multi-layered governance process, involving many actors at different levels: international institutions, governments at various levels (national, state, local), business and civil society (multinational firms, NGOs, local associations etc). Nonetheless, the role of governments is a central element of the analysis, as they define the modalities of the governance of the policy. Three main roles of governments can be identified:

- Taking a proactive leadership role: This mainly refers to strategic planning. Government induces the actors to build, in a more or less participative way, a "strategic plan" and incites them to implement it. Infrastructure policies are a typical example.

- Supporting the actors (companies, communities, civil society) through assistance and service measures. The aim is to help the actors express their needs and expectations; to guarantee the participation of the greatest number.
- Financing initiatives. The government does not intervene directly in elaboration processes. It limits itself to providing financial support to society's activities.
- Participation of users must be analyzed together with the role of government. Three levels of public participation can be distinguished:
- Methods of public *communication* enable the government to inform citizens. These methods do not ensure a true public participation, but their role is essential for processes of public consultation or participation. Public communication covers such things as published advertisements, reports, newspaper articles, official statements, press conferences and websites.
- Modes of public *consultation* enable governments to invite the views of the population on public policy issues, but interaction generally remains limited. Information circulates in only one direction, i.e. from the population to government. Classical means of public consultation include public assemblies, opinion polls, public audiences, discussion groups, referendums and meetings with government staff.
- Modes of public *participation* enable interaction between citizens, and between citizens and the government, i.e. there is an exchange of information between them. Deliberation is important in this process (which usually takes place in groups). Representatives are designated by each of the two parts in various proportions, according to the methods employed. Deliberative intervention helps to transform opinions, of both sides, into enlightened and advised judgments.

In spite of great advances, particularly in the field of deliberative methods, which create an active participation of citizens and enable a true dialogue between them and to government, true participation often remains difficult.

2.6 Governmental instruments for policy implementation

- *Regulations*, as instruments of injunction and control of the execution, generally defining standards (quantified objectives that must be achieved, or on the contrary, that must not be exceeded), to which the regulated person must conform (injunction), under threat of penalty and of sanction (control).
- *Incentives or taxation*: the objective is to render certain practices or actions either less expensive (incentives) or more expensive (taxation) in terms of money, time or effort. Incentives leave people entirely free to choose, under condition of realising their rights. Agri-environmental measures to encourage agricultural practices that respect the environment are an example of such incentives.
- *Information*, as an intervention tool, aims at convincing actors so that they carry out actions voluntarily. It informs the public about other intervention tools - by revealing their existence, their purpose and their availability. Information can also be managed, and constitute a cumulative database, about experiences, instruments, their design, their choice and their relevance.

These instruments will often influence the market, which plays a major role in the implementation of the policies. The government can liberalize a sector, or it can regulate the market, by fixing prices (such as of water). Taxes and incentives can influence prices, more or less voluntarily.

2.7 Elements characterizing the relation to land

Space can be considered as a physical entity that can be occupied (cadastral systems); or as a locality connected to other localities through more or less proximity; or, finally, it can become an appropriated space, with a certain identity.

Appropriation of space also influences the extent to which the stakeholders feel involved in a local issue. If they feel strongly linked to their land, they may feel more keen about preserving the resources.

2.8 Links between orientation, governance and relation to land

In summary, we suggest to use the following elements to characterize the diversity of land use policies:

- Elements concerning the orientation of the policy: which resources, what practices, and whether the focus is sectoral, resource-based, social or territorial;
- Elements concerning governance: how the policy is decided, implemented and evaluated, the role of the government, of the market, of the different stakeholders, the policy instruments used;
- Elements concerning the level of appropriation: at what level the policy is decided, implemented, what is the conception of land (space, proximity, identity).

Our assumption is that one type of orientation will probably be linked to one type of governance and to a specific relation to land. Sectoral policies tend to be applied at a national level, sometimes regional level, through state control or market control. Resource-oriented policies seem to be applied mostly at a regional or local level, through market incentives or actor involvement. Social policies seem to be mainly proposed at a national level, through regulations. Territorial policies tend to be applied at a regional level by local actors. These elements will form our analytical framework for the comparison of land use policies in the different case studies.

3 Part III: Sustainable development

3.1 Defining sustainable development (SD)

This section is based on (McNeill *et al.*, forthcoming).

With the presentation of the Brundtland UN commission report "Our Common Future" in 1987 (UNWCED, 1987) the issue of sustainable development was put on the political agenda. It was defined as *'…a development that meets the needs of the present without compromising the ability of future generations to meet their own needs.* The concept has been much debated and criticised (Redclift, 1992) and numerous alternative definitions have been proposed (such as Robinson, 2002). No consensus has been – or is likely to be – reached on any other definition; in part because for most people the concept is normative. What is clear is that the central issue is the potential, or actual, conflict between development and the environment, and hence between the interests of present and future generations (See Weaver and Rotmans, 2006). (Ewert *et al.*, 2011) have argued, with respect to the sustainability of agricultural systems, that the appropriate definition will depend on the specific problem to be analysed. While we do not see it as necessary to propose an alternative to the WCED definition of SD, it is appropriate to clarify how we interpret it, as a basis for the analysis that follows.

In the literature the term 'sustainable' is sometimes used to mean simply 'capable of lasting over time'; as for example in the expression 'sustainable institutions'. To avoid confusion, we will use the term 'sustainable' in a more restricted sense – relating specifically to the environment. Thus, in the expression sustainable development, 'sustainable' will refer only to the environmental dimension, and we will avoid referring to a system as being economically, socially, or institutionally sustainable. And we propose to interpret environmentally sustainable as avoiding the risk of radical ecosystem disrupture, i.e. somewhere between the extremes of 'weak' and 'strong' sustainability (see below). The term 'development' covers the economic and social dimensions, and this also is much-debated. We propose an interpretation that focuses particularly on the elimination of poverty, of present and future generations.

The distinction between the social and the economic dimension may be interpreted in different ways. Some choose to include 'equity' under the former rather than the latter. We have chosen to follow this approach, which serves also to emphasise the issue of inequality, which is important in many countries in the South, including several of our case studies. We also argue for treating institutional issues separately; not as merely one of several 'social objectives', but rather as a framing dimension, the overarching governance context in which these three dimensions are manifested. In summary, our framework is as shown in Figure 2.

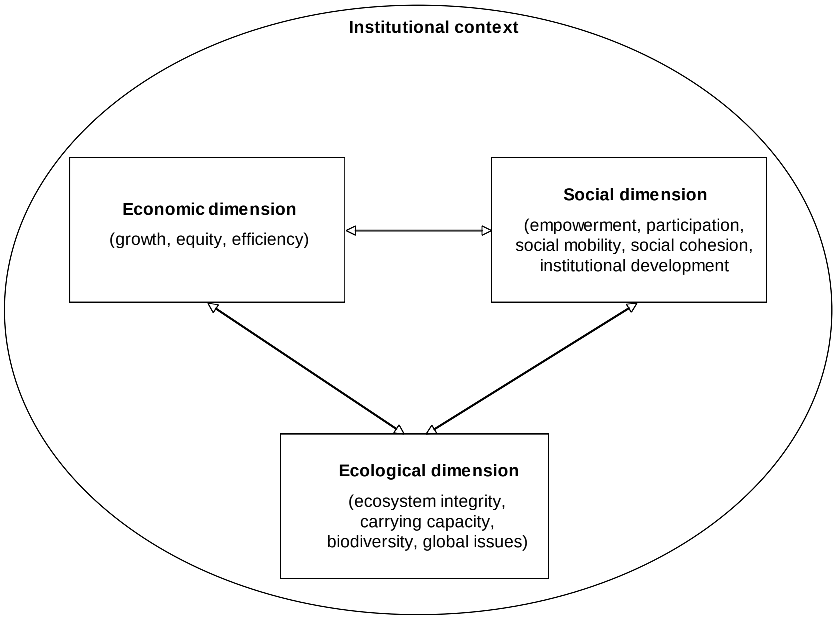


Figure 2: Dimensions of sustainable development>

3.2 Weak and strong sustainability

Much of the debate, both theoretical and practical, concerning SD revolves around trade-offs between these three dimensions: economic, social and environmental. It is important, we suggest, to distinguish between what might be called 'factual' and 'value' trade-offs – although the distinction can sometimes be difficult to maintain in practice. An example of a factual trade-off – between environmental and economic objectives - is where money is saved at the cost of increased pollution. It is, in principle, possible to assess empirically the terms of this trade-off, i.e. exactly how much it would cost to eliminate a specified level of pollution. Another example of a factual trade-off – this time between social and economic - is where efficiency is sacrificed in order to increase participation. It is more difficult to measure the terms of this trade-off exactly, but the important point is that in each of these two examples we are dealing with what is the case, and not a normative issue (of what some person or group believes should be the case).

In many cases a trade off analysis shows that in order to promote one objective, it is necessary to make some sacrifice with regard to another objective; the most obvious, and common, example is sacrificing an environmental objective in order to achieve an economic objective, at least in the short term. This issue is even more evident in developing countries, where immediate priorities often demand that the economic dimension prevails over the environmental and sometimes even over the social dimension. This then leads to the second issue, the value trade-off, which relates to what choice should be made in the light of these facts: whether, for example, an individual, or a country, should choose higher income at the expense of environmental or social benefits. Here one enters the realm of politics; but here also use can be made of tools to assist in decision-making, such as multi-criteria analysis, cost-benefit analysis, and various participatory methods.

The terms of the 'factual' trade-off are in some cases disputed. This is manifest in the discussion between those advocating 'strong' and 'weak' sustainability, who disagree as to the extent to which it is possible to substitute between natural and man-made capital. Weak sustainability refers to the view that natural resources can – at least to some extent - be substituted by man-made resources. There has for some years been a heated 'economic-environmental' debate reflecting a range of different viewpoints concerning "weak" versus "strong" sustainability (See Pearce and Atkinson, 1995; Brekke, 1997). The former view, associated particularly with economists, has been criticised by others - for example Ayres et al. (1998) who assert that under this interpretation an economy can be perfectly sustainable while having devastating effects on the environment. 'Strong' sustainability challenges the substitutability of different types of capital (environmental, economic, and, according to some, social capital), and requires that minimum amounts of the former should be independently maintained.

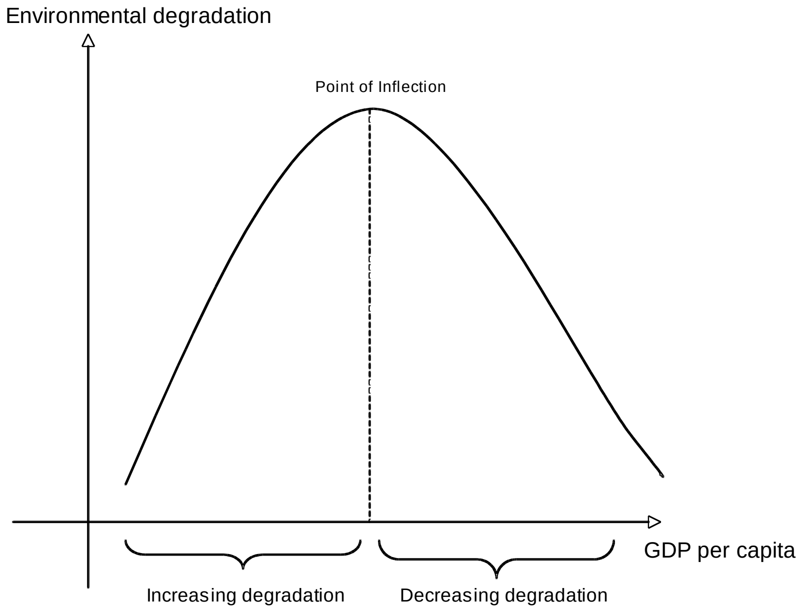


Figure 3: The Environmental Kuznets curve.

The relation between economic development and the environment has been described by some in terms of an environmental Kuznets curve (Grossmann and Krueger, 1991; Stern *et al.*, 1996). It is postulated that there exists an inverted U-shaped relation between macro-economic growth and environmental conditions (see Figure 3). According to this view, with increasing economic growth the environmental conditions initially deteriorate; but, beyond a certain point, subsequent economic growth can be used to counteract environmental degradation, so that environmental conditions improve again. This optimistic view obviously has important policy implications. At the extreme it might be argued that economic growth can solve environmental problems in the long run, and should therefore take priority over environmental conservation. There are however critical arguments that this supposed relation between economic growth and the environment does not hold (Arrow *et al.*, 1995); that the empirical evidence is weak and very sensitive to the econometric techniques that are used (Stern *et al.*, 1996; Perman and Stern, 2003; Dinda, 2004; Galeottia *et al.*, 2006). It is certainly arguable that pollution is a very different type of environmental challenge than the use of non-renewable resources, or destruction of biodiversity, and that the environmental Kuznets curve hypothesis may be valid only for the former.

The overall environmental cost of economic growth is difficult to quantify. One common approach is 'green accounting'. Another approach to measuring environmental impact is the ecological footprint. The ecological footprint, developed by Wackernagel and Reese (1996) is an account that expresses the environmental pressure of production and consumption on an area basis. Thus the footprint measures the area per person (measured in global hectares per capita) needed for production and consumption; the areas being aggregated at the country level (see Figure 3.5). Countries with high GDP, also show a high footprint since higher income leads to more consumption and therefore a higher area demand. The ecological footprint value tends to rise with increasing national income, eventually flattening out at higher levels. But these levels are well in excess of one, implying that these richer countries must be externalising some of the environmental costs they impose on the globe, as do many developed countries today.

It is argued that increasing productivity can serve to decrease the footprint; but productivity increases may well be associated with increased pollution, which is not accounted for by the ecological footprint measure. For this reason, other measures are also needed. The environmental performance index (EPI) indicates the environmental quality of national economies. This index relates to various spatial scales. For example, at a local scale air pollution, water quality and local biodiversity are accounted for, while on a global scale it is national greenhouse gas emissions that are relevant. The EPI is a unit-less measure combining many indicators that are roughly divided into a measure of environmental health and ecosystem vitality, each of which contribute 50% to the final EPI measure. Although the list of indicators that address various aspects of health and vitality is quite substantial, most of them relate to the local level. Hence, global issues like greenhouse gas emissions have only a minor impact on the final EPI value. We see that the EPI values increase with the country's GDP per capita. In other words, rich countries show a larger, or 'better', environmental performance than poor countries. But this may be explained partly by the fact that rich countries have the money to pay for environmental damage and the institutions necessary to enforce the necessary policies, and partly by their capacity to transfer the costs to poorer countries.

The challenge of discovering the empirical relationship between economic growth and the environment is complicated by the fact that some environmental change is not gradual, but sudden. Although it is very difficult to establish the thresholds at which such radical changes occur, their existence cannot be denied. (It might be argued that sudden radical change can occur in social terms; but there is certainly no way of forecasting any threshold in this case). The question of radical change is closely related to that of irreversibility. Growing scientific evidence show that changes in ecosystems can be irreversible. Many ecosystems respond in almost chaotic patterns to stresses, disturbances and other human interference. Based on mathematical equilibrium analysis, ecosystems can move from one stable state to the next with only a marginal increase of the stress variable (See Folke *et al.*, 2002 for a review). Ecosystems play a crucial role in economic development since ecosystems regulate many natural processes and provide goods like timber, fish and other, often non-marketable, products. In humid and productive areas the win-lose situation may alter into win-neutral situations with governmental interventions on ecosystem protection and conservation. In fragile and often arid environments the carrying capacity of the environment is low and rural communities dependent on local resources may often slide into lose-lose situations. In such cases the resource depletion leads to further deterioration of the environment and communities fall into a poverty trap.

It appears that we are here faced by two inconsistent conclusions regarding the relationship between economic growth and the environment, and the validity of the environmental Kuznets curve hypothesis. The ecological footprint of a country generally increases with increasing income, while the environmental performance index tends to improve. The crucial difference is that unlike the ecological footprint the EPI does not take into account effects of foreign trade; that is why many rich countries have better EPI scores. The analysis also underlines the importance of taking a global rather than a national view when assessing a country's policies for sustainable development: both when it comes to identifying the causes of environmental problems and to recommending appropriate responses.

3.3 Governance and Sustainable Development

The role of government in planning for sustainable development is two-fold: to obtain better knowledge of the complex interactions between economic, environmental and social factors; and to design policies to promote sustainable development – seeking to achieve an optimal combination of (largely conflicting) objectives. The purpose of the LUPIS study has been to assess the merits of analytical tools to assist in both these exercises. The detailed case studies clearly show how complex the first task can be – identifying the causal linkages between economic, social and environmental factors – at different levels from local to global. They also show how different groups, with differing perspectives and interests, can have differing views as to the relative importance of the three dimensions (and sub-categories) of sustainable development. For the latter reason, planning for sustainable development is an intensely political exercise, in which governance plays a crucial role. But a further challenge, in seeking to devise models for the assessment of alternative policies, is that there may be a large gap between policies on paper and policies in practice.

Governments are often highly constrained when seeking to implement policies. Quite apart from limitations on their capacity (in the form of human and financial resources), a government may not be strong enough to resist powerful interests. A policy which is deemed optimal by the planners may well run counter to the interests of groups who are strong in economic or political terms. In Brazil, for example, environmental legislation is very strict, but weak law enforcement and corruption contribute to severe deforestation. Governance bottlenecks can be detected among governmental agencies; and there are evident conflicts between public policies: for example, providing energy and transportation, and settling peasants in a region can only encourage the advancement of the economic frontier towards the rainforest, even though environmental protection is also a clear governmental goal. Faced with this reality, it is the task of government to take difficult decisions; to balance the various concerns in the best interests of the country as a whole. (This should include also future generations, but where there is weak governance, their interests tend to be under-represented). There will necessarily be winners and losers, and policy-making here, as always, is a political exercise. Experts can provide valuable guidance, contributing empirical knowledge and high quality analysis. And these may include techniques specifically designed to assist in decision-making, such as social cost-benefit analysis. But expertise cannot wholly replace political process; and there are many who argue for a greater and more formalised participation of people in decision-making. The ideal, perhaps, is a combination of the two; deliberative democracy, wherein decisions are based on expert knowledge and analysis, but with very active involvement of the people. But in many countries, the current practice is far removed from this ideal; and the policies of government are far from optimal from a sustainable development point of view. Furthermore, the stated policies of government may not actually be put into practice. This may be because powerful groups within a country actively resist them; or simply for lack of the necessary resources, expertise or a favourable institutional environment. The governance dimension of sustainable development not only plays a crucial part as one of the causal factors contributing to the current situation; but also as a constraint (and resource) when it comes to translating desired objectives into policies and effective implementation.

In planning for sustainable development, the importance of the institutional dimension is often under-estimated. No matter how good a study may be – with regard to the data, analysis and recommended policies - the practical outcome for people and the environment will depend entirely on the willingness and ability of key actors, and most particularly the government, to implement the recommended policies. We argue for treating institutional/governance issues as a fourth dimension of sustainable development, which cuts across (or transcends) the other three - the social, the environmental and the economic. It needs to be treated differently because there is not generally a trade-off of the institutional dimension against one or more of the other three; rather, the institutional factor acts as a constraint on the others – a sort of filter through which all policies (which integrate economic, social and environmental concerns) must pass in order to bring about the desired effect.

We suggest that poor governance be seen as a sort of ‘dampening effect’ on policies; reducing their effectiveness. Thus when forecasting the impact of a proposed policy, one could contrast two alternative outcomes: one based on the assumption that the policy is fully and effectively implemented, the other on the assumption that governance is, say, only 50% effective; as a result the actual outcome is less than was planned. (For example, water pollution is reduced as a result of a ban on certain pollutants, but the ban is not fully implemented, so that some degree of pollution remains). Although this makes sense in principle, it still raises difficult questions: How do you measure governance effectiveness? And what precisely does it mean for governance to be only 50% effective?

We suggest that what may be more useful are indicators that measure the effectiveness of government in implementing specific policies. The solution that we propose is thus to develop what we call ‘policy-specific governance indicators’: that is, indicators not of general government performance across all sectors, ministries and types of policy and policy instrument, but rather indicators of the actual performance of particular policies and instruments (or, if necessary, suitable proxies derived from similar policies and instruments). It may even be possible to estimate institutional indicators based on the three main types of instrument: command and control instruments; economic instruments, e.g. taxes and subsidies; and behavioral instruments such as public information and education. Even this will not be easy; but it has the considerable merit that it should be possible to assess governance effectiveness on the basis of quite reliable, and even quantifiable, information. The importance of the governance dimension must not be ignored, if one is to make a practical contribution to improved methods of assessing the impact of land use policies on sustainable development; but it is evidently a major challenge to devise appropriate tools.

4 Part IV: Theoretical framework applied in the project

4.1 Introduction

This chapter is based on (Reidsma *et al.*, 2011).

As stated in Part I, the objective of the LUPIS project (Land Use Policies and Sustainable Development in Developing Countries) is to improve knowledge of the impact that different land use policy options will have on the sustainable development of developing countries. Seven case studies have been selected, each relating to a specific land use problem, and each problem requires targeted land use policies. In this chapter we will present the framework, step by step.

The framework developed in LUPIS is meant to be generic and flexible, so that it can be applied across a range of issues and countries. It builds upon two complementary methodologies; SEAMLESS - System for Environmental and Agricultural Modelling: Linking European Science and Society, and SENSOR - Sustainability Impact Assessment: Tools for Environmental, Social and Economic Effects of Multifunctional Land Use in European Regions, developed in the European context, which have been enhanced and adapted for use in developing countries. Using these two methodologies as building blocks, allows addressing a wide variety of land use problems, with a focus on agriculture, which is at the core of sustainable development in most developing countries.

4.2 Methodological framework: Overview

The SIA procedure has been adapted from the SEAMLESS methodology (Ewert *et al.*, 2009) and includes a sustainable development (SD) evaluation procedure based largely on the SENSOR approach (Pérez-Soba *et al.*, 2008) (Helming *et al.*, 2008a). The SIA procedure is subdivided in three main phases (see Figure 4), a pre-modelling phase (problem and scenario definition), a modelling phase (assessing the impacts of policies on multiple indicators) and a post-modelling phase (assessing policy options in terms of their contribution to sustainable development). Modelling is at the core of the framework and refers to computer-based models, but also includes qualitative approaches.

Involving stakeholders in the SIA is important in order to understand the regional and local problems and constraints, build trust, and have impact on policy making processes (Lebel *et al.*, 2006; Van Paassen *et al.*, 2007; Giller *et al.*, 2008). Part of the framework is therefore to organize policy fora with stakeholders in each phase of the process.

The collection and presentation of data is important in all steps of the framework. Initially, this is done separately for each case study. But to enhance mutual understanding in this multidisciplinary and multi-cultural research consortium, sharing of knowledge between researchers is as important as involvement of stakeholders. A data portal was therefore developed to present the main findings of the pre-, modelling and post-modelling phases (http://lupis.cirad.fr).

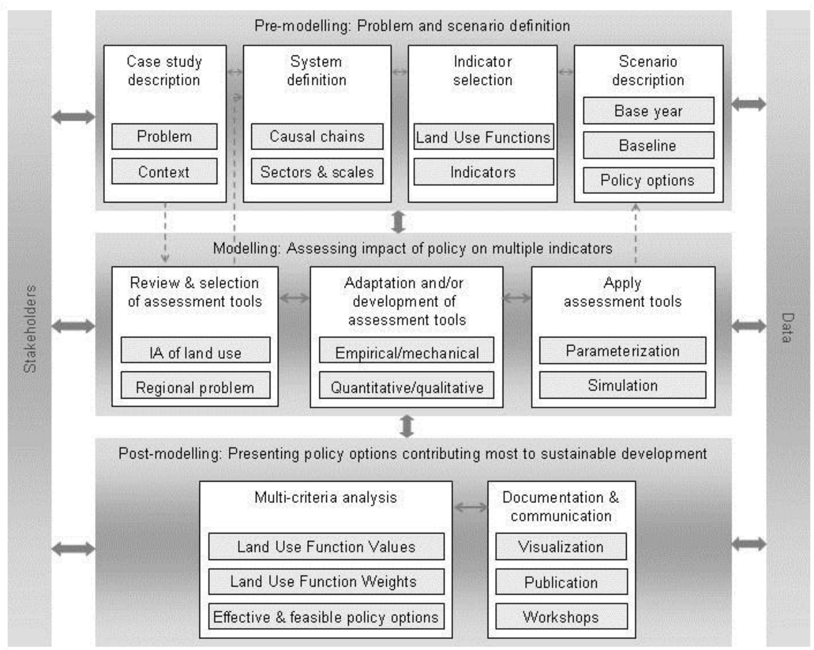


Figure 4: Methodological framework for sustainability impact assessment (SIA) of land use policies (Reidsma et al., 2011).

4.3 Pre-modelling stage in integrated impact assessment

4.3.1 Case study description: Defining the problem, context, system for analysis, causal chains and scales

The selection of each case study in LUPIS is determined by a land use related problem chosen by the country team, in collaboration with the rest of the consortium. This problem creates the need for a change in policy. It is important to understand what the problem is, who perceives it as a problem, and why. In developing countries, the major problem is often seen as how to reduce poverty, through economic growth. But research often reveals that environmental and social drivers are at the core of the problem (e.g. land degradation leads to low productivity and poverty; high population pressure leads to sub-division of land and lower returns to labour). In middle-income countries, environmental problems including water and air pollution are increasing, and as they are starting to affect economic and social development, finding solutions for these problems is being put higher on the policy and research agendas.

In order to increase understanding of the problem a description of the context of the case study area is required. This includes 1) the historical context, giving an overview of the development of the problem over time, 2), the environmental context, including information on climatic and other biophysical conditions, 3) the social and economic context, indicating the importance of different economic sectors in the region and population characteristics, 4) the policy and institutional context, reviewing the existing policies that are relevant to the land use problem, and discussing the institutions responsible for implementing and monitoring the policies and their effectiveness.

In preparation for the modelling phase, it is necessary to go beyond a narrative description; the boundaries of the system that is affected by the problem and, specifically, the system of study, need to be clearly defined.

An important step in an ex-ante impact assessment is to analyse the complex causal relations between the various economic, environmental, social and institutional aspects of the situation; or, more precisely, to identify the causal chains between drivers and impacts. The Driver, Pressure, State, Impact, Response (DPSIR) framework is widely regarded as a good basis to identify these causal chains (Smeets and Weterings, 1999; Helming *et al.*, 2008c), for more on the DPSIR framework, see section 3.5 in this report. Although the DPSIR framework clearly helps to understand causal chains, it is important to emphasise the feedbacks. Causal chains are not one-directional; there are feedbacks between drivers, policies and indicators; and many of the indicators are interlinked. These linkages need to be taken into account in order to obtain a valid causal model of the case study problem. This model can be used in the next steps to identify relevant sectors and scales, most important impact indicators, and to develop scenarios.

'Land use sectors' refer to the economic sectors related to the land in the case study region that affect or are affected by the problem to be assessed. 'Land use' includes those human activities that exhibit a spatial dimension and that change the bio-geophysical conditions of the land (Helming *et al.*, 2008c). Main land use sectors include agriculture and forestry in rural areas; transport and energy infrastructure; tourism; and nature conservation as a 'regulatory activity' occupying land.

The spatial scale defines the boundaries of the case study area and the specific assessments to be undertaken. The boundaries of the case study area depend on the drivers, pressures, states and indicators relevant for the problem. For an impact assessment, the complete case study area can be considered, but it is also possible to subdivide the region in different sub-regions and assess one sub-region in detail. All the LUPIS case studies consider problems at regional (sub-national) level; and selected policies to address these are applied at regional level. Therefore, assessments are performed at regional level. Since a case study region as a whole can be heterogeneous, a sub-division in smaller regions (administrative regions or agro-environmental zones) or farm types may be necessary Impacts at lower levels can be up-scaled for a regional impact assessment. How to up-scale depends on the indicator. What is appropriate and feasible depends on the objectives, the available data and the capabilities of selected models.

4.3.2 Indicator selection and Land Use Functions

The next step in sustainability impact assessment is the selection of indicators. In order to guide a balanced selection of indicators, an indicator framework is nested in the methodological framework. In LUPIS, the indicator framework is generic, while the specific set of indicators differs in each case study.

The indicator framework in LUPIS builds around the concept of Land Use Functions (LUF) (Pérez-Soba et al., 2008). For sustainable development, multiple functions of land are of importance. For example, with regard to grassland the function could be grass production (economic), biodiversity conservation (environmental), and conserving the cultural landscape (social). Nine regional Land Use Functions (LUFs) are identified, three per dimension (i.e., economic, social, environmental), that are considered relevant for all case studies, but can be adapted for the specific context (see Figure 5). Land Use Functions illustrate the most relevant sustainability issues at regional level and are defined as types of goods and services provided to human society (e.g., economic: food production; social: provision of work; environmental: maintenance of ecosystem processes).

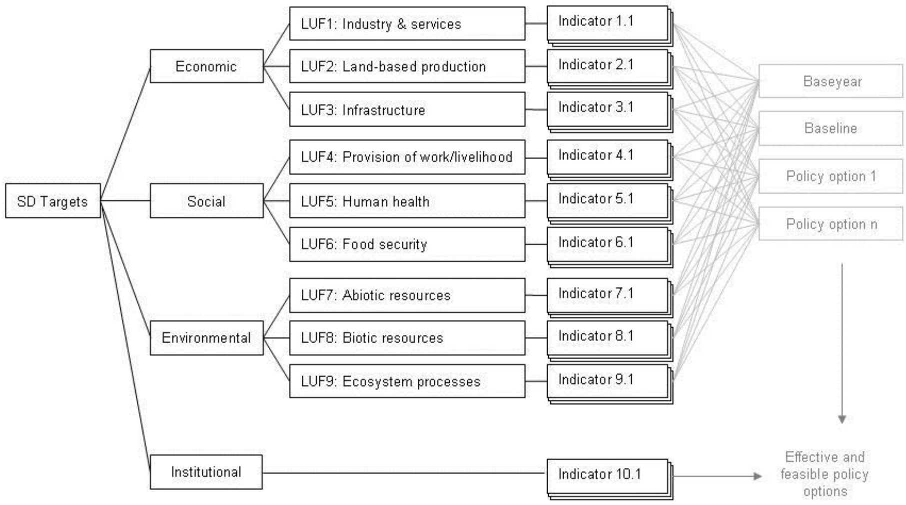


Figure 5: The indicator framework for sustainability impact assessment (SIA) using Sustainable Development (SD) targets, Land Use Functions (LUF) and indicators

The tailoring of LUFs and indicators to each case study is guided by identifying Sustainable Development (SD) targets. Based on these SD targets, the LUFs that contribute to sustainable development can be identified and evaluated. The sub-criteria are the nine LUFs, with an equal distribution of three per dimension. LUF indicators are selected taking into account 1) their relevance to SD targets/LUFs in the case study, 2) their likely responsiveness to selected policy options, 3) the availability of data and models to assess changes in indicators, and 4) non-redundancy. Selecting a single indicator per LUF allows for a straightforward communication with stakeholders, experts and other scientists. Selecting several indicators per LUF is more holistic, but also more complex, as it requires aggregation of multiple indicators into one LUF, for which methods have been developed but not yet widely applied (Paracchini *et al.*, 2011). The decision alternatives are the different scenarios (current situation, baseline, policy options), for which the values of the indicators will differ (see Figure 2.2).

Besides the selection of economic, social and environmental indicators that link to LUFs in these dimensions, for sustainability impact assessment of policy options it is also necessary to take account of institutional factors. However good the data, analysis and resulting policies may be, the practical outcome for people and the environment will depend entirely on the willingness and ability of government to implement the policies.

4.3.3 Scenario's: current situation, baseline and policy options

In the last step of the pre-modelling phase, scenarios that will be assessed are specified in terms of parameters. Different policy options can be included in alternative policy scenarios, to be compared to the current situation and the baseline scenario. The impacts on selected indicators are assessed in the modelling phase.

In order to develop a projection of the future situation, the current situation needs first to be specified. The biophysical, social and economic context for the current situation should be quantitatively described. This includes the most relevant information on drivers (including policies) that affect the selected indicators. The base year is the latest year(s) for which data are available.

For LUPIS, the target years are 2015 and 2025. For policy makers and stakeholders a short time horizon is mostly relevant (2015), while for an assessment of sustainable development in the longer term it is relevant to have a more distant year to complement the assessment (2025). In LUPIS, the focus of the analysis is on the impact of policies in specific case study areas. These are evaluated against a single baseline, a so-called ‘business-as-usual’ scenario where currently observed trends persist in the future. To construct a baseline scenario for a case study, the drivers as specified in the DPSIR framework are used and their development over time projected.

A review of current policies related to the problem and the institutional context are important in order to understand the current situation. For ex-ante assessment towards 2015 or 2025 policy options are selected that are thought to have the capability to improve sustainable development in the case study region. The policy fora and other interactions with stakeholders are important in formulating sound policy options.

4.4 Modelling stage in integrated impact assessment: Selection, Adaptation and Application of assessment tools

Modelling, in this methodological framework, refers to quantitatively assessing the impact of policies on selected indicators. The modelling phase will in practice run in parallel with the finalizing of the pre-modelling phase, calling for multiple iterations between the two. Iteration between phases and steps is needed, as research tools and questions to be addressed must be harmonized.

For integrated ex-ante assessment, the generic approaches developed in the European context in the SEAMLESS and SENSOR projects can potentially be used as a basis. SEAMLESS has developed an integrated modelling framework (Van Ittersum *et al.*, 2008a) for assessment of sustainable development in agricultural systems, with models at different levels of organization (i.e. field, farm, region, continent, globe) and from different disciplines (i.e. ecological, economic, social, institutional). The SENSOR methodology aiming at indicator assessment by response functions (quantitative) and knowledge rules (qualitative), is a generic approach that can be used both when detailed data and models are available, but also when only expert knowledge is at hand (Sieber *et al.*, 2008). Although these generic models provide a basis for SIA in the case studies, the selection of models should depend on the case study objectives. The models should allow assessment of the identified causal chains between drivers, policies and indicators for the land use sector(s) and at the scale(s) as identified in the pre-modelling phase. Besides the nature of the problem chosen in the case study, also important for the selection of tools are thus the availability of data and knowledge on relevant processes. Section 3, in this deliverable describes more in depth the different models that have been used in the different case studies.

When a specific model is used for another type of application or in another context, data need to be collected as input in the model, and adaptations to the model structure often need to be made. Adaptations and developments differ between case studies and between models, for more detailed presentation of model tools please see Part V. Participatory and interactive tools that cover the whole range of impact assessment phases, used in SENSOR, have been further developed in LUPIS to define scenarios, specify the regional sustainability context, and to conduct a participatory impact assessment based on expert judgments (FoPIA; Framework for Participatory Impact Assessment, see König *et al.*, 2010) and to visualize and communicate land use changes and impacts on indicators and Land Use Functions (ProVision; visualization and communication tool, see Morris *et al.*, 2009). These tools are especially useful in countries where data availability is scarce.

The application of a model starts with the definition of the context and the scenario. The quality of the output of a model largely depends on the quality of the input. For qualitative models inputs depend on the experts and stakeholders selected; for quantitative empirical models on the quality of the data collected; and for quantitative mechanistic models mainly on experiments and literature. In quantitative mechanistic models, parameterization of simulated processes is also of importance. In iteration with the pre-modelling phase and model adaptation and/or development, data need to be collected in order to use the model or develop a knowledge rule. In most regions data are available from national and regional statistics, theoretical models, and earlier studies. This often needs to be complemented by surveys. Sensitivity analyses may be applied to assess the sensitivity of the model to changes in different parameters (e.g. yield, price, decision-making variables).

4.5 Post-modelling stage in integrated impact assessment

4.5.1 Evaluating contributions to sustainable development

In the post-modelling phase, the changes in indicator values associated with the corresponding LUFs for the different scenarios are evaluated for 1) the impact on the specific problem, and for 2) sustainable development in the wider context. Multi-criteria analysis (MCA) is used to assess which land use policy option scores best, given the preferences of stakeholders. This starts with the indicator selection (Figure 2.2). Changes in values of the indicators are assessed in the modelling phase, while the weights of LUFs and indicators are based on consultation with stakeholders and experts. First of all, trade-offs between economic, environmental and social indicators and between LUFs can be analysed. Secondly, normalizing LUFs and aggregating them using weights defined by stakeholders, summarizes multiple indicators into single scores, thereby indicating which scenario contributes best to SD.

Using an MCA to derive a single SD index is mainly relevant for discussions with stakeholders and experts. Presenting a single SD index including the importance of different LUFs based on the values and weights will help understanding of the indicators and the procedure, which may form a basis for improvements. Caution should however be taken when presenting results as scientific, as the reliability depends on the stakeholders and experts selected. Furthermore, for deriving a single score per scenario, indicators should be normalized considering their targets and thresholds (what is considered bad and what is considered good). The latter are generally difficult to establish. They can be based on policy targets derived from legal documents, ecological thresholds, general trends and expert knowledge. Which value is considered as sustainable determines the normalized indicator and hence the importance for the SD evaluation.

Based on the multi-criteria analysis including economic, environmental and social indicators, and the institutional assessment, effective and feasible policy options can be identified.

4.6 Documentation and visualization

A dataportal is used within the project to systematize and compare findings across seven country-specific applications in the pre-modelling, modeling and post-modelling stages (http://lupis.cirad.fr). The main purpose of the dataportal is the enhancing of communication: between scientists (within and between working groups), and between scientists and policy makers. Further details about the content of the Dataportal can be found in Part VII of this report.

Furthermore, national policy fora and stakeholder workshops have been especially useful in discussing the steps throughout the process.

5 Part V: Overview of impact assessment methods applied in LUPIS

5.1 DPSIR – a framework to define causalities

This section is based on (Nesheim *et al.*, forthcoming). The driver, pressure, state, impact, response (DPSIR) framework was used to analyze the causal relationships between the various economic, environmental, social and institutional aspects within each case study; an important step in an ex-ante impact assessments (OECD, 1993; Reidsma *et al.*, 2011) (Helming *et al.*, 2008a). The components of the framework distinguish between driving forces of change, pressures on land use, state of the natural and socio-economic environment, and the impacts on sustainable development(see Figure 6). The use of this conceptual framework based on causality between interacting components of social, economic and environmental systems has important benefits by providing clear and concise communication to decision makers (See also Kohsaka, 2010; Rounsevell *et al.*, 2010). The DPSIR framework was originally developed to analyse environmental impacts and therefore has a strong environmental focus. The causal chain connects *Drivers* (for example, economic activities such as transport or agriculture) through *Pressures* (e.g., emissions of pollutants) that influence *States* of the environment (e.g., soil pH, vegetation type). The changes in these states are the *Impacts* on the environment, specified by indicators (e.g., increase in pH or species loss). These may lead to *Responses*, such as setting limits to air pollution or promoting new farming systems (OECD, 1993; Petit *et al.*, 2008).

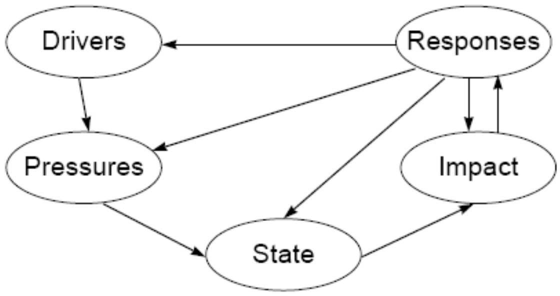


Figure 6: The DPSIR framework

In LUPIS, to guide the problem analysis, the DPSIR framework (see Figure 6) is nested within the LUPIS framework (see Figure 4 from Part IV). The driver component of the framework has in LUPIS been specified as: underlying drivers, proximate drivers and policy drivers. The *Underlying Drivers* are fundamental forces that underpin the more obvious proximate drivers. They are comprised of a complex set of social, political, economic, demographic, technological and cultural factors, such as economic growth, technological development, climate change and population growth. The *Proximate Drivers* are human activities that directly affect the problem and thus constitute proximate sources of change (Geist and Lambin, 2001). These are drivers (including policies) linked to economic sectors (e.g., agriculture, forestry, industry). In Figure 6, the proximate drivers are presented in two compartments; proximate drivers and policy drivers (existing policies with identified important impact on the identified problem). The distinction between underlying and proximate drivers was seen as important to understand which aspects are difficult to modify / change as they are out of control of the case study stakeholders, and which drivers can be modified (proximate drivers such as existing policies, human actions such as immigration and agricultural intensification). The proximate drivers directly influence land use change, which is represented by the *Pressure* component. The *Pressures* towards sustainability considered in LUPIS are changes in land use activities/intensities. These pressures influence the *State*, as represented by relevant social, environmental and economic indicators. The *Impacts* are measured as the changes in indicators, which determine the impacts on sustainable development (SD). We adapted the DPSIR framework so as to cover not only the environmental dimension as in the original form of the framework (OECD, 1993), but to include also the social and economic dimension. This was performed by providing an indicator framework including three indicators related to “Land Use Functions (LUFs)” within each of the three sustainable development dimensions (Paracchini *et al.*, 2011; Reidsma *et al.*, 2011). The *Responses* refer to identified policy options that contribute to sustainable development.

The drivers, pressures, states and impacts, and the causal links including feedback mechanisms were identified based on literature reviews and interaction between researchers, decision makers and civil society in National Policy Forums. These discussions on the problems in the case study area, their drivers, and the major impacts were translated into DPSIR story lines by the research teams, which were later verified in a subsequent National Policy Forum. The National Policy Forums selected relevant policies based upon their potential to improve the situation; these policies were evaluated as part of the policy review in the project (Bonin *et al.*, forthcoming).

5.2 TechnoGIN: A modelling tool at the field level to derive agro-ecological relationships

5.2.1 TecnoGIN: A Generic structure

This section is based on D4.4.1 (Reidsma *et al.*, 2008b). Technical Coefficient Generators (TCGs) differ in their structures, options, database management systems, user interfaces, etc. These differences partly depend on user preferences, but more importantly on the biophysical and socio-economic characteristics of the case study and the objective functions, constraints and other settings as defined in the bio-economic model (Ponsioen *et al.*, 2003).

TechnoGIN was originally developed to calculate TCs for cropping systems in Ilocos Norte province, Phillipines, in the context of the SysNet project (Roetter *et al.*, 2005). Within another project, the IRMLA project, it was re-designed to make it a more generic tool. This means that it can be applied in other cases with similar agro-ecological conditions, at other scales and it can be adapted according to data availability. TechnoGIN is programmed in Excel, with macro programming in Microsoft Visual Basic for Applications. The file with the model interface, calculations and generated outputs is separated from the file with the data and model parameters (i.e., two Excel files with various worksheets). When opening TechnoGIN, a model interface with several buttons appears in a TechnoGIN sheet (see Figure 7).

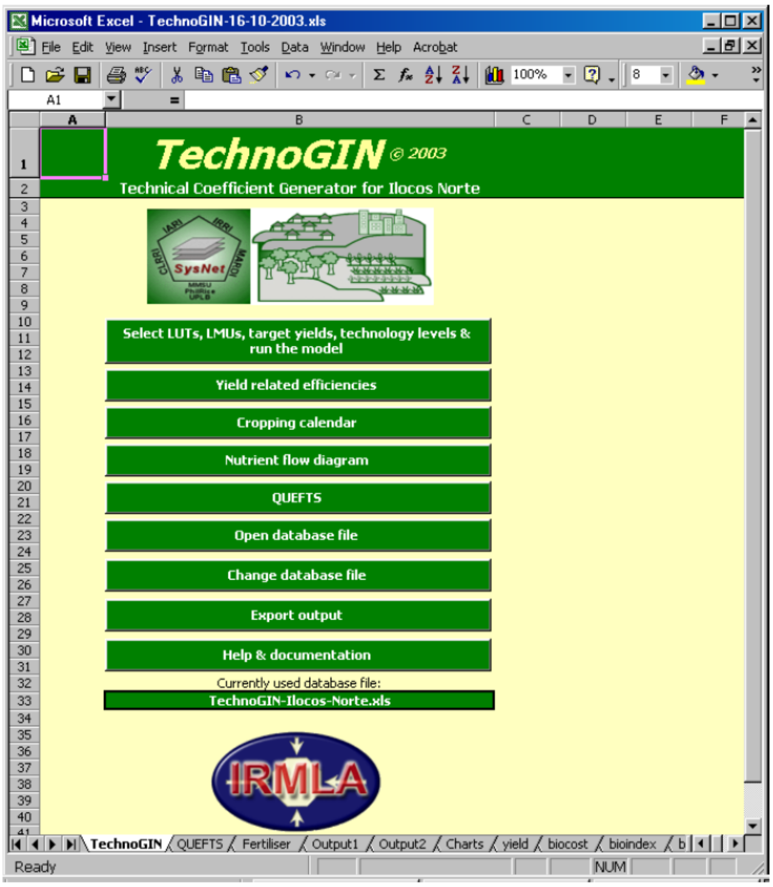


Figure 7: Screenshot of the TechnoGIN opening sheet (Source: Ponsioen et al. (2003)

Behind each of the buttons is a user form, which are designed for database management, selection of land use types, target yields, land units and technology levels for model runs and output analysis. The calculations are performed in a macro (in Visual Basic) and two worksheets containing Solvers (an 'add-in module' in Excel). The data in the database file can be extended, deleted, modified and saved under a different name. The worksheets in the database file (Nutrient, Efficiency, Technology, Crop, LUT, LMU, Biocides, Currency and Fertiliser) contain the databases that are used in the macro to calculate the TCs of the combinations on land use types (LUTs, i.e. production activity), land management units (LMUs; i.e. agro-environmental zone), target yields and technology levels. Combinations of these can be selected in the Select form (see Figure 8), and after running the output will be exported to an Excel or ASII file. Figure 4.3 gives a schematic overview of TechnoGIN.

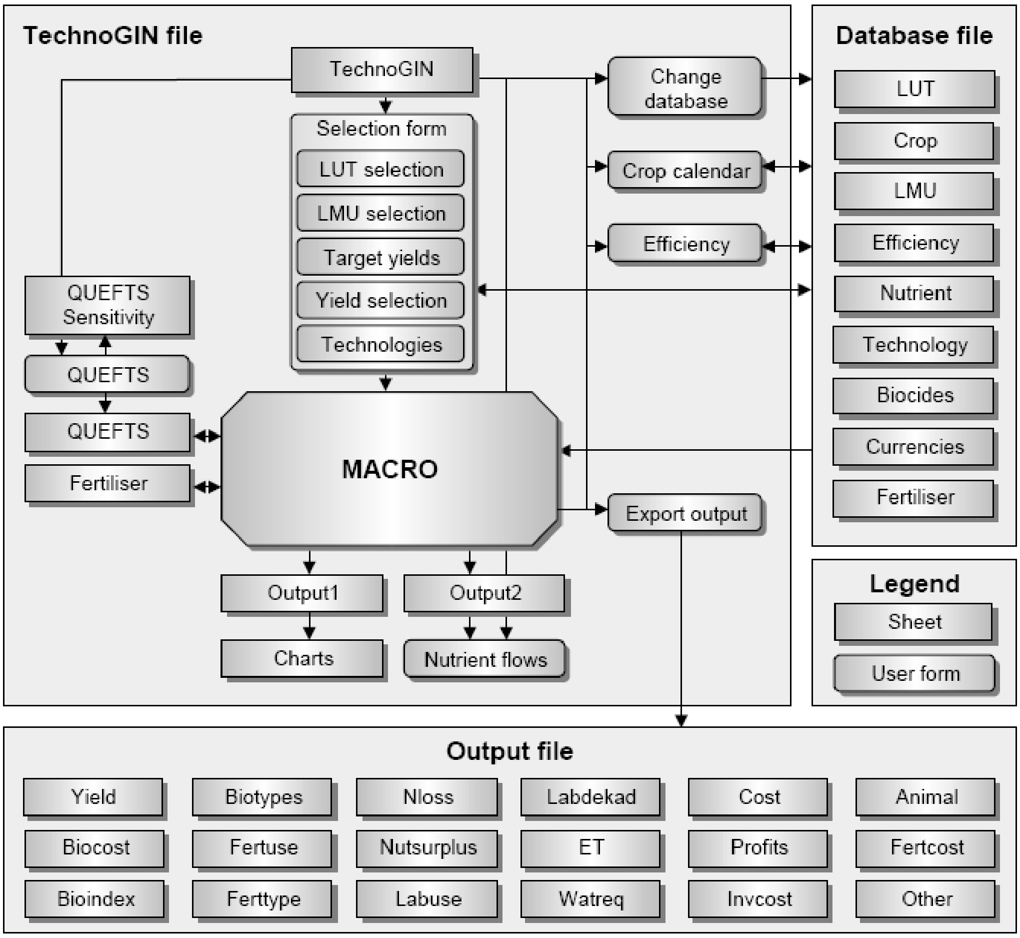


Figure 8: Schematic overview of TechnoGIN (Source: Ponsioen et al. (2003)

The model is described in detail in Ponsioen et al. (2003) and in Ponsioen et al. (2006). For complete information including all the equations, codes and other details the reader is referred to these references. These reports and the model can be obtained from the authors of this deliverable. Below we will shortly summarize the most important features.

The technical coefficients that are produced by TechnoGIN are:

- Yields and animal product
- Fertiliser requirement, nutrient losses and balance
- Biocide use and index
- Water requirement (monthly)
- Labour use (monthly)
- Fuel machine, animal and seed use
- Costs per input and profits

Some of these TCs are directly calculated based on the data that is collected and included in the model. The calculations of some TCs need extra calculations based on theoretical models.

5.2.2 TechnoGIN: Nutrient uptake

To estimate nutrient uptake at a target yield the QUEFTS (Quantitative Evaluation of the Fertility of Tropical Soils) approach is used (Janssen *et al.*, 1990; Witt *et al.*, 1999). With the maximum dilution and maximum accumulation of nitrogen, phosphorus and potassium (kg harvestable product/ kg N, P and K respectively) as constraints, the internal efficiencies of N, P and K are calculated. Internal nutrient efficiencies depend on the availability of the different nutrients in the soil. For example, when N is abundantly available and P is limiting, N efficiencies will be closer to maximum accumulation, while P efficiencies will be closer to maximum dilution. Relatively, the crop will take up more N compared to P.

In TechnoGIN, N, P and K uptake is calculated assuming a balanced nutrient uptake by the selected crop. Data required for these calculations are read from the Crop sheet (potential yield, harvest index, dry matter content, minimum and maximum N, P an K in harvestable product, and crop residues). Instead of calculating yields as in the original approach, a target yield is defined (based on survey data or a crop model) and nutrient uptake is calculated. Calculations are thus independent of soil data in the LMU sheet.

5.2.3 TechnoGIN: Nutrient flows

Flows of N, P and K (see Figure 9) of land use systems are calculated per season, based on soil properties (clay content), precipitation, crop characteristics and management efficiency. The model includes all possible flows for consistency and for evaluation, but not all flows are parameterized. Flows that have little influence and are excluded from the calculations are irrigation, free-living N-fixation, capillary rise, dissolution and sedimentation. Flows that are assumed to be in balance are run-off/run-on, erosion/sedimentation, immobilisation/mineralisation.

In current systems, the amount of fertilisers applied are fixed and based on available data. Considering these, nutrient efficiencies are calculated with QUEFTS. Most of the parameters for the transfer functions that calculate the different flows are read from the Nutrient sheet. For alternative systems, the yearly fertiliser applications are calculated by balancing the inorganic and organic nutrient pools, so that the fertiliser applications and target yields can be repeated without mining the soil or building up a soil nutrient reserve.

Fertiliser requirements of alternative systems are calculated by subtracting inflows into the system (mainly from the soil and the atmosphere) from the plant uptake (calculated by QUEFTS) and dividing this by the recovery fraction corrected with technology, yield and crop related factors, and subtracting the recycled nutrients taken up by the previous crop. The correction factors give the opportunity to specify nutrient recoveries for different / alternative technologies, yields and crop characteristics.

The losses that are calculated by TechnoGIN are N and K leaching, P and K fixation, denitrification and nitrogen volatisation.

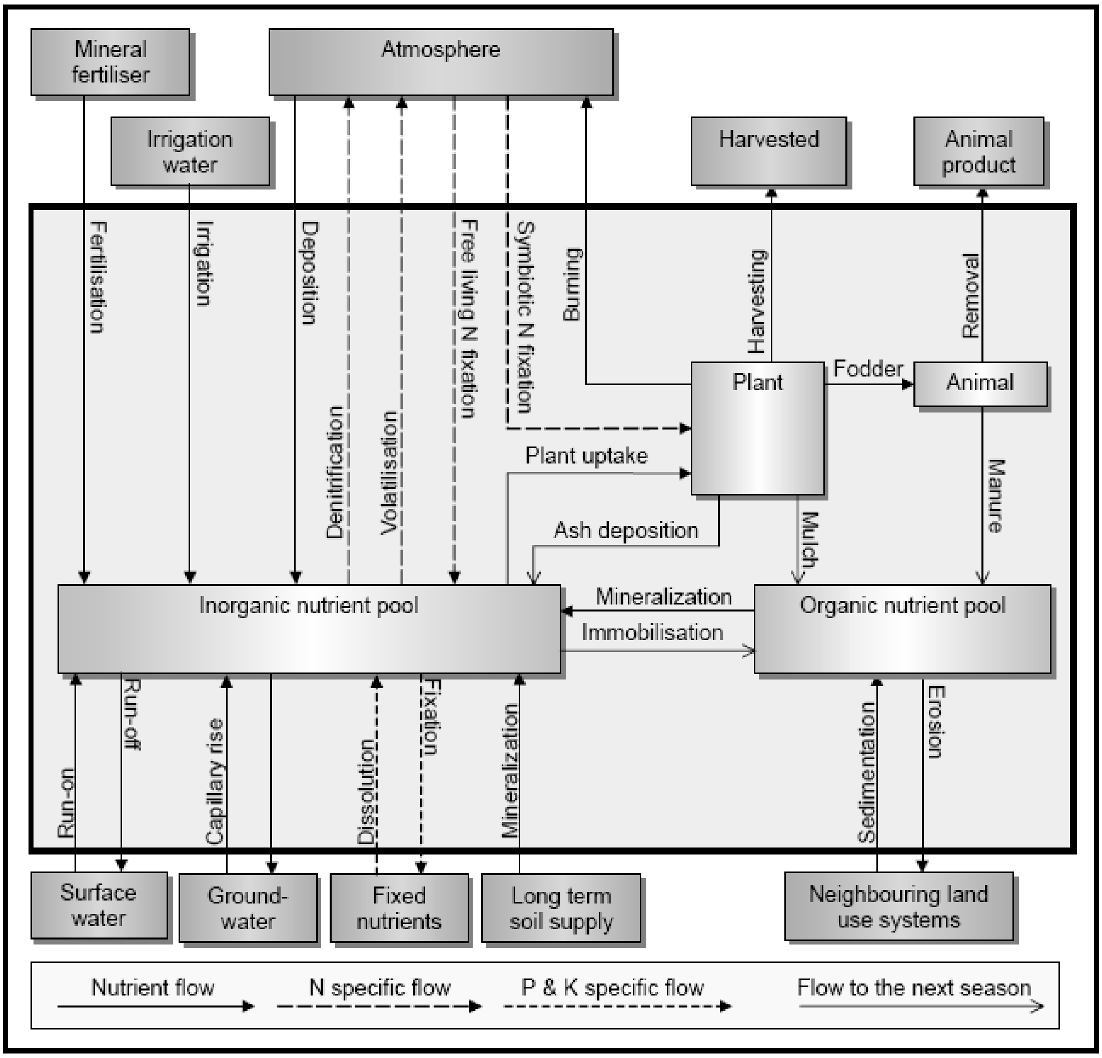


Figure 9: Nutrient flows per cropping season in a land use system (Source: Ponsioen et al. (2003)

5.2.4 TechnoGIN: Efficiencies and input requirements

Yield related efficiency factors are calculated for nutrient, biocides and water use. Input use efficiencies decrease with high application rates and high yields. Therefore, five reference yields have been identified (as % of the maximum yield) for which different efficiency factors can be defined. The chosen target yield defines the calculated efficiency factors, which are obtained by linear interpolation between the reference yields.

Labour requirements are calculated per decade (i.e., 10 days). Labour is required for land preparation, crop establishment, crop management and harvesting. Input data is required for these four periods, TechnoGIN translates it to decades. Labour requirements (labour-days) depend on target yields, technology factors and the number of days in which certain types of management take place. The labour-days multiplied with the wage rates determine the costs.

Water requirements are based on simple water balances on a basis of decades. Per crop, actual evapotranspiration is calculated by multiplying reference evapotranspiration with crop coefficients. When there is a second crop, the crop coefficient is multiplied by a yield efficiency factor for water and a technology related water use correction factor. With regard to biocides, the total use in active ingredients, the costs and the biocide index are calculated for up to 30 different kinds of biocides (i.e., herbicides, pesticides and fungicides). The biocide index is calculated based on the amount of each chemical, its toxicity index and a half-life in soil.Fuel use, machine rent, animal rent, irrigation fees and investment costs are read from the Crop sheet and multiplied by the technology correction factor.

5.2.5 TechnoGIN: Databases

The file with the databases needs to be adapted per case study. Worksheets include:

- Crop per crop
- LUT per land use type
- LMU per land management unit
- Nutrient nutrient loss transfer functions
- Efficiency yield related efficiencies
- Biocide per biocide type
- Fertiliser per fertiliser type
- Currencies conversion factors

Complete information on these databases can be found in Ponsioen et al. (2003). Certain data types need to be collected by surveys, measurements or statistics (e.g. labour requirements per activity), some can additionally be estimated with models (e.g. maximum yields), while other data types are based on literature and expert knowledge (e.g. N, P & K concentrations).

Information on the reliability of these data is often lacking. Nevertheless the integration of the data and processes in a model, makes TechnoGIN a useful tool. Especially data and assumptions in the model that are difficult to quantify are accessible through user forms and can be modified directly in the spreadsheets, so calculations are transparent for the user. Table 1 in Ponsioen et al. (2006) gives a clear overview of the data requirements per datasheet in TechnoGIN, indicating whether values are generally applicable and can be considered as fixed (e.g. dry matter content of crops), whether values should be established specifically (e.g. biocide use) or whether the value is a relative fraction (e.g. relative nutrient use for an alternative production technique).

5.3 CropSyst: a cropping systems simulation model to study the relationships between cropping systems productivity and the environment

The cropping system model CropSyst (Stöckle *et al.*, 2003) was used to quantify the relationship between crop production and environmental effects at field scale. CropSyst implements modules capable of simulating crop response to a wide range of weather, soil and management conditions using daily time steps, for periods ranging from one year to a hundred years. CropSyst is a multi-year, multi-crop, daily time step cropping system model. It can simulate the soil water budget, soil–plant nitrogen budget, crop phenology, crop canopy and root growth, biomass production, crop yield, residue production and decomposition, soil erosion by water, and pesticide fate. Crops are simulated using a generic crop simulator, in which some processes (e.g. photoperiod response, vernalization) can be switched on or off using appropriate parameter values (Belhouchette *et al.*, 2011). CropSyst simulates plant growth as potential growth and under water, nitrogen, and temperature stresses. Water infiltration and runoff are estimated either using the soil curve number approach or a mechanistic approach which accounts for soil surface roughness. Water redistribution in the soil profile is simulated either using the cascading approach (in its simplest form, without retention time) or using a finite difference solution of Richard's equation, in which the soil is subdivided into layers and the numerical solution considers the centre of layers as nodes. Appropriate boundary conditions are defined to simulate irrigation, free drainage, and a shallow water table.

In addition, CropSyst simulates possible water and nitrogen stress and the effect of agronomic treatments (irrigation and nitrogen fertilization). Also, the crop component is based on a generic crop simulator, allowing easy calibration for the introduction of crops for which CropSyst had not been used before (such as durum wheat).

The main input data required to run CropSyst are weather information (minimum and maximum air daily temperature, daily global solar radiation, daily rain), main soil characteristics (texture, field capacity and wilting point, organic matter content) and management practices (sowing date, irrigation, fertilization, tillage). The calibrated parameters of the crop component relate to crop phenology, biomass production (radiation use efficiency) and leaf area index expansion (specific leaf area). The key phenological parameters were calibrated using observed data for emergence, flowering and harvest time (Belhouchette *et al.*, 2011).

5.4 Farming Systems Simulator (FSSIM) – a modelling tool at the farm level

FSSIM is a generic bio-economic farm model can be applied in the combination with the higher level models to assess farm level impact of future policy scenarios for different farm types in different regions. It is an optimization model which maximizes a farm's total gross margin subject to a set of resource and policy constraints. Total gross margin is defined as total revenues including sales from agricultural products and subsidies minus total variable costs from crop and animal production (Louhichi *et al.*, 2010a).Total variable costs include costs of fertilizers, costs of irrigation water, costs of crop protection, costs of seeds and plant material, costs of animal feed and costs of hired labour. A quadratic objective function is used to account for increasing variable costs per unit of production because of inadequate machinery and management capacity and decreasing yields due to land heterogeneity (Howitt, 1995). The general mathematical formulation of FSSIM is presented below:

Maximise: $Z = w'x - x'Qx$

Subject to: $Ax \leq b; x \geq 0$ (1)

Where *Z* is the total gross margin, *w* is the n x 1 vector of the parameters of the linear part of the activities' gross margin, *Q* is the n x n matrix of parameters of the quadratic part of the activities' gross margin, *x* is the n x 1 vector simulated levels of the agricultural activities, *A* is a the m x n matrix of the technical coefficient, and *b* is the m x1 vector of available resources and upper bounds to the policy constraints.

A different model formulation has already been implemented and can be used if detailed agro-management information is available or if it is important to account for the risk averse attitude of the farmer explicitly. In this model formulation the farmer's utility is maximized. Utility is defined as gross margin minus risk for this specification a linear gross margin function is assumed (Louhichi et al, 2010).

Maximise: $U = w'x - \varphi\sigma$

Subject to: $Ax \leq b; x \geq 0$ (2)

Where φ is the risk aversion parameter that assumes constant absolute risk aversion and σ is the standard deviation of the total gross margin. The agricultural activities (*i*) are defined in FSSIM model as a combination of crop rotation (*r*), soil type (*s*), period *(p)*, production technique (*t*) and production orientation (*sys*) (i.e. *i=r,s,t,sys*). That is, an agricultural activity is a way of growing a rotation taking into account the management type. However, if data on crop rotations are missing the agricultural activities can be defined using individual crops (i.e. mono-crop rotations). The principal technical and socio-economic constraints that are implemented in FSSIM-MP are: arable land per soil type (or agri-environmental zone), irrigable land per soil type, labour and water constraints. The same rule was applied for all of these constraints: the sum of the requirements for each resource cannot exceed resource availability.

FSSIM is a positive model, where the main objective is to reproduce the observed levels (base year). The Positive Mathematical Programming approach is used to calibrate the model and the guarantee exact reproduction of the observed situation without using additional calibration constraints whish are difficult to justify in way consists consistent with existing economic theory (Heckelei, 2003). PMP is a generic and fully automated procedure which means that it can be easily adapted and used in different regions and farm types without additional specific information.

FSSIM can be calibrated using any all of the following approaches, (i) the standard Positive programming PMP procedure developed by Howitt (Howitt, 1995), (ii) the Röhm and Dabbert's PMP approach (Rohm and Dabbert, 2003), (iii) PMP variants approach (Kanellopoulos *et al.*, 2010).

FSSIM has a modular set-up, including modules on crops, livestock, perennial, investment, premium, risk, policy and Positive Mathematical Programming (PMP). These modules are linked indirectly by an integrative module named the "common module" involving the objective function and the common constraints are presented in Figure 10. Each module generates at least one variable which is used to define the common module's equations, thus providing a link between the different modules.

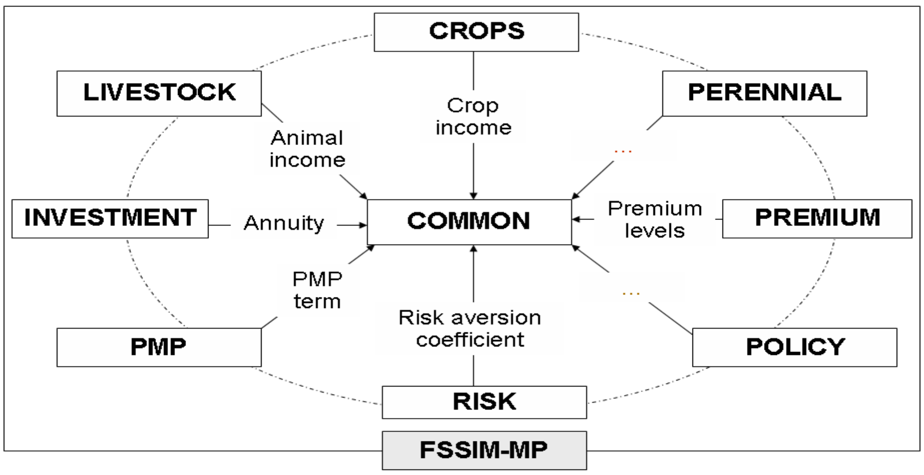


Figure 10: FSSIM-MP structure (Louhichi *et al.*, 2010b)

5.5 Multiple regression analysis

Multiple Regression analysis was used as a facilitator for other quantitative impact assessment tools. It was used to understand the significant causal relationships between variables. The results obtained from multiple regression analysis were used to provide inputs to the structure of the Simultaneous Equations Models (SEM) and provide inputs for multi-criteria assessment.

The theoretical model developed for the Indian case study addresses the main issue of linking agricultural changes to policy drivers through change in indicators of their impact. Three dimensions of sustainability were taken into account for this (SEM) analysis- the **E**cological (E), **F**inancial (F) and **S**ocio-cultural (S) dimensions. Composite indices for E, S and F were found using the variance for weights method for corresponding indicators within each dimension for two time periods 2006 and 2009 (Purushothaman *et al.*, 2011). The difference in the composite indices between two time periods was represented as change in the level of sustainability dimensions influenced by policy driven farming practices. Significant explanatory variables for $\Delta\mathrm{E}, \Delta\mathrm{F}, \Delta S$ were found using multiple regression analysis. Since the change in the dimensions of sustainability simultaneously affects each other, the SEM was structured to solve using 3 Stage Least Square (3 SLS) regression method. Two composite scenarios were developed based on past trends in significant explanatory variables found with multiple regression analysis and also based on consultation with local experts. Using comparative statics approach, the change in each sustainability dimension was estimated at a future point when it becomes asymptotic with X axis. The estimated change in dimension was added to the average composite indices of dimensions of sustainability to get the future values of indices. The scenario “With policy” that presents promotion of sustainable agriculture was found to result improving all the dimensions of sustainability than a “Business As Usual” scenario.

5.6 Computable general equilibrium (CGE) model as a modelling tool at the regional level

5.6.1 CGE: A Theoretical background

This section is based on D7.2 (Sghaier *et al.*, 2011).

The model description is kept as general as possible, however modelling assumptions are discussed in direct relation to the case study area: Medenine province in Tunisia.

Computable General Equilibrium models are a standard empirical tool used to assess the impacts of exogenous shocks and policies changes transmitted through different markets. The starting point for the CGE model is the circular flow of commodities in a closed economy (see Figure 11. The main actors presented in the economy are the household, who own the production factors and are the final consumers, the firms, who rent the factors of production to produce commodities and the government, who collect the taxes and distributes the revenues.

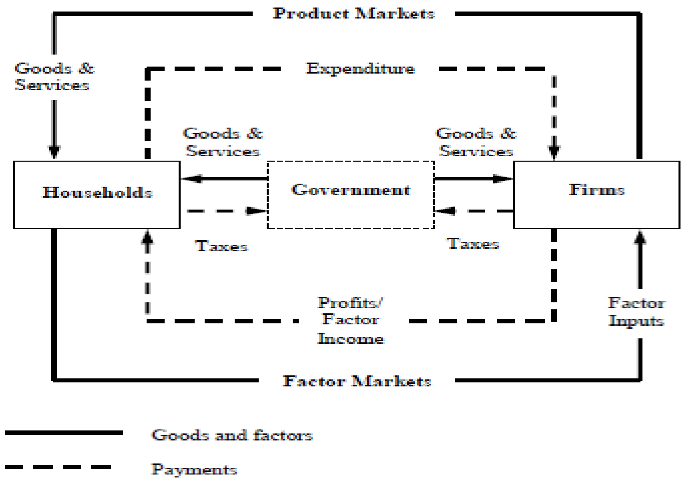


Figure 11: The circular flow of the economy

5.6.2 Social Accounting Matrix as input data to CGE

The realistic economic data needed to solve numerically the CGE model are arranged in an accounting table known as a Social Accounting Matrix (SAM). A Social Accounting Matrix (SAM) is a matrix in which each economic account has both a row and a column. The expenditures for each account are recorded as column entries while the incomes for each account are recorded as row entries. Thus a SAM is a form of double entry bookkeeping in matrix form, in which the entries in each cell identify the magnitude, source (expenditure) and destination (income) account of a transaction. SAMs as a analysis tools were originally used mostly for national accounting purposes, but later a demand grew to apply them at regional and local levels. The SAMs can provide both a descriptive and prescriptive analysis of a regional economy.

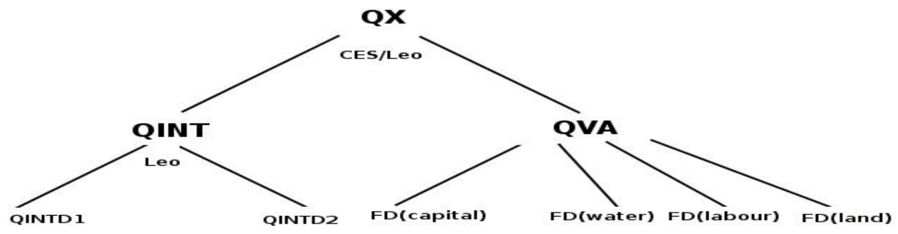
The SAM is read from column to row, so each entry in the matrix comes from its column heading, going to the row heading. Finally columns and rows are added up, to ensure accounting consistency, and the total of each column must equal the total of the corresponding row (see Table 1).

Table 1. Standard form of SAM

	Industry	Commodity	Factors	Institutions	Government	Trade	TOTAL
Industry (detail)		Make					Total Industry Output
Commodity (detail)	Use			Consumption		Exports Output	Total Commodity
Factors -land -labour -capital	Returns to Primary Factors (value added)					Exported Primary Factors (e.g. labour flow)	Total Factor Income
-Institutions -households -other	Sales	Sales	Distribution of factor Income		Transfer Payments	Exports	Total Institutional Income
Government	Indirect Business Taxes	Sales Tax	Factor Taxes		Intergovernmental Transfers		Total Government Income
Trade	Imported Purchased Inputs	Imports	Imports			Trans-shipments	Total imports
TOTAL	Total Industry Outlay	Total Commodity Outlay	Total Factor Outlay	Total Institutional Outlay	Total Government Outlay	Total Exports	

5.6.3 Behavioural Relationships in the Model

The form of the SAM determines the agents that can be included within the model, and the transactions recorded in the SAM identify the transactions that took place in the base year. The model is defined by the behavioural relationships. The behavioural relationships in the Medenine CGE model are represented by a mix of non-linear and linear relationships. According to micro-economic theory, households are assumed to maximise their utility subject to their income constraint. The utility function is a Stone-Geary function. Producers are assumed to maximise their profit under initial capital availability. The production function is a combination of constant elasticity of substitution (CES) function and Leontief function as shown in Figure 12.



Where Leo indicates Leontief technologies, CES indicates a CES function, QX is the output of an activity, QINT is the aggregate intermediate input, QINTD1 and QINTD2 are representative intermediate inputs and QVA is the aggregate quantity of value added. FD is factor demand and is shown for capital, labour (unskilled urban labourers, skilled urban labourers, unskilled rural labourers and farmers), land (agricultural land, non agricultural land, grazing land) and water (surface water, groundwater).

Figure 12: Production function structure

5.6.4 Data

As mentioned above the data needed in a CGE framework are arranged in a Social Accounting Matrix. In developing a Social Accounting Matrix, a choice must be made between a top down approach and bottom-up approach. For the Medenine SAM we used hybrid procedures, if the data is available at the regional level it is integrated directly into the SAM, if not we use the top down procedure by regionalizing the national data. The RAS methods (technique used to update input-output tables on the basis of benchmark tables compiled with comprehensive census and survey data) are used to estimate, update and balance the SAM.

Social Accounting Matrix (SAM) for the province of Médenine

Following the aims of the study, the economic situation of the study area and the data availability, a typical structure for a regional Accounting Matrix is developed. The SAM includes accounts for production (activities), commodities, factors of production, and various actors (institutions) and the rest of world.

The activities accounts are disaggregated into agricultural, industry, and tourism activities. The agricultural activities receive special attention and are disaggregated into livestock, fishing, irrigated agriculture activity and dry agriculture activity. A one product for one activity assumption was made for the non-agriculture activities, while the irrigated agriculture and the dry agriculture activities produce several commodities.

The factors of production included in the SAM are farmers, rural unskilled labour, urban unskilled labour and skilled labour, capital, and natural resources (land and water resources). To incorporate the several types of land and water production factors we use the opportunity cost (water) and the rent value (land). Special accounts that describe national and provincial taxes were integrated on the SAM.

The institutional accounts are the households, enterprises, and the national and provincial government. Due to the lack of data availability and the time involved, we aggregated the rest of the world and the rest of Tunisia. The regional SAM structure was chosen to be as large as possible, so a large set of existing commodities and activities in the Medenine governorate, especially for agriculture activities, are integrated in the GAMS database. The first step of the GAMS regional SAM building program consists of the agriculture supply and use matrix calculation from various data mentioned above. The irrigated and dry agriculture activities and the livestock activity intermediate uses (seeds, manure, pesticides forage, etc.) are mapped in consistent manner. According to the available data, the GAMS program calculates the intermediate consumption and the output of each agriculture activities. The data for the non-agriculture activities, the use of non-agriculture commodities by agriculture activity such as intermediate consumption and the use of agriculture commodities by non-agriculture activity such as intermediate consumption are taken directly from the regional Supply and Use Matrix. All other data for the SAM accounts are handled in an Excel worksheet. The second step of the program consists of the micro SAM and macro SAM calculations. The macro SAM represents an aggregation of the micro SAM. Furthermore, the GAMS SAM building program calculates the regional GDP with the expenditure approach and income approach.

Regional supply and Use /Input output tables for the Medenine governorate

Regional input-output tables have traditionally been constructed from national industry by industry tables. However, with the publication of the new international guidelines for national accounting (UN 1993, and Eurostat 1996), there is an increasing interest to compile regional Input output tables using national supply and use (S/U) matrix rather than national industry by industry input output tables as a reference. The regionalization of Supply and Use / Input Output matrices for the Tunisia case study consists of three steps: the regionalization of the supply and use matrix, the regionalization of the final demand and the regionalization of the trade flow. The number of employees at the regional level was used in the regionalization procedure.

Agricultural commodities and activities

The agriculture sector receives specific attention in the SAM building procedure given its importance in the Medenine governorate. The agricultural commodity account is disaggregated into eleven agricultural commodities and the agricultural activity account into four agricultural activities. The categories for both the commodity and activity are selected based on the characteristics of the study area and the information available in the structure agricultural census (2004) complied by the ministry of agriculture. The agricultural commodities and activities are listed in Table 3 in the appendix. The agricultural activities account represent the agricultural specificity of the region as it produces a combination of agricultural commodities and can be viewed as comprising multiproduct firms.

Other activities and commodities

Agriculture, industry and tourism are the principal activities of the governorate. Ninety industrial companies are established in the governorate of which nine companies are completely export-focused. The companies operate primarily in the agro alimentary, building materials, and textiles and clothing sectors. The area also include 48 foreign companies with mixed capital which operate primarily in the sectors of tourism, industry and services. More than 96 hotel units of high standing exist in the province of Médenine, with a total capacity of 35000 beds. Approximately five million nights are booked annually; primarily in Djerba and Zarzis. Furthermore, we can consider the Tunisian electric and gas company (STEG) and the national water use and disturbances company (SONED) as a specific activities that produce electricity commodities and pipe water respectively.. Aside from the agricultural activities, each activity produces one commodity (see Table 4 in the appendix).

The Use matrix

The use matrix is taken directly from the regionalized Supply and Use table. In the first step the agriculture activities were split into agriculture activities and fishing activities at the national level. The disaggregation procedure was applied according to the number of employees in each activity. The intermediate consumption of the fishing activity was given directly by the regionalized input output table. The intermediate consumption of the other agriculture activities such as irrigated activities, dry activities and livestock activities was calculated using regional data taken from the CRDA statistics which were compiled using the specific GAMS SAM building program described above. The cross account non-agriculture activities and agriculture activities are calculated according to the number of employees needed to produce each commodity.

Household account

Household consumption is given by the INS consumption survey (2005). In the INS consumption survey (2005) the national territory is divided into 6 sub-regions , north east, north west, centre east, centre west, south west and south east. The province of Medenine is part of the south east region. We assume that the rural and urban national consumer pattern is the same in the Medenine governorate. Given that we only have 29 commodities, all commodities included in the survey are aggregated into the set of commodities used in the Medenine SAM. Some assumptions were made, for example, total cereal consumption demand is assumed to be met by dry cereal. To calculate the Medenine household consumption we used an adjustment procedure to convert the national consumption pattern to a regional consumption pattern.

Production Factors

We consider four groups of factors of production: water, land, labour and capital. To capture the specificities of the region these factors of production are disaggregated into 10 factors (see Table 5 in the appendix).

The remuneration of factors used by agricultural activities was estimated from data given by regional statistics (Specific survey on livestock and animal production system (2006) in the province of Medenine (CRDA of Medenine) and Surveys of farm structure (regional level) concerning agricultural production including factor of production use (land, water, labour and capital)). Labour incomes were divided between farmer, unskilled and skilled urban, and unskilled rural labourers according to the number of employees. Some assumptions were made, for example that skilled rural labourers don’t work for agriculture activities. The remuneration of factors of production by non-agriculture activities are given by the regionalized input output table.

The groundwater and surface water was allocated to the irrigated activities and evaluated according to the water pricing system. Rainfall water is allocated to dry agriculture and breeding activities according to the dry land and grazing land and evaluated according to the opportunity cost. Dry and irrigated agricultural land, and grazing land, is evaluated according to the rental value whereas the costs of non-agriculture land are estimated according to their commercial value. Specific calculations were made, for example, the value of the industrial zone area is shared between all activities using statistics given by the ODS office except for value of land used by building and public work and tourism activities which have a specific calculation. The capital remuneration is calculated as a residual and therefore equals value added less the remuneration of all other factors.

5.7 CORMAS: Common-pool Resources and Multi-Agent Systems

CORMAS (Common-pool Resources and Multi-Agent Systems) is a multi-agent simulation platform specially designed for renewable resource management (Le Page *et al.*, unknown). It provides the framework for building models of interactions between individuals and groups sharing natural resources (see Figure 13), and thus are suitable to address multi-scale issues.

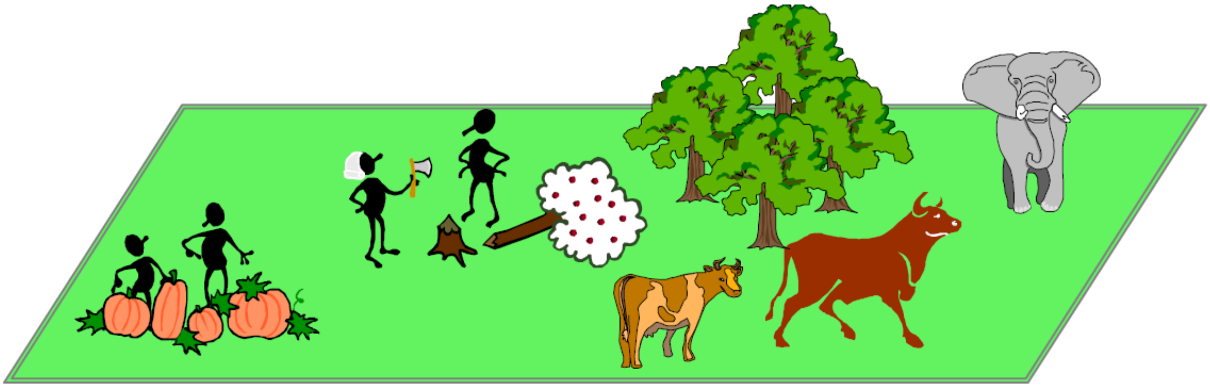


Figure 13: MAS and Natural Resources Management. The MAS environment is made of a collection of elementary spatial entities (cells) defining a topological support for the agents. Each cell may hold some resources that are used or managed by the agents in a specific way ((Le Page *et al.*, unknown))

Multi-agent systems (MAS) are based on the principles of distribution and interaction. Creating a MAS involves reproducing for experimental purposes an artificial world. Multiagent systems are made of collections of agents, an agent being a computerised autonomous entity that is able to act locally in response to stimuli from the environment or to communication with other agents (see Figure 14).

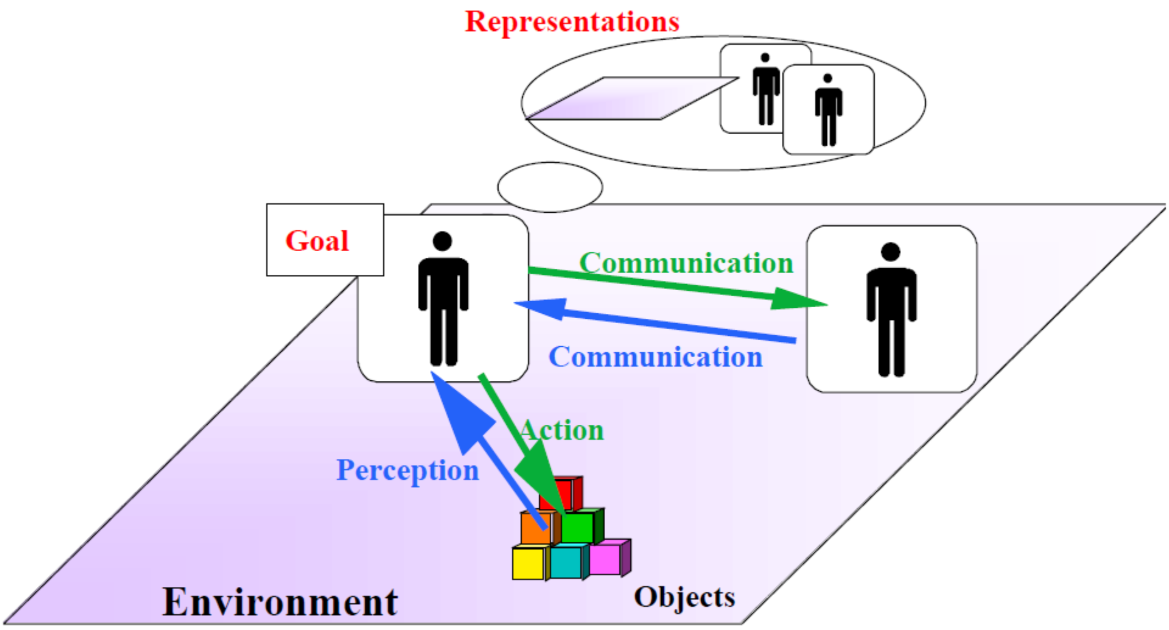


Figure 14: MAS general principles (from (Le Page et al., unknown)

Agents have:

· internal data representations (memory or state),

· means for modifying their internal data representations (perceptions),

· means for modifying their environment (behaviours)

The key-concept of MAS concerns the interactions between agents. These interactions may occur through the environment, either by being at the same place at the same time or less directly (for instance by ownership, resource depletion, pheromone depletion), or may occur explicitly, either via direct communication (exchanges of messages) or via transactions (e.g., financial). Knowledge is represented at the microscopic level and phenomena are represented at the macroscopic level. For several years, MAS have been used to study the relationships among different hierarchical levels. The macroscopic level is represented in the form of a group or macro-agent. The question is how interactions between entities at the microscopic level can cause phenomena at the macroscopic level, and conversely, how the macroscopic level affects processes at the microscopic level. It is possible to depict interactions between agents at different levels in a single MAS. For instance, a farmer agent interacts with a tree agent while a village agent interacts with a forest agent. The challenge is to move from the concept of a simple hierarchy to that of dynamics interconnected hierarchies, which corresponds to the reality of the natural environment.

CORMAS provides a set a heuristics for thinking about common-pool resources management in a decentralized and distributed way. The main goal of the CORMAS tool is not to make accurate predictions about the behavior of complex systems, but rather to provide a framework to help people develop new ways of thinking. As people make use of the simulation tool, they naturally engage in thinking about these ideas. We had to find a compromise to enable people to build their own models as easier as possible, while preserving flexibility and providing interesting functionalities especially to define realistic environments.

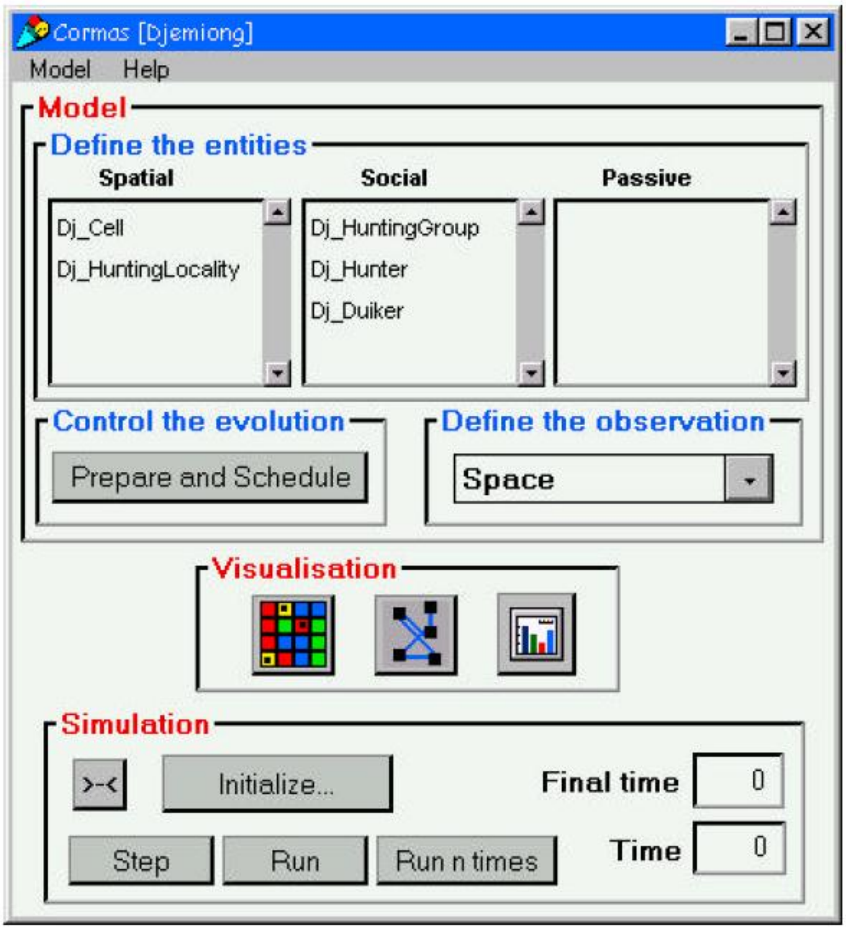


Figure 15: The CORMAS main interface ((Le Page *et al.*, unknown))

CORMAS is based on the software VisualWorks which, in turn, is a programming environment based on Smalltalk. Cincom, the American company that markets VisualWorks, distributes the software freely (for educational and research purposes). The architecture of the main interface of the platform (see Figure 15) has been designed to guide the user of Cormas during the modelling process. The organisation of the modelling group box in the upper part suggests three successive steps. The first one consists in defining the entities of the model into three categories (spatial, social, passive). Objects are defined as computational entities that encapsulate some state, are able to perform actions, or methods on this state, and communicate by messages passing. While there are obvious similarities between objects and agents, there are also significant differences. The main one deals with the degree of autonomy. In the object-oriented case, the decision about whether to execute an action lies with the object that invokes the method. In the agent-oriented case, the decision lies with the agent that receives the request.

Numerous applications can be found in the literature using this modelling platform. The case study in Mali has also adopted this framework.

5.8 IDRISI: A dynamic land use simulation modelling tool

Markov Cellular Automata Model (MCAM) is one of the extensions in IDRISI. IDRISI is an integrated geographic information system (GIS) and remote sensing software developed by Clark Labs (IDRISI, 2011) for the analysis and display of digital geospatial information. IDRISI is a PC grid-based system that offers tools for researchers and scientists engaged in analyzing earth system dynamics for effective and responsible decision making for environmental management, sustainable resource development and equitable resource allocation.

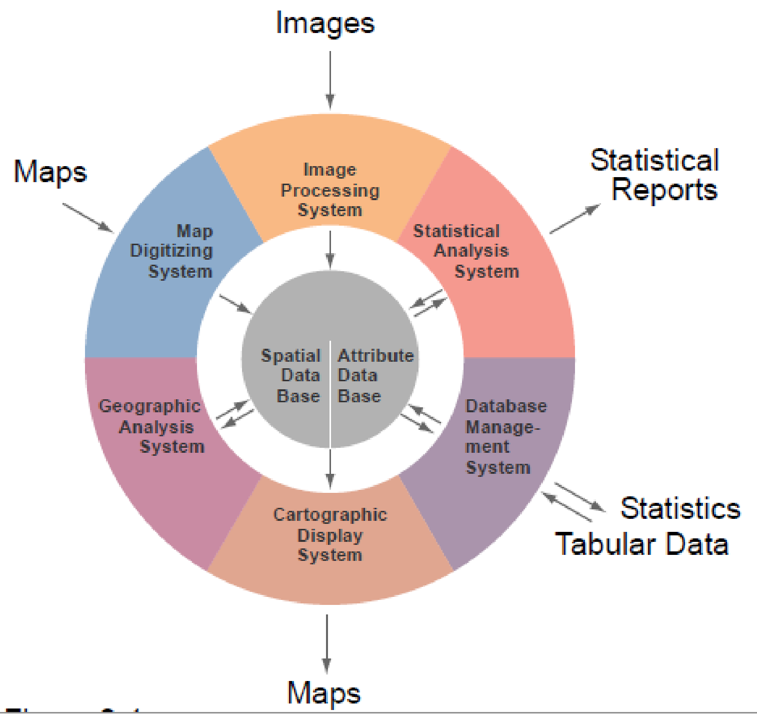


Figure 16. Database of IDRISI that integrates the spatial and attribute databases (reference: (Eastman, 2003)

Key features of IDRISI include:

- a complete GIS analysis package for basic and advanced spatial analysis, including tools for surface and statistical analysis, decision support, land change and prediction, and image time series analysis;

- a complete Image Processing system with extensive hard and soft classifiers, including machine learning classifiers such as neural networks and classification tree analysis, as well as image segmentation for classification;

- integrated modeling environments including the Earth Trends Modeler for image time series of environmental trends and Land Change Modeler for land change analysis and prediction.

A geographic database in IDRISIS is organized in a fashion similar to a collection of maps (see Figure 16).

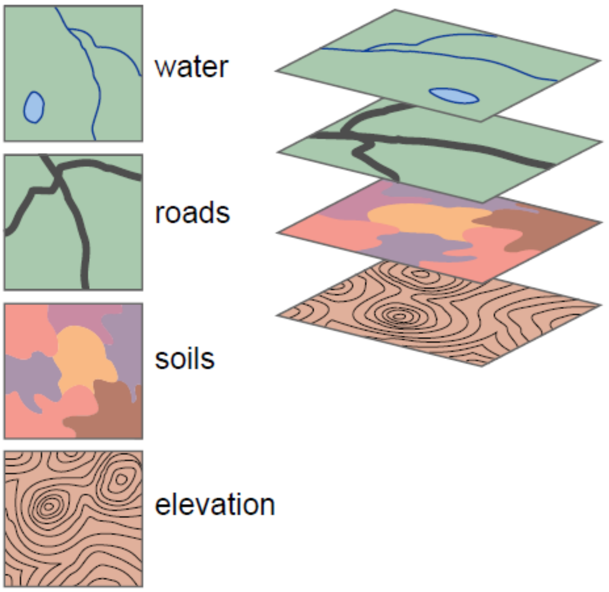


Figure 17: IDRISI links a feature identifier layer (a layer that contains the identifiers of the features located at each grid cell) with attribute tables

MCAM model is used to find out the change of land use. The transition aspect in MCAM is useful to represent the spatial aspect, so it is sufficient for using MCAM in land use change modeling. The MCAM itself comprises two approaches which are Markov Chain analysis and Cellular Automata. This GIS-based model was conducted in IDRISI Kilimanjaro environment.

Markov chains have been widely used to model land use changes including both urban and non urban areas at large spatial scales (Jahan, 1986; Muller and Middleton, 1994). Markov chains were used to gain the percentage and probability for each type land use convert to another function. Markov chain is completely determined by the Markov transition matrix P:

$$P = (p_{ij}) = \begin{vmatrix} P_{11} & P_{12} & \cdots & P_{1n} \\ P_{21} & P_{22} & \cdots & P_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ P_{n1} & P_{n2} & \cdots & P_{nn} \end{vmatrix}, \quad \sum_{j=1}^{n} p_{ij} = 1 \qquad (1)$$

Where, P = the Markov transition matrix P

i, *j* = the land type of the first and second time period

P*ij* = the probability from land type *i* to land type *j*

The difference is the provisions of change transitions, namely the cellular automata transition changes not only based on previous conditions but also based on the conditions in the surrounding cells. In this case the cellular automata have a spatial aspect, while the transition changes in the Markov does not represent the spatial aspects. Thereby, to be able to represent the spatial linkages of forest cover change and be used for projection or prediction changes in the spatial dimension, Markov Chain and Cellular Automata are integrated.

To investigate the projected land use of e.g. 2025 under particular circumstances, another GIS-based model was applied in ProVision environment. Pro-vision model is applied to find out the influencing factor or driver and how the policies overcome the land use change by visualizing what could happen in the next 25 years. Pro-Vision is compatible for Geographic Information System and easier to use which bridges the researcher and government to gain understanding of spatial distribution of land use change. Pro-vision is useful for improving the knowledge of stakeholder about regional sustainability issues. Its description can be found in section 5.12.

5.9 LUSMAPA – a modelling tool at the regional level

The Land Use Simulator Mato Grosso Para (LUSMAPA) tool is specially developed for the project and the case study. It can therefore not directly be applied to other cases, but the modeling environment is relatively easy to be adapted for future uses, other cases and even different regional levels.

The model is developed in Berkeley-Madonna, a software package similar to STELLA but available in a freeware version. The description of model formula is given in deliverable 13.2 (Rodrigues Filho *et al.*, 2011), while the user guide is given in this section. The model is still in development and after the completion of the LUPIS project a user shell is still not operational. Simulation and data handling is therefore carried out in Berkeley-Madonna (simulation) and MS-Excel (data processing). Future versions may include an integrative package in which data do not have to be exported.

5.9.1 Model architecture

Figure 18: Opening screen of the LUSMAPA model

Starting the model, results in an opening screen (see Figure 18) which can be passed to go to the flowchart of the model. The model is constructed around a main flowchart (see Figure 19) in which the land use changes are depicted.

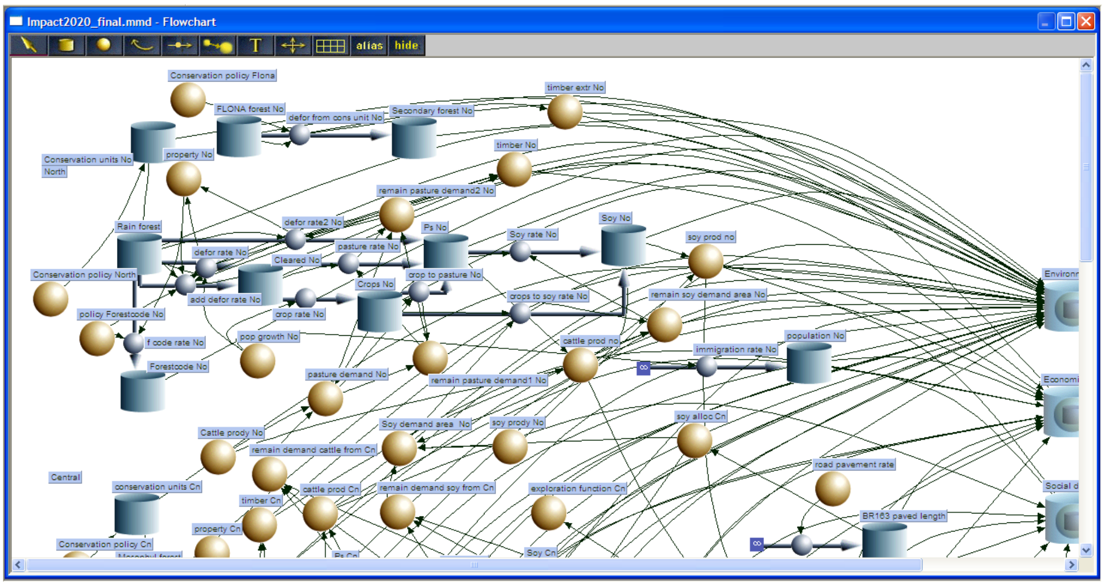
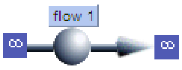


Figure 19: Part of the main flow chart of land use changes in the model

The architecture of the model is constructed around three different “icons”:

which refers to a state variable; in LUSMAPA the areas of different land uses, population in the different regions and the total length of the paved part of BR-163 are state variables.



which refers to a flow; in LUSMAPA these are land use conversions like deforestation, or conversion from pasture to soya, crops to soya, demographic growth or paving speed of BR-163.

which refers to a function; in LUSMAPA the land use conversions are based upon deterministic relations (see deliverable 13.2) like saturation functions. The conversions of land use types to other types (by flows) are thus described by such formula functions. Also scalar functions (from price to area) and the calculation of indicators are described with such functions.

All functions affecting flows are connected with thin arrows (called relations) in the flowchart.

By double clicking an icon an input screen is shown. Here values (for state variables) or functions can be added (see Figure 20 and Figure 21).

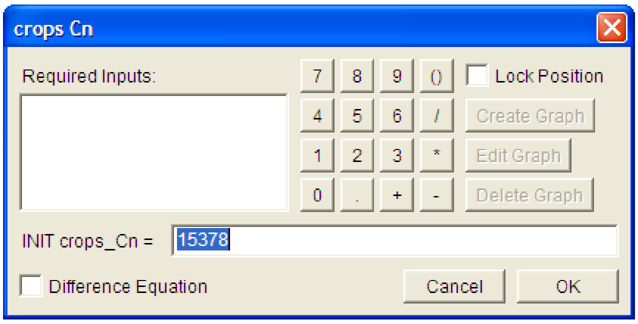


Figure 20: An example of an input screen of the state variable crops_Cn. After INIT crops_Cn a value should be added which denotes the area of crops at the start of the simulation (INIT for initialization)

While the input screens of the state variables usually only requires an input value for the initial state (the amount of land in the year the simulation should start; Berkeley-Madonna always starts with t=0, hence years should later be added during post processing of data), input screens of functions require formula (see Figure 21).

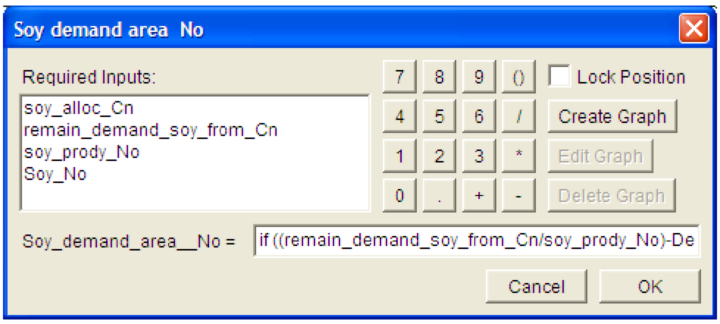


Figure 21: An example of an input screen of the function “Soy_demand_area_No. The function requires different inputs and the function is described as: Soy_demand_area_No = if ((remain_demand_Soy_from_Cn/soy_prody_No)- etc. where in the white screen the formula can be defined.

The main flowchart of LUSMAPA, thus containing the different land uses, the number of people in the three regions and the size of the paved part of BR-163, is connected to three sub-models (see Figure 22). These sub-models each calculate a set of indicators for the different sustainable development dimensions.

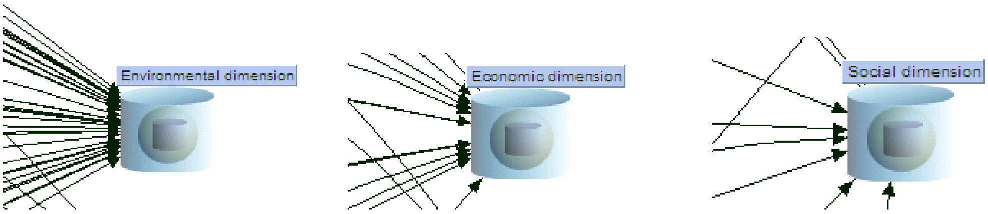
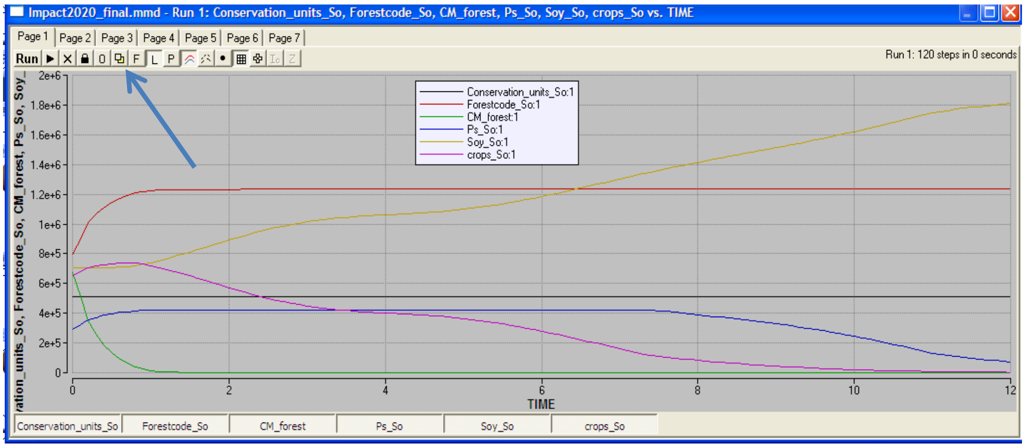


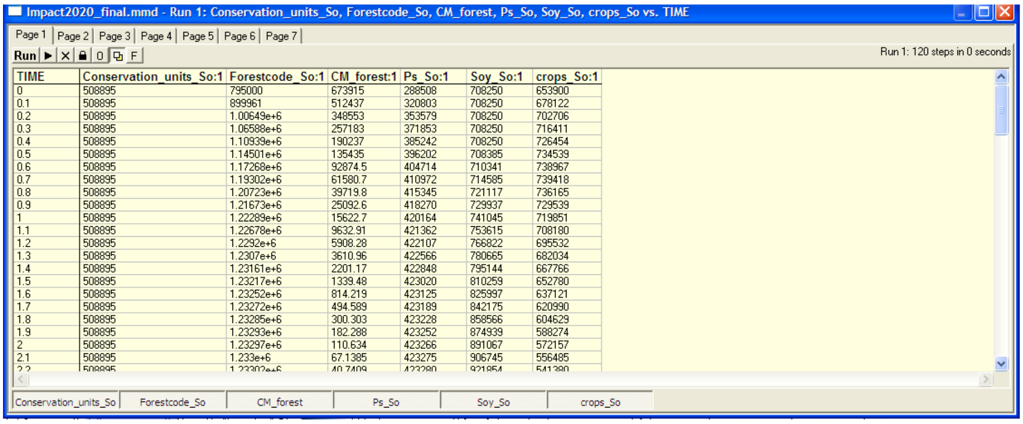
Figure 22: the three sub-models; environmental dimension, economic dimension and social dimension.

By double clicking on a sub-model the corresponding and underlying flowchart of that sub-model will open. In those flowcharts the calculation of indicators is depicted. Since this calculation is based on state variables or functions (like deforestation) in the main model, many of the functions in the sub-models show direct relations, depicted by the many arrows going from the main flowchart to the three sub-models.

5.9.2 Simulation

By clicking 'window" a menu will open. The menu includes various options and the one with an array of state variables ending with "vs. TIME" refers to the data output screen. By clicking this menu option the graph window will open (see Figure 23).





TIME	Conservation_units_So:1	Forestcode_So:1	CM_forest:1	Ps_So:1	Soy_So:1	crops_So:1
0	508895	795000	673915	288508	708250	653900
0.1	508895	899961	512437	320803	708250	678122
0.2	508895	1.00649e+6	348553	353579	708250	702706
0.3	508895	1.06588e+6	257183	371853	708250	716411
0.4	508895	1.10939e+6	190237	385242	708250	726454
0.5	508895	1.14501e+6	135435	396202	708385	734539
0.6	508895	1.17268e+6	92874.5	404714	710341	738967
0.7	508895	1.19302e+6	61580.7	410972	714585	739418
0.8	508895	1.20723e+6	39719.8	415345	721117	736165
0.9	508895	1.21673e+6	25092.6	418270	729937	729539
1	508895	1.22289e+6	15622.7	420164	741045	719851
1.1	508895	1.22678e+6	9632.91	421362	753615	708180
1.2	508895	1.2292e+6	5908.28	422107	766822	695532
1.3	508895	1.2307e+6	3610.96	422566	780665	682034
1.4	508895	1.23161e+6	2201.17	422848	795144	667766
1.5	508895	1.23217e+6	1339.48	423020	810259	652780
1.6	508895	1.23252e+6	814.219	423125	825997	637121
1.7	508895	1.23272e+6	494.589	423189	842175	620990
1.8	508895	1.23285e+6	300.303	423228	858566	604629
1.9	508895	1.23293e+6	182.288	423252	874939	588274
2	508895	1.23297e+6	110.634	423266	891067	572157
2.1	508895	1.233e+6	67.1385	423275	906745	556485

Figure 23: Simulation window in LUSMAPA

Figure 23 the graph window, with above a graphical representation of a simulation and below the data. By clicking on the icon (see arrow) the datasheet becomes visible.

The graph menu shows on the bottom the selected state variables, flows or functions. By clicking on "run" the model will simulate a particular run, depending on the policies and scenarios studied (see section below). For further analysis, data might be exported to Excel for further data processing. For this the data, instead of the graphs, should be exported.

To do so, the icon within the graph window should be clicked. Than the data view of the graph (see Figure 23 below) is shown. By easy copy-paste, the table can be exported to Excel. In the graph window four graph sheets are predefined; three graphs that include the state variables (land use types) in the three regions and one sheet that contain all indicators.

To run a simulation various aspects should be kept in mind. First, the time interval of a simulation should be defined (within the LUPIS project up to 2020, hence a time lap between 2007 - 2020 thus requires 12 time steps), the integration method and the integration time step. Those issues can be found by clicking on "parameters" and selection of "parameter window" in the main menu. The parameter window is depicted in Figure 24.

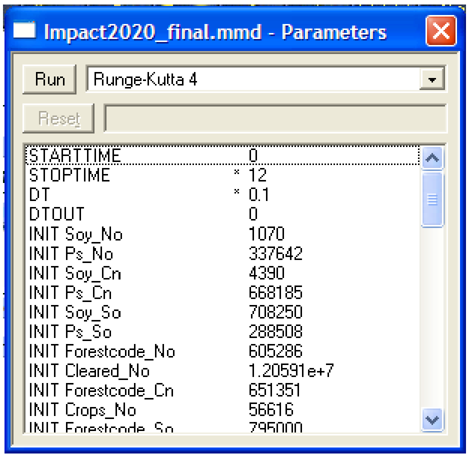


Figure 24: Parameter window.

Figure 24 depicts various data, of which some are described here. First, right to the run button the integration method can be selected. For LUSMAPA the Runga-Kutta 4 method is used, the most precise integration method that also requires the longest run time and therefore calls for a fast CPU computer processor. Moreover the start and stop time of a simulation is given. Since Berkeley-Madonna works with relative time (always starting with 0) the time axis should be adapted in the post processing of the data. If a start time should be set op 2007 (t=0) than the stop time of say 2020, should be set on 12. Next, the integration step should be defined, denoted as DT. Berkeley-Madonna uses a default value for this, but test runs have shown LUSMAPA runs best with integration steps of 0.1. This means, relatively speaking, that for each year an integration step of one tenth is made. This also results in data tables with steps of 0.1 year (ten data points per year), which require some post processing in Excel to convert to one data point per year. Furthermore, initial values of state variables can also be changed in this window.

In a typical simulation scenarios and policies can be changed. Scenarios include different prices for soya and beef and different demographic growth rates. These scenarios are pre-processed in Excel and exported as data files to Berkeley-Madonna (text files using Notepad). Each scenario is easily called by double clicking on the corresponding function. In the example of Figure 25 the data set is declared in the function “soy price”.

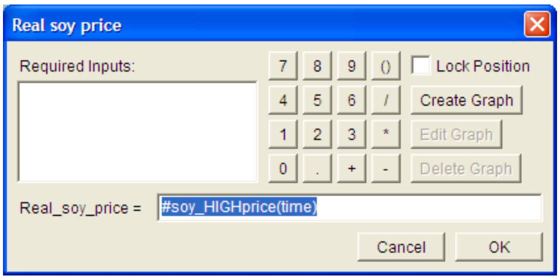


Figure 25: The function “Real soy price”

Figure 25 includes the dataset “soy_HIGHprice“ which refers to the data file (with extension .txt) with the similar name. The “#” and “(time)” are Berkeley-Madonna scripts that refer to input of a data set.

The data sets that are used for the scenarios:

Soy: low price and high price

Beef: low price and high price

Population North: low growth and high growth

Population Central: low growth and high growth

Population South: low growth and high growth

A high price scenario thus includes both high price for beef and soy and corresponding high population growth in the three regions. Hence for each scenario 5 functions (soy price, beef price, population North, Central, South) have to be adapted.

The policies are changed by using the sliders in the LUSMAPA model (see Figure 26)

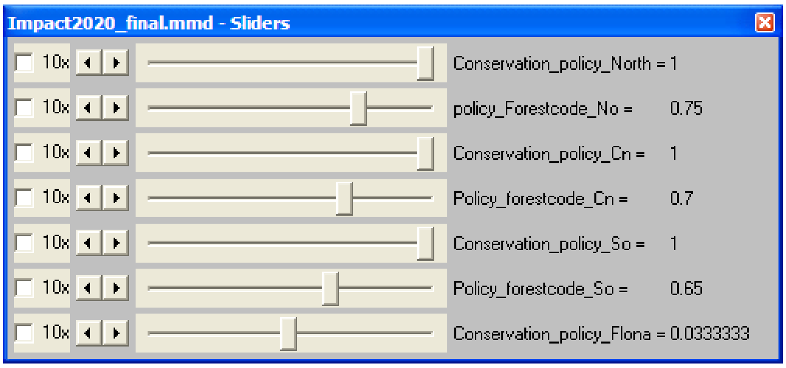


Figure 26: The slider window that include the policies

The policy slider window includes 7 policies: the conservation units in the three regions (North (No), Central (Cn) and South (So)), the policy on forest code in the three regions and the additional conservation policy on FLONA forests in the North region. For all policies, expect the FLONA, values can be changed from 0 to 1, referring to the efficiency or amount of policy that is effective in the model. 0 refers to 0% of effectiveness, meaning that no forest will be under conservation unit and no forest is conserved under the forest code. 1 refers to 100% of the area protected under conservation unit (thus if in a region 200,000 ha is defined as conservation unit, than all 200,000 ha is indeed protected). For forest code 100% implies that for each ha of forest that will be converted to agricultural use the same amount (1:1) will be protected under the forest code with no additional deforestation. Currently the model only allows a 1/33 conversion of conservation unit under FLONA to secondary forest per time step.

5.10 IMPACT – a Modelling Tool at the national level

The International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) is a freely available model of international agricultural trade developed by the International Food Policy Research Institute (IFPRI) at the beginning of the 1990s (Rosegrant et al., 2005a. The IMPACT model examines the links between food production and demand and food security at the national level. It has been used in several important research publications from IFPRI. The description of the IMPACT model provided in this section gives an overview of the model. For comprehensive explanations of the model see the model description (Rosegrant et al., 2005a) and the model instructions (Rosegrant et al., 2005b).

Figure 27: Screenshot of IMPACT model start-up

Distributed version 1.0 (see Figure 27) is used for LUPIS which can be freely downloaded from:

www.ifpri.org/themes/impact/impactresearch.asp.

The source of supply and demand data of the model is the FAOSTAT database, population data are taken from the UN (1998) and elasticities and growth rates are obtained from literature reviews and expert estimates. Most price data are obtained from the World Bank's Global Commodity Markets; A Comprehensive Review and Price Forecast (World Bank, 2000). Prices that were not available were collected from the Food and Agriculture Organization (FAO 2000a, 2000b) and the USDA's National Agricultural Statistics Service (NASS) (USDA, 2000).

In the IMPACT model, the world is divided into 36 countries and regions. Supply, demand and prices of 32 agricultural commodities are determined within each country or region. The supply and demand of each commodity are approximated using a system of supply and demand price elasticities which are different for each of the 36 markets and incorporated into a series of linear and nonlinear equations. The link between markets within each countries or regions is revealed by cross-price elasticities and intermediate demands such as feed demand for livestock production. The link between countries or regions is through trade with a separate, unique "world market" for each commodity. The world price of a commodity is determined annually at levels that clear international market. The description of the model structure provided in this section closely follows Rosegrant et al. (2005a).

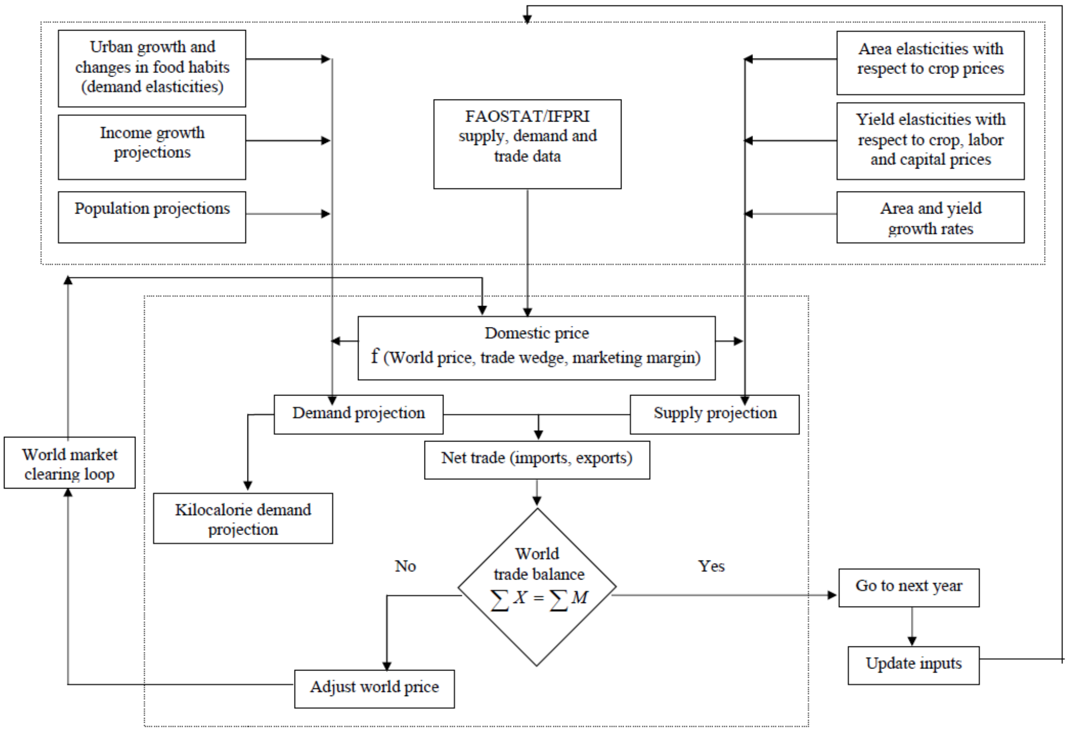


Figure 28: Schematic presentation of IMPACT model (Rosegrant *et al.*, 2005).

An important feature of any model is the extent to which it can be adjusted to reflect more recent information or used to conduct impact analyses. These two factors relate to the components, or 'levers' of the model that can be changed by the user. Five levers are provided in the IMPACT model for exploring the influences of policies and sensitivities to various model features (see Figure 28):

- Income growth by country
- Population growth by time period and country
- Yield growth by time period, commodity and country
- Crop area/herd size growth by time period, commodity and country
- Irrigation growth by commodity and country

5.11 FoPIA: the Framework for Participatory Impact Assessment

This section is based on D4.3.2 (König *et al.*, 2008) and (König *et al.*, in review). The FoPIA consists of a sequence of steps to conduct impact assessments of alternative land use scenarios, drawing on the knowledge and expertise of participating stakeholders. The implementation of this approach at case study level follows three main steps: the (i) scenario development, the (ii) specification of the sustainability context, and the (iii) impact assessment (see Figure 29). Stakeholder participation is at the core of this method and considered in each assessment step. The FoPIA comprises two assessment directions: firstly, a discursive examination of causal relationships and attributions of changes between human activities and regional SD targets, and secondly, the exploration of scenario impacts and possible trade-offs on selected sustainability criteria at regional level. For the FoPIA, a one (sometimes two) day workshop was organized for each case study and facilitated by a moderation team including: one workshop moderator, one translator (if needed), and two persons responsible for the processing of interim-results and reporting.

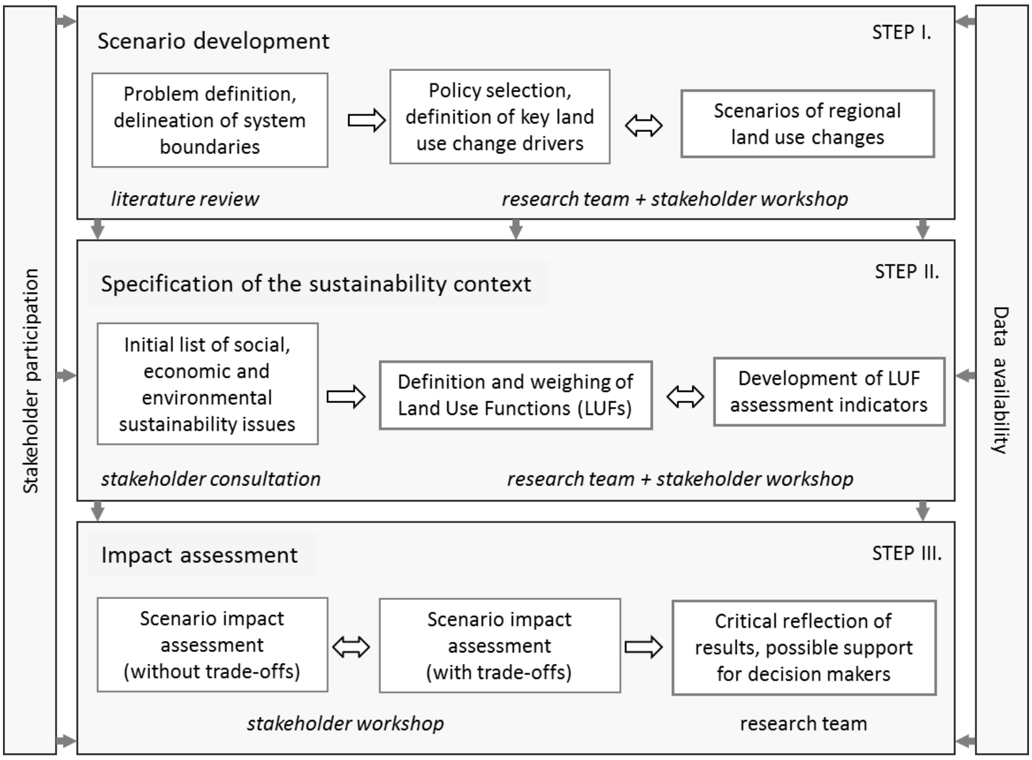


Figure 29: Implementation structure of the FoPIA framework

5.11.1 Step I in FoPIA: Scenario development

Scenarios are one way of looking into the future to explore possible directions and alternative outcomes. In impact assessment, scenarios have become a widely accepted instrument in analysis of SD (Duinker and Greig, 2007). For this study, simplistic assumptions were made in order to develop alternative region-specific future land management scenarios. The scenario development starts with the definition of the impact assessment problem and the delineation of the case study boundaries and the selection of one or two policy instruments that aim to address the regional land use problem. The credibility of a scenario is of high importance and determined by the degree to which the stakeholders perceive the scenarios as plausible (Alcamo, 2001). Therefore, scenario assumptions were widely discussed with stakeholders to achieve transparency, understanding and scenario plausibility. All scenarios were exposed to the same general trends with regard to economic development and population growth assuming that these drivers lead to increasing consumption of natural resources and changes in land use patterns. Land use included main land use sectors (i.e. agriculture, forestry, nature conservation, and construction (industry and services, infrastructure/transport). As a result, scenario narratives were developed for each case study independently, including two policy scenarios and one reference scenario (‘business as usual’), respectively.

In the stakeholder workshop (Part I), scenarios are presented to the participating stakeholders. The introduction of scenarios was accompanied by a presentation of figures of key drivers of land use changes and expected trends based on expected economic growth development and population growth rates. Particular attention was paid to the regional implementation and implications of land use policies on future land management practices. Stakeholders were given the opportunity to share their implicit knowledge and to propose changes to the initial scenarios.

After group discussion and upon common agreement a final set of scenarios and assumptions was defined.

5.11.2 Step II in FoPIA: Specification of the sustainability context

Putting the concept of SD into the regional context, the FoPIA makes use of so-called “Land Use Functions (LUFs)” after Pérez-Soba et al. (2008). The fundamental premises of the LUF concept builds upon the idea that, firstly, land use constitutes the main pressures on SD in rural regions, and secondly, SD can only be achieved if social, economic, and ecological aspects are equally considered (Schößer *et al.*, 2010). LUFs are defined as ‘goods and services’ summarizing those sustainability criteria that can be used to represent sustainability in a balanced way (Paracchini *et al.*, 2011). They are a pragmatic way for stakeholder-driven sustainability impact assessment of land use changes and allow comparisons between different regions (Helming *et al.*, 2011a). In impact assessment, LUFs facilitate the identification of those social, economic, and environmental functions of the land that may be damaged or enhanced under a given land use scenario (Morris *et al.*, 2011). In the second step of the stakeholder workshop, the research team presented and a common set of nine LUFs which were adapted from the EU SENSOR project after Pérez-Soba et al. (2008) to each stakeholder group. This predefined list included three economic LUFs (land based production, non-land based production, infrastructure), three social LUFs (provision of work, food security, quality of life), and three environmental LUFs (maintenance of ecosystem processes, provision of biotic and provision of abiotic resources).

In a first step, stakeholders, in each case study region, were given the opportunity to reflect and comment on each LUF and to propose changes in their definitions of LUFs (Table 2). Based on a predefined set of LUFs as developed for the European context after Pérez-Soba et al. (2008), stakeholders in each non-European country under consideration had the opportunity to adapt or modify these LUFs towards the regional context. Modifications have been made for the social dimension of LUFs in which “food security” was introduced and replaced the LUF “cultural identity” in all regions expect in the case of Tunisia. Among the social LUFs, food security appeared to be a general concern of local people. In the case of Tunisia, food security was not considered to be a major sustainability issue whereas cultural identity, in the form of traditional knowledge, instead, was argued to be an important asset for rural people struggling to survive in this particularly dry region. The social LUF “human health” was modified and redefined to “quality of life” in order to consider regional factors affecting rural life in general; i.e. human health but also income available to improve the living standards of rural people. The definition of economic and environmental LUFs was largely accepted and adapted from the proposed set of LUFs as used under the European context. After open discussion and upon common agreement among participants, a final list of LUFs was defined.

In a second step, stakeholders assigned weights of ‘perceived importance’ to each LUF by taking into account regional needs and SD targets (0 = less important up to 10 = most important). The same weight could be assigned to more than one function. After the assignment of individual weights, average weights were calculated and presented back to the group. This step was carried out to stimulate discussions around the main differences and similarities in regional functions and to obtain a holistic picture about regional sustainability.

The main purpose of LUFs was to address changes in sustainability within a broader context, supporting the communication of the SD concept among interdisciplinary stakeholder groups and to allow comparison among different regions. In addition, each LUF was assigned a corresponding indicator in order to have a precise measurement for the scenario impact assessment.

The indicator selection process was realized in two steps: firstly, the research team developed a list of generally suitable indicators together with local partners from research institutions in the five regions based on literature review, experiences and data availability.

For the indicator selection, the following four criteria were applied:

(1) the indicator should be relevant and sensitive to the corresponding LUF and policy

(2) the indicator should be as precise as possible and measurable

(3) the indicator should be clear and understandable to stakeholders

(4) the indicator should not be redundant (i.e. covered by another indicator).

Secondly, the corresponding list of these indicators was presented to local stakeholders (stakeholder workshop, Part II.) and intensively discussed among participants. Stakeholders were given the opportunity to comment on each indicator and to propose changes or adjustment upon common agreement of the group. Thereby, local perceptions about indicator relevance and understanding were taken into account and resulted in a final list of LUF assessment indicators.

5.11.3 Step III in FoPIA: Impact assessment

In the third part of the FoPIA workshop, the stakeholders assess the impact of each of the three scenarios on the identified Land Use Functions. Of note is that the FoPIA does not only produce quantitative results for analysis of LUFs and indicator scoring. Numbers were also used to promote discussion and social learning among stakeholders.

A scoring scale from - 3 to + 3 was used to assess negative or positive impacts, respectively, with the following scores: 0 = no impact; - 1 and + 1 moderate impact; - 2 and + 2 high impact; and - 3 and + 3 extremely high impact (cf. Morris *et al.*, 2011). The scoring scale could also be adjusted to the regional context, for example, given a range from -2 to +2, which was applied in the case of India in order to make the method applicable to the understanding of rural farmers. On completion of the individual scoring, average impact scores for each scenario on each assessment indicator were calculated and presented to the group as bar charts and spider diagrams. To initiate a discussion among participants, the moderator highlighted contrasting positive and negative scenario impact scores given by individual participants (scoring extremes). This step was important to make the participants reveal their arguments for the different scorings. It therefore helped to make implicit knowledge of the experts explicit and to exchange different views of anticipated scenario impacts. All arguments were collected by the moderation team and, after open discussion; a second scoring round was undertaken in which experts could adjust the scores of the first scoring round as needed. Final results were presented back to the stakeholder group who were given the opportunity to reflect and comment on the final outcome.

In a second step of the impact assessment, impact assessment results (scores) and LUF weights were aggregated along the three dimensions of sustainability (economic, social, environmental) using following equation:

$$wi_d = \sum_{f=1}^{n} w_{f,d} * i_{f,d} \quad \text{(equation 1)}$$

With: wi = weighted impact, w = weights assigned to each land use function (scoring), i = average impacts as assessed by the experts on each land use function (impact assessment), d = sustainability dimension (economic, social, ecological), f = land use function function (n = 9).

This aggregation was made to allow for a weighted interpretation of the impacts according to the priorities assigned to each LUF, and to better understand the trade-offs associated with each scenario.

This allowed for comparison of alternative scenarios, a ranking of the scenarios, based on which, possible implications for land management and decision support could be discussed and comparative analysis among different regions.

5.12 ProVISION: An interactive supporting tool for stakeholder inclusive impact assessment and expert research

This section is based on D4.3.2 (König *et al.*, 2008). The Pro-Vision tool (see Figure 30) has been developed as a visualisation and communication tool to support the communication between complex research issues and stakeholders.

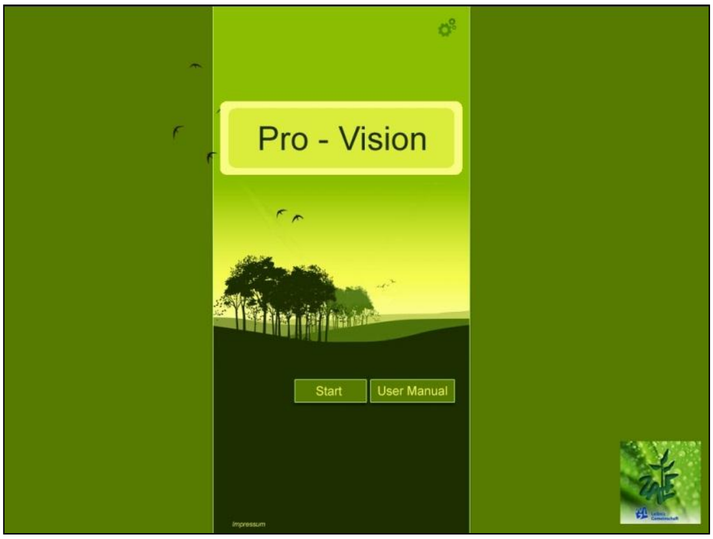


Figure 30: Pro-Vision is an interactive supporting tool for stakeholder inclusive impact assessment and expert research.

Pro-Vision can be used to perform a simplified sustainability impact assessment for land use changes. The tool enables the users to elaborate on alternative land use change scenarios (interactively) and to evaluate the likely impacts on regional sustainability issues in a participatory manner. The Pro-Vision tool has been developed to support the impact assessment procedure by visualising land use change and sustainable development issues.

The Pro-Vision tool has been developed as a visualisation and communication tool to support the communication between complex research issues and stakeholders. The focus areas of Pro-Vision are on land use and Sustainable Development (SD) for regional Impact Assessment (IA).

Pro-Vision can be used to perform a stakeholder based sustainability impact assessment of regional land use changes. The tool enables the users to elaborate on alternative land use change scenarios (interactively) and to evaluate the likely impacts on regional sustainability issues in a participatory manner. The Pro-Vision tool has been developed to support the impact assessment procedure by visualising land use change and sustainable development issues.

Pro-Vision has been adapted from the land use planning tool ‘Pimp Your Landscape’ which has been developed within the research projects IT-REG-EU (Integrated Trans-Regional Land-use Decision-Support in the Euro-Region Neisse, http://boku.forst.tu-dresden.de/IT_Reg_EU/index.html), Reg-

Transekt project (REGioncrossing TRANSfEr and marKeTing of tools and system-solutions for supporting land use planning and management, http://boku.forst.tu-dresden.de/Reg_Transekt/index_englisch.html) and ENFORCHANGE (Environment and Forests under Changing Conditions, www.enforchange.de) (Pimp Your Landscape web site: www.letsmap.de). Conceptual aspects for integrated impact assessment have been adapted from the SENSOR project (www.sensor-ip.org). The adapted version has extended its foci from the planning level to the assessment level. Therefore Pro-Vision now allows in an interactive way the (a) development of regional land use change scenarios and the (b) evaluation of land use change impacts on rural, urban and natural sustainable development issues.

Conceptual aspects in Pro-Vision have been adapted from the Pimp Your Landscape tool and from the EU FP6 Integrated Project SENSOR (Sustainability Impact Assessment: Tools for Environmental, Social and Economic Effects of Multifunctional Land Use in European Regions - Priority Area 1.1.6.3 "Global Change and Ecosystems"; www.sensor-ip.org).

The sustainability assessment of land use changes in Pro-Vision is based on the concept of Land Use Functions (LUFs). This approach enables the evaluation and visualisation of possible impacts of land use changes on regional sustainability issues. LUFs are defined as those goods and services which are provided by the land to the society in the target region. The user needs to identify and define a set of 9 regional LUFs which should be equally balanced between the three dimensions of sustainability (3 economic LUFs, 3 environmental LUFs, 3 social LUFs). The LUFs template can be edited for the value assignment under the modus ‘type definition’.

Scenarios of land use change provide alternative views of future landscapes and can be used tools to assess impacts of land use change and discuss the role of land use policies and autonomous developments between scientists and policy makers. In LUPIS, land use scenarios need to be developed to assess ex ante the impacts of land use policies on sustainable development issues.

A rule setting is used in Pro-Vision providing a simple land conversion matrix to support the implementation of land use change scenarios into spatial maps. The principle idea is to either restrict or allow certain land use types to be converted into another when developing the land use change scenarios.

The simulation mode of Pro-Vision allows an interactive development of alternative scenarios and its translation into spatially explicit land use changes. Scenario impacts will be visualised in the spider diagram (see Figure 31 for an example) and highlight possible development trends in regional LUFs (simulation vs. reference comparison). Principle scenario rules can be defined which either restrict or allow certain changes of land use in the map. The simple and flexible mapping procedure should also allow a direct consideration of implicit and regional knowledge to be visualised and verified.

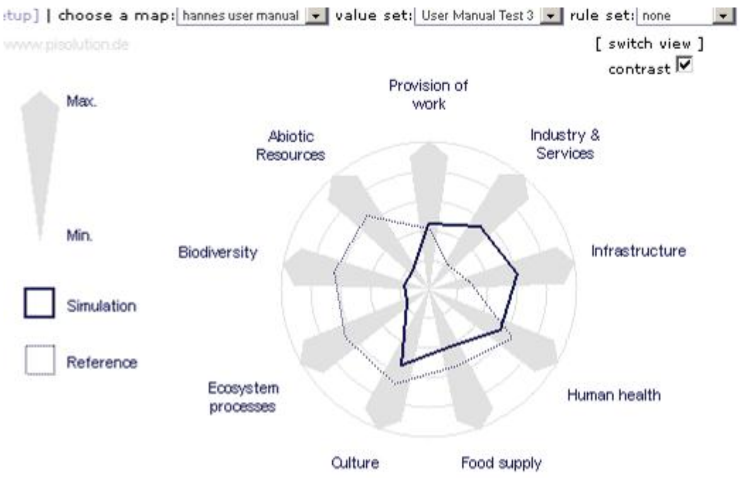


Figure 31. Example of land use changes depicted in a spider diagram.

The base map serves as the basis for a land use change scenario. Regional sustainability issues are reflected by the LUFs diagram (spider) and will directly respond to land use changes in the map. All changes in LUFs are related to the respective map and the corresponding land use shares in the map (regional approach). While explicit causal-chain relationships between land use types and LUFs are considered within the 'value definition' matrix.

5.13 Multi-criteria analysis – a tool for evaluation of alternative options

This section is based on D4.1 (Reidsma *et al.*, 2009). The central aim of a multi criteria analysis (MCA) is to choose among different alternatives (i.e. scenarios, policy options), based on various preferences of criteria (i.e. importance of indicators) that are used for the choice of an alternative. The analysis itself does not choose an alternative; it merely shows the contribution of criteria to the alternatives, based on the weights (preferences) that are given. To carry out a MCA various steps have to be undertaken. For this section a simplified example is used and the various steps that are needed to complete the full evaluation are described. The steps can be arranged as follows:

- Setting up criteria and alternatives in a brainstorm session with expert groups
- Building a hierarchical tree based on the brainstorm session
- Collect preferences of stakeholders using participatory techniques
- Collect outputs on indicators from models (modelling phase)
- Carry out the MCA
- Evaluate the contributions of criteria to the preferred alternative
- Discuss the alternative and test the institutional capability

The first step in a MCA is to define the alternatives to choose among. In LUPIS these are the baseline scenario ('business as usual') and the different land use policies that are designed and simulated. The criteria that underlie the choice of a policy are various and include the dimensions of sustainable development, the LUFs and the indicators that are the building blocks of the LUFs. In this example, only the dimensions and LUFs are shown. The brainstorm session should define the full hierarchical tree and will be carried out in close cooperation with experts or the national policy forms (see Figure 32, Figure 33).

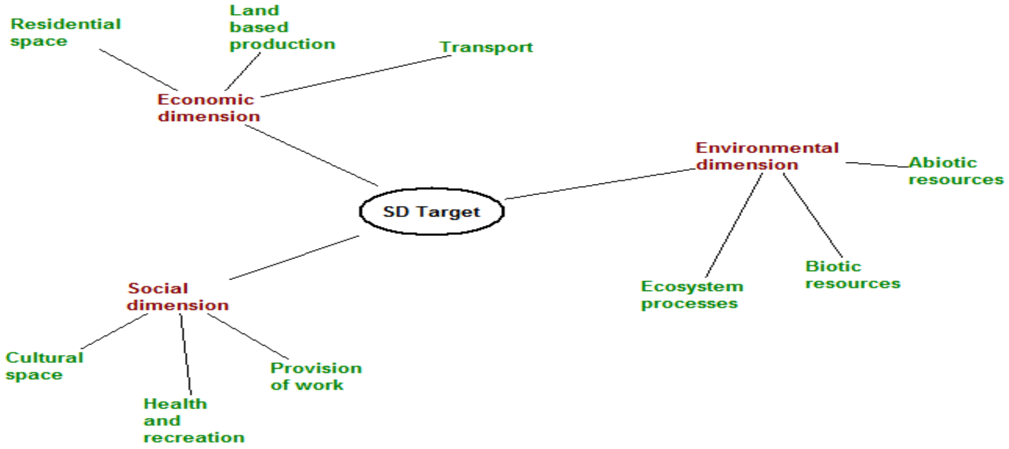


Figure 32: A brainstorm graph of the relations between the main MCA objective and the dimensions of sustainable development and the relations between the different land use functions within each dimension.

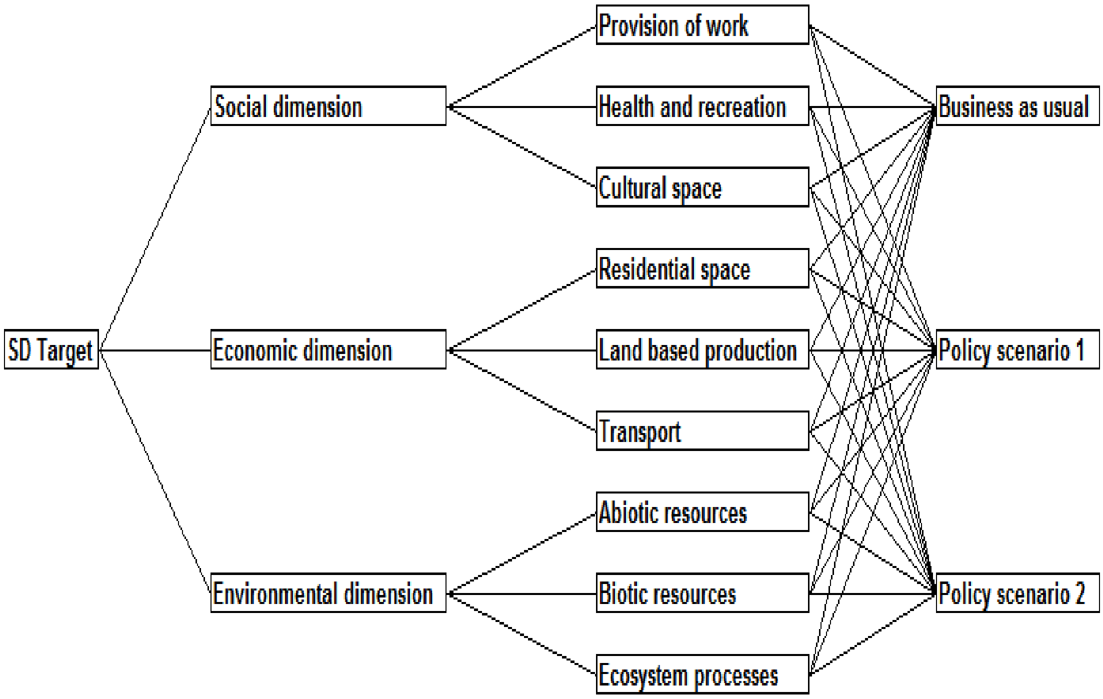


Figure 33: The hierarchical MCA tree based on the brainstorm session, depicted in Figure 6.1.

Figure 32 depicts a brainstorm session to build the relationships between dimensions and LUFs. The dimensions of sustainable development are connected to the main goal of the MCA; the sustainable development goal. The corresponding hierarchical tree based upon this brainstorm session is depicted in Figure 33. In this example three alternatives are included; the business as usual, policy scenario 1 and policy scenario 2. In a MCA the number of alternatives to choose from has no bound, but as a rule of thumb, choosing between 3-6 alternatives is probably an optimum. As can be found in Figure 6.2, the lowest level of criteria, in the example the LUFs, are connected to the alternatives. Adding indicators to the LUFs would impose a lower hierarchical level (below the LUFs). In that case, the indicators are directly linked to the alternatives. This does not mean that the highest level (the dimensions in this example) do not contribute to the alternatives. The weighing of this level, however, is between dimensions, not on the basis of weighing the alternatives.

In a MCA, criteria values can be compared directly, but need to be consistent. This means, that ‘apples and pears' can be compared. For example, in a MCA biodiversity values from the environmental dimension and economic values like income can directly be included with their own units of measurement. The units and the related measurements for a specific indicator should however be the same for all alternatives. In other words, if for example biodiversity is measured in terms of number of species, then this measurement (nrs) should be the same for all policy options (alternatives). If in one policy option values are measured in a different unit, than a direct comparison in not feasible.

The values of indicators are derived in the modelling phase for the current situation, the baseline and different policy options (see Figure 34). The indicators are the lowest level of criteria in the proposed MCA tree. The obtained indicator values can directly be incorporated into a MCA. Most software packages require a predefined scale for the measures. Most convenient is to use the lowest and highest value of all alternatives as the lower and upper boundary. Some packages can only work with relative values; then a rescaling is needed where for example the highest value of the indicator value (for a particular alternative) is set to 100% (or 1) and the other derived values a relatively scaled. One important aspect in a MCA is the consistency of directions of indicator values. Suppose a number of indicators are calculated in monetary units, like costs or income. Then the direction of such values all need the same form. Thus, when for one indicator the costs are calculated, then for the other monetary based indicators, like a benefit, the values should be inverted. Some caution is needed when software packages cannot handle non-linear responses. For some indicators a non-linear response function for alternatives may occur. In that case a rescaling is also needed in a way that the indicators are rescaled to a linear form.

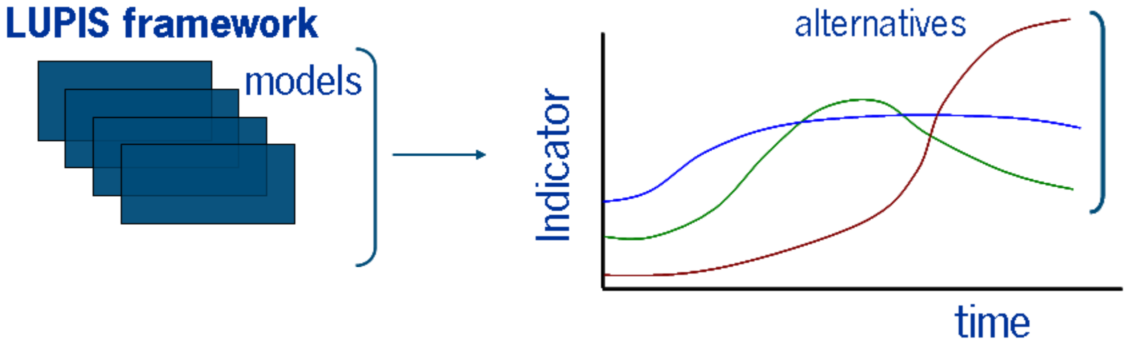


Figure 34. In the modelling phase in LUPIS models and knowledge rules are used to calculate values of indicators. For each indicator, values are calculated for the current situation, the baseline scenario and for **different land use policy options (alternatives). These calculated values of indicators are used in the MCA.**

A number of criteria do not have measuring values; these criteria are subject to the preferences of stakeholders. In the example, values for the different dimensions and probably values of the LUFs are to be discussed by the policy forums for each study case separately. Various techniques are available for such group decision. The 6th EU framework program Sustainability A-Test provides and describes a number of participatory tools that should result in preference values of stakeholders. The mostly used participatory techniques are interactive backcasting, focus group and Delphi method (see http://ivm5.ivm.vu.nl/sat/?chap=35). These different participatory approaches share in common that preference values of stakeholders are derived. It is most likely that stakeholder participation will lead to different preferences of criteria. Most software packages can deal with such differences by calculating standard deviations of different preference values for each criterion separately. Such deviation can become important information during the evaluation of alternatives.

When all values (preferences, indicator values) are included, the MCA will calculate matrices for each hierarchical level separately (see Figure 35). The consistency checks are performed (see also D2.3; Verburg *et al.*, 2008b). These checks are necessary to make sure the criteria are in the right order. After these checks, values are generated for the different alternatives with respect to the main goal, in this case the SD target. In the example each criterion was provided by arbitrary values, thus differences between alternatives (policy options) do not exist, but are used for illustration purposes only.

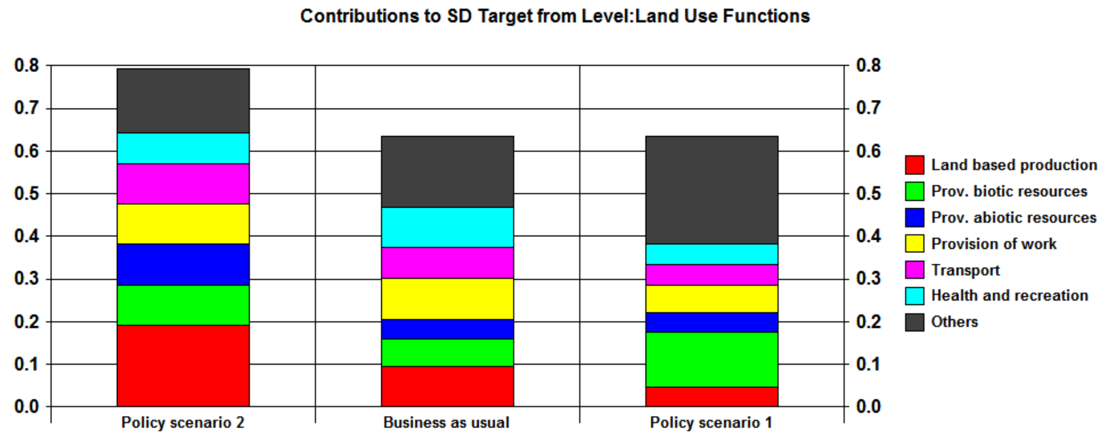


Figure 35: The contribution of the second order criteria (the land use functions (LUF) in the example) to the choice of different policy options in the MCA example. Policy option 2 has the highest decision score and is preferred. In the example the LUFs 'land based production', 'abiotic resources and 'transport' strongly contributes to the solution. Some LUFs show higher preferences for other policy alternatives like the LUF 'biotic resources'.

Figure 35 depicts the relative contribution of the land use functions (the lowest level) criteria to the different policy options. A similar graph could be made for the higher order criteria, like the dimensions of SD. In the example, the policy option 2 has the highest score, based on preferences and perhaps calculated values derived from the models. Based on the a-priory setting of preferences, policy option 2 should be chosen. However, a MCA is usually a starting point of discussion among stakeholders. Such discussions may include the choice of an alternative, the preferences of criteria that are the basis of the alternative choice and so on. Useful tools to support discussion and for scientific validation are sensitivity analyses of the criteria. Some software packages provide such tools and it is recommended to use them. In any way, the MCA only provides insight in the weight of preferences relative to the alternatives that are chosen among. The tool should not be used as a definite answer the problem of multiple attributes in decision making; it only assists.

For each criterion a sensitivity analysis can be carried out relative to the main objective of the MCA. In the example below (see Figure 36) the main social dimension alternative scores are depicted. As can be seen the current value is chosen to be 0.29 (arbitrary value) and given this value and those of the other dimensions, policy scenario 2 is the best option. Decreasing the relative weight of this dimension, and keeping the values of all other criteria as they are, does not affect the outcome of the choice. Increasing the preference value up to 0.58 (and keeping all other criteria constant), would imply an alternative choice, in this example business as usual. Thus doubling the preference weight of the social dimension in this case will alter the choice of alternatives.

A sensitivity analysis can also be performed for the other dimensions, and for land use functions or for indicators. Note that indicator values cannot change, but indicator weights can change. Indicator values are calculated with models, indicator weights are decided upon in the MCA. Land use function values depend on the previous step 'indicator integration and formation' and land use function weights are decided upon in the MCA.

The sensitivity analysis also shows the room for manoeuvre. Small deviations from the original preference values of criteria that do not change the alternative choice imply that the choice for a particular alternative is robust. If small changes lead to large changes in alternative choice then the different alternatives should carefully be re-evaluated.

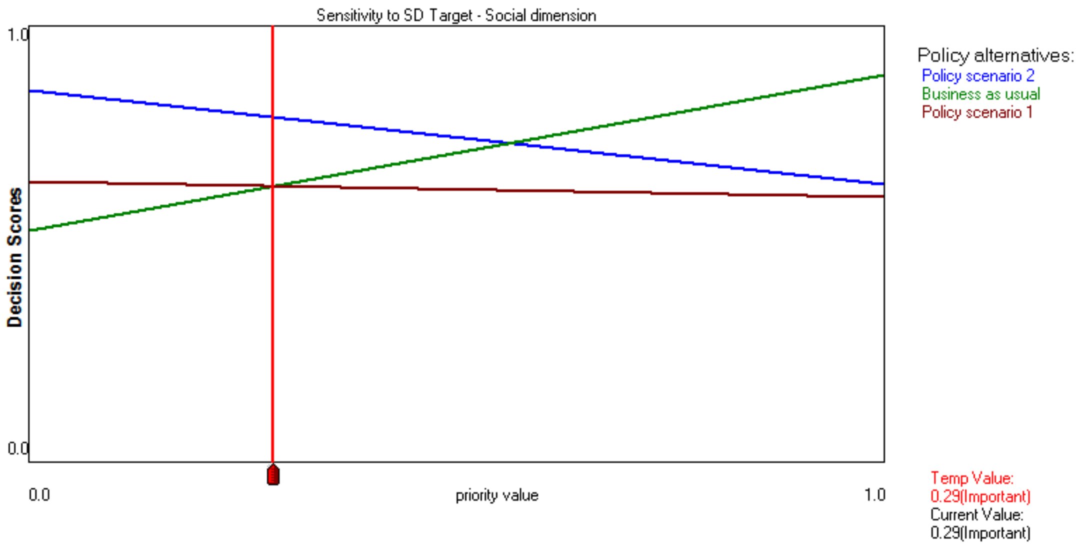


Figure 36. Sensibility graph of the value (preference value) of the social dimension relative to the main goal. For each alternative (policy option) the change is given. The vertical ride line indicates the present value of the criterion social dimension. Decreasing the present value does not change alternative choice, but increasing the value will lead to a changed preference to business as usual.

6 Part VI: Results of impact assessments in the case studies

6.1 Introduction

In the frame of the LUPIS project (Land Use Policies and Sustainable Development in Developing Countries), seven case studies have been selected in seven developing countries which are in different stages of development (Table 2). The main land use problems all have are related with agriculture. In China, India, Tunisia and Kenya impact assessment is largely restricted to the agricultural sector, while in Mali, Indonesia and Brazil interactions with other land use sectors such as forestry and urban land use are also considered important. The problems are usually directly related to one dimension of sustainable development (e.g. environmental in China, economic in India), but indirectly all other dimensions are of importance (e.g. no safe drinking water is a social issue in China, and environmental change is one of the reasons leading to the agrarian crisis in India). Furthermore, the problems are influenced by drivers at different levels, from trade liberalization at global level to fertilizer application at field level, and impacts differ at different levels of organization.

In **Kenya**, the case study area is Narok District where the problem is land degradation and land use conflicts linked to land fragmentation and a changing land tenure situation ((Gicheru *et al.*, forthcoming)). Narok had extensive rangelands and group ranges used by agro pastoralists, pastoralists and wildlife, but much of this land has been divided into individual land holdings during the last two decades (Serneels and Lambin, 2001). Land subdivision has attracted those with little land elsewhere to migrate to Narok, causing land scarcity and related land use conflicts. The conversion of land tenure has had far-reaching environmental and socio-economic implications, in particular on the pastoralist. On the socio-economic side, the subdivided units and parcels lead to a reduction of the livestock, which accounts for a significant proportion of household incomes. On the environmental side, the subdivision of land has caused a decline in pastoral land and overgrazing. Loss of land cover (grass, bushes and trees) has further reduced pasture availability for livestock, exposed the soil to erosion and loss of fertility (Pingali, 1989).

The case study area in **Mali**, the Office Du Niger (see also (Cissé *et al.*, forthcoming), provides an example of problems related to overlapping pastoral, agricultural and forestry areas. The Office du Niger, a public owned enterprise, is one of the oldest sub-Saharan hydro-agricultural projects, based on the Markala dam and developed in order to meet the increasing demand for rice nationally and in West Africa as a whole. The area presently produces more than 45% of the national rice, and is thus of major importance for food self-sufficiency in the country. The Land expansion and privatization policy and the Policy of investment aim to meet the increasing demand for rice. These policies will be implemented through the expansion of lands by at least 200 000 ha for rice production in the Office du Niger before the year 2020. However, the excessive deforestation resulting from land development work for rice production is not being followed by systematic reforestation. The area is presently characterized by an increasing trend in numbers of people and areas of rice production and by a decreasing trend in wood and pasture resources with serious environmental and social problems (Brondeau, 2000).

The Médénine governorate in **Tunisia** provides a case study area that is representative of land degradation in the country (see also (Sghaier *et al.*, forthcoming). Land vulnerable to desertification is estimated at 83% of the whole country (Ministère de l'Environnement et de l'Aménagement du Territoire MEAT, 1998). The area is characterized by sedentarization and accelerated land privatization (since 19xx), involving land fragmentation and increased pressure on the land. The pressure on natural resources, mainly land, is high due to increasing human needs and agricultural development; involving huge agrarian transformation through a rapid expansion of rain fed agriculture by conversion of natural rangelands. There is an increase in human consumption related to population increase, modified lifestyles and financial investments often dependent upon external sources. There is excessive water consumption for irrigation, as the cultivated irrigated crops consume a great quantity of water, while the efficiency of irrigation is low. This causes land degradation, a significant decrease of yield and great fragility of soil and vegetation cover.

The focus of the case study in **China** is the beautiful Taihu Lake Basin located in the fringe of the Yangtze River Delta. In the recent decades however, the area has undergone a rapid population increase, and an enormous intensification of agriculture including increased application of fertilizers and pesticides (Feng *et al.*, forthcoming) linked to governmental aims of increased agricultural production and food self-sufficiency (Asai *et al.*, 2011). The intensified agriculture has resulted in high yields and economic development in the area, but excess fertilizers and pesticides have seriously polluted the lake (Yang and Wang, 2003); (Zhang *et al.*, 2004). Agricultural products from this region now run a risk of being contaminated by polluted water, and industries, such as textiles and brewing, face a shortage of high quality water, which is affecting further development of processing industries in this region (Feng *et al.*, forthcoming). More important, water pollution and eutrophication reduce people's access to safe drinking water and are detrimental to human health.

In **India**, the case study is located in Karnataka, where the agrarian distress is a large problem, just like in other states of the country (see also (Purushothaman *et al.*, forthcoming). Agriculture is an important economic activity providing employment to almost two thirds of the state's workers. In the last decades, patterns of agricultural land use have been influenced by commercialization and intensification policies, aiming at increasing agricultural production, and liberalization policies to open the economy for increased trade and competition among farmers. This has however led to a range of problems, including on the environmental side, soil degradation, reduced water availability and agro-biodiversity, while economic problems include adverse terms of trade, conversion of agricultural lands, volatile prices and indebtedness among farming communities (Jeromi, 2007) (Shroff, 2008). The combination of intensification, trade and liberalization policies, have led farmers to take big risks; and combined with lack of social security the outcome for several have been financial and personal crises. The agrarian distress is manifested by the tragedy of nearly 200 000 farmers committing suicide between 1997-2008 (National crime records bureau).

The case study area in **Indonesia**, Yogyakarta special region Daerah Istimewa Yogyakarta (DIY) is among the fastest growing provinces in Indonesia (see also (Novira *et al.*, forthcoming). The rapid economic growth, the high standards of education services and the images of DIY as a good and convenient place to live in, have attracted more and more people to migrate into the area. However as a result, rapid urbanization has become a threat to the environment. There has been a tremendous decrease in water availability in DIY and a lack of waste management pollutes the water. Furthermore, land conversion reduces agricultural land in DIY, which threatens food security in the country (Marwasta, 2010). With regard to the social dimension, a high immigration of socially well-off people causes conflicts with the local residents (Faturohman *et al.*, 2004). Government policies to attract investment, through improved infrastructure, have stimulated the growth of DIY. However, the policies issued to control land use change have not been very effective.

The case study of **Brazil** is conducted alongside road BR-163, that crosses the states of Mato Grosso and Pará; the most deforested states of the Brazilian Amazon (see also (Rodrigues-Filho *et al.*, forthcoming). Deforestation of the Amazon has been demonstrated to be closely related to road access. Currently, highway BR-163 is partially paved as an effort made by the Mato Grosso state government to provide accessibility to the market for local soybean farmers. Increasing trade in soybeans under the influence of market liberalization has made it attractive for the government to pave the still unpaved part of the highway BR-163, an extension of almost 1000 km. Brazil is the largest soy exporter in the world, and the state of Mato Grosso obtained the leader position of the nation production of soybean in 2008 (MAPA, 2009). Increasing trade coincides with the increase in deforestation of the Legal Amazon; a tendency observed since 2000 (Brandão, 2005). Hence the effectiveness of environmental policies that protect the Amazon is crucial. The planned paving has caused intense migration into the area, causing land grabbing and land speculation, intensifying social conflicts. Deforestation, especially of the Amazon rain forest, is the main driver of both greenhouse gas emissions and biodiversity loss (Fearnside *et al.*, 2010).

Table 2. The most important drivers, pressure, state/impact in the seven case studies.

Case studies	Drivers	Pressure	State / Impact	Level
Narok district, Kenya	Economic growth, population growth, immigration, land privatization.	Land subdivision, overgrazing, deforestation	Land degradation, reduced biodiversity, reduced water availability, reduced agricultural production, increased economic inequity, increased social conflicts, poverty.	Regional
Médénine governorate, Tunisia	Economic growth, technological change, climate change, liberalization polices, climate change, migration, agricultural intensification.	Intensified agriculture, land subdivision, overgrazing, urbanization.	Land degradation, desertification, reduced biodiversity, reduced water availability, increased agricultural productivity,(?) increased income from tourism, increased food security, reduced agricultural labour use.	Watershed (Oum Zessar)~~Regional~~
Thaihu lake basin, China	Economic growth, agricultural development, food demand.	Intensified agriculture	Reduced water quality, reduced biodiversity, increased agricultural productivity, increased food security, reduced agricultural labor use.	Regional/ watershed?
Karnataka, India	Economic growth, technology development, migration, HYV seeds, access to credit, irritation.	Expansion of commercial agriculture, conversion of agricultural land for industries and infrastructure.	Agrarian distress, land degradation, reduced biodiversity, reduced water availability, reduced economic growth from the agricultural sector, increased economic growth from other sectors, increased economic inequity.	Regional (Bijapur and Udupi) or whole state?
Yogyakarta, Indonesia	Economic growth, immigration, investment.	Urbanization	Reduced water quality, reduced water availability, reduced economic growth from the agricultural sector, increased economic growth from other sectors, reduced food security, increased economic inequity, cultural conflicts.	Regional
Office du Niger, Mali	Economic growth, climate change, technological development, agricultural intensification, investments	Agricultural expansion, intensified agriculture.	Land degradation, reduced biodiversity, reduced water availability, increased agricultural production, increased food security, increased economic inequity, cultural conflicts.	Regional
Mato Grosso and Pará, Brazil	Demand for commodities, immigration, infrastructure projects, economic growth.	Agricultural expansion.	Deforestation, Loss of biodiversity, climate change, increased agricultural production, increased income, increased economic inequity (?), cultural conflicts.	Regional to global

Source: (Nesheim *et al.*, in review).

Table 2. The most important drivers, pressure, state/impact in the seven case studies.presents in detail the D, P, S, and I components for each of the seven cases as defined by the Nation Policy Forums. From the case studies it is clear that the main underlying drivers of the land use problems are, in all cases, economic growth, technological development, and natural population growth. The underlying and proximate drivers of the DPSIR story lines are linked in complex ways; hence we should be careful to think that there exist exclusive inter-dependencies among the drivers and the environmental, social, and economic impacts in the case studies. However, the story lines presented may illuminate some general trends. The more important drivers among the case studies include economic growth,

technological change, migration and agricultural intensification. However, the level of these drivers are heavily influenced by institutional factors, including changing land tenure patterns, different types of domestic financial support and liberalization policies. Such factors mediate important drivers such as immigration both rural –rural and rural-urban migration and agricultural intensification – all closely linked with the identified sustainable development problem in the cases.

6.2 Overview of methods used in case studies

Table 3 indicates a variety of tools being applied in seven case studies during impact assessments of selected policies. These tools were described in Part V. All case studies presented below have applied the LUPIS methodological framework (Reidsma *et al.*, 2011), which is also presented in Section 4.

Table 3: Tools used for impact assessment in 7 case studies of LUPIS

Case study	Field level	Farm level	Regional level	Country level	Evaluation method
Tunisia	CropSys	FSSIM	CGE	IMPACT	MCA, FoPIA
Kenya			FoPIA	IMPACT	FoPIA
India	TechnoGIN	Multiple regression	Upscaling	IMPACT	MCA, FoPIA
China	TechnoGIN	FSSIM	Upscaling	IMPACT	MCA
Mali			CORMAS	IMPACT	
Indonesia			IDRISI, Pro-Vision	IMPACT	MCA, FoPIA
Brazil			LUSMAPA	IMPACT	MCA

The variety of tools applied along the execution of impact assessments does differ per case study. This is mainly explained by the scale of assessment (field, farm, region, country), data availability and composition of research teams.

6.3 Case study 1: Impact on sustainable development of implementing water conservation measures in Medenine region of Tunisia

This section is based on D7.2 (Sghaier *et al.*, 2011).

6.3.1 Problem

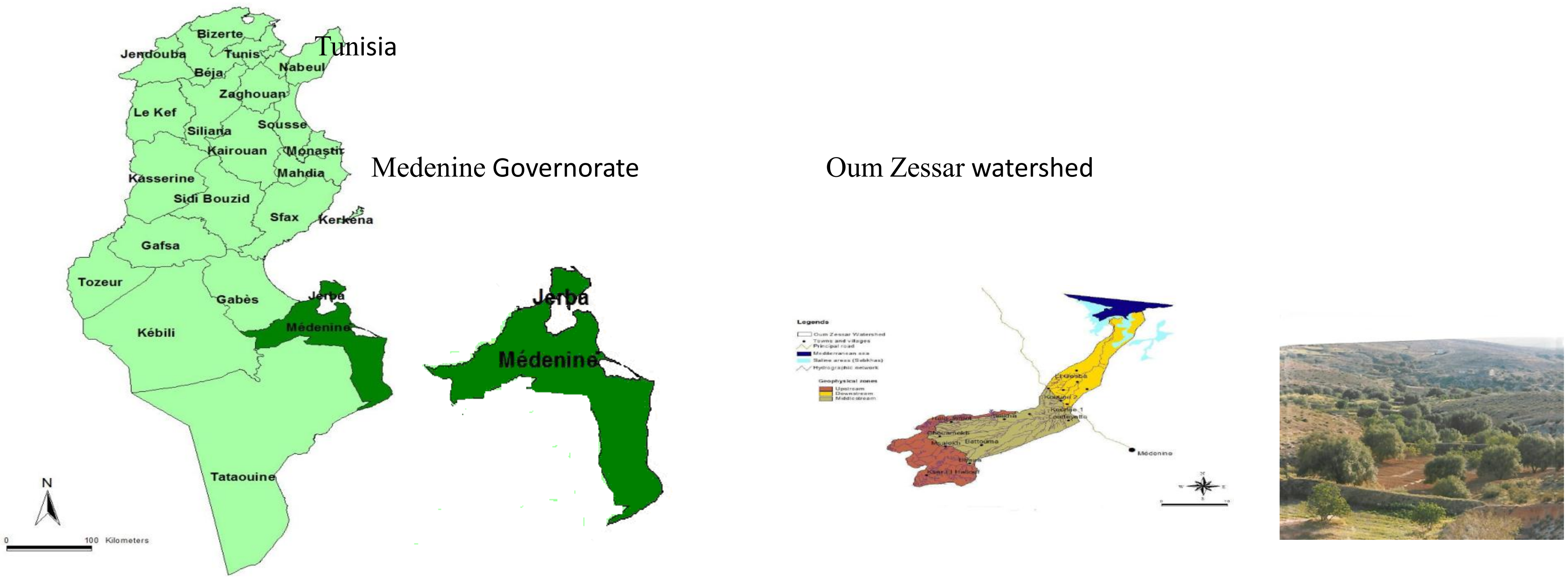
This case study focuses on water and soil conservation policies in the Arid Regions in Tunisia. How do these policies contribute to the three dimensions of sustainable development? The pressure on natural resources, and particularly on land resources, is becoming very high in the South east of Tunisia. This is induced by increased human needs and the development of agriculture. It leads to land degradation and a significant decrease of crop yield to the detriment of the socio-economic situation of local population. Several water and soil conservation policies have been implemented by the government at the regional level to deal with the land degradation problem.

The assessment of policies is concerned with water pricing, water reform and Water and Soil Conservation (see Table 4**Error! Reference source not found.**). The goals of the impact assessment are as follows :

Irrigated water prices: impact of variations on the farm income and the level of the input use. The assessed scenario consists of the increase of irrigation water price annually by 13% on the public and private irrigation systems towards 2015.

Water reform: impact of a recent investment in ground water desalination on tourism and redirecting medium quality water formerly used in tourism to agriculture. The baseline consists of maintaining the current situation concerning the water allocation plan. The first scenario consists of the increase by 50% of water availability and the second scenario consists of the increase by 100% of water availability.

Water and Soil Conservation policy: impact on the natural resources allocation and farm income . A reference scenario was developed that considered an implementation of SWC measures at 85%. This scenario follows the original implementation. The second scenario assumed a fall in the current implementation rate of SWC measures to 70%, and the third scenario considered a full implementation of SWC measures at 100% coverage of the watershed area.



National level Regional level Watershed level Farm level

Figure 37: Three nested spatial scales in the study area

Table 4: Policies and scenarios in the case study of Tunisia

Policies		Baseline scenario	Scenario 1	Scenario 2
Water saving	Water pricing	The current situation will be maintained	increase of water pricing at the public irrigated system by 13%	increase of water pumping cost at the private irrigated system by 13%
	Water reform	The current situation will be maintained	increase of water availability by 50%	increase of water availability by 100%
Water and soil conservation policy		The current situation will be maintained (an implementation of SWC measures at 85%)	A fall in the current implementation rate of SWC measures to 70%	A full implementation at of SWC measures at 100% coverage of the watershed.

For the analysis three nested scales are considered: provincial scale (Province of Medenine), watershed scale (Oum Zessar watershed in the Province of Medenine) and the farm scale level (Figure 37).

The province of Medenine is located at the south-east of Tunisia with an area of 0.92 million ha. The province is mainly covered by agriculture (91 % of the total surface). It is an arid zone with annual rainfall not exceeding 200 mm distributed over approximately 30 days. The case study area has thus rather extreme climatic conditions. In these conditions human pressure on agricultural land has a large impact on the natural environment and ecosystems.

Oum Zessar watershed is located in the North of the province of Medenine and its area covers almost 37,000 hectares. It has a strategic importance as its water table is used for drinking water by the governorates of Medenine and Tataouine. It has also a high socio-economic importance with its agricultural sector. The watershed can represent the whole zone of the South East of Tunisia.

6.3.2 Impact Assessment results

The water pricing policy meets the principal objective, i.e. the environmental conservation in the short term. The soil erosion shows a decrease by 13% at target 2015 and the water use shows a decrease by 18%. The policy thus contributes positively to the environmental objectives. However, the social and economic dimensions are negatively affected by the increase of the water price. The farm income decreases by 8% for water price increases by 13%. Given the complementarity between water and land factor, the decrease in water uses leads to less land use. By consequence the water price increase influences negatively the rural employment (approximately -2% of labour use by hectare).

The impact of providing more non-conventional water to economic activities was identified as an important question for the Medenine region. The results of the analysis show an increase in GDP in the region of 0.09 % and 0.16% respectively with increasing water availability by 50% and 100%. Total investment expenditure increases by 0.16% for scenario 1 and 0.29% for scenario 2. The production of domestic irrigated agriculture increases by 0.37% and 0.65%, in scenarios 1 and 2 respectively. In terms of social impact scenario 2 leads to few labour use increase by almost 1% at the regional level. Besides the economic and social benefits, the use of non-conventional water can alleviate the pressure exerted on the groundwater.

The results for the Water and Soil Conservation Policy assessment show that, firstly, the social and to a lesser extent also the economic dimensions benefit most under the policy. This means that environmental factors highly influence the performance of the selected social and economic indicators. Secondly, a full implementation of the SWC for the entire watershed may lead to the highest sustainability contribution, whereas an implementation at 85% has already almost similar positive effects, while having less negative impacts on ecosystem processes. The decision may be to balance between implementation at 85% and 100% of Water and Soil Conservation.

6.3.3 Implications

The integrated ex-ante policy impact assessment cross-scale leads to a rich and diverse picture of impact.

At the farm level, higher water prices seem to have an overall positive impact on water use and soil erosion (decrease). The impact is negative with respect to the development of farm income and employment.

At the watershed level, water and soil conservation measures show positive results in terms of off-farm activities, increase of labour use and life expectancy.

At the provincial level, water reform has an overall positive impact on regional GDP and employment. The environmental impact depends on the source of water (groundwater or non-conventional resource) and on the degree of agriculture intensification.

The results of the study serve as a dashboard of sustainability to regional stakeholders and policymakers. This is especially useful for policy-orientation and decision making. However, the results should be interpreted with caution given the various assumptions and limitations of the work.

6.4 Case study 2: Impact on sustainable development of implementing group ranch subdivision policy in Narok district of Kenya

This section is based on D8.2 (Chen et al.).

6.4.1 Problem

This case study assesses land use options for sustainable development in Kenya. The Narok District is chosen as the study area, because of land use conflicts among market oriented crop farmers, traditional livestock keeping and wildlife.

Traditionally, the Maasai moved their livestock from place to place, depending on the availability of pastures, water and incidence of diseases. Land in these areas was held communally, and all the Maasai had the right to pasture, but the livestock was individually owned. In the late 1960s, the Group Ranch Scheme was launched by the Kenyan government to avoid overstocking and overgrazing and increasing productivity of pastoral lands through increased off-take. Under this regime, communal lands were divided into smaller units (group ranches) which were registered in the names of group representatives (3 to 10 members). The scheme restricted the free movement of livestock. However, the Maasai continued their traditional grazing system. Over the years, group ranches came under considerable pressure especially from the well-educated members on the community to subdivide the group ranches into individual units. The Kenyan government initially opposed the sub-division but accepted group ranch sub-division in the 1980s. Members of the group ranches were issued title deeds to individual plots. The majority of the land is allocated to the group ranch committee members, their friends, relatives, and wealthy herders. Attempts by the Maasai to continue rearing large numbers of livestock for subsistence on their small individual plots with limited mobility has increased land degradation. Individual land owners have subdivided and sold or leased their land for cultivating cash crops, mainly maize and wheat. The agricultural intensification has increased the use of pesticides and other chemicals. Agricultural expansion also has led to human wildlife conflicts and claims on natural resources such as land and water.

Narok District covers an area of 15,087.8 km^2. It is situated to the south western side of the country (see **Figure 38**) and lies to the southern part of the Rift Valley Province. It is divided into two main physical divisions: the highland zone that is over 2300 meters and lowland zone that is between 1000 and 2300 meters ASL. The highlands have rich volcanic soils suitable for intensive agricultural production. Large-scale farmers inhabit the highlands areas. The lowlands have high potential for livestock rearing. Nomadic pastoralist and small-scale subsistence cultivators inhabit the lowland areas. The area has poor quality soils and the rains are unreliable.

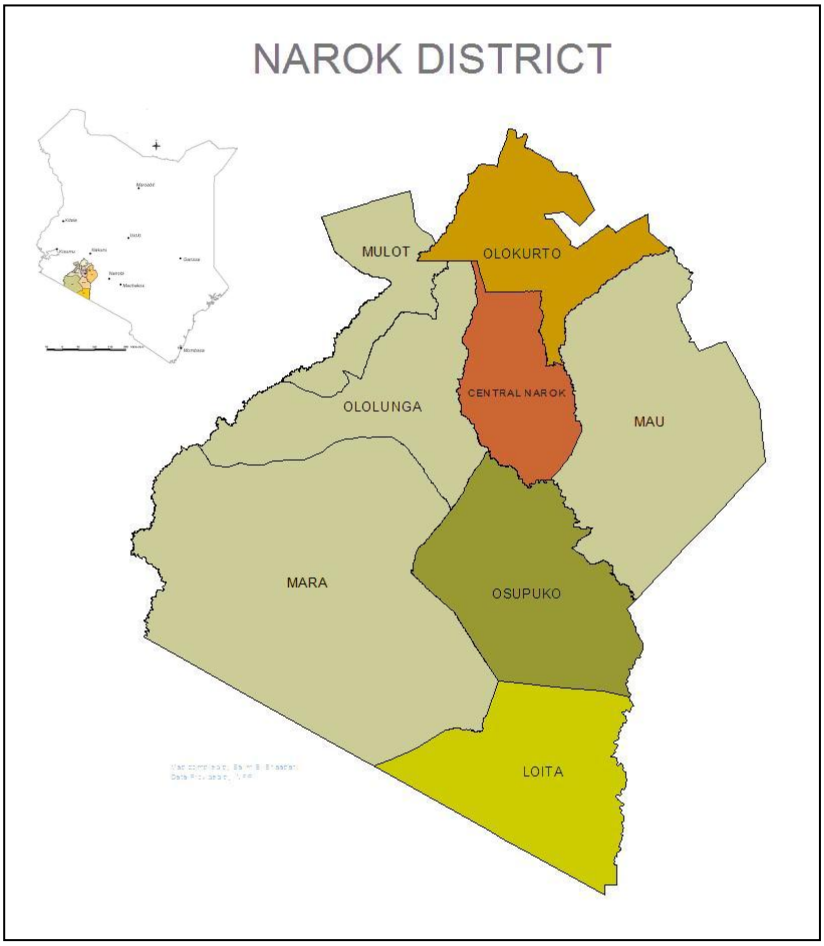


Figure 38: Location of Narok District in Kenya and its Administrative Divisions

Since the subdivision, crop cultivation concentrates in the northern part of the district, wildlife conservancies in the south-western part of the district and livestock production in the central and southern parts of the district. Livestock intensification has led to overgrazing and arable intensification has led to soil erosion.

With a view to address the future of the Narok District, three land use scenarios have been developed (see Table 5): (i) prevalence of crop farming (S1. Cropping), (ii) prevalence of livestock rearing (S2. Livestock), and (iii) prevalence of eco-tourism (S3. Ecotourism).

Table 5: Scenarios in the case study of Kenya

Drivers & assumptions	S1. Cropping	S2. Livestock	S3. Eco-tourism
Population growth	2.6% (annually)		
Economic development	4.0% (annually)		
Land used for agriculture	60%	50%	20%
Land used for livestock	30%	40%	40%
Land used for wildlife	10%	10%	40%

All three scenarios are based on the same set of drivers, i.e. population growth and economic development. Population growth was assumed to be 2.6% annually and economic growth was assumed to be 4.0% annually. Moreover, it was assumed that due to the uncertainty of confiscation of trust land, more group ranches will be subdivided by 2030.

6.4.2 Impact Assessment results

Under the cropping scenario (S1), which serves also as the baseline, the subdivided land that is suitable for cultivation will be converted to arable land. Livestock production remains stable and wildlife decreases sharply.

The livestock scenario (S2) leads to an increase in livestock production. More land is used for livestock production and less land for arable production. Land reserved for wildlife remains the same as in the baseline.

In the eco-tourism scenario (S3) land with high density and varieties of wildlife is joined by individual owners to promote exclusive safari tourism. The exclusive safari is aimed at a small group of individual tourists and charges a high price to avoid the mass-market tourists. Such type of tourism is in the form of a conservancy. In this case more land is used for conservancies and less land is used for cultivation comparing to S1 and S2.

The eco-tourism scenario contributes the most to the environmental dimension of sustainability. The cropping scenario is most favourable for the economic dimension, whereas the livestock scenario contributes most to the social dimension. Overall, the ecotourism scenario contributes the most to sustainable development in Narok district.

6.4.3 Implications

The project follows up on the needs to find means of facilitating action by individuals and groups of farmers to pursue sustainable land management practices. Fostering indigenous knowledge-science linkages and local initiatives provides the cornerstone for sustainable land management on which all programmes aimed at sustainable agricultural production must be constructed. The government should empower households and communities with tools and data for making informed choices on land management.

The realization of any of the scenarios depends greatly on a harmonized and consistent policy environment, e.g. consistency between the wildlife policy and the land tenure system. The implementation of the Draft National Land Policy (i.e. reallocation of land resources) will have profound implications on poverty reduction. Once this policy is implemented, the likelihood of the three scenarios is very low – land is likely to be reallocated that will interrupt the current economic development.

But does the eco-tourism scenario have a good chance under the current policy environment? Contrary to the situation in Namibia, individual and communal landowners have no ownership or user rights over wildlife in Kenya. Wildlife resources are state property. However, about 65% of Kenya's wildlife is found on private and communal land (e.g. group ranches). The fact that wildlife is owned by the state ignores the interaction of different land uses in ecosystems and habitats. The institutional inconsistency creates an ambiguous policy environment that entitles the government to capture revenues from eco-tourism once it decides to do so. If this happens, the emerging eco-tourism market will come to an end in its infancy. To counter this, property rights over wildlife should be devolved to individual landowners.

The case study has shown that there are many policies and Acts of Parliament regulating land management issues in Kenya in general and Narok in particular. However, these are mainly sectoral in nature. In some cases, the policies in various sectors related to land management duplicate one another or at times are antagonistic. There is a need to harmonize and/or streamline the activities of these sectors if sustainable land management is to be realized. The Environmental and Co-ordination Act (1999) and the on-going national land policy formulation are positive initiatives in this respect.

6.5 Case study 3: Impact on sustainable development of implementing organic farming policies in Karnataka state of India

This section is based on D9.2 (Purushothaman et al., 2011).

6.5.1 Problem

India has a high population pressure on land and other resources to meet its food and development needs. The natural resource base of land, water and biodiversity is under severe pressure. The massive increase in population (despite the slowing down of the rate of growth) and substantial income growth, require significant increases in the production of grains, livestock, fish and horticultural products. This case study focuses on the promotion of organic farming in the state of Karnataka, of which Bangalore is the main city. Karnataka is one of the four southern states of India (see Figure 39 and 40). Agriculture in the state of Karnataka is at crossroads as reflected in ecological, economic and social problems faced by farmers. Despite the state pioneering policy formulations and implementation to mitigate problems, the share of agriculture in the state domestic product (GSDP) has fallen drastically in the past few decades. Since about 2/3rd of the population depends on agriculture for their livelihood, the sector is vital for the overall development of the state. The socio-ecological linkage to the agricultural economy is a crucial missing link to be explored. Socio-ecological problems in the agrarian sector appear as symptoms of distress: farmers' suicides, increase in fallow lands, loss of soil fertility, decreasing ground water levels, water salinity, stagnating yields and slow agricultural growth (annual growth below 1.5%). Non profitability and high risk involved in agriculture as a source of living, loss of agricultural biodiversity, marginalisation and subdivision of land holdings loom large in the backdrop of policies, investments and institutions to tackle the crisis.

Figure 39: Map of India showing Karnataka[1]

Figure 40: Agro-climatic zones in Karnataka[2]

Karnataka State Policy on Organic Farming: (KSPoOF 2004 policy) was implemented from 2006-07 to reduce debt, improve soil productivity, water use efficiency, food security, and mitigation of drought in small farms. KSPoOF claims that its approach is sustainable in terms of both agriculture's contribution to biodiversity and biodiversity's contribution to agriculture (http://raitamitra.kar.nic.in/kda_booklet.pdf). Organic farming as defined in this policy requires less external inputs and relies more heavily on the natural and human resources that are available in the farms (see Table 6). Thus, it aims at reducing farmers' financial burdens and engages them in activities on their farms, curbing migration to urban areas. Such policies of the state aim to extend benefits of sustainable agriculture to farmers as well as consumers. Within a span of two years the overall number of beneficiaries (farmers registered under the policy) has grown fivefold.

Table 6: Organic farming versus conventional farming

	Organic Farming	Conventional Farming
Description	No use of chemical inputs Use of organic inputs	Use of chemical inputs No use of organic inputs

The case study deals with the sectoral policy of promoting sustainable agriculture and assesses its impact on sustainability of small and marginal farmers of the region. The policy meets the requirements of continuity into the future and of impacting agricultural land use and sustainability. The study intends to assess agricultural sustainability, looking at the ecological, economic and socio-cultural dimensions of sustainability. The study compares the sustainability of intensive, conventional

[1] Source: 'Karnataka.' *Wikipedia, The Free Encyclopaedia*. 19 Mar 2008, 15:41 UTC. Wikimedia Foundation, Inc. 25 Mar 2008.

[2] Karnataka Agriculture - A Profile, Department of Agriculture, GOK, 2000.

small scale agriculture with that of organic farms (comparing 2009 with 2006) in different villages of Karnataka, and project these changes towards 2015.

The policy scenarios to be analysed for sustainability of small farms in Karnataka till 2015 with the introduction of organic practices (from KSPoOF) include:

- with policy: combination of policies that favor organic farming
- without policy: with policies that favor conventional / intensive farming

Two districts in the state of Karnataka are selected for the study. Bijapur is the district in a dry region with low average rainfall and comparatively less resources than the district of Udupi which falls in the rainfall abundant region of the state.

6.5.2 Impact Assessment results

In Bijapur, the ‘with policy’ scenario shows a higher level of sustainability than the ‘without policy’ scenario. The ‘without policy’ scenario is better than the ‘current’ situation; the contribution from ecological dimension to overall sustainability dominates other dimensions in both the scenarios. Contribution from the economical dimension remains more or less the same in both scenarios. The socio-cultural dimension contributes more to sustainability in ‘with policy’ scenario compared with ‘without policy’ scenario.

On the other hand in Udupi, overall sustainability suffers a setback with policy. However, without the policy the situation is even worse. Nevertheless, the contribution from the economic dimension of sustainability is negative, due to the already negative rate of change in this dimension.

In both the districts, ‘with policy’ scenario looks relatively better, but the reasons differ – ecological in Bijapur and Socio-cultural in Udupi. With respect to the policy’s expected achievements, apart from ecological sustainability, tackling economic factors in Udupi and socio-cultural factors in Bijapur seems vital.

Considering increased government and private investment in water management projects, the study envisages an increase in irrigated area in future, irrespective of the presence or absence of policies favouring organic farming. The area under commercial crops (CC) may decrease by 10% with policy, because one of the objectives of the policies favouring organic farming is to reduce the cultivation of intensive commercial crops that demand expensive marketed inputs to be applied. Also the proportion of area under commercial crops in Udupi (64%) is already higher than in Bijapur (48%). With respect to cropping intensity, since irrigation is expected to expand in future, this will rise along with it, irrespective of presence or absence of policies favouring organic farming.

Considering the objectives of the organic farming policy in the state, home grown food consumption and freedom from overdue loan are excepted to grow in future with ‘with policy’ scenario. Landholding (average 2.1 acre in Bijapur and 3.3 acre in Udupi) will not have any change in future in both the scenarios, again due to independence of this variable from the policies under consideration. Literacy is expected to grow due to efforts from government as well as voluntary agencies to raise awareness about importance of education. One of the major differences between two scenarios has been the application of organic and inorganic inputs, based on objectives of the organic farming policy. It is expected that organic input application will grow by 30% in future in ‘with policy’ scenario, and decrease by 30% in ‘without policy’ scenario. Similarly, application of inorganic input is expected to decrease by 30% in ‘with policy’ and increase by 30% in the ‘without policy’ scenario.

The results obtained from various methods used for impact assessment gave more-or-less convergent results for two districts. The study revealed that in Bijapur, policies favouring organic agriculture and sustainable farming practices prove beneficial to the environment in terms of improved soil and water quality and agro-biodiversity. Economic and socio-cultural impact assessment gave some divergent results with different methods. Multi-criteria assessment showed that such policies may result in financial stagnation, whereas the comparative statics approach reveals less improvement in socio-cultural and economic dimension of sustainability, while the ecological dimension shows significant improvement.

On the other hand, in Udupi impact of such policies on the environment was minimal, irrespective of the method of assessment. However, the other dimensions- economic and socio-cultural, are benefited by such policy reforms.

The policy has been successful, as the popularisation of organic farming by NGOs has been successful. In the current situation, many farmers practice mixed farming, as completely converting to organic farming takes time, due to lack of adequate amount of farm yard manure.

6.5.3 Implications

Several lessons can be drawn from this case study:

- Small farmers perceive food security and occupational satisfaction as more important functions of their agricultural land holding than profit maximisation.
- Small farmers prefer to follow labour intensive, sustainable practices, producing inputs required for cultivation.
- Organic farming and sustainable agriculture practices are beneficial in terms of soil and water quality and agro-biodiversity.
- Support for small farmers must incentivise sustainable agricultural practices in order to reduce poverty and to ensure food security.
- The continuity of new farming practices in resource poor situation like Bijapur is favoured by effective local governance and cohesive community.

Indian agriculture policies often focus on enhancing productivity and farm income. Minimisation of cost and risk appear to have a low priority. The KSPoOF is one of the few policies that consider other aspects that have caused the agrarian distress in the last decades. The results of the study show that farmers in the less endowed regions like Bijapur would like to first ensure food security and good health, while farmers from Udupi emphasized the importance of the link to markets. Thus, food security appears to be necessary condition for small farmers to become market oriented and raise commercial crops. To ensure food security in small farms, organic farming works better, with reduced costs and risks. This implies that incentives for organic farming become crucial for small farms even if the state wants them to be market oriented.

6.6 Case study 4: Impact on sustainable development of implementing water pollution control measures in Taihu Lake Basin of China

This section is based on D10.2 (Feng et al., 2011).

6.6.1 Problem

Economic growth has been a major aim of the Chinese government in recent decades. This has led to increasing economic welfare for most of the population, but it increasingly conflicts with social cohesion and environmental quality. Urban sprawl is increasing, while agricultural land use is becoming more intensive, leading to reduced areas for natural ecosystems and broader impacts on the environment, such as air and water pollution. Water pollution is one of the most crucial environmental problems in China. These problems are exemplified in Chinese lakes.

One of the regions that is confronted with high population pressure, high economic development, but serious water pollution, is Taihu Lake Basin. Taihu Lake is the third largest fresh water lake in China (see Figure 41).

Figure 41: Location of the Taihu Lake Basin

The beautiful lake and mountain landscape views attract a large number of Chinese and foreign visitors to come sightseeing. It is not only a tourist destination, but also an important drinking water source for large and medium-size Focus regions in the basin. The lake also serves many other purposes, such as storage of flood water, transport, irrigation and aquaculture. In recent decades, with the rapid population increase and economic development, the water in major rivers running into the lake, and in the lake itself, have become seriously polluted, and the nitrogen and phosphorus eutrophication of water has become a major environmental problem.

The Taihu Lake Basin is an economically important region in China. Water pollution and eutrophication have significantly affected regional sustainable development. Agricultural products from this region now risk being contaminated by polluted water and can hardly satisfy people's increasing demand for quality food and reach international quality standards for export. Industries, such as textiles and brewing, are now facing a shortage of high quality water, which is affecting further development of processing industries in this region. More important, water pollution and eutrophication reduce people's access to safe drinking water and are detrimental to human health.

Pollution control in Taihu Lake Basin has until now focused on industrial point source pollution. Less attention has been paid to agricultural non-point source pollution. Though rapid urbanization and industrialization have resulted in considerable loss of cultivated land, intensive arable farming, livestock breeding and aquaculture are still of great importance. Agricultural non-point source pollution, caused by inorganic fertilizers and pesticides from arable farming, the emission of animal waste from livestock breeding and inputs of feedstuff and inorganic fertilizers in aquaculture, have become the most important causes of water pollution and eutrophication in Taihu Lake Basin.

The major objective of this case study is to analyse policy options which may reduce water pollution and in the meantime stimulate sustainable development at large. Policies to reduce pollution from the agricultural sector include measures for arable farming and for livestock.

Table 7: Policy options for reducing water pollution from agriculture

	Option	Description
1	Conversion from arable land to trees	This policy aims to create an ecological green belt in areas close to rivers and the lake. Farmers who have land in these areas get compensation payments, but can no longer grow crops on these lands. Planting trees along the rivers and around the lake reduces the total farmland area where fertilizers are applied, and hence the nutrient emission. These ecological green belts also reduce nutrient leaching towards rivers and lake.
2	Stimulation of the use of site-specific nutrient management	State and local government have provided subsidies for site-specific recommendations on nutrient management based on soil samples. Generally used fertilizers in Taihu Lake Basin usually contain too much nitrogen and too little potassium. Also, too much nitrogen is often applied at first application, while the uptake is not very high in the beginning of the growing season, and hence nutrient leaching occurs. A better formula for fertilizers and a better timing will reduce nutrient pollution, and may also have positive side-effects on input costs, crop yields and income.
3	Stimulation of mechanical rice transplanting	Subsidies are provided to farmers and specialized mechanical service providers if they want to purchase agricultural machinery, such as machines for rice transplanting. Mechanical instead of hand transplanting of rice can reduce labour use, reduce pesticide use and increase yields and income.
4	Stimulation of the use of biogas digesters in livestock breeding farms	Farmers and livestock breeding farms are subsidized to build biogas digesters. The amount of the subsidy differs by location and by the scale of the biogas digester. The use of biogas digesters in livestock breeding farms can reduce nutrient pollution. As a positive side-effect, biogas digesters can generate energy and thus reduce energy costs, and can accordingly increase income for livestock breeding farms.

The case study consists of ex ante impact assessments of land use policies implemented in Taihu lake basin, including (i) multiple land use sectors (arable, perennial, livestock and fish), (ii) multiple dimensions of sustainability (economic, environmental and social), and (iii) multiple scales (farm, sector and region).

6.6.2 Impact Assessment results

The effects of policies on water pollution and sustainable development have been studied for Wuxi, Changzhou and Zhenjiang cities. The results indicate that in general, compared to other policy scenarios, the combination of formula fertilizer (option 2) and biogas digester (option 4) contributes highest to regional sustainable development. Taking Wuxi city as an example, compared to base year (2008), indicators such as crop production, rice yield, chemical fertilizer use, pesticide use in all policy scenarios have displayed a negative effect on sustainable development, while indicators such as net farmer income, labor use, fertilizer K/N ratio and nitrogen input have a positive impact on sustainable development. Equivalent emission decreases greatly with option 4 and the combination of options 2 and 4, but increases in option 2. This indicates that even though formula fertilizer has pollution removal effect, pollution emissions from the livestock sector are more serious. Formula fertilizer can improve soil quality, which is good for crop production and for the improvement of environment, while biogas digester is very important for pollution alleviation.

For livestock and poultry farms the choice of three frequent ways in handling livestock manure are assessed: sale, return to the field as organic fertilizer and biogas production. Results indicate that the area of livestock farm and administrative requirements such as correction or relocation have positive effects on the choice of biogas production, but negative effects on the choice of sale as organic fertilizer. Livestock farms specialized in pig and cattle production tend to apply biogas production in handling their manure, while livestock farms having difficulties in accessing to loan are less likely to do so. Times of oral propaganda have a positive effect on the choice of sale and return to the field as organic fertilizer, but have no effect on the choice of biogas production. Therefore, if the government wants to effectively promote biogas digesters, large-scale livestock enterprises should be the policy target. Economic incentives such as preferential loans and subsidies instead of oral propaganda should be provided. For those livestock farms that violate emission standards, administrative measures such as correction and relocation instead of oral propaganda should be enforced.

Although promotion of site-specific nutrient management (SSNM) can improve environmental, economic and social land use functions, stimulating its adoption is not straightforward. SSNM is more knowledge and labour intensive than conventional management, whereas labour availability is limited. In policy scenarios, environmental impacts are projected to decrease compared to 2008, partly due to the adoption of SSNM. However, the main reason is the decreasing labour availability towards 2015 which causes a switch from double to single cropping. This, however, leads to lower food production. Abolishing fertilizer subsidies for farmers that do not adopt SSNM, in combination with training appears to be the best way to stimulate SSNM adoption for improving the different land use functions. Stimulating mechanical transplanting of rice reduces labour use and can become profitable when subsidized, but will not reverse the trend towards single cropping and has little influence on nutrient pollution. The regional policy of creating riparian buffer zones along water bodies appears to be promising, as it can strongly reduce nutrient leaching from farm land to rivers and lakes.

6.6.3 Implications

Due to rapid industrialization and urbanization in Taihu Lake Basin, agricultural modernization has been the main policy objective in this region. Agricultural development is moving towards large scale, machinery and technology intensive agriculture. This raises questions about the impact of agricultural modernization on agricultural non-point source pollution.

In Taihu Lake Basin, the central and provincial level governments have made great efforts in solving water pollution issue. Many strategic plans have been designed and pollution reduction targets have been set. It is important to assess how these strategic plans (goals of government) should be achieved. That is how to structure and layout different crops to achieve the water pollution targets.

This case study has shown several problems of policy effectiveness: biogas digesters seem to be under used, the trees converted from farmland are not properly managed, and so on. Policy makers are concerned about why these good (in terms of environmental objectives) and costly (huge subsidies) policies did not achieve good results. Future research should address options to increase the effectiveness of such policies.

6.7 Case study 5: Impact on sustainable development of implementing plans towards expanding land under irrigation in the Office du Niger in Mali

This section is based on D11.2 (Cissé et al., 2011).

6.7.1 Problem

The Office du Niger (ON) in Mali is one of the oldest sub-Saharan hydro-agricultural installation projects. Since 1947, the Markala dam has allowed for the irrigation of managed land by gravitation through raising the water level of the Niger. Initially, the irrigation of 1 million hectares was planned. The potentially irrigable rice land available today is estimated to be 250,000 ha, while less than 100,000 ha is cultivated. The expansion of rice land is one of the strategic stakes in the Office du Niger Master Plan, which calls for the creation of a 120,000 ha newly irrigated zone located in the vicinity of the existing primary irrigation canal. The Malian government is appealing to new investors (private, public, national and non-national) to develop irrigation infrastructures in new areas. Thus, the cost of the irrigation scheme's development is to be recovered by renting lands to agribusiness societies. This is an important change from the first phase of the Office du Niger irrigation scheme, when the government of Mali, in association with international donors, developed a strategy to consolidate family farming.

Officially, the two existing models, enterprise farming and family farming, are not in competition. Less than 10% of the irrigable lands will be converted into an ON zone. There should be space for everyone, and farmers would not lose their land. However, the official perspective does not take into account two elements: water scarcity and pre-existing land scarcity.

When the irrigation of very large areas may be guaranteed during flood periods, this is not the case when the water level of the Niger is low or when the irrigated channels are being maintained. In the latter case, the floods are reduced or cancelled purposely to facilitate the task. Only 12% to 17% of the total areas is used for growing rice off season and vegetable crops. When water levels are low, some upland areas that have already been converted cannot be irrigated because the floods cannot reach these areas which are also far away from the main channel.. Due to demographic growth, the size of land initially allocated to individual families in the early period of the "Office du Niger" has decreased during the last twenty years. Land was allocated based on the number of active labourers in the families. The latter become larger through time or broke down because of internal conflicts. In these cases, the available land is split into small pieces, raising the need for more space.

Land irrigation of the dead delta was made possible thanks to the regulation dam of Markala located on the Niger River approximately 275 km from Bamako (The capital of Mali) and 35 from the city of Ségou. The dam raises the water level approximately 5.5 m to gravitationally put water into the Falas which, in their turn, feed a complex hydraulic network of several thousands of works and kilometers of channels. This network was conceived at the beginning to irrigate a potential of more than 2 million hectares; the currently developed area covers only approximately 87662 ha in 2007 (see Figure 42 below).

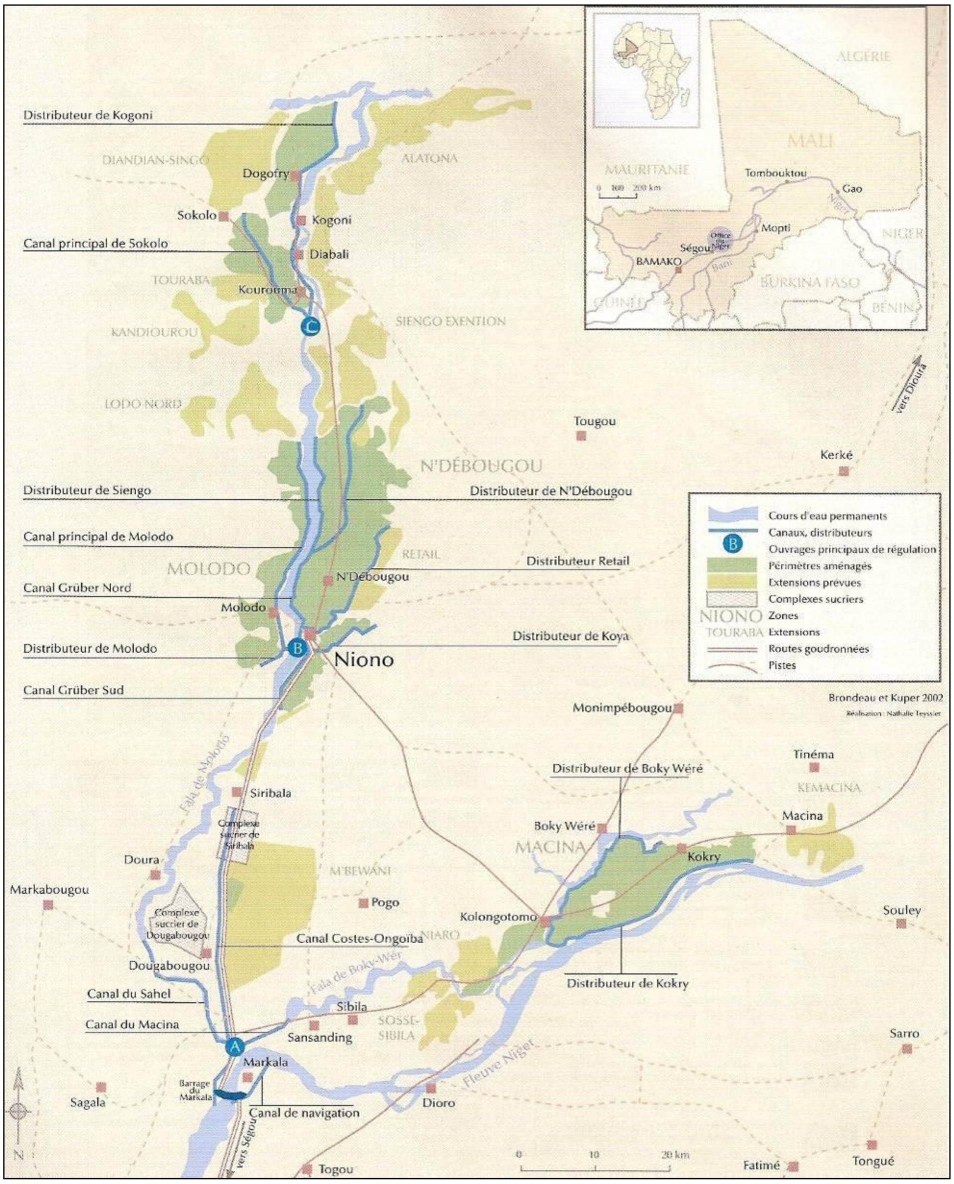


Figure 42: The developed land of the "l'Office du Niger" (Cirad / Karthala, 20

Land is available but used in priority for rice production. Therefore, land expansion applies to forests and pastures bringing about the scarcity of woods and pasturelands which is a serious problem. The main question raised by many stakeholders is as follows: How will the supply of wood and pasture resources be managed under the new land expansion policy? In the case study various policy options have been distinguished (see Table 8).

Table 8: Policy options for the management of wood and pasture resources

Policy option		Description
1	Regulation by the market	Rural wood markets are functioning and are relied upon for the provision of wood resources. Rice grower-stockbreeders in the Office du Niger area consume wood resources available in the communal territory
2	Uncontrolled situation	Creation of a new rice perimeter, thus reducing the area of the natural resource lands. A population growth rate of 3% is assumed.
3	Intensification and regulation of forest and livestock management	This option is based on i) the impact of planting trees inside and outside the irrigated perimeters to compensate for trees removed during the expansion of rice lands and ii) the impact of beef-fattening and selling activities on the size of herds and the income of farmers
4	Systems of production intensification for livestock fattening	Farmers in irrigated areas allocate 25% of their rice plot for the production of off-season fodder crops, with a yield of 10 tons/ha over 3 months, with 3 harvests.
5	Development of lands devoted to pastures in non-irrigated areas	Villages in non-irrigated areas fetch wood products from a wider radius, while the towns and villages in the irrigated areas would also fulfil their wood needs from the non-irrigated areas. Drinking water availability for livestock supplied through re-digging some of the existing water points and turning them into permanent water sources.

Stakeholders found that the joint scenario of 4 and 5 not only feasible but also more sustainable because it helped decongest the area by developing the upland areas for breeding purposes and the rational management of flocks. Rationalised management makes breeding a business instead of a social privilege based on the size of one's herd. According to the stakeholders, land resources are scarce in the irrigated areas for activities other than rice production. Therefore, the size of herds must be kept under control. An optimal herd size is preferable to a large size. On political and administrative grounds alone, this policy option seemed to be more acceptable to all parties, as it was not contradictory to any of the government's action plans. The policy put forward by the state of Mali and the administrative role the Office du Niger Authority had to be taken into account.

6.7.2 Impact Assessment results

For wood resources, the simulation scenarios propose two different systems for the harvesting of wood and two ways of increasing the supply of wood. The first harvest system allows wood cutters from the irrigating villages and the city to go wherever they want. The second system, called the secured system, allows dryland area villages to collect wood for themselves and the irrigating villages and city within a large area around their villages.

Whatever the harvesting system, the resource is depleting very rapidly. The second possible action is to increase the supply of wood by planting. Two scenarios are distinguished: a compensatory scenario in which trees are planted on 10% of the land area dedicated to new irrigation schemes, or a "plantation" scenario in which trees are planted to fulfil the needs of the population. This second scenario corresponds to the emergence of private plantations growing wood. The simulation results show that the compensatory approach can slow down resource depletion; the results are even better if the wood is also available to city inhabitants. However, if the problem must be solved locally, without the introduction of external wood, then the best solution is to adjust the tree plantation production to demand.

For fodder production, the simulation scenarios have the same basis: farmers keep part of their livestock on their farm and let the remaining part move on the area with the herd. Then, modifications are tested by increasing the resources available for the animals. The first simulation selects part of the area and raises the production of fodder for the herd. The second simulation has the farmers in the irrigated areas grow crops on their irrigated land and keep more animals on the farm. An additional modification improves water availability: permanent rather than temporary ponds or wells will allow the herd to go farther and harvest fodder from larger areas. The simulation results show that permanent ponds are efficient for some time (5 years) and then gradually experience problems as the population grows. Would the number of livestock remain the same? Would the permanent ponds be enough for the herd's needs? The problem is the fodder for animals living on the farm itself; the fodder production is efficient for the herd. In the model, the problem is solved for the herd. However, the problem remains for the in-farm animals. A beef-fattening scenario also solves the problem for the herd.

As farmers grow crops to feed their animals, they also need more fodder for their animals at home as they are not fed only by the crops. Thus, the problem of the local consumption of fodder increases.

6.7.3 Implications

The Office du Niger is evaluated only on the quantity of rice grown in this area. The underlying idea encourages the exclusion of any other use of the land that could decrease rice production. However, the issues of rangelands and wood supply for fuel have to be managed in interaction with agriculture. In addition, the state agencies and technical services tasked with raising agricultural production have fewer and fewer means with which they can fulfil their duties. The number of extension agents has decreased from 3,000 to 300. These agencies and technical services must rely on individual private initiatives to achieve their objectives. However, these initiatives must be controlled. In addition, the technical services staff want their expertise to be used and applied to these problems.

Trees need to be planted. However, the problem comes down to land tenure and economic profit. At the individual level, farmers who settle in this area aim to grow rice and other types of cash crops. Planting trees on small areas is not profitable. The farmer must profit immediately and grow rice to fulfil the objective of the Office du Niger. When farmers consider planting trees on part of their land, they first consider fruit trees. The second problem is that of land tenure: growing trees is possible only if land is allocated for long time. The Office du Niger claims that for a long time, access to the land was easy. It was simply a matter of requesting land for a given project. It appears that a large area was allocated, and for the last two years (2009-2010), the Office du Niger cancelled many contracts (280,000 ha in 2010). The Office du Niger also claims that for the last couple of years, any additional irrigated scheme plan had 10% of its surface area set aside for trees. The land is allocated, but trees are not grown. There is a lack of control due to the small number of staff available. What concerns large-scale tree plantations, the profitability is greater for other types of wood production. Wood is sold for "bois d'oeuvre", which is more profitable. Only the by-products of the plantation are sold as fuel wood.

The Office du Niger wants to decrease the number of animals and restrict their movement in the area. Livestock experts want to apply new methods and technologies. However, this creates various problems. Increasing the production of fodder requires that it be made at a long distance. Farmers and the Office du Niger do not want to have large quantities of animals close to the irrigated scheme ("animals and irrigated schemes don't go together"). Those areas lead to problems of access, tax issues, and local conflicts over alternative uses of the land. Fattening animals in-farm raises the problem of availability of fodder. Crops are not sufficient, and the surrounding areas are rapidly overharvested. Because animals cannot move under this approach to management, fodder must be provided to the animals. In addition, this management approach raises many technical problems that are beyond the scope of this study.

6.8 Case study 6: Impact on sustainable development of implementing land conversion control policies in Yogyakarta province of Indonesia

This section is based on D12.2 (Novira et al., 2011).

6.8.1 Problem

Indonesia is facing major problems concerning land conversion. Forests are to a large degree converted to plantations, and agricultural fields are converted to settlements and business areas. Indonesia consists of five main islands. Among these islands, Java Island is the most developed island due to the potential of both natural and human resources.

The Yogyakarta Special Region (Daerah Istimewa Yogyakarta, or DIY, see Figure 43) is a fast growing province in Java.

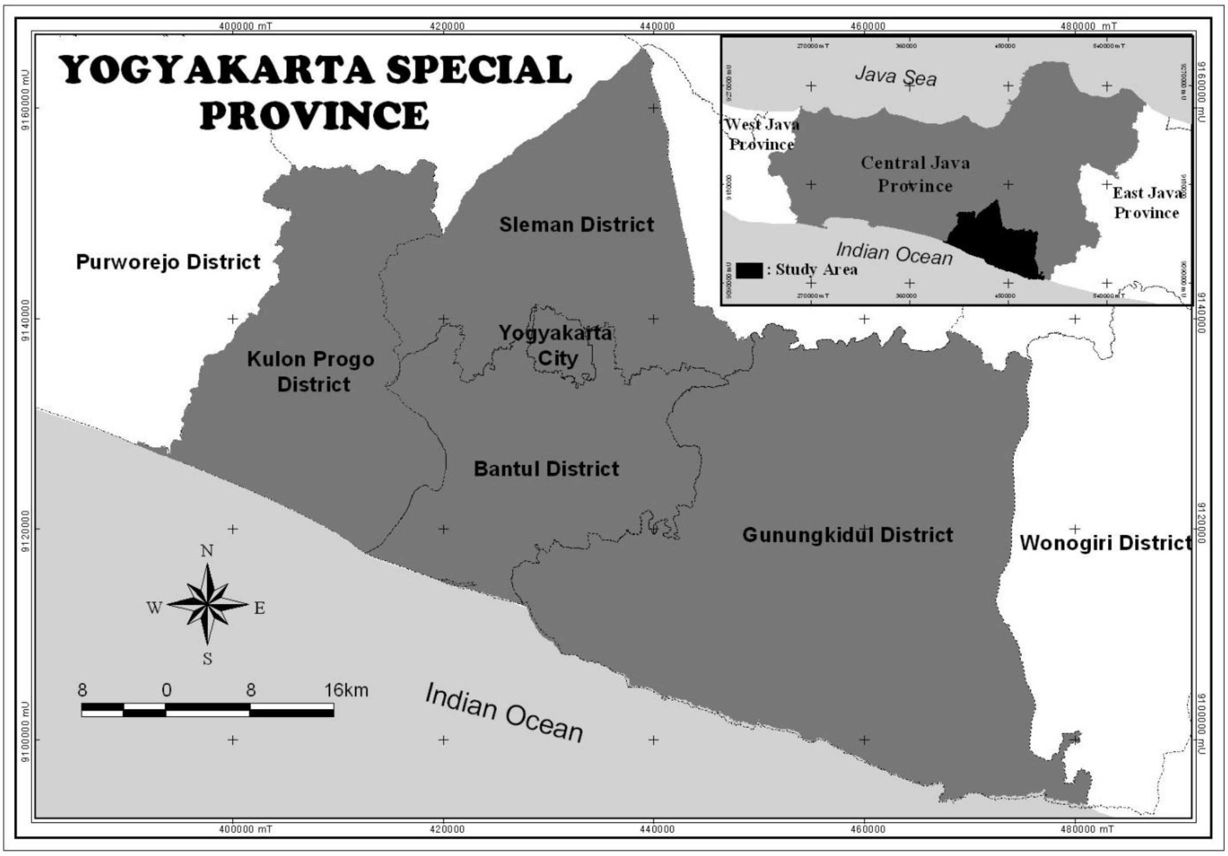


Figure 43: The case study area in Yogyakarta, Indonesia

***Source*: Adapted from Digital Indonesian Earth Surface Map, 1998.**

The rapid economic growth, the high standards of education services and the images of DIY as a good and convenient place to live in, have attracted more and more people to migrate into the area. On the other hand, migration has been the motor for a fast growing economy. In DIY, urbanization is the main driver of land conversion from agricultural use to settlement and business area. The rapid urbanization and migration into the area has become a threat to both the environmental and the social dimensions of sustainable development. Urbanization is linked to land conversion; deforestation and reduced agricultural land. And there has been a tremendous decrease in water availability in DIY, and a lack of waste management pollutes the water. With regard to the social dimension, a high immigration of socially well-off people causes conflicts with the local residents.

This case study focuses on the conservation of spatial planning policy, the forest protection policy and the sustainable rice field policy Nr 41/2009 (see Table 9).

+

Table 9: Scenarios in the case study of Indonesia

Scenario	Name	Explanation
S0	Business as usual	The baseline scenario consists of trends into the future. The projection year is 2025. Driving factors considered are population growth, economic growth, infrastructure development and Natural disaster. The main external driver expected to affect the land use change is the global economy.
S1	Spatial planning scenario	Spatial planning Act (PERDA DIY Nr. 5 Year 1992): Recommends appropriate land uses for various parcels of land, specified in a grand master plan map at a scale of 1:5000
S2	Forest protection scenario	National Act of Foresty Nr. 41/1999 defines the conservation forest as an area functioned for protecting biological diversity and ecosystem for flora and fauna. Conservation forests are divided into three different categories such as sanctuary reserves, nature conservation areas, and hunting areas.
S3	Sustainable rice field scenario	Sustainable Rice Field Act (Act Nr. 41 Year 2009) established to protect national food security through proper management and decision-making.

6.8.2 Impact Assessment results

The land conversion in DIY is dominated from the agricultural area (paddy field) to settlement. The land use change is mostly located in Sleman and Kulonprogo Regency. The conversion is affected by the flat topography and adequate groundwater availability for domestic use. High land demand for settlement forces the development reaching the agricultural area. Converting the agricultural land to settlement brings more advantages than maintaining the agricultural land as it is.

The projection of land use change of 2025 under scenario S1 and S3 shows a similar pattern as the reference. The selection of the policies to control the land use transition was not powerful enough to create significant differences from the baseline.

The business as usual scenario will decrease the food security level and provision for non-land based activity compared to reference condition. The second scenario results in a similar pattern as the first scenario. The simulated condition is almost in the same position as the reference condition when last scenario implemented. Compared to the other scenarios, conserving the agricultural area seems to be the best solution to maintain food security.

The most effective policy for limiting land use changes seems to be the Sustainable Rice Field Policy (Act Nr 41/2009). Land is considered as a private good. In the case of paddy field, land use type that is widely converted, since it is privately owned, the owner can decide with his land. Whether to sell it, to convert it, or to utilize it still as paddy field is the owner’s decision. This makes any policy trying to regulate land conversion problematic. The Act Nr 41/2009 on Sustainable Rice Field is expected to overcome this problem. However, some problems persist in the implementation. The area which will be proposed for sustainable rice field is not yet determined. There is no exact area mentioned in the Act Nr 41/2009. In the National Level, the implementation of the Sustainable Rice Field Policy has not yet been clear until this day. Further supporting regulations must be formulated. These are not yet present until today, thus this act is not yet implementable.

The implementation of land conversion tariff turns out to not be able to decrease land conversion, since the tariff is too low when compared to the income potentially generated by the land when it is converted. Realizing this, the local government has reacted in issuing a substitute. The land conversion tariff policy will be substituted with The Government Regulation Nr 13/2010 on Land Conversion. This substitute is expected to be more effective compared to the Land Conversion Tariff policy. This regulation was just being implemented in the beginning of 2011, thus evaluation could not be performed yet.

6.8.3 Implications

Many law enforcement interventions and policy of land use change have been set up by the local and national government. The aim was to overcome the land use malfunction and to manage the developer and industrial related needs. The set up policy tends to be double-edged. It supports the environmental sustainability and yet becomes the “enemy” of the economic sector. There will be trade-off between the idealism and the market needs.

The population growth was initially assumed as a significant driver of land change in many regions. However, the result of the case study indicates that the policy also plays an important role in the land use change. In the economic point view, the land use change related policy may be a constraint for the national development. Policy program for infrastructure support, taxation, privatization, and reforestation would provoke the land conversion.

In case of DIY, policies concerning land use change were slightly contradictory. Land conversion tariff of Bantul Regency does not protect the agriculture area as tight as of Sleman Regency. In addition to that, Perda Nr 41/2009 prohibits the land conversion due to agricultural sustainability. Thus, developers invest their capital to southern part of Yogyakarta. This situation economically advantages the local government and endangers the paddy field sustainability.

Land use planning is necessary to enable the government to provide the required space for the implementation of development activities. Essentially, land use planning is the spatial dimension of development planning. The second point to be clearly understood is that land use planning is prepared in response of the presence of development plans. Therefore, a land use plan can only be prepared if the development plan has been established. The third point is that land use planning in the framework of spatial planning is one of the bases of land management. A sound land use and spatial plan will not only give maximum benefit in using land, but also provide foundation for the environment protection and maintenance, so as to support a sustainable development. Land use practices are usually not in accord with the plan or maybe planning is not available. That is why there should be a proper decision for re-planning and rearrangement of the existing land use and land tenure which does not match its potential and the need for development.

6.9 Case study 7: Impact on sustainable development of implementing land and forest conservation policies in Brazilian Amazon

This section is based on D13.2 (Rodrigues Filho et al., 2011).

6.9.1 Problem

The Amazon biome is the single largest continuous tropical rainforest, and one of the richest stock areas of biodiversity on Earth. This area is highly threatened by deforestation, causing genetic erosion and a great amount of greenhouse gas emissions. The states of Mato Grosso and Pará in Brazil are facing a conflict between agricultural expansion (largely due to an increase in the international demand for commodities) and conservation of the Amazon rainforests, important for carbon storage.

The issue and the problems chosen to be studied in this case study are related to the impacts of the paving of highway BR-163 in the north of Mato Grosso (MT) and the south of Pará (PA) in Brazil (see Figure 44). The highway was partially paved as an effort made by the Mato Grosso state government to provide accessibility to the market for local soybean farmers. This has already caused intense migration into the area, deforestation, land grabbing and speculation, provoking a fast and radical change in land use, and intensifying social conflicts. However, 956 km are still not paved and the overall conditions are precarious. Increasing trade in soybeans under the influence of globalization has made it attractive for the government to pave the still unpaved part of the highway BR-163.

So far, however, many of the political actions aimed at preserving the environment – in their vast majority limited to mechanisms for deforestation control -, seem to have been less than effective.

The study focuses on two main policies: the Brazilian Forest Policy Code (from year 1965), a revised Forest code (now partially approved in the Parliament (May 2011), but not yet approved by the Senate) and the Creation of Protected Areas (Law 9,985, of July 18, 2000). In each case two alternative levels of implementation as the basis for the scenarios are considered: one based on an optimistic assessment of governance effectiveness, “high governance”, the other on a realistic assessment, “low governance” (see Table 10). As the international economy is determinant for the Brazilian commodity market and hence also for the outcome of these scenarios, low or high international economic growth are also included as variables in this scenario setup.

The complete paving of BR-163 was taken as a premise in all scenarios, once the still non paved stretches between the border of MT/PA and Santarem – about 900km – are forecasted to 2012. It is estimated that the road paving will reduce 35% of costs in transport of production, therefore causing strong implications in the land use dynamics of the region.

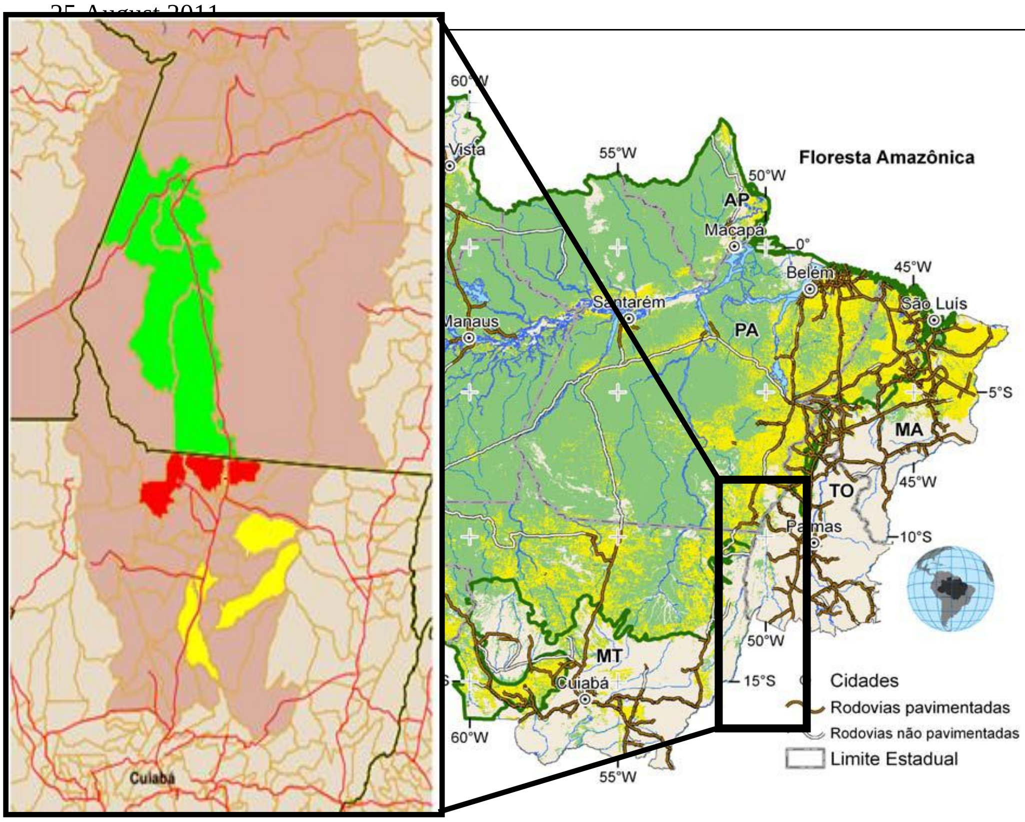


Figure 44 The study area along road BR-163 from Cuiabá in Mato Grosso to Santarém in Pará

Notes: Yellow: the municipalities *Feliz Natal*, *Marcelândia*, *Sinop* and *Sorriso* in the South region, Red: the municipalities *Alta Floresta*, *Guarantã do Norte* and *Novo Mundo* in the Central region, Green: the *Itaituba*, *Novo Progresso*, *Rurópolis* and *Trairão* in the North region.

Table 10: Scenarios and assumptions in the case study of Brazil

Scenario	*Political – Institutional Drivers*		*Economic Growth*
	Policies	*Governance*	
Baseline	Forest Code Conservation Units	Low	Low
	Forest Code Conservation Units	Low	High
Revised Baseline	Revised Forest Code Conservation Units	Low	Low
	Revised Forest Code Conservation Units	Low	High
Governance	Forest Code Conservation Units	High	High
	Forest Code Conservation Units	High	Low
Revised Governance	Revised Forest Code Conservation Units	High	High
	Revised Forest Code Conservation Units	High	Low

6.9.2 Impact Assessment results

The low price scenario shows that the policy scenarios hardly affect the areas under agricultural use (pasture, soy) or other crops in all regions. In the north, the pasture area most remarkably changes, with the largest amount of area in the "governance scenario" by 2020. In both the central and south region the effect of the revised Forest code on additional deforestation becomes clear in the areas of other crops; those areas increase compared to the policy scenarios with high forest code.

The policy scenarios affect the area of protected forest (forest code or conservation units). The forested areas defined as "protected" will affect future agricultural area only when the area available for production is limited. In the low price scenario both in the south and in the central region, the forest areas become limiting and in 2020 no forest is left to deforest. Therefore, agricultural land use areas cannot increase much in these regions, meaning that here the defined policy scenarios have little effect on forest or agricultural area.

The small effects on agricultural land uses have consequently small effects on the indicator performances, since many of those are dependent on some form of economic activity (mostly agricultural related). Hence only small differences are expected with regard to the social and economic dimensions, but larger effects for indicators in the environmental dimension.

In the low price scenario the governance policy scenario shows a decrease in soy income (-3.3%) while the revised baseline and the revised governance policy scenario show respectively a 6.7% and 2.3% increase in soy income. Beef income shows a very modest increase in both revised policy scenarios compared to the baseline.

In the high price scenario the pattern differs largely from the low price scenario. In all policy scenarios a decrease in beef income can be observed, while in the governance policy scenario and revised baseline scenario also a decrease in soy income can be found. The differences with the baseline policy scenario are smaller than in the low price scenario, because more other crop area is already in use to meet the demand for soy. Moreover, the governance policy scenario leads to a potential decrease in beef and soy income due to a high forest code protection value, the revised baseline scenario to an increase in beef income but a decrease in soy income compared to the baseline, while the revised governance policy scenario shows the opposite.

The different patterns between policy scenarios and between the high and low price scenario in additional beef or soya income are the result of the regional differences in available land of other crops in the north, central and south region. While under the high price scenario less other crop area is available due to soy conversion under the world price demand, the effects of protection of conservation units also become clear. Since a full protection level of 100% will lead to a lesser amount of forest that can be deforested, the lower protection level of 95% in the two baseline policy scenarios have a larger amount of 'free forest'. Since the amount of forest is very limited in the central and south region, this addition of 'free forest', albeit low in amount, becomes available for forest conversion and agricultural expansion.

The results show that if the Brazilian Forest Policy Code was reformed in such a way, to expand the agricultural frontier over forests in those states, the estimated increase in deforestation would be of 47% until 2020. Revision of Forest Code strongly increases deforestation and CO_2 emissions. With equal policy preferences the high governance policy scenario (effective protection of Forest Code) scores highest at both low and high price scenario. In low governance policy scenarios economic indicators have more impact. In the low price scenario policy preferences do not strongly affect policy ranking. In the high price scenario there is a strong trade-off between economic and environmental dimension.

6.9.3 Implications

The reform of the Forest Code, which is strongly debated in the Brazilian National Congress in 2011, displays the difficulties to overcome the dilemma between development and environment in developing countries such as Brazil. There is a consensus between environmentalists and "ruralists" about the need to update the Forest Code, currently suffering from certain anachronisms that no longer reflect Brazil's agrarian reality and potentialities. Nevertheless, the reform proposal steered by the ruralist lobby at the National Congress is a clear setback that can result in an augmentation of the already alarming deforestation levels in the Amazon and Cerrado biomes.

Complementary policies other than the current command and control strategy should also be envisioned. In this context, economic instruments that foster the conservation and intensification of production practices - such as the payment for environmental services – are not only possible but also attractive pathways.

The already degraded areas in Brazil's national territory, estimated at 50 million hectares at present, could be devoted to the agribusiness sector if properly managed through soil-recovering techniques. Tax reduction and more sustainable options privileging the intensification of production and native vegetation conservation, together with higher tributes to predatory techniques, constitute efficient mechanisms for the convergence between environmental preservation and economic development. If properly implemented, resources such as the Climate Fund and the Amazonian Fund are important mechanisms to overcome the above-mentioned dilemma.

The national policy on climate change (Law 1.187/2009) has become an important instrument to establish clear targets to reduce carbon and GGE´s Brazilian emissions. It states that more than 80% of the targets will be realized through the reduction of deforestation in the Amazonia and Cerrado, as well as by the intensification of agribusiness. Considering that the BR-163 axis is the Brazilian region whereas the agribusiness expansion towards the forest and Cerrado was the highest, this area would be a priority target of actions managed by a national climate programme.

Although a great number of public policies have been conceived in Brazil to address the challenge of environmental governance in the study area, they are obviously jeopardized by local institutional conditions, which are severely weakened. Agricultural development policies implemented in Northern Mato Grosso and Southern Pará coexist with conservation policies. The latest are at stake, however, due to the inefficient state institutions and low governance levels, often associated with corrupt officials. A great deal of public policies remains only on paper.

The role of consumers should be also highlighted. Most of the agribusiness production surrounding the BR-163 highway region have European (e.g. Netherlands and Great Britain) and Asian markets (e.g. China) as final destinations. Any possibility of a delicate balance between development and sustainability depends on Brazil's administrative and political decisions. But such a balance is also challenged by international markets and by countries that rely heavily on the commodity production of Southern countries to maintain their consumption patterns. Such actors could play a vital role in the design of more sustainable production chains.

As for the existing environmental management policies in Brazil, two measures should be urgently implemented: the improvement of technologies for the remote monitoring of land use changes and the strengthening of environmental institutions, including an environmental surveillance system. In this regard, the Ecological Economic Zoning (EEZ), both statewide and regional, could make a positive difference. Unfortunately, so far EEZ in Mato Grosso and Pará has been implemented as a mere technical tool rather than as a support instrument for political decision-making in territorial planning.

7 Part VII: LUPIS data portal

7.1 Introduction

This section is based on (Imbernon *et al.*) and (Imbernon *et al.*, 2011). The LUPIS Data Portal aims at providing access to data and results from the LUPIS project, giving users a gateway to selected information. Its online database holds a large number of data: local (case studies), national and global statistics, geospatial data sets (maps) covering various themes or public policies documents.

Through this information, the LUPIS data portal provides on-line documentation and understanding on the impacts of land use policies on sustainable development.

7.2 Main features of the data portal and access

To meet these different objectives, a set of features have been implemented. These capabilities range from research data to their representation as graphs or dynamic mapping. Thus the main issues of the data portal menu are related to:

- Land use policies and their analysis
- Global and national statistical data (most of them socio-economic data)
- Mapping of spatial information and multi-scale dynamics
- Impact assessment results
- Technical and scientific published papers

The LUPIS Data Portal is available through whatever web browser at the following address: http://LUPIS.cirad.fr (see Figure 45).

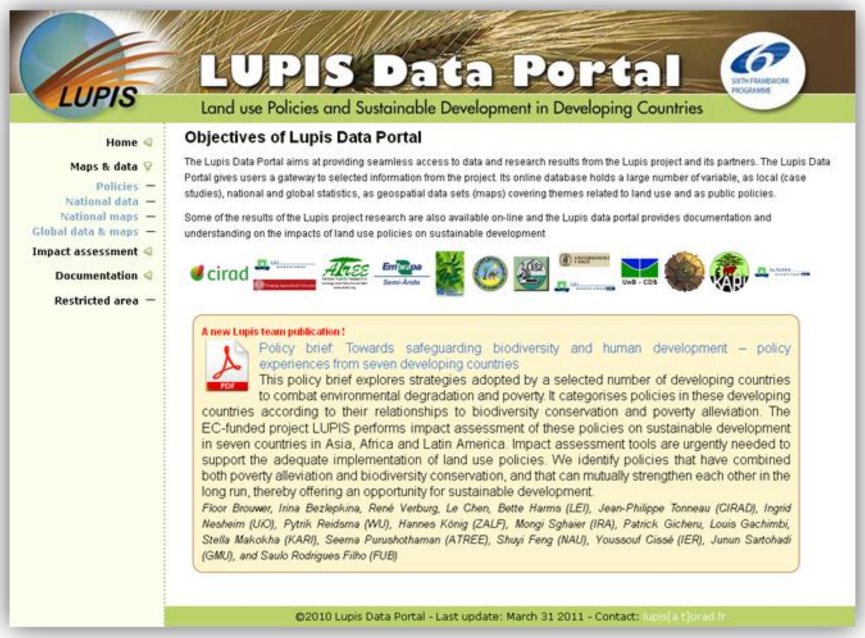


Figure 45. The Home page of the LUPIS Data Portal.

7.3 Maps and Data menu

7.3.1 Policies

Three main types of policies, at different level, were identified by the LUPIS project (see WP3):

- Sectorial policies, led by the State, at a national level;
- Domestic policies, left mostly to market rules, at a local level;
- Integrated policies, where actors have an important role, at a regional/territorial level.

This typology provides a logical framework to classify and analyse the various land use policies in the different countries where the LUPIS project was involved.

Thus requests on policies information in the LUPIS data portal are based on three hierarchical criteria: level of policy, type of policy and type of land use.

Results are displayed as a list of references corresponding to the user request. For each item of the list, the user can display a brief description for the policy. This summary contains a link to the more detailed documents related to the policy: official documents and brief analysis.

To search for a policy, click the left menu "Maps & Data", then "Policies". Four selecting boxes appear (see Figure 46). The first one is the implementation level with 3 options: national, local or regional. Multiple choices are allowed.

Select all
For each list, it is possible to select all options at once. To do it, click on the button 'all level" at the bottom of the list of choices.

Once user has selected one or several levels of implementation, a second list of choices appears: the type of policy; then a third list about land use type. The final list of choices that appears allows user to select the countries.

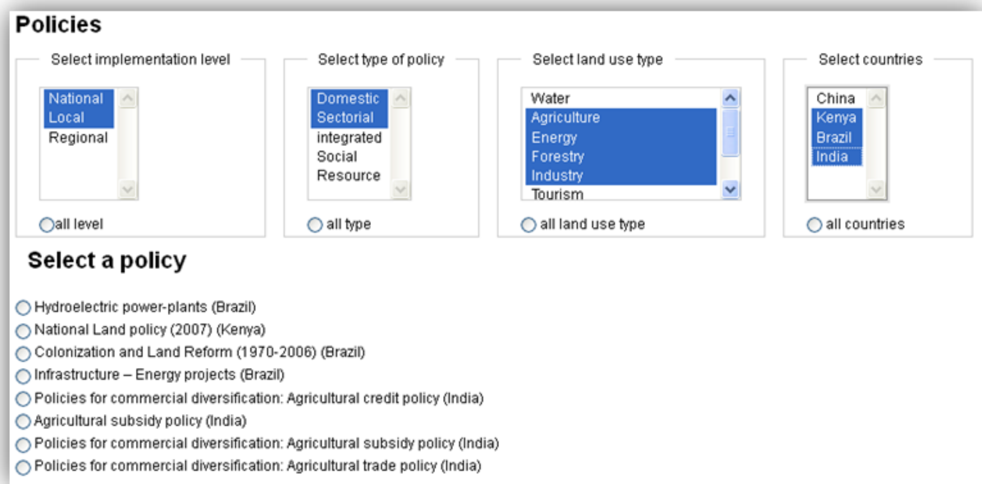
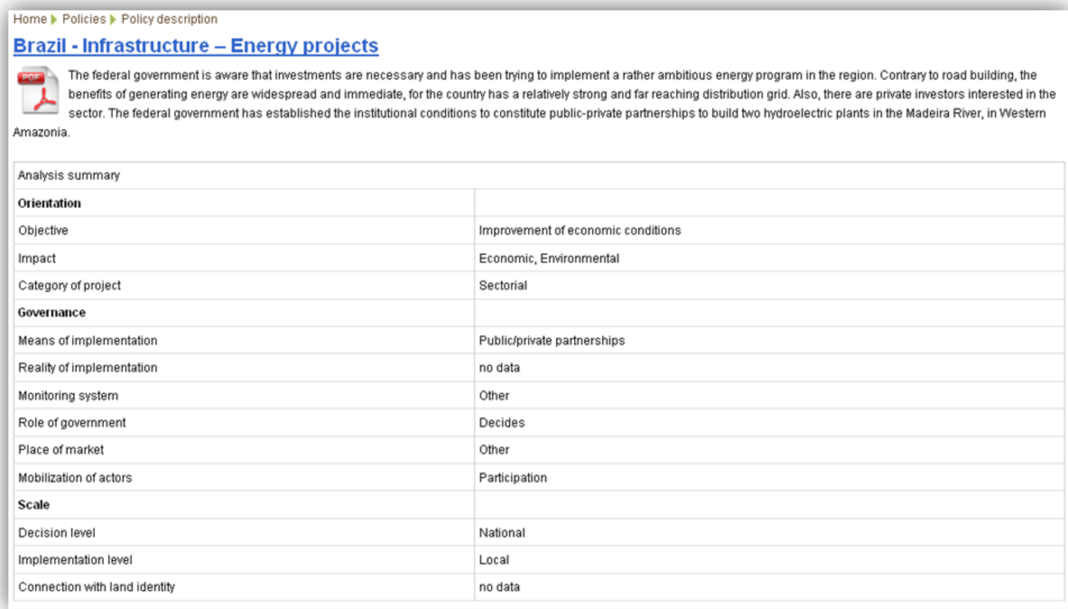


Figure 46. The different lists for selecting policies.

Once user has selected your criteria, a list of policies corresponding to these criteria is displayed. User has to select one of them.

Information about this selected policy is provided(see Figure 47) :

- The title of the policy and a .pdf file that can be downloaded to describe the policy
- A short summary of the policy
- A table describing the major issues of this policy: Orientation, Scale and Governance.



Home ▸ Policies ▸ Policy description

Brazil - Infrastructure – Energy projects

The federal government is aware that investments are necessary and has been trying to implement a rather ambitious energy program in the region. Contrary to road building, the benefits of generating energy are widespread and immediate, for the country has a relatively strong and far reaching distribution grid. Also, there are private investors interested in the sector. The federal government has established the institutional conditions to constitute public-private partnerships to build two hydroelectric plants in the Madeira River, in Western Amazonia.

Analysis summary	
Orientation	
Objective	Improvement of economic conditions
Impact	Economic, Environmental
Category of project	Sectorial
Governance	
Means of implementation	Public/private partnerships
Reality of implementation	no data
Monitoring system	Other
Role of government	Decides
Place of market	Other
Mobilization of actors	Participation
Scale	
Decision level	National
Implementation level	Local
Connection with land identity	no data

Figure 47. Brief description of the selected policy.

Navigation aid in the user interface

At the top of the page, user can see a "breadcrumb":

This feature allows user to get back to the previous page without losing your research context. This breadcrumb can help user to find your previous research context.

7.3.2 National data and maps

National data from the 7 countries where LUPIS was involved can be displayed on-the-fly as maps, graphs and tables or can be downloaded in different formats.

To search for data at national level, click the left menu "Maps & Data" then click "National Data". Then select search criteria (single or multiple) in the choice lists: countries, years and categories (Figure 48).

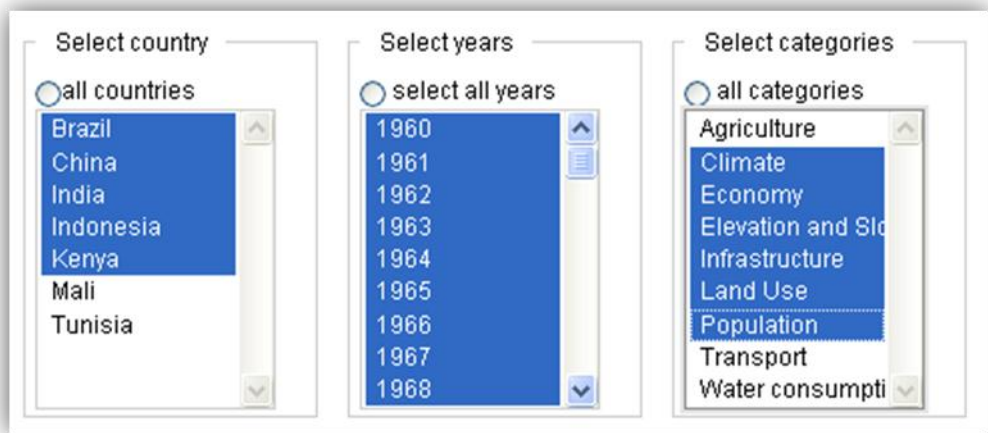


Figure 48. Search interface for national data.

When user has selected your search criteria, two tables matching your criteria are generated: the first displayed single variables and the second groups of variables (Figure 49).

Show 10 entries Search:

# dataset	Variable	Country	Dataset type	Covered time	Download allow	Data provider	Last update
234	Gross Production 1999-2001	Brazil	tabular	1961 - 2005	Yes	FAO	
235	Net Production 1999-2001	Brazil	tabular	1961 - 2005	Yes	FAO	
236	Gross PIN base 1999-2001	Brazil	tabular	1961 - 2005	Yes	FAO	
237	Grs per capita PIN base 1999-2001	Brazil	tabular	1961 - 2005	Yes	FAO	
238	Net PIN base 1999-2001	Brazil	tabular	1961 - 2005	Yes	FAO	
239	Net per capita PIN base 1999-2001	Brazil	tabular	1961 - 2005	Yes	FAO	
296	Gross Production 1999-2001	China	tabular	1961 - 2005	Yes	FAOStat	
297	Net Production 1999-2001	China	tabular	1961 - 2005	Yes	FAOStat	
298	Gross PIN base 1999-2001	China	tabular	1961 - 2005	Yes	FAOStat	
299	Grs per capita PIN base 1999-2001	China	tabular	1961 - 2005	Yes	FAOStat	

Showing 1 to 10 of 292 entries First Previous 1 2 3 4 5 Next Last

continue...

Select a group of variable

Display group of available variable following your criteria that have the same topic and unit.

Show 10 entries Search:

# group	Group of variables	Variables exprimed in	Country	Dataset type	Download allow	Data provider	Last update
77	Area under important crops in Karntaka	hectares	India	tabular	Yes		
78	Land use to Brasil	hectares	Brazil	tabular	Yes	FAO	
80	Population in Brasil	1000 inhabitants	Brazil	tabular	Yes	FAO	
80	Population in Brasil	Inhabitant per Square Kilometer	Brazil	tabular	Yes	FAO	
81	Agriculture in India	1000 I$	India	tabular	Yes	FAO	
81	Agriculture in India	not applicable	India	tabular	Yes	FAO	
85	Land use in India	hectares	India	tabular	Yes	FAO	
86	National population in India	1000 inhabitants	India	tabular	Yes	FAO	
86	National population in India	Inhabitant per Square Kilometer	India	tabular	Yes	FAO	
111	Agriculture Commodity Prices	1000 I$	Brazil	tabular	Yes	FAO	

Showing 1 to 10 of 27 entries First Previous 1 2 3 Next Last

Figure 49. Example of variables and groups of variables matching the selected criteria.

When selecting variables or groups of variable within these tables, different options are proposed: Graph (graphics), Data (tables), and Download in various formats (Figure 50).

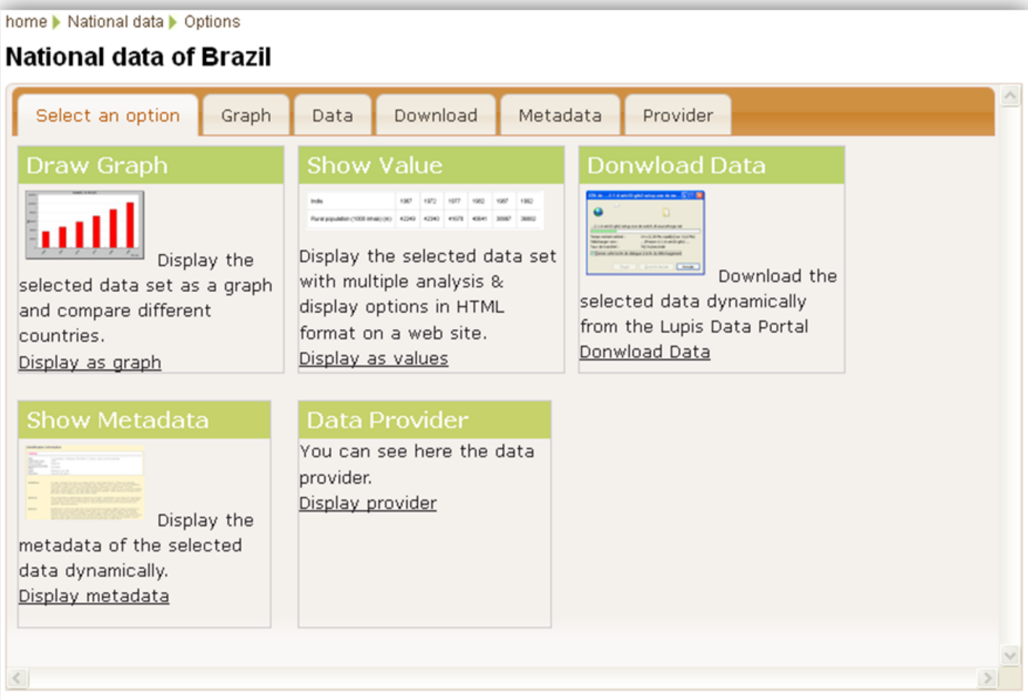


Figure 50. The various options offered for visualizing the selected variables.

As in the feature "Policies", a "breadcrumb" is activated when user selects a variable or variable group, in order to allow user to easily return to the previous menu.

Particular attention has been paid in customizing graphics. On the right of the page, it is possible to change the chart type (line, column or area), the color or the type of points (Figure 51).

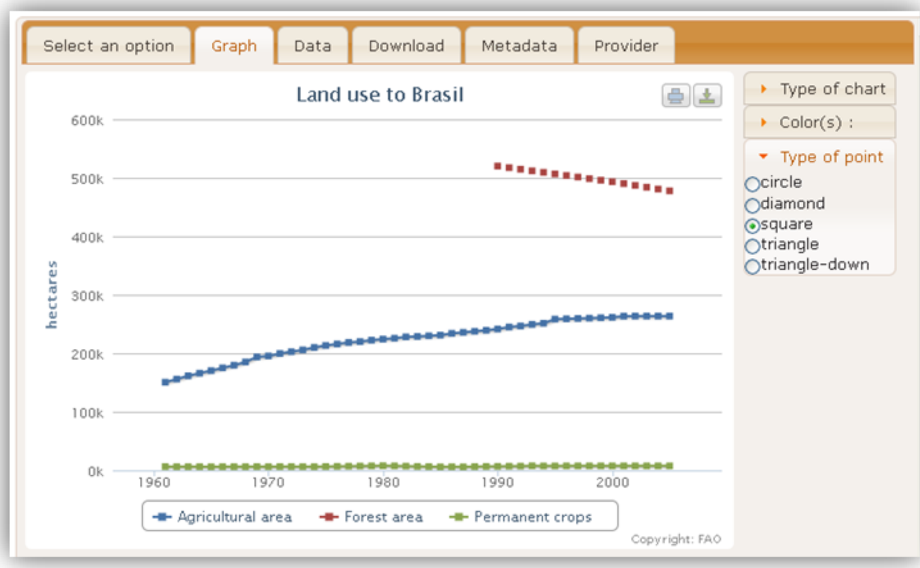


Figure 51. The graph option to display data and its various interactive functions.

The displayed graph can be exported as image file (jpeg, png, pdf or svg) or directly printed.

It is possible to hide a serie of data by clicking on the name of the series in the legend. The y-axis is adapted on-the-fly to the range of the dataset (Figure 52).

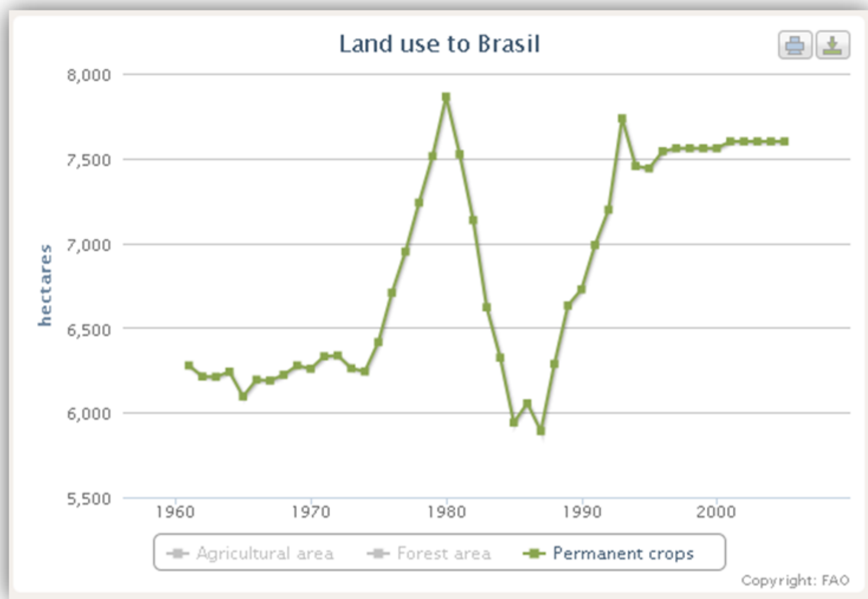
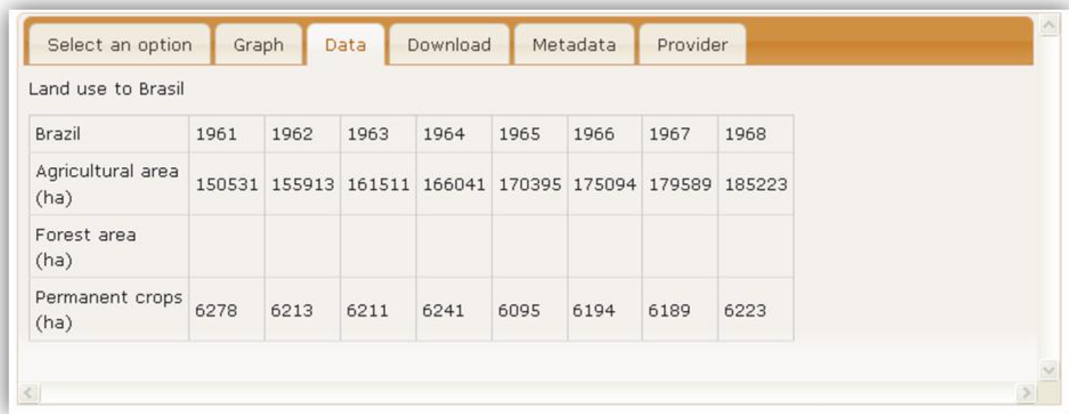


Figure 52. Example of interactivity of the graph option.

The “Data” options allows to display the selected data in a table (Figure 53).



Brazil	1961	1962	1963	1964	1965	1966	1967	1968
Agricultural area (ha)	150531	155913	161511	166041	170395	175094	179589	185223
Forest area (ha)								
Permanent crops (ha)	6278	6213	6211	6241	6095	6194	6189	6223

Figure 53. The data option and visualization as table.

The "Download" options allows to download these data and toget a file in one of these three formats: xls), cvs or pdf (Figure 54).

Figure 54. The data download option and the different formats.

The following option allows viewing metadata:

- Description: Data type, language, abstract ...
- Geographical metrics: extent, scale ...
- Organisms / Participants: owner, contact, distributor
- Constraints to access to data: access constraints, use constraints

The last option displays the logo of the data provider and a brief description of its organization.

Here can be displayed interactive maps. To access to a map on one of the LUPIS partner country, click the left menu "Maps & Data", then click "National maps", and select the country (Figure 55).

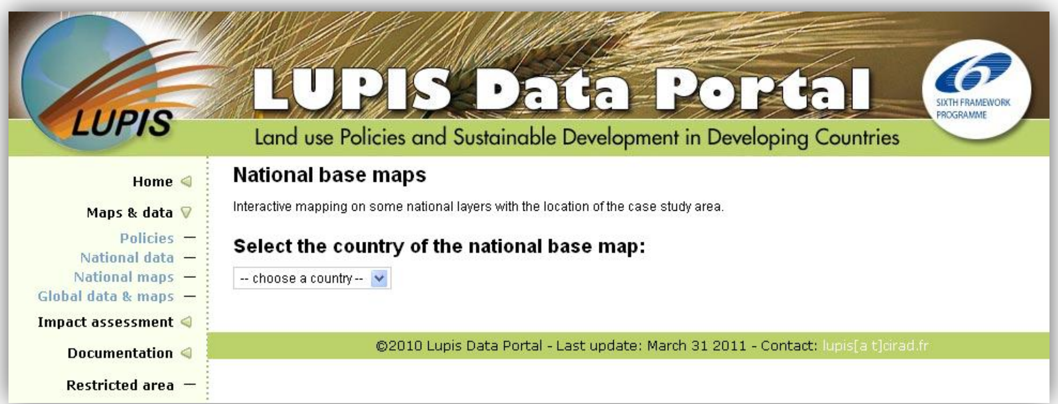


Figure 55. The national base maps menu.

Then a drop-down list "Switch to...choose a country…" will be available at the top right corner of the page in order to switch very quickly to another country (Figure 56).

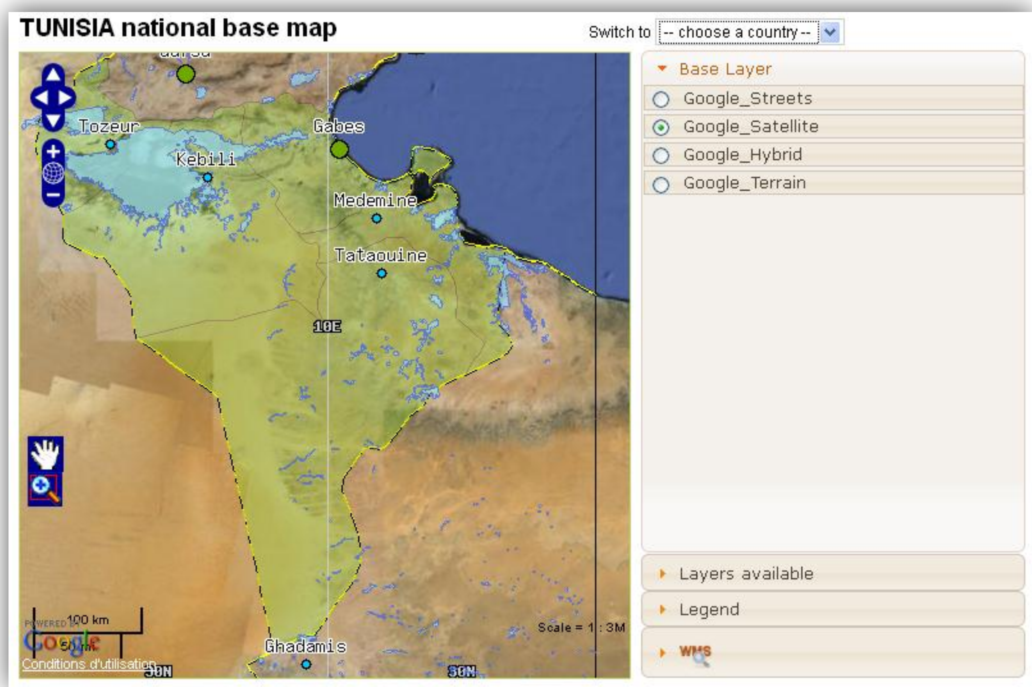


Figure 56. Example of the web mapping interface with a Tunisian base map.

This customizable dynamic mapping feature, using a webmapping interface, is also avalaible in "Global Data and maps" and in "Pre-modeling" features.

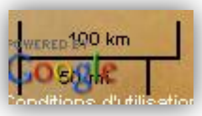
<u>The webmapping interface</u>

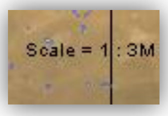
The coordinate system of all the maps which can be displayed within the LUPIS Data Portal is World Geodetic System 1984 or WGS84 (ESPG: 4326). The projection is Spherical Mercator (EPSG: 900913).

The interface webmapping is composed of two parts: the map and the layer switcher. The map allows direct visualization of the data and it incorporates controls for panoramic or zoom (by clicking on the globe, the map returns to a predefined zoom level).

The 'hand' control allows moving the map with the mouse. The magnifying glass icon with a '+' is used to zoom into a specific area of the map. Just click on the magnifying glass then draw a rectangle as an area of interest.

Information about the scale of the map displayed is on both sides of the lower part of the map.





To display the information related to a polygon of a map, just click on the map. For the land use for example, the information returned is based on data from ESA GLOBCOVER for 2005-2006 (in this example: “bare areas”).

<u>The layer switcher</u>

The layer switcher is the component located to the right of the page that allows handling all layers available. In general, the principle is to overlay the thematic layers on a background with base layers (Figure 57). These layers can be vectors or grids.

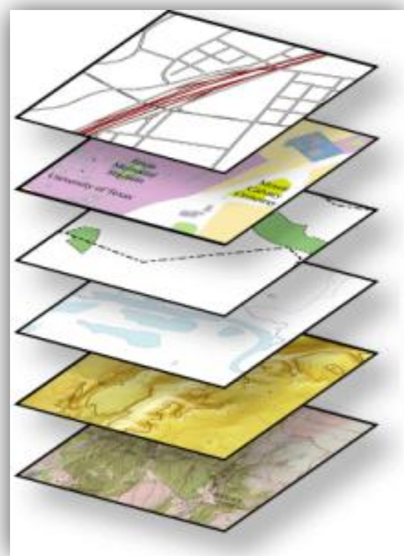


Figure 57. Overlaying thematic layers with base layers.

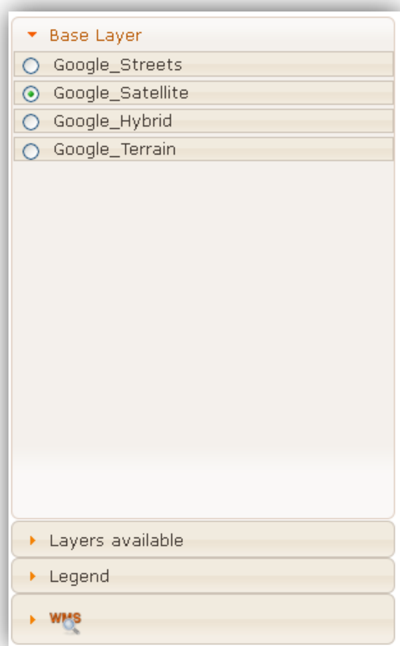
With the LUPIS Webmapping interface, it is possible to define the transparency of each overlay and the order in displaying layers (overlaying).

Available baselayers

The baselayers chosen for the LUPIS webmapping are those available on the Google Map API service:

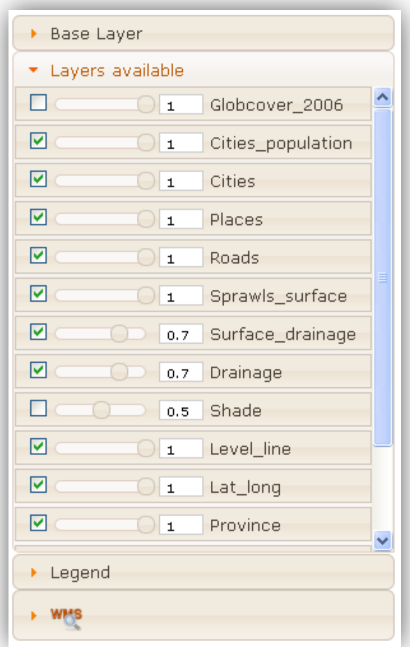
- Google Streets.
- Google Satellite.
- Google Hybrid, mixing Google Street and Google Satellite.
- Google Terrain, displaying elevation.

Only one baselayer can be activated at the same time as background and it is not possible to manage their transparency.



Available overlayers

These layers in the LUPIS Data Portal are frequently vector layers, representing discrete entities such as lines, points and polygons (roads, administrative boundaries, location of cities...). The other format is the grid format (raster layer) as the Globcover 2006 for the land use mapping or the Digital Terrain Model (DTM) for the elevation.



Layers available on the different sites are:

- Globcolver 2006, a land use map derived from MERIS ENVISAT imagery by ESA, at a 300 meters resolution.
- Cities population representing the demographic size of the major cities
- Places: location of towns and villages
- Main roads
- Urban sprawl area
- Water bodies (surface_drainage) and hydrological networks (drainage)
- Administrative boundary: country, provinces, regions
- Extension of the LUPOS case studies sites

Displaying information and scale of the display
All the overlays do not appear simultaneously whatever the scale is. The map server is programmed to display each layer in a specific zoom range.

Layer Switcher Features

The different layers can be managed for displaying. Their properties can be easily changed by a layer switcher (Figure 58).

The possibilities offered by this layer switcher are the following: show or hide a layer, define the transparency and change the order of displaying layers. To show or hide a layer, clik (display) or unclick (hide) the radio box next to the name of the layer. To define the transparency, move the cursor left (transparent) or right (opaque), or enter a value between 0 and 1. To change the order of the layers, drag and drop layers: click and hold clicked on a layer, and move it further above or below its actual position.

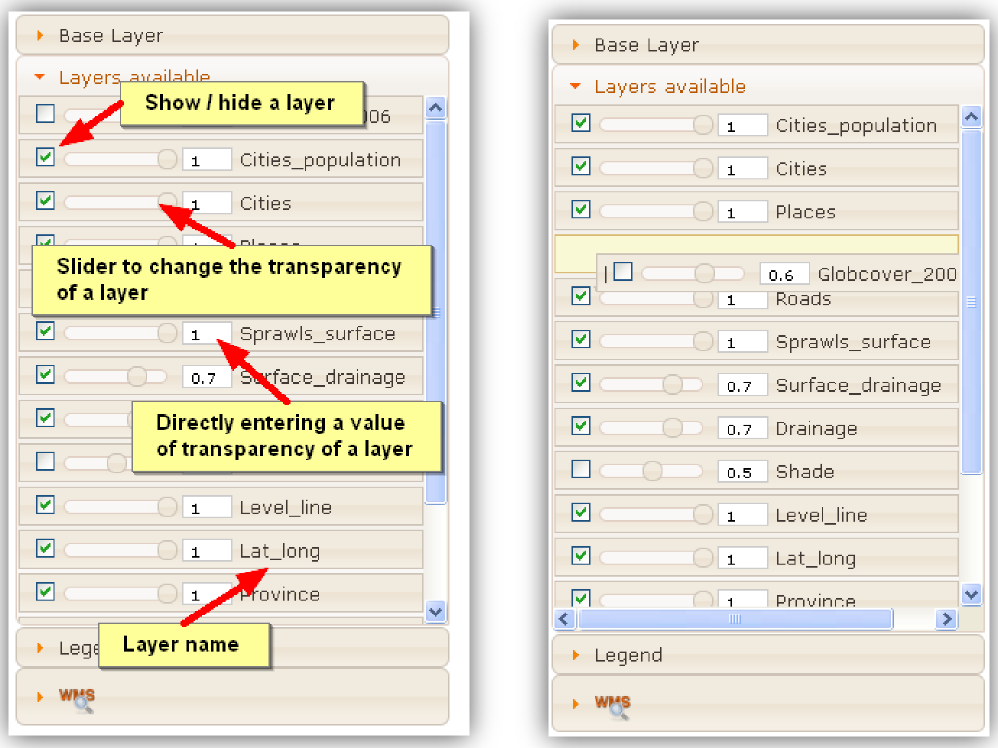


Figure 58. The layer Switcher Features in the web-mapping interface.

<u>Legend</u>

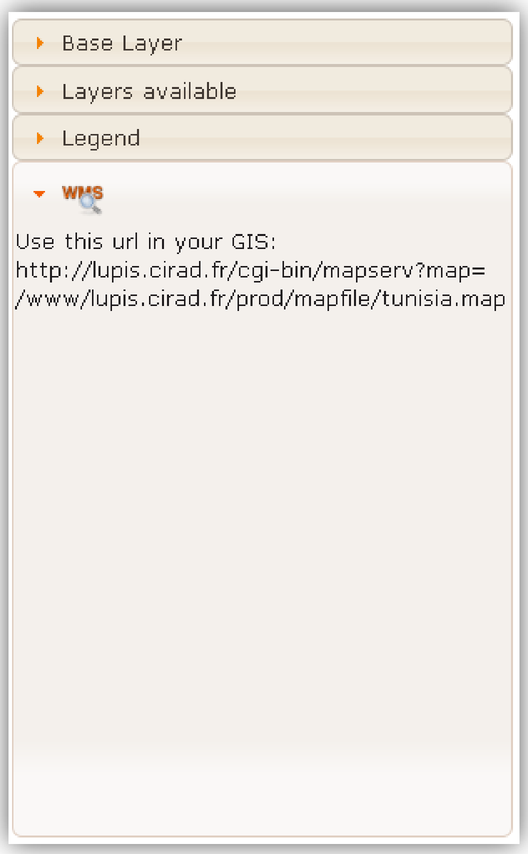
This information is on the tab "Legend"

WMS

The LUPIS Data Portal provides a Web Map Service (WMS) for each displayed map.

> *"The OpenGIS® Web Map Service Interface Standard (WMS) provides a simple HTTP interface for requesting geo-registered map images from one or more distributed geospatial databases. A WMS request defines the geographic layer(s) and area of interest to be processed. The response to the request is one or more geo-registered map images (returned as JPEG, PNG, etc) that can be displayed in a browser application. The interface also supports the ability to specify whether the returned images should be transparent so that layers from multiple servers can be combined or not."*
>
> *http://www.opengeospatial.org*

The WMS option allows the user to get URL needed to operate further WMS map server.



If user want to use these data with another tool, it is easy. For example, for using it with QuantumGIS, copy the URL generated by yhe LUPIS Data Portal, open QuantumGIS and click on the icon "Connect WMS": a window will open as following (Figure 59).

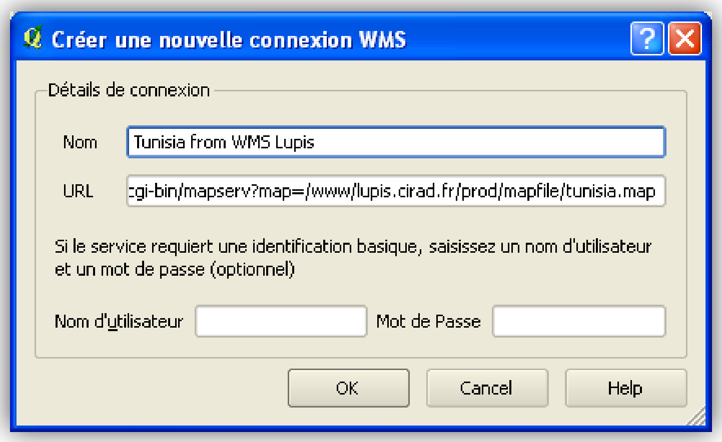


Figure 59. Using the LUPIS data with a GIS software through WMS.

Paste the WMS URL and click OK. Then click the Connect button. The list of available layers on the LUPIS Data Portal map server will appear. Simply click one by one the layers to add to your QuantumGIS application (Figure 60).

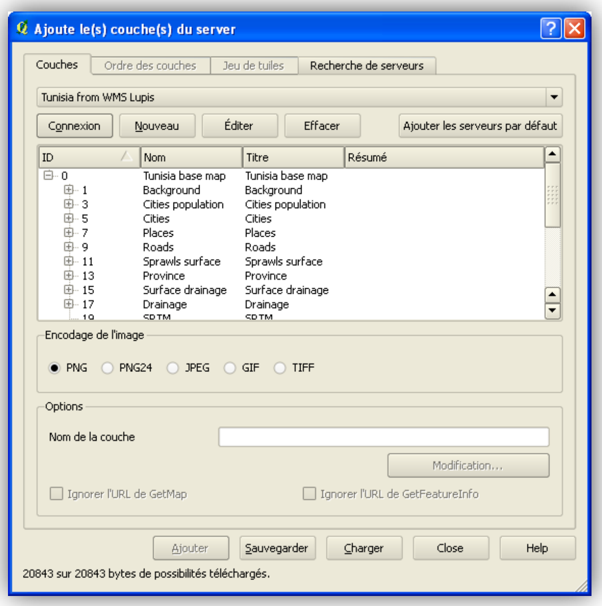


Figure 60. Selecting the layer that user wants to display with a GIS software.

Here is the result of a map drawn with QuantumGIS using data from the WMS on the national map of Tunisia, with the layers "Background", "Country", "LUPIS site " and "Cities population".

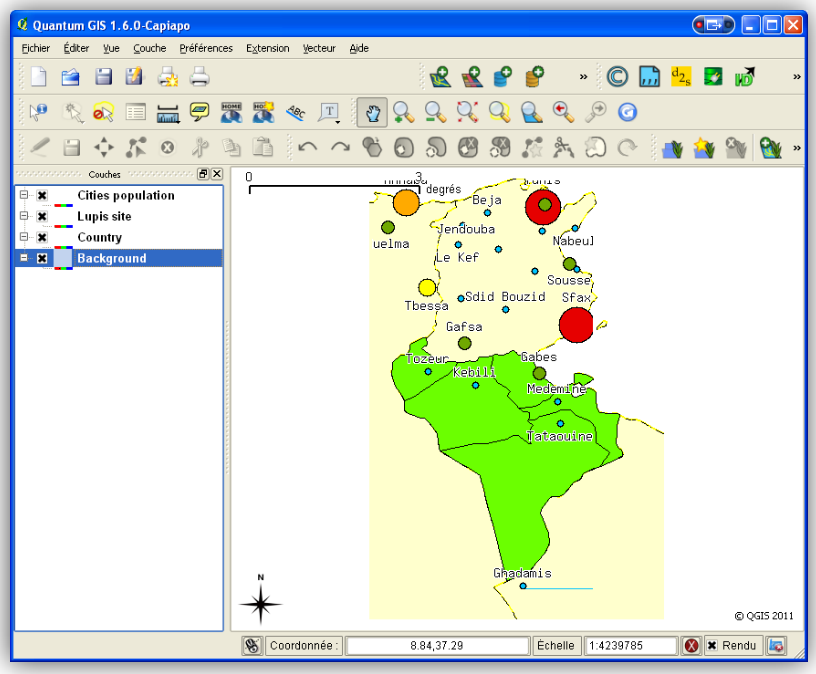


Figure 61. Example of mapping Tunisian data from the LUPIS data Portal by using the QuantumGis software.

7.3.3 Global data and maps

These data have been collected from different global data base, and mainly the FAO database. These data were organized in similar categories than the Geo Data Portal (GRID- UNEP). They cover time series, and can be mapped at global scale.

To search for global data, click on the left menu "Maps & Data"; then click on "Global data & maps". To search data, select criteria: categories, variable, year. For each criteria, multiple selection is possible (Figure 62).

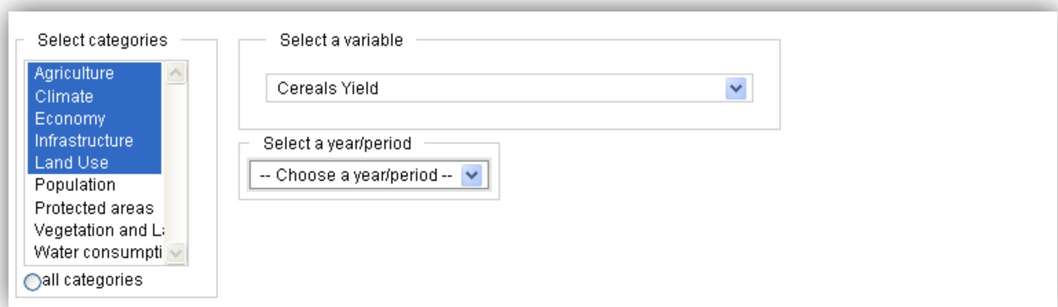


Figure 62. Search interface for global data and maps.

The map corresponding to the search is automatically displayed (Figure 63).

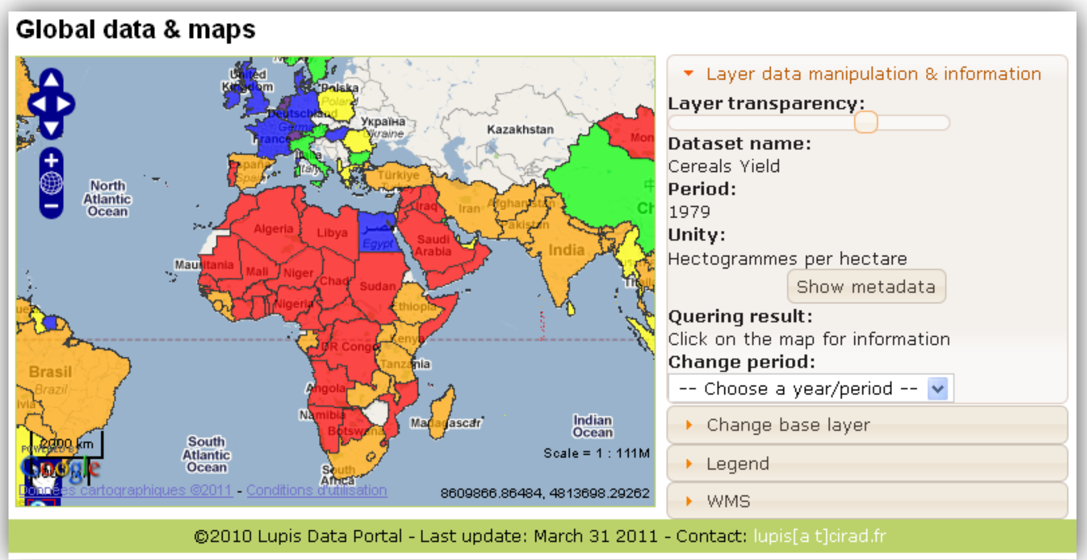


Figure 63. Example of the web mapping interface for global data.

The user can customize the map by changing the base layer. The user can also modify the transparency of the layer. Different information are available on the right side of the map: name of the variable, year and unit.

This layer itself is searchable by clicking on one of the country. The value of the variable for the country appears below "Quering result". The user can also modify the year with the box "Change period ".

Legend and WMS are also Available.

WMS is 24 hours active
It should be noted that these maps are generated when requested by the user and that the WMS is active for only 24 hours. Beyond this period, the user must re-create the map on the LUPIS Data Portal to retrieve a new URL.

7.4 Impact assessment

The impact assessment menu within the LUPIS data portal is designed by using the following methodological framework: pre-modelling, modeling and post-modelling (Figure 65). Two complementary researches were developed: commodities and trade modeling at global scale and stakeholders interactions at local scale. Results of these different activities are presented in the LUPIS data portal.

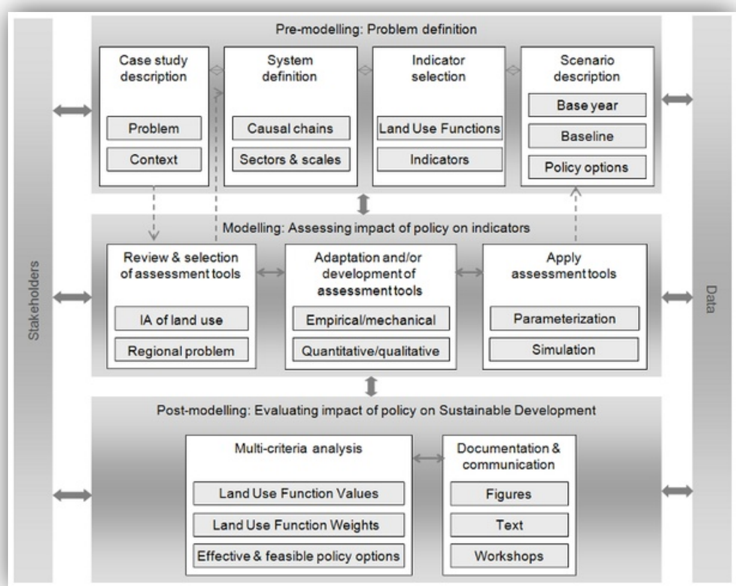


Figure 64. The LUPIS methodological framework for impact assessment.

7.4.1 Pre-modeling phase

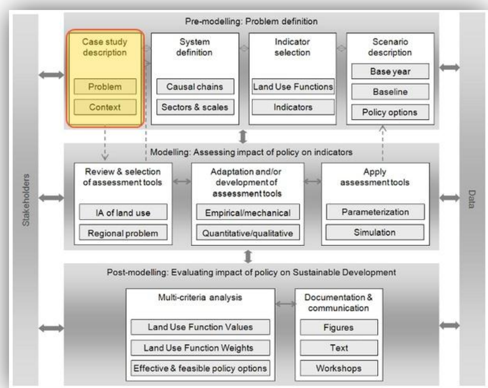


Figure 65. Activated pre-modelling phase of the LUPIS methodological framework for impact assessment.

In the pre-modelling phase, the problem is translated into scenario descriptions. The land use related problem is identified, and information is collected to describe the biophysical, socio-economic and institutional context in which a policy will be assessed. This assessment includes an evaluation of the current policies that are being implemented.

Based on the case study definition, causal chains between drivers, policies and (possible) indicators can be defined and a selection of relevant indicators is made. After that, scenarios can be described, including quantitative information on the current situation, baseline scenario and selected policy options.

To browse the various LUPIS case studies sites, click on the left menu "Impact assessment", then click "Pre-modeling”.

A drop-down list allows choosing the case study. Once your selection made, the case study page appears (Figure 66).

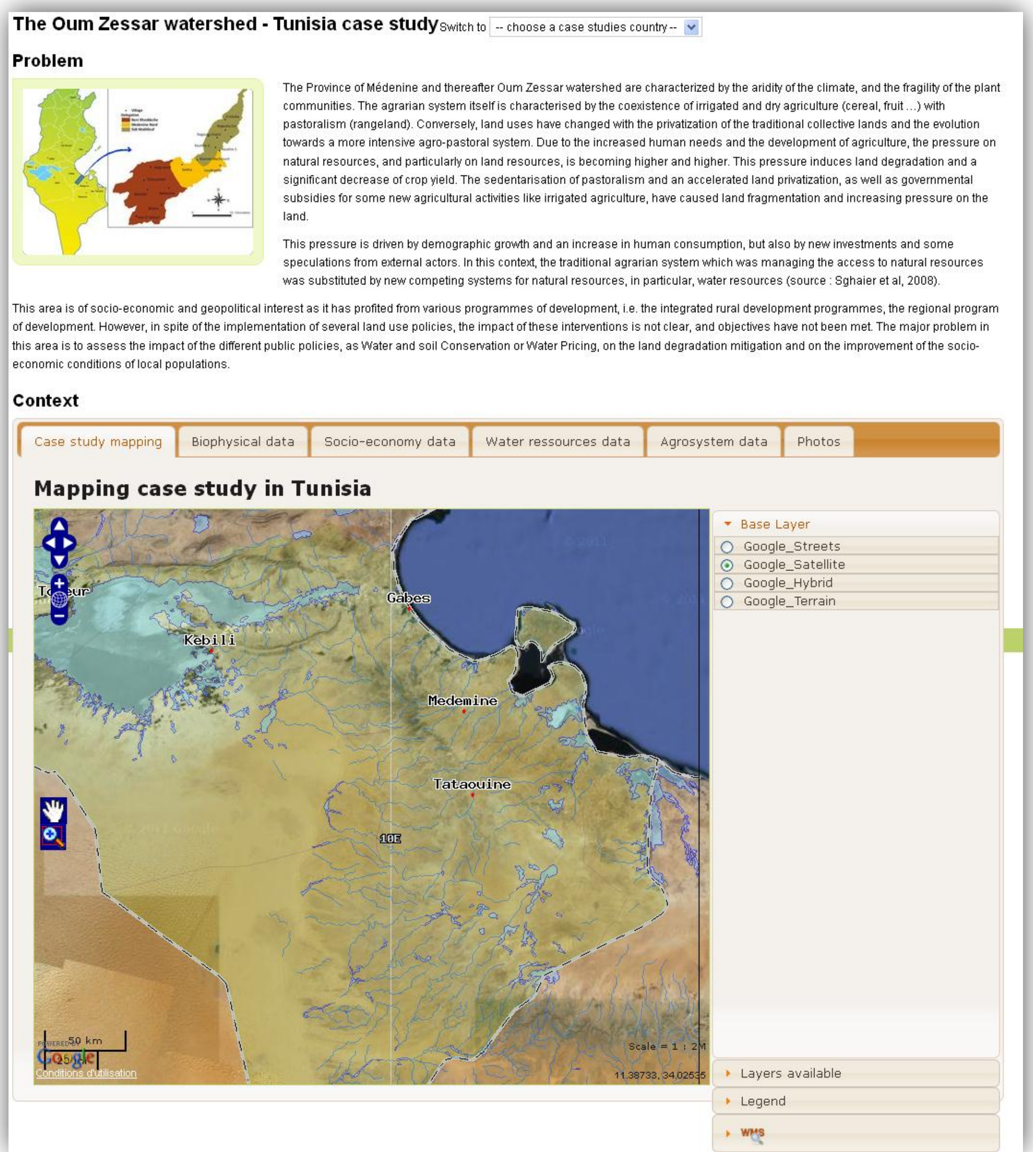
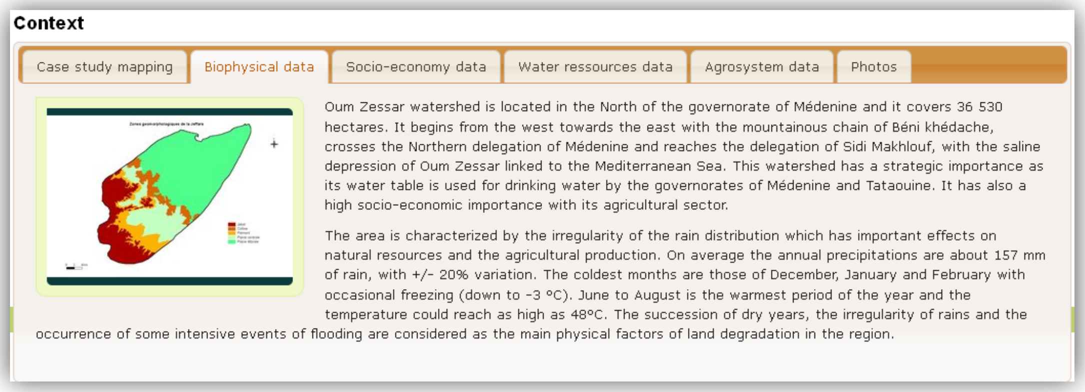


Figure 66. Pre-modeling phase. Example of Tunisian site description.

To present the context of the case study, different elements of context are displayed as tabs. In these tabs, there is always a tab "Case study mapping" with an interactive mapping tool.

In the following example, biophysical data can be displayed as an image of the area. This image can be enlarged by clicking on it.



7.4.2 Modeling phase

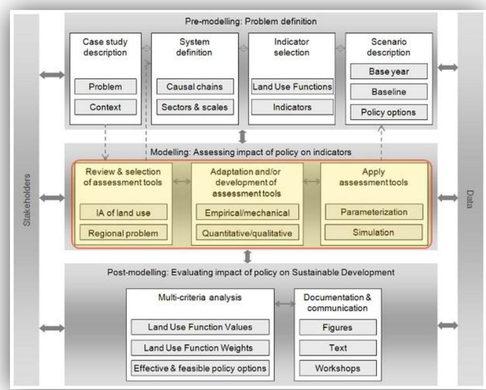


Figure 67. Activated modelling phase of the LUPIS methodological framework for impact assessment.

In the modelling phase, assessment tools are reviewed and selected in a first step. SEAMLESS and SENSOR have provided a range of models, but in some cases other existing models have been used. In the second step these models are adapted and/or developed and in the third step these models are applied.

To browse the various case study assessments, click on the left menu "Impact assessment", then click on "Modelling".

A drop-down list allows user choosing the case study and displaying models used by the different LUPIS partners.

7.4.3 Post-modeling phase

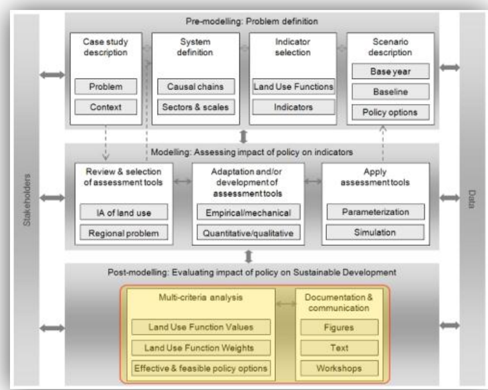


Figure 68. Activated modelling phase of the LUPIS methodological framework for impact assessment.

In the post-modelling phase, the outputs (indicators) are evaluated. These indicators have been aggregated into Land Use Functions and evaluated against Sustainable Development targets. This post-modelling phase refers to evaluating the indicator changes. A common procedure for SD evaluation based on a multi-criteria analysis (MCA) and/or a trade-off analysis should allow cross-country comparisons, even when different type of problems, indicators and models are selected. Changes in environmental, economic and social indicators can be evaluated with these methods. The indicators and their analysis are available here.

7.4.4 Stakeholders interactions

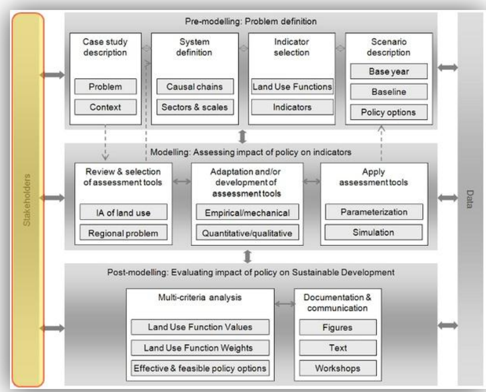


Figure 69. Activated stakeholder interaction platform of the LUPIS methodological framework for impact assessment.

The FoPIA is a stand-alone method bases on stakeholders interactions that can be used to structure and conduct an expert-based Sustainability Impact Assessment (SIA). The implementation of the FoPIA approach was structured into three parts: (i) scenario development, (ii) specification of the sustainability context, and (iii) scenario impact assessment.

During a preparation phase, available information and materials were gathered and evaluated with a focus on the case study region and related problem issues. Several expert workshops were first used to select potential policy instruments and drivers of regional land use changes to be developed into plausible and alternative future scenarios.

For the specification of the regional sustainability context, Land Use Functions (LUF) concept was applied allowing a balanced classification of key sustainability issues into economic, social, and environmental assessment groups. For this purpose, regional stakeholder workshops were organized to identify and define key sets of LUFs and related assessment indicators. Then during the impact assessment, the scenario impacts were scored and discussed for each LUF.

To browse the various sites, click on the left menu "Impact assessment", and then click on "Stakeholders interactions”. Once the case study has been selected in the drop-down list, the results of the FOPIA approach are presented.

7.4.5 Commodities and Trade Modeling

The International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) developed by the International Food Policy Research Institute (IFPRI) has been used as a global model. IMPACT is a partial equilibrium model focusing on the agricultural sector. The IMPACT model contains 32 (agricultural) commodities and 87 countries and regions. The model uses the GTAP database and the source of its supply and demand data is the FAOSTAT database.

The projections of the IMPACT model regarding world agricultural prices, production and demand are presented in the LUPIS Data Portal for three reference years: 2005, 2015 and 2025. The results of the model indicate that global prices in agricultural products will fall between 2005 and the LUPIS reference years 2015 and 2025 for all commodities except for High Value fish products.

In order to explore several IMPACT indicators over time, dynamic chart can be displayed. To browse these results graphically, click the left menu entitled "Impact assessment ", then click on "Commodities and Trade Modeling" (Figure 70).

By click on the Y axis, user can select the variable that user wants to display. User can also choose logarithmic (Log.) or arithmetic (Lin.) Y axis. By clicking on the X axis, user can select to represent time (Year per default) or another variable.

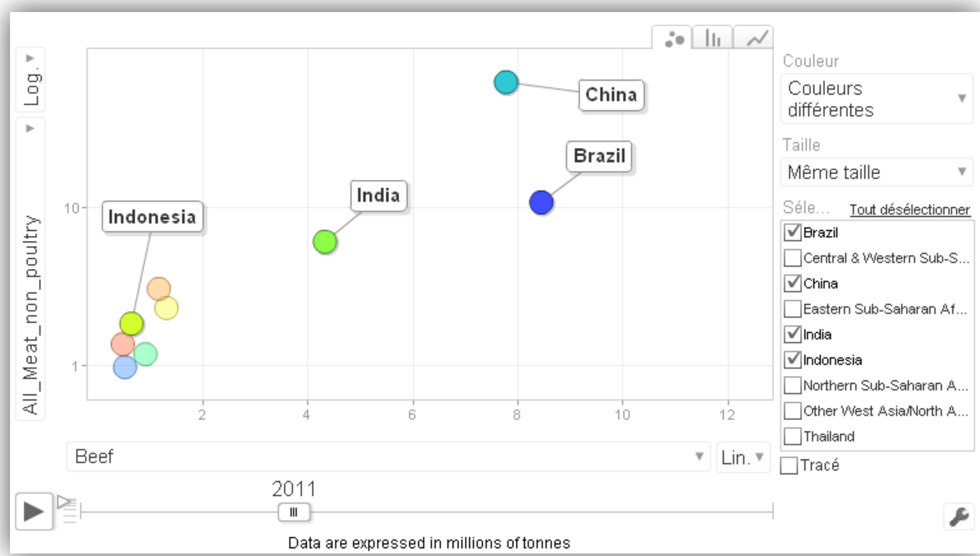


Figure 70. Example of animated graphic with Impact modeling results.

When selection has been done, dots can be animated by clicking on the following button:

.

This dynamic chart can be customize by changing the speed of the movie, displaying the tracing of dot, modifying the type of graphic, the colors or the size of the dots (proportional size).

7.5 Documentation

7.5.1 Publication & reports

To view the available documents, click on the left menu "Documentation", then click on "Publications & reports".

The documents available in the LUPIS Data Portal are categorized by “work package”. These is an additional category called "Publications", for papers published in scientific journal or for published books (Figure 71).

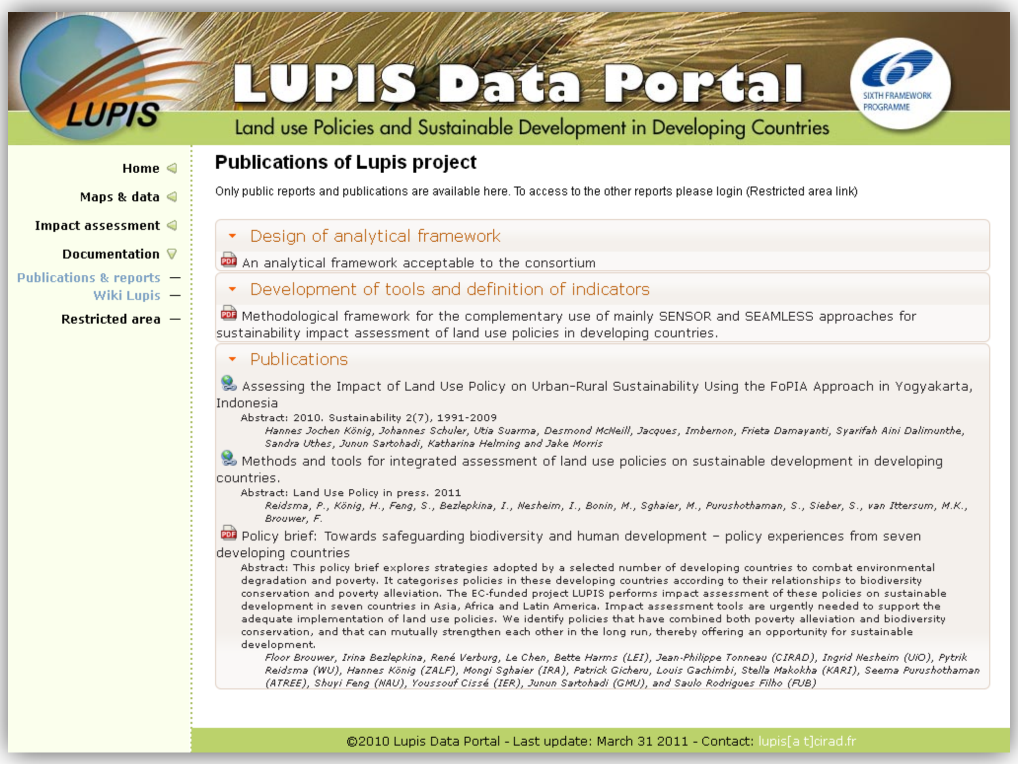


Figure 71. Access to LUPIS publications and reports.

For each of the documents, administrator assigns two properties: public or not, and "finalized" paper or draft". Only the public and finalized documents are available in the LUPIS Data Portal.

To have access to other documents, it is necessary to be identified in the "Restricted area". Depending on your level of accreditations, user will have access to all documents, including the drafts.

7.5.2 Wiki LUPIS

« A wiki is a website that allows the creation and editing of any number of interlinked web pages via a web browser using a simplified markup language (…) and are often used collaboratively by multiple users.»

Source Wikipedia.

The LUPIS Data Portal includes a Wiki application for the LUPIS purpose (Figure 72). To know how to use a Wiki, please read the text at:

http://meta.wikimedia.org/wiki/Help:Editor

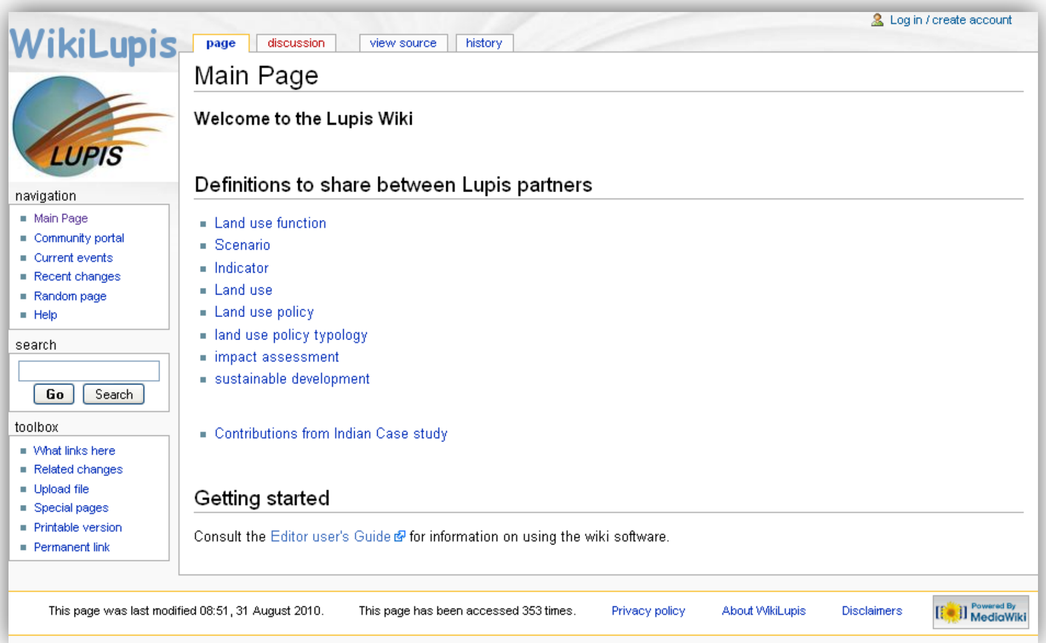


Figure 72. The WikiLUPIS page.

7.6 Administration and maintenance

An administration space (or back office) has been implemented for advanced users. Thus access to this space is reserved to users who have administrative rights. It is therefore necessary to identify himself in the "Restricted area" menu (Figure 73).

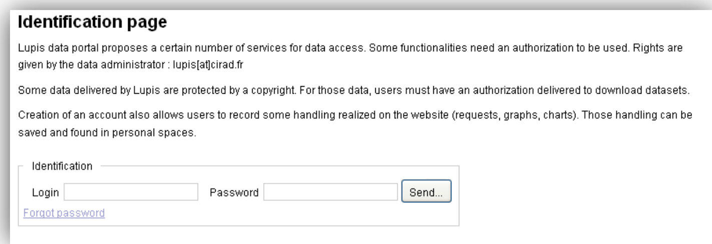


Figure 73. The identification page to access to restricted area.

Various possibilities are offered to the administrator: managing users and assigning access rights, adding data as tables (Excel, csv, txt), layers or new policy, and manage the data set (Figure 74).

Figure 74. The various options for administering the LUPIS data Portal.

For example, it is quite easy to add new data: first inform metadata as following then add the data set (Figure 75).

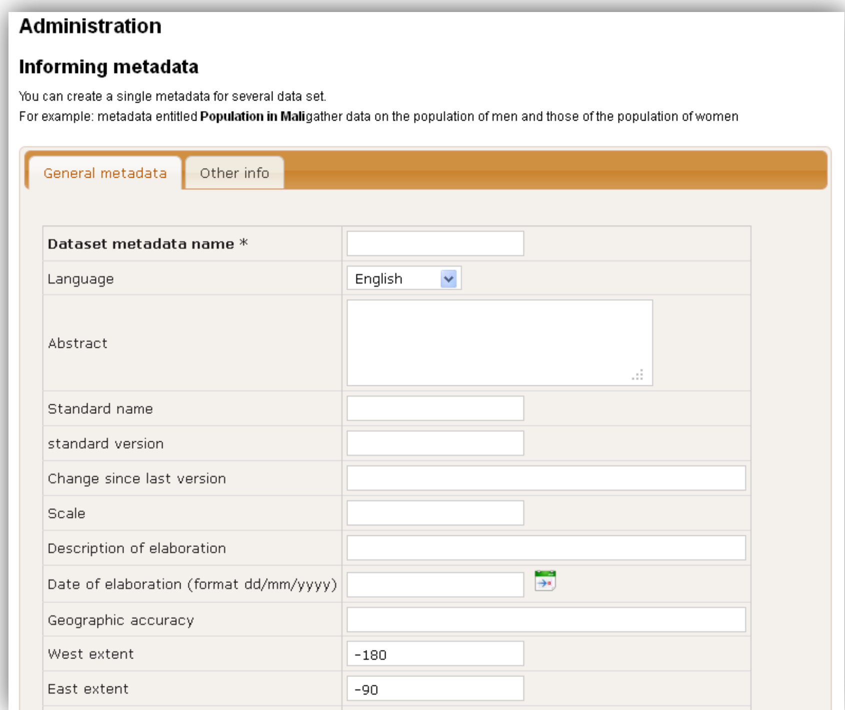
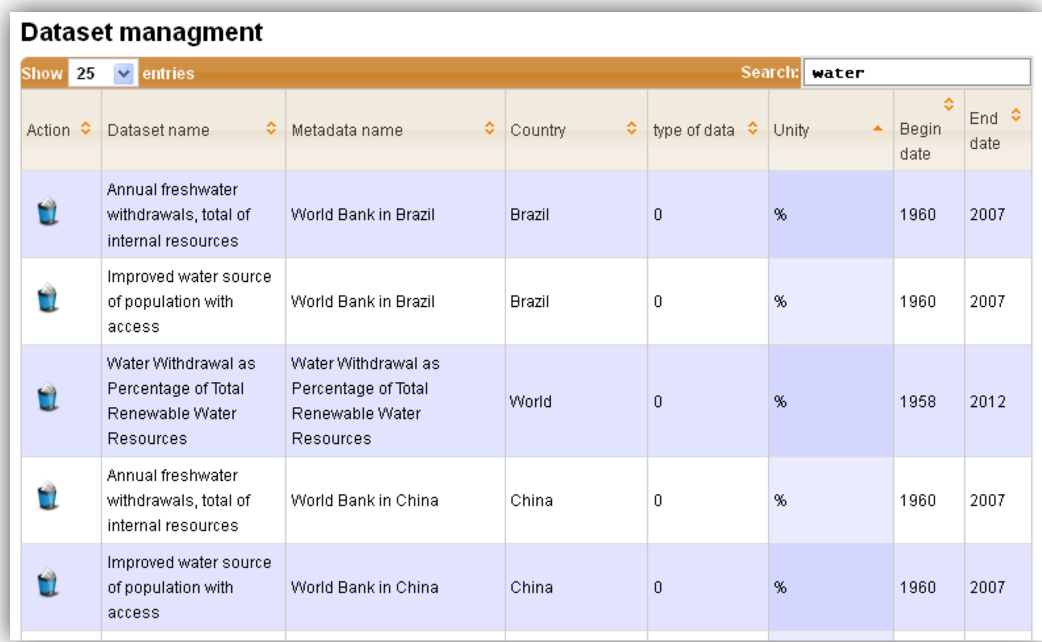


Figure 75. Interface for entering new metadata in the LUPIS data Portal.

The data management is accessible by the option "Manage Dataset" presented below and is also quite easy to use (Figure 76):



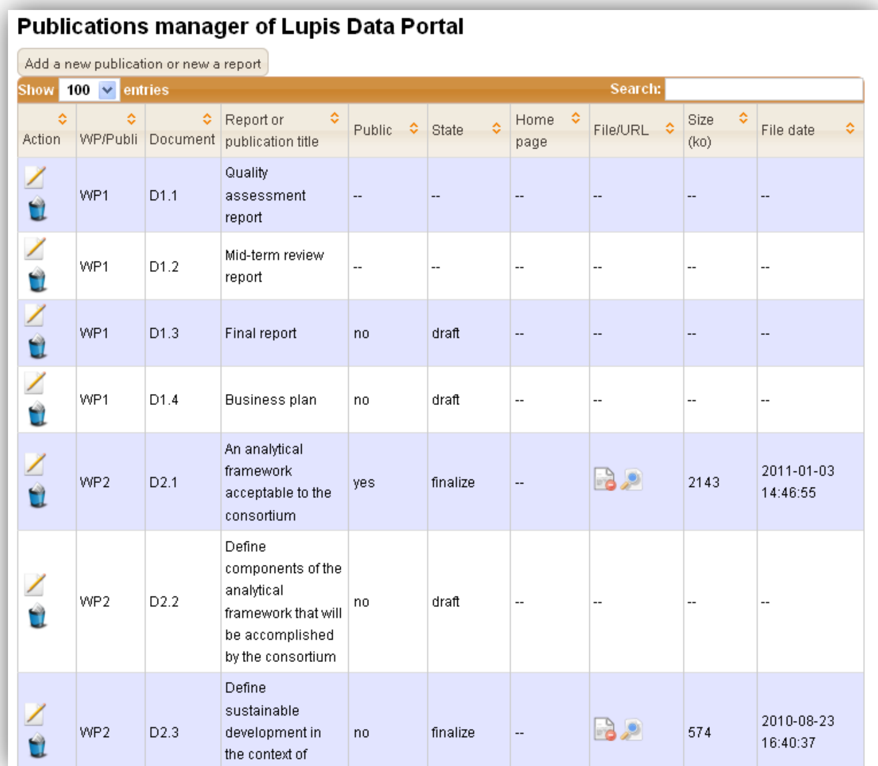
Dataset managment

Show 25 entries Search: water

Action	Dataset name	Metadata name	Country	type of data	Unity	Begin date	End date
	Annual freshwater withdrawals, total of internal resources	World Bank in Brazil	Brazil	0	%	1960	2007
	Improved water source of population with access	World Bank in Brazil	Brazil	0	%	1960	2007
	Water Withdrawal as Percentage of Total Renewable Water Resources	Water Withdrawal as Percentage of Total Renewable Water Resources	World	0	%	1958	2012
	Annual freshwater withdrawals, total of internal resources	World Bank in China	China	0	%	1960	2007
	Improved water source of population with access	World Bank in China	China	0	%	1960	2007

Figure 76. Interface to manage data sets in the LUPIS data Portal.

There is also an interface for managing publications, assigning a workpackage report or a deliverable and to manage the tag "Public" and "States" for each document (Figure 77).



Publications manager of Lupis Data Portal

Add a new publication or new a report

Show 100 entries Search:

Action	WP/Publi	Document	Report or publication title	Public	State	Home page	File/URL	Size (ko)	File date
	WP1	D1.1	Quality assessment report	--	--	--	--	--	--
	WP1	D1.2	Mid-term review report	--	--	--	--	--	--
	WP1	D1.3	Final report	no	draft	--	--	--	--
	WP1	D1.4	Business plan	no	draft	--	--	--	--
	WP2	D2.1	An analytical framework acceptable to the consortium	yes	finalize	--		2143	2011-01-03 14:46:55
	WP2	D2.2	Define components of the analytical framework that will be accomplished by the consortium	no	draft	--	--	--	--
	WP2	D2.3	Define sustainable development in the context of	no	finalize	--		574	2010-08-23 16:40:37

Figure 77. Interface to manage publications and reports.

The modern technical solutions implemented within the system allow an easy maintenance of the portal at low cost as only international standards and open source libraries were used. At the end of the project, the portal maintenance will keep the system clean so that it will not lose functionality, but no modification of the information system will be made.

The most important at this stage is the reusability of the various developments made based on open source software for further applications.

7.7 Interoperability of the system

Developments made for the LUPIS Data Portal have been made in order to ensure the interoperability with other systems, and particularly with GEOSS, for example the ISO 19115 metadata standard or the WMS web services. The Web Standards of the World Wide Web Consortium have been respected. The main operating systems can be used when accessing to the LUPIS Data Portal.

Microsoft Windows© Apple MacOs© Linux

The presented below web browsers have been successfully tested.

8. General Discussion and Conclusions

In Europe, ex-ante Integrated Assessment studies boosted the scientific literature in recent years (e.g., Helming *et al.*, 2008b; Tscherning *et al.*, 2008; Van Ittersum *et al.*, 2008a; Thiel, 2009), due to the introduction of the Impact Assessment (IA) Guidelines in the European Union (EC, 2005). Besides other objectives, these were introduced in order to make policy development more transparent and improve the quality of European policies (Bäcklund, 2009). In developing countries such incentives from policy makers are few, and hence impact assessments of policies are usually of ex-post nature (e.g. Fan *et al.*, 2008). Ex-ante assessments in developing countries generally explore potential technological or policy options instead of forecasting the impacts of more immediate and feasible options (e.g. Van Ittersum *et al.*, 1998; Van den Berg *et al.*, 2007; Tittonell *et al.*, 2009).

In this project a common analytical framework to screen and select land use policies for impact assessment studies has been developed. This framework includes elements regarding the orientation, the governance of land use policies and their relation to land. In spite of a trend towards liberalization of trade, state intervention remains in sectoral policies. Resources and social policies which are disconnected from sectoral policies do not tackle the causes of environmental problems and poverty. Territorial policies seem innovative and promising, but they must be well articulated with other policies.

The standard definition of sustainable development has been adapted to the purpose of the project, the merits of the Environmental Kuznets Curve hypothesis has been debated, and the implications of 'weak' and 'strong' sustainability has been examined. The potential trade-offs between sustainable development objectives – economic, social and environmental have been discussed, and it is stressed that the institutional (governance) dimension is crucial, an aspect which is often given inadequate attention in studies of land-use policies for sustainable development.

In this project, seven case studies have been selected in seven developing countries (China, India, Indonesia, Brazil, Tunisia, Kenya, Mali) for performing ex-ante impact assessments of land use policies (McNeill *et al.*, 2011). Each case study has its own specific land use problem, and each problem requires targeted land use policies. Ex-ante impact assessments are performed for the time horizon of 2015-2025. In China, for example, the projections had a short time horizon (2015) due to its relevance to the 5-year planning strategy adopted in China.

With heavy modelling exercises in China, Tunisia, India, Brazil, the impact of models has been less than aimed for in other case studies (Mali, Indonesia, Kenya). Nevertheless, positive effects on social learning, such as adapted problem definitions, direction setting, representation and management of boundaries and negotiation strategies, have been shown (Bouma *et al.*, 2007; Pahl-Wostl *et al.*, 2007). Involving policy makers and stakeholders throughout the modelling process is important to contextualize the modeling work, to create confidence in the work and to increase changes for the actual use of results (Sterk *et al.*, 2011). In the LUPIS methodological framework the pre-modelling phase and the involvement of stakeholders have therefore received much attention (Reidsma *et al.*, 2011).

One of the project objectives is to test the applicability of integrated assessment tools developed in the European context , namely SEAMLESS-Integrated Framework (from SEAMLESS project) and SIAT-Sustainability Impact Assessment Tool (from SENSOR project). In this project these computerised integrated tools appeared too complex to be adapted to the specific research questions in the non-European context and thus were only partially used. However, the main principles of doing IA research, some building blocks behind the interfaces of SEAMLESS-IF and SIAT were used.

The challenges of adapting the individual tools from SEAMLESS and SENSOR to such varied case studies have led to the tools as being viewed as a set of available methodologies and not tools per se to be used in the non-EU context (Chant et al., 2009). The use of a common methodological framework therefore provides the link between individual case studies rather than necessarily the use of common models from SEAMLESS and SENSOR. This framework is described in Part IV of this report. The methodological framework has proven to be useful in structuring and performing a sustainability impact assessment of land use policies (McNeill *et al.*, 2011). It has been applied in six case studies with different land use problems, SD targets and modelling tools. Although the case studies diverge enormously in nature of local issues that are studied (e.g., agrarian crisis leading to suicides in India, land degradation and poverty in arid regions in Tunisia; www.lupis.eu), the flexibility of the framework has allowed applying it for different situations and its generic feature facilitates comparisons between case studies (Reidsma *et al.*, 2011). The variety of individual tools finally applied along the execution of impact assessments does differ per case study. This is mainly explained by the scale of assessment (field, farm, region, country), data availability and composition of research teams.

The LUPIS data portal contributed within the project to the integrated assessment research by collecting, organizing and sharing information related to case studies environments and policies, and gathering documents and results produced by the research teams. The data portal contributed to a vision of the different parts of the research activities, and in that way the contribution was very positive. The data portal also contributed to practice a common language within an interdisciplinary and multicultural research team, where communication was not very easy.

The main difficulty was that the data portal development occurred at the same time as the project developments. Even if the framework of the project would have been really clear from the beginning, the final content was defined only during the last period of the project. The major part of the project duration was dedicated to policy, scenarios, indicators, and models selection. Thus it has been really difficult to design the data portal and many changes occurred as the different research activities themselves were being executed.

Outside of the LUPIS consortium, the data portal is giving access to public in large to the methods developed and results obtained by the project, as well as information on the EU project in general, on the different partners and on the case studies. After the project, the data portal will be maintained as it is. It will allow getting access to project documents, information and results. The developments based on open source libraries and international standards will ensure interoperability with other systems and the modularity of the system will allow reusability of the various results for further applications.

References

Abaza, H., Bisset, R., Sadler, B., (2004). Environmental Impact Assessment and Strategic Environmental Assessment: Towards an Integrated Approach. UNEP, Geneva, Switzerland.

Advanced-EVAL, (2010). Development and application of advanced quantitative methods to ex-ante and ex-post evaluations of rural development programmes in the EU (http://www.advanced-eval.eu/).

Antunes, P., R. Santos, and N. Videira, (2006). Participatory decision making for sustainable development - the use of mediated modelling techniques, *Land Use Policy* **23** (1): 44-52.

Arrow, K., B. Bolin, R. Costanza, P. Dasgupta, C. Folke, C. S. Holling, B. O. Jansson, S. Levin, K. G. Maler, C. Perrings, and D. Pimentel, (1995). Economic-growth, carrying-capacity, and the environment, *Science* **268**: 520-521.

Asai, M., P. Reidsma, and S. Feng, (2011). Impacts of agricultural land-use changes on biodiversity in Taihu Lake Basin, China: a multi-scale cause-effect approach considering multiple land-use functions, *International Journal of Biodiversity Science, Ecosystem Services and Management*.

ATLAS, (2010). Action for Training in Land use And Sustainability (http://www.atlas-eu.org/).

Ayres, R. U., J. C. J. M. van den Bergh, and J. M. Gowdy, (1998). Viewpoint: weak versus strong sustainability. Tinbergen Institute Discussion Papers University of Amsterdam, Amsterdam.

Bäcklund, A. K., (2009). Impact assessment in the European Commission - a system with multiple objectives, *Environmental Science and Policy* **12** (9): 1077-1087.

Barnes, G., (2003). Lessons learned: an evaluation of land administration initiatives in Latin America over the past two decades, *Land Use Policy* **20** (4): 367-374.

Belhouchette, H., K. Louhichi, O. Therond, I. Mouratiadou, J. Wery, M. v. Ittersum, and G. Flichman, (2011). Assessing the impact of the Nitrate Directive on farming systems using a bio-economic modelling chain, *Agricultural Systems* **104** (2): 135-145.

Bezlepkina, I., P. Reidsma, S. Sieber, and K. Helming, (2011). Integrated assessment of sustainability of agricultural systems and land use: Methods, tools and applications, *Agricultural Systems* **104** (2): 105-109.

Binder, C. R., G. Feola, and J. K. Steinberger, (2010). Considering the normative, systemic and procedural dimensions in indicator-based sustainability assessments in agriculture, *Environmental Impact Assessment Review* **30** (2): 71-81.

Bonin, M., E. Coudel, Y. Cissé, S. Feng, P. Gicheru, N. Novira, N. Ounalli, S. Purushothaman, S. Rodrigues-Filho, M. Sghaier, X. Shi, and J. P. Tonneau, (forthcoming). Critical Analysis of Land Use Policies. In *Land Use Policies for Sustainable Development: Exploring Integrated Assessment Methods*, D. McNeill, Nesheim, I., Brouwer, F. (ed.): Edward Elgar Publishing.

Bouma, J., J. J. Stoorvogel, R. Quiroz, S. Staal, M. Herrero, W. Immerzeel, R. P. Roetter, H. van den Bosch, G. Sterk, R. Rabbinge, and S. Chater, (2007). Ecoregional Research for Development, *Advances in Agronomy* **93**: 257-311.

Brandão, A. S. P., (2005). Crescimento agrícola no Brasil no período de 1999/2004, explosão da soja e da pecuária bovina e seu impacto sobre o meio ambiente. IPEA, Rio de Janeiro, 26.

Brekke, K. A., (1997). *Economic growth and the environment: On the measurement of income and welfare*. 182. Cheltenham: Edward Elgar.

Brondeau, F., (2000). Macina forestry resources and wood supply for the Office of Niger (Mali), *Cahiers Agricultures* **9** (6): 485-503.

Callaghan, O., (1996). *Land use: the interaction of economics, ecology & hydrology*. London: Chapman & Hall.

Chant, L., M. Sghaier, H. Jeder, P. Reidsma, S. Makokha, L. Chen, L. Gachimbi, S. Purushothaman, S. Patil, S. Kashyap, I. Bezlepkina, S. Feng, X. Shi, F. Qu, Y. Cissé, M. Bonin, U. Suarma, F. Nur Mohammad, H. König, S. Rodrigues-Filho, D. Lindoso, N. Debortoli, F. Bakker, and M.

Støen, (2009). D6.1 Review of Modelling Tools and their Applicability to the Seven Case Studies. LUPIS project, EU 6th Framework Programme, contract no. 36955, www.lupis.eu.

Chen, L., P. Gicheru, H. J. Koenig, and S. Makokha, (2011). D8.2 Assessment of the impact of selected land use related policy(ies) on sustainable development and critical factors of its implementation in the case study of Kenya. LUPIS project, EU 6th Framework Programme, contract no. 36955, www.lupis.eu PU.

Cissé, Y., M. Bonin, I. Nesheim, J. P. Tonneau, and R. Verburg, (forthcoming). Land Degradation in the Office du Noger Irrigation Scheme, Mali. In *Land Use Policies for Sustainable Development: Exploring Integrated Assessment Methods*, D. McNeill, Nesheim, I., Brouwer, F. (ed.): Edward Elgar Publishing.

Cissé, Y., F. Bousquet, and J. P. Tonneau, (2011). D11.2 Assessment of the impact of selected land use related policy(ies) on sustainable development and critical factors of its implementation in the case study of Mali. LUPIS project, EU 6th Framework Programme, contract no. 36955, www.lupis.eu PU.

Dawe, D., (2001). How far down the path to free trade? The importance of rice price stabilization in developing Asia, *Food Policy* **26** (2): 163-175.

Dilly, O. and D. Pannell, (2009). Sustainability impact assessment and land-use policies for sensitive regions, *Environmental Science & Policy* **12** (8): 1075-1076.

Dinda, S., (2004). Environmental Kuznets curve hypothesis. A survey, *Ecological Economics* **49**: 431-455.

Eastman, J. R., (2003). IDRISI Kilimanjaro. Guide to GIS and Image Processing. Manual Version 14.00. Clark Labs, Clark University, Worcester, USA.

EC, (2005). Impact Assessment Guidelines, SEC 2005(791), http://ec.europa.eu/governance/impact/docs/SEC2005_791_IA%20guidelines_annexes.pdf.

EC, (2009). Impact Assessment Guidelines. 15 January 2009, SEC(2009) 92. 51, European Commission.

Ewert, F., M. K. van Ittersum, I. Bezlepkina, O. Therond, E. Andersen, H. Belhouchette, C. Bockstaller, F. Brouwer, T. Heckelei, S. Janssen, R. Knapen, M. Kuiper, K. Louhichi, J. A. Olsson, N. Turpin, J. Wery, J. E. Wien, and J. Wolf, (2009). A methodology for enhanced flexibility of integrated assessment in agriculture, *Environmental Science and Policy* **12**: 546-561.

Ewert, F., M. K. van Ittersum, T. Heckelei, O. Therond, I. Bezlepkina, and E. Andersen, (2011). Scale changes and model linking methods for integrated assessment of agri-environmental systems, *Agriculture, Ecosystems & Environment* **142** (1-2): 6-17.

Fan, S., A. Gulati, and S. Thorat, (2008). Investment, subsidies, and pro-poor growth in rural India, *Agricultural Economics* **39** (2): 163-170.

Faturohman, D. Wicaksono, M. Setiyadi, and L. Syahbudin, (2004). Dimanika Kependudukan dan Kebijakan. Centre for Population and Policy Studies, Yogyakarta.

Fearnside, P. M., C. A. Righi, P. M. L. A. Graça, E. W. H. Keizer, C. C. Cerri, E. M. Nogueira, and R. I. Barbosa, (2010). Biomass and greenhouse-gas emissions from land-use change in Brazil's Amazonian "arc of deforestation": The states of Mato Grosso and Rondônia, *Forest Ecology and Management* **258** (9): 1968-1978.

Feng, S., P. Reidsma, X. Luo, and F. Qu, (2011). D10.2 Assessment of the impact of selected land use related policy(ies) on sustainable development and critical factors of its implementation in the case study of China. LUPIS project, EU 6th Framework Programme, contract no. 36955, www.lupis.eu PU.

Feng, S., X. Shi, P. Reidsma, X. Ma, and F. Futian Qu, (forthcoming). Agricultural Non Point Source Pollution in Taihau Lake Basin, China In *Land Use Policies for Sustainable Development: Exploring Integrated Assessment Methods*, D. McNeill, Nesheim, I., Brouwer, F. (ed.): Edward Elgar Publishing.

Folke, C., S. Carpenter, T. Elmqvist, L. Gunderson, C. S. Holling, and B. Walker, (2002). Resilience and sustainable development: Building adaptive capacity in a world of transformations, *Ambio* **31**: 437-440.

Fürst, C., M. Volk, and F. Makeschin, (in press). Squaring the Circle? Combining Models, Indicators, Experts and End-Users in Integrated Land-Use Management Support Tools, *Environmental Management*: 1-5.

Galeottia, M., A. Lanza, and F. Pauli, (2006). Reassessing the environmental Kuznets curve for CO2 emissions: A robustness exercise, *Ecological Economics* **57**: 152-163.

Geist, H. J. and E. F. Lambin, (2001). What Drives Tropical Deforestation? A meta-analysis for proximate and underlying causes of deforestation based on subnational case study evidence. LUCC Report Series no. 4.

Gicheru, P., S. Makokha, L. Chen, L. Gachimbi, and J. Wamuongo, (forthcoming). Land Subdivision and Degradation in Narock, Kenya. In *Land Use Policies for Sustainable Development: Exploring Integrated Assessment Methods*, D. McNeill, Nesheim, I., Brouwer, F. (ed.): Edward Elgar Publishing.

Giller, K. E., C. Leeuwis, J. A. Andersson, W. Andriesse, A. Brouwer, P. Frost, P. Hebinck, I. Heitkönig, M. K. Van Ittersum, N. Koning, R. Ruben, M. Slingerland, H. Udo, T. Veldkamp, C. Van de Vijver, M. T. Van Wijk, and P. Windmeijer, (2008). Competing claims on natural resources: What role for science?, *Ecology and Society* **13(2)**: 34.

Glendining, M. J., A. G. Dailey, A. G. Williams, F. K. v. Evert, K. W. T. Goulding, and A. P. Whitmore, (2009). Is it possible to increase the sustainability of arable and ruminant agriculture by reducing inputs?, *Agricultural Systems* **99** (2-3): 117-125.

Grossmann, G. M. and A. B. Krueger, (1991). Environmental impacts of a North American free trade agreement. NBER Working papers National Bureau of Economic Research, Cambridge.

Haberl, H., M. Wackernagel, and T. Wrbka, (2004). Land use and sustainability indicators. An introduction, *Land Use Policy* **21** (3): 193-198.

Helming, K. and M. Perez-Soba, (in press). Landscape Scenarios and Multifunctionality – Making Land Use Assessment Operational in Ecology and Society Special Feature Vol. 15.

Helming, K., M. Perez-Soba, and P. Tabbush (Eds). (2008a), Sustainability impact assessment of land use changes 507. Berlin: Springer.

Helming, K., M. Pérez-Soba, and P. Tabbush (Eds). (2008b), Sustainability Impact Assessment of Land Use Changes. Berlin, Germany: Springer.

Helming, K., K. Tscherning, B. König, S. Sieber, H. Wiggering, T. Kuhlman, D. Wascher, M. Perez-Soba, P. Smeets, P. Tabbush, O. Dilly, R. Hüttl, and H. Bach, (2008c). Ex ante assessment of land use changes in European regions - the SENSOR approach In *Sustainability Impact Assessment of Land Use Changes*, K. Helming and M. Pérez-Soba and P. Tabbush (eds.) Pp. 77-105. Berlin: Springer.

Houet, T., P. Verburg, and T. Loveland, (2010). Monitoring and modelling landscape dynamics, *Landscape Ecology* **25** (2): 163-167.

Howitt, R. E., (1995). Positive Mathematical Programming, *American Journal of Agricultural Economics* **77** (2): 329-342.

IDRISI, (2011). IDRISI software (http://www.clarklabs.org/products/index.cfm).

Imbernon, J., V. Bonnal, and F. Chouikhi, (2011). D5.4 Implementation of a partner's operative data base and information system. LUPIS project, EU 6th Framework Programme, contract no. 36955, www.lupis.eu RE.

Imbernon, J., V. Bonnal, Y. van Randen, and J. Bridon, D5.3 Implementation of the main operative data base and information system. LUPIS project, EU 6th Framework Programme, contract no. 36955, www.lupis.eu RE.

INDI-LINK, (2010). Indicator-based evaluation of interlinkages between different sustainable development objectives (www.indi-link.net) (http://www.indi-link.net/, accessed

Jacob, K., J. Hertin, P. Hjerp, C. Radaelli, A. Meuwese, O. Wolf, C. Pacchi, and K. Rennings, (2008). Improving the practice of impact assessment.

Janssen, B. H., F. C. T. Guiking, D. van der Eijk, E. M. A. Smaling, J. Wolf, and H. van Reuler, (1990). A system for quantitative evaluation of the fertility of tropical soils (QUEFTS), *Geoderma* **46** (4): 299-318.

Jeromi, P. D., (2007). Farmers' indebtedness and suicides: impact of agricultural trade liberalisation in Kerala, *Economic and Political Weekly* **42** (31): 3241-3247.

Kanellopoulos, A., P. B. M. Berentsen, T. Heckelei, M. K. van Ittersum, and A. G. J. M. Oude Lansink, (2010). Assessing the forecasting performance of a generic bio-economic farm model calibrated with two different PMP variants, *Journal of Agricultural Economics* **61** (2): 274-294.

Kasperczyk, N. and K. Knickel, (2006). Sustainability A-Test. Advanced Techniques for Evaluation of Sustainability Assessment Tools. Institute for Environmental Studies (IVM), Amsterdam, 52.

Kates, R. W., W. C. Clark, R. Corell, J. M. Hall, C. C. Jaeger, I. Lowe, J. J. McCarthy, H. J. Schellnhuber, B. Bolin, N. M. Dickson, S. Faucheux, G. C. Gallopin, A. Grübler, B. Huntley, J. Jäger, N. S. Jodha, R. E. Kasperson, A. Mabogunje, P. Matson, H. Mooney, B. Moore III, T. O'Riordan, and U. Svedin, (2001). Environment and development: Sustainability science, *Science* **292** (5517): 641-642.

Kohsaka, R., (2010). Developing biodiversity indicators for cities: applying the DPSIR model to Nagoya and integrating social and ecological aspects, *Ecological Research* **25** (5): 925-936.

Kok, K., P. H. Verburg, and T. Veldkamp, (2007). Integrated Assessment of the land system: The future of land use, *Land Use Policy* **24** (3): 517-520.

König, H., S. Purushothaman, U. Suarma, S. Makokha, M. Sghaier, L. Zheng, J. Schuler, L. Chen, K. Helming, S. Uthes, J. Morris, F. Brouwer, and H. Wiggering, (in review). Participatory impact assessment of land use policies: a cross-country comparison of five cases using the FoPIA approach, *Land Use Policy*.

König, H., S. Rodrigues-Filho, S. Purushothaman, P. Reidsma, I. Bezlepkina, I. Nesheim, K. Helming, and S. Sieber, (2008). D4.3.2 Definition of SIAT causal chain relationships between policies, land use changes and sustainability impacts. LUPIS project, EU 6th Framework Programme, contract no. 36955, www.lupis.eu RE.

König, J. H., J. Schuler, U. Suarma, D. McNeill, J. Imbernon, D. F., S. A. Dalimunthe, S. Uthes, J. Sartohadi, K. Helming, and J. Morris, (2010). Assessing the impacts of land use plicy on uban-rural sustainability using the FoPIA approach in Yogyakarta, Indonesia, *Sustainability* **2**: 1991-2009.

Koomen, E., P. Rietveld, and T. Nijs, (2008). Modelling land-use change for spatial planning support, *Annals of Regional Science* **42** (1): 1-10.

Landais, E., J. P. Deffontaines, and M. Benoit, (1988). Les pratiques des agriculteurs. Point de vue sur un courant de la recherche agronomique, *Etudes rurales* **109**: 125-158.

Le Page, C., F. Bousquet, I. Bakam, A. Bah, and C. Baron, (unknown). CORMAS : A multiagent simulation toolkit to model natural and social dynamics at multiple scales (http://cormas.cirad.fr/pdf/cormasw.pdf).

Lebel, L., J. M. Anderies, B. Campbell, C. Folke, S. Hatfield-Dodds, T. P. Hughes, and J. Wilson, (2006). Governance and the capacity to manage resilience in regional social-ecological systems, *Ecology and Society* **11 (1)**: 19.

Lindner, M., T. Suominen, T. Palosuo, J. Garcia-Gonzalo, P. Verweij, S. Zudin, and R. Päivinen, (2010). ToSIA--A tool for sustainability impact assessment of forest-wood-chains, *Ecological Modelling* **221** (18): 2197-2205.

Louhichi, K., A. Kanellopoulos, S. Janssen, G. Flichman, M. Blanco, H. Hengsdijk, T. Heckelei, P. Berentsen, A. Oude Lansink, and M. K. Van Ittersum, (2010a). FSSIM, a bio-economic farm model for simulating the response of EU farming systems to agricultural and environmental policies, *Agricultural Systems* **103** (8): 585-597.

Louhichi, K., J. S., A. Kanellopoulos, H. Li, N. Borkowski, G. Flichman, H. Hengsdijk, P. Zander, M. Blanco Fonseca, G. Stokstad, I. N. Athanasiadis, A. Rizzoli, D. Huber, T. Heckelei, and M. Van Ittersum, (2010b). A Generic Farming System Simulator. In *Environmental and* *agricultural modelling. Integrated approaches for policy impact assessment*, F. M. Brouwer and M. Van Ittersum (eds.) Pp. 109-132. Berlin: Springer.

Mander, Ü. and E. Uuemaa, (2010). Landscape assessment for sustainable planning, *Ecological Indicators* **10** (1): 1-3.

MAPA, M. d. A., Pecuária e Agricultura, (2009). (www.mapa.gov.br, accessed: December 17 2009).

Marwasta, D., (2010). Yogyakarta urban growth versus smart growth : Towards Yogyakarta slow city proposal. Seminar On " To Solve Social Problem Trough Art and Cultural Activities", Urban Research Plaza Yogyakarta Sub-Center, Yogyakarta.

McCracken, D. I. and E. M. Bignal, (1998). Applying the results of ecological studies to land-use policies and practices, *Journal of Applied Ecology* **35** (6): 961-967.

McNeill, D., F. Brouwer, and I. Nesheim (Eds). (2011), Land Use Policies for Sustainable Development: Exploring Integrated Assessment Tools. Cheltenham: Edward Elgar Publishing Ltd.

McNeill, D., R. Verburg, and M. Bursztyn, (forthcoming). Institutional Context for Sustainable Development. In *Land Use Policies for Sustainable Development: Exploring Integrated Assessment Methods*, D. McNeill, Nesheim, I., Brouwer, F. (ed.): Edward Elgar Publishing.

Ministère de l'Environnement et de l'Aménagement du Territoire MEAT, (1998). Plan d'action national de lute contre la désertification. Tunis.

Mooney, H., A. Cropper, and W. Reid, (2005). Confronting the human dilemma, *Nature* **434** (7033): 561-562.

Morris, J., P. Tabbush, S. Moncada, M. Camilleri, Z. Imrichova, F. Farrington, O. Dilly, C. Doerrie, T. Stuczynski, R. Korzeniowska, G. Siebielec, P. Koza, A. Lopatka, R. Pudelko, M. Kowalik, Z. Izakovicova, P. Kenderessy, T. Oja, A. Kull, and Ü. Mander, (2009). D7.4.2 / D6.3.2 - Final report on stakeholder-inclusive SIAT validation. , SENSOR, EU 6th Framework Programme.

Nesheim, I., D. McNeill, I. Bezlepkina, F. Brouwer, Y. Cissé, S. Feng, P. Gicheru, N. Novira, P. Purushothaman, S. Rodrigues-Filho, and M. Sghaier, (forthcoming). Lessons from a Comparative Analysis of Case Studies. In *Land Use Policies for Sustainable Development: Exploring Integrated Assessment Methods*, D. McNeill, Nesheim, I., Brouwer, F. (ed.): Edward Elgar Publishing.

Nesheim, I., P. Reidsma, I. Bezlepkina, R. Verburg, M. A. Abdeladhim, M. Bursztyn, L. Chen, Y. Cissé, S. Feng, P. Gicheru, H. König, N. Novira, S. Purushothaman, S. Rodrigues-Filho, and M. Sghaier, (in review). Analyzing causal chains and policy trade offs for sustainable development: experience from seven countries in the south, *Land Use Policy*.

Ness, B., S. Anderberg, and L. Olsson, (2010). Structuring problems in sustainability science: The multi-level DPSIR framework, *Geoforum* **41** (3): 479-488.

Nilsson, K., T. S. Nielsen, and S. Pauleit, (2009). Integrated European research on sustainable urban development and periurban land use relationships, *Urbanistica* **138**: 106-109.

Novira, N., S. Aini, Dalimunthe, N. I. S. Dewi, T. S. Rahayu, A. P. Wicaksono, H. König, and J. Schuler, (forthcoming). Pressure on Land in the Yogyakarta Region, Indonisia. In *Land Use Policies for Sustainable Development: Exploring Integrated Assessment Methods*, D. McNeill, Nesheim, I., Brouwer, F. (ed.): Edward Elgar Publishing.

Novira, N., H. König, S. A. Dalimunthe, F. Damayanti, N. I. S. Dewi, T. S. Rahayu, and J. Sartohadi, (2011). D12.2 Assessment of the impact of selected land use related policies on sustainable development and critical factors of its implementation in the case study of Indonesia. LUPIS project, EU 6th Framework Programme, contract no. 36955, www.lupis.eu PU.

OECD, (1993). Core Set of Indicators for Environmental Performance Reviews. Environmental Monographs 83, Paris.

Pagiola, S., (1996). Price policy and returns to soil conservation in semi-arid Kenya, *Environmental and Resource Economics* **8** (3): 255-271.

Pahl-Wostl, C., M. Craps, A. Dewulf, E. Mostert, D. Tabara, and T. Taillieu, (2007). Social learning and water resources management, *Ecology and Society* **12 (2)**: 5.

Panayotou, T., (1994). Conservation of biodiversity and economic development: The concept of transferable development rights, *Environmental & Resource Economics* **4** (1): 91-110.

Paracchini, M. L., C. Pacini, M. L. M. Jones, and M. Pérez-Soba, (2011). An aggregation framework to link indicators associated with multifunctional land use to the stakeholder evaluation of policy options, *Ecological Indicators* **11** (1): 71-80.

Pearce, D. W. and G. Atkinson, (1995). Measuring sustainable development. In *The handbook of Environmental Economics,* D. W. Bromley (ed.) Pp. 166-181. Oxford: Blackwell.

Pérez-Soba, M., S. Petit, L. Jones, N. Bertrand, V. Briquel, L. Omodei-Zorini, C. Contini, K. Helming, J. Farrington, M. Tinacci Mossello, D. Wascher, F. Kienast, and D. de Groot, (2008). Land use functions – a multifunctionality approach to assess the impact of land use change on land use sustainability. In *Sustainability impact assessment of land use changes*, K. Helming and P. Tabbush and M. Pérez-Soba (eds.) Pp. 375-404. Berlin: Springer.

Perman, R. and D. I. Stern, (2003). Evidence from panel unit root and cointegration tests that the Environmental Kuznets curve does not exist, *Australian Journal of Agricultural and Resource Economics* **47**: 325-347.

Petit, S. and P. Frederiksen, (2010). Modelling land use change impacts for sustainability assessment

Ecological Indicators **doi:10.1016/j.physletb.2003.10.071**.

Petit, S., F. P. Vinther, P. J. Verkerk, L. G. Firbank, N. Halberg, T. Dalgaard, C. Kjeldsen, M. Lindsen, and S. Zudin, (2008). Indicators for assessing the environmental impacts of land use change across Europe. In *Sustainability Impact Assessment of Land Use Changes*, K. Helming and M. Pérez-Soba and P. Tabbush (eds.) Pp. 305-324. Berlin: Springer.

Pingali, S., (1989).*Adaptative window flow control in ISDN frame relay networks*. Clemson University.

Piorr, A., F. Ungaro, A. Ciancaglini, K. Happe, A. Sahrbacher, C. Sattler, S. Uthes, and P. Zander, (2009). Integrated assessment of future CAP policies: land use changes, spatial patterns and targeting, *Environmental Science & Policy* **12** (8): 1122-1136.

Ponsioen, T. C., H. Hengsdijk, J. Wolf, M. K. Van Ittersum, R. P. Roetter, T. T. Son, and A. G. Laborte, (2006). TechnoGIN, a tool for exploring and evaluating resource use efficiency of cropping systems in East and Southeast Asia, *Agricultural Systems* **87** (1): 80-100.

Ponsioen, T. C., A. G. Laborte, R. P. Roetter, H. Hengsdijk, and J. Wolf, (2003). TechnogGIN-3: a technical coefficient generator for cropping systems in East and Southeast Asia. Quantitative Approaches to Systems Analysis No. 26, Wageningen, The Netherlands.

Prato, T., (2007). Evaluating land use plans under uncertainty, *Land Use Policy* **24** (1): 165-174.

Pugh, C., (1996). Methodology, political economy and economics in land studies for developing countries, *Land Use Policy* **13** (3): 165-179.

Purushothaman, S., S. Patil, and I. Francis, (2011). D9.2 Implementation of assessment of the impact of selected land use related policy(ies) on sustainable development and critical factors of its implementation in the case study of India. LUPIS project, EU 6th Framework Programme, contract no. 36955, www.lupis.eu PU.

Purushothaman, S., S. Patil, and S. Kashyap, (forthcoming). Agrarian Crisis and Policy Links: a Framework for Karnataka, India. In *Land Use Policies for Sustainable Development: Exploring Integrated Assessment Methods*, D. McNeill, Nesheim, I., Brouwer, F. (ed.): Edward Elgar Publishing.

Rajabifard, A., I. Williamson, D. Steudler, A. Binns, and M. King, (2007). Assessing the worldwide comparison of cadastral systems, *Land Use Policy* **24** (1): 275-288.

Redclift, M., (1992). The meaning of sustainable development, *Geoforum* **23** (3): 395-403.

Reidsma, P., H. König, S. Feng, I. Bezlepkina, I. Nesheim, M. Bonin, M. Sghaier, S. Purushothaman, S. Sieber, M. K. van Ittersum, and F. Brouwer, (2011). Methods and tools for integrated assessment of land use policies on sustainable development in developing countries, *Land Use Policy* **28** (3): 604-617.

Reidsma, P., H. König, S. Feng, I. Bezlepkina, R. Verburg, M. van Ittersum, H. van Keulen, F. Ewert, I. Nesheim, D. McNeill, M. Kuiper, M. Bonin, S. Sieber, K. Tscherning, K. Helming, and F. Brouwer, (2009). D4.1 Methodological framework for the complementary use of mainly SENSOR and SEAMLESS approaches for sustainability impact assessment of land use policies in developing countries. LUPIS project, EU 6th Framework Programme, contract no. 36955, www.lupis.eu PU.

Reidsma, P., H. König, S. Feng, I. Bezlepkina, R. Verburg, M. K. Van Ittersum, H. Van Keulen, F. Ewert, I. Nesheim, D. McNeill, M. Kuiper, M. Bonin, S. Sieber, K. Tscherning, K. Helming, and F. Brouwer, (2008a). D4.1 - Methodological framework for the complementary use of mainly SENSOR and SEAMLESS approaches for sustainability impact assessment of land use policies in developing countries. LUPIS, EU 6th Framework Programme (www.lupis.eu).

Reidsma, P., T. Tekelenburg, M. Van den Berg, and J. R. M. Alkemade, (2006). Impacts of land-use change on biodiversity: an assessment of agricultural biodiversity in the European Union, *Agriculture, Ecosystems & Environment* **114**: 86-102.

Reidsma, P., M. van Ittersum, H. van Keulen, and S. Feng, (2008b). D4.4.1 Procedures for assessing agro-ecological relationships and quantifying alternative production systems. LUPIS project, EU 6th Framework Programme, contract no. 36955, www.lupis.eu RE.

Renn, O., (2006). Participatory processes for designing environmental policies, *Land Use Policy* **23** (1): 34-43.

Robinson, J., (2002). Squaring the circle: on the very idea of sustainable development. In *Sustainable development: mandate or mantra?*, W. Chesworth and M. Moss and V. Thomas (eds.): Faculty of Environmental Studies, University of Guelph.

Roca, Z. and M. D. Oliveira-Roca, (2007). Affirmation of territorial identity: A development policy issue, *Land Use Policy* **24** (2): 434-442.

Rodrigues-Filho, S., M. Bursztyn, D. Lindoso, N. Debortoli, I. Nesheim, and R. Verburg, (forthcoming). Road Development and Deforestation in Amazonia, Brazil. In *Land Use Policies for Sustainable Development: Exploring Integrated Assessment Methods*, D. McNeill, Nesheim, I., Brouwer, F. (ed.): Edward Elgar Publishing.

Rodrigues Filho, S., R. Verburg, M. Bursztyn, D. Lindoso, N. Debortoli, G. Litre, I. Nesheim, and D. McNeil, (2011). D13.2 Assessment of the impact of selected land use related policy(ies) on sustainable development and critical factors of its implementation in the case study of Brazil. LUPIS project, EU 6th Framework Programme, contract no. 36955, www.lupis.eu PU.

Roetter, R. P., C. T. Hoanh, A. G. Laborte, H. Van Keulen, M. K. Van Ittersum, C. Dreiser, C. A. Van Diepen, N. De Ridder, and H. H. Van Laar, (2005). Integration of Systems Network (SysNet) tools for regional land use scenario analysis in Asia, *Environmental Modelling and Software* **20** (3): 291-307.

Rohm, O. and S. Dabbert, (2003). Integrating agri-environmental programs into regional production models: an extension of positive mathematical programming, *American Journal of Agricultural Economics* **85** (1): 254-265.

Rosegrant, M. W., T. B. Sulser, C. Ringler, S. A. Cline, and S. Msangi (2005). International Model for Policy analysis of Agricultural Commodities and Trade (IMPACT): Distributed Version 1.0., International Food Policy Research Institute, Environment and Production Technology Division, Washington, D.C.

Rotmans, J., (1998). Methods for IA: The challenges and opportunities ahead, *Environmental Modeling and Assessment* **3** (3): 155-179.

Rounsevell, M. D. A., T. P. Dawson, and P. A. Harrison, (2010). A conceptual framework to assess the effects of environmental change on ecosystem services, *Biodiversity and Conservation* **19** (10): 2823-2842.

Schößer, B., K. Helming, and H. Wiggering, (2010). Assessing Land Use Change Impacts – a comparison of the SENSOR Land Use Function approach with other frameworks, *Journal of Land Use Science* **5**: 159-178.

Schröter, D., W. Cramer, R. Leemans, I. C. Prentice, M. B. Araújo, N. W. Arnell, A. Bondeau, H. Bugmann, T. R. Carter, C. A. Gracia, A. C. De La Vega-Leinert, M. Erhard, F. Ewert, M. Glendining, J. I. House, S. Kankaanpää, R. J. T. Klein, S. Lavorel, M. Lindner, M. J. Metzger, J. Meyer, T. D. Mitchell, I. Reginster, M. Rounsevell, S. SabatÃ©, S. Sitch, B. Smith, J. Smith, P. Smith, M. T. Sykes, K. Thonicke, W. Thuiller, G. Tuck, S. Zaehle, and B. Zierl, (2005). Ecology: Ecosystem service supply and vulnerability to global change in Europe, *Science* **310** (5752): 1333-1337.

Serneels, S. and E. F. Lambin, (2001). Proximate causes of land-use change in Narok district, Kenya: A spatial statistical model, *Agriculture, Ecosystems and Environment* **85** (1-3): 65-81.

Sghaier, M., A. M. Abdeladhim, J. P. Tonneau, J. Imbernon, N. Ounalli, J. Houcine, R. Bechir, F. Chouikhi, L. Chant, H. Koenig, J. Schuler, and V. Bonnal, (2011). D7.2 Assessment of the impact of selected land use related policies on sustainable development, and critical factors of its implementation, in the case study of Tunisia. LUPIS project, EU 6th Framework Programme, contract no. 36955, www.lupis.eu PU.

Sghaier, M., M. Abdeladhim, J.-P. Tonneau, N. Ounalli, H. Djeder, and M. Bonin, (forthcoming). Land Degradation in the Arid Jeffara Region, Tunisia. In *Land Use Policies for Sustainable Development: Exploring Integrated Assessment Methods*, D. McNeill, Nesheim, I., Brouwer, F. (ed.): Edward Elgar Publishing.

Shroff, S., (2008). Agrarian distress and farmers' suicide in India: Focus on Maharashtra, *The India Economic Review* **5**: 204-209.

Sieber, S., K. Müller, P. Verweij, H. Haraldsson, K. Fricke, C. Pacini, K. Tscherning, K. Helming, and T. Jansson, (2008). Transfer into decision support: The sustainability impact assessment tool. In *Sustainability impact assessment of land use changes*, K. Helming and M. Pérez-Soba and P. Tabbush (eds.) Pp. 108-128. Berlin: Springer.

Sieber, S. and I. Pérez Domínguez, (2010). Decision Support for Impact Assessment of Agrifood Policies in Europe: Methods, Tools and Applications, *Journal of Policy Modelling*.

Sieber, S. and I. Pérez Domínguez, (in press). Decision Support for Impact Assessment of Agrifood Policies in Europe: Methods, Tools and Applications, *Journal of Policy Modelling*.

Sieber, S., P. Zander, P. H. Verburg, and M. Van Ittersum, (2010). Model-based systems to support impact assessment--Methods, tools and applications, *Ecological Modelling* **221** (18): 2133-2135.

Smeets, E. and R. Weterings, (1999). Environmental indicators: typology and overview. Report nr. 25., European Environmental Agency (EAA), Copenhagen, Denmark.

Sterk, B., M. K. van Ittersum, and C. Leeuwis, (2011). How, when, and for what reasons does land use modelling contribute to societal problem solving?, *Environmental Modelling and Software*. **In Press. DOI: 10.1016/j.envsoft.2010.06.004**.

Stern, D. I., M. S. Common, and E. B. Barbier, (1996). Economic growth and environmental degradation: The environmental Kuznets curve and sustainable development, *World Development* **24** (7): 1151- 1160.

Steudler, D., A. Rajabifard, and I. P. Williamson, (2004). Evaluation of land administration systems, *Land Use Policy* **21** (4): 371-380.

Stirling, A., (2006). Analysis, participation and power: justification and closure in participatory multi-criteria analysis, *Land Use Policy* **23** (1): 95-107.

Stöckle, C. O., M. Donatelli, and R. Nelson, (2003). CropSyst, a cropping systems simulation model, *European Journal of Agronomy* **18** (3-4): 289-307.

Thiel, A., (2009). The use of ex-ante modelling tools in European Impact Assessment: What role does land use play?, *Land Use Policy* **26** (4): 1138-1148.

Tittonell, P., M. T. van Wijk, M. Herrero, M. C. Rufino, N. de Ridder, and K. E. Giller, (2009). Beyond resource constraints - Exploring the biophysical feasibility of options for the intensification of smallholder crop-livestock systems in Vihiga district, Kenya, *Agricultural Systems* **101**: 1-19.

Tscherning, K., H. König, B. Schösser, K. Helming, and S. Sieber, (2008). Ex-ante Impact Assessments (IA) in the European Commission – an overview. In *Sustainability Impact Assessment of Land Use Changes*, K. Helming and M. Pérez-Soba and P. Tabbush (eds.) 8-33. Berlin, Germany: Springer.

UN, (2003). Integrated Environmental and Economic Accounting. United Nations, European Commission, International Monetary Fund, OECD and World Bank, New York.

UNWCED, (1987). Our common future. Brundtland Report

Van den Berg, M. M., H. Hengsdijk, J. Wolf, M. K. Van Ittersum, W. Guanghuo, and R. P. Roetter, (2007). The impact of increasing farm size and mechanization on rural income and rice production in Zhejiang province, China, *Agricultural Systems* **94** (3): 841-850.

Van Ittersum, M. K. and F. Brouwer, (2009). Integrated assessment of agricultural and environmental policies--concepts and tools, *Environmental Science & Policy* **12** (5): 543-545.

Van Ittersum, M. K., F. Ewert, T. Heckelei, J. Wery, J. Alkan Olsson, E. Andersen, I. Bezlepkina, S. Brogaard, M. Donatelli, G. Flichman, L. Olsson, A. Rizzoli, T. van der Wal, J. E. Wien, and J. Wolf, (2008a). Integrated assessment of agricultural systems – A component-based framework for the European Union (SEAMLESS), *Agricultural Systems* **96**: 150-165.

Van Ittersum, M. K., F. Ewert, T. Heckelei, J. Wery, J. Alkan Olsson, E. Andersen, I. Bezlepkina, F. Brouwer, M. Donatelli, G. Flichman, L. Olsson, A. E. Rizzoli, T. van der Wal, J. E. Wien, and J. Wolf, (2008b). Integrated assessment of agricultural systems - A component-based framework for the European Union (SEAMLESS), *Agricultural Systems* **96** (1-3): 150-165.

Van Ittersum, M. K., R. Rabbinge, and H. C. van Latesteijn, (1998). Exploratory land use studies and their role in strategic policy making, *Agricultural Systems* **58** (3): 309-330.

Van Paassen, A., R. P. Roetter, H. Van Keulen, and C. T. Hoanh, (2007). Can computer models stimulate learning about sustainable land use? Experience with LUPAS in the humid (sub-) tropics of Asia, *Agricultural Systems* **94** (3): 874-887.

Verburg, P. H., B. Eickhout, and H. Meijl, (2008a). A multi-scale, multi-model approach for analyzing the future dynamics of European land use, *Annals of Regional Science* **42** (1): 57-77.

Verburg, P. H. and A. Veldkamp, (2005). Introduction to the Special Issue on Spatial modeling to explore land use dynamics, *International Journal of Geographical Information Science* **19** (2): 99-102.

Verburg, P. H., A. Veldkamp, and M. D. A. Rounsevell, (2006). Scenario-based studies of future land use in Europe, *Agriculture, Ecosystems & Environment* **114** (1): 1-6.

Verburg, R., I. Bezlepkina, D. McNeill, M. Bonin, S. Sieber, P. Reidsma, L. Gcahimbi, P. Gicheru, M. Sghaier, S. Feng, S. Purushothaman, W. Widyatmanti, J. Sartohadi, and S. Rodrigues, (2008b). D2.3 - Defining sustainable development in the context of LUPIS. LUPIS integrated project, EU 6th Framework Programme (www.lupis.eu).

Vink, A. P. A., (1983). *Landscape ecology and land use*. pp. 264. London: Longman Group Limited.

von Braun, J., A. Ahmed, K. Asenso-Okyere, S. Fan, A. Gulati, R. Hoddinott, J. Pandya-Lorch, M. W. Rosegrant, M. Ruel, M. Torero, T. van Rheenen, and K. von Grebmer, (2008). High food prices: The what, who, and how of proposed policy actions. IFPRI Policy Brief, International Food Policy Research Institute, Washington, DC.

Wackernagel, M. and W. Rees, (1996). *Our Ecological Footprint: Reducing Human Impact on the Earth*. 128. Gabriola Island, BC and Philadelphia, PA: New Society Publishers.

Weaver, P. M. and J. Rotmans, (2006). Integrated sustainability assessment. What? Why? How? MATISSE Working papers 1, MATISSE EU 6th FP.

Witt, C., A. Dobermann, S. Abdulrachman, H. C. Gines, W. Guanghuo, R. Nagarajan, S. Satawatananont, T. Thuc Son, P. Sy Tan, L. Van Tiem, G. C. Simbahan, and D. C. Olk, (1999). Internal nutrient efficiencies of irrigated lowland rice in tropical and subtropical Asia, *Field Crops Research* **63** (2): 113-138.

Wood, D. and J. M. Lenne, (2005). 'Received Wisdom' in agricultural land use policy: 10 years on from Rio, *Land Use Policy* **22** (2): 75-93.

Yang, G. and D. Wang (Eds). (2003), Economic development, water environment and water disaster in Taihu Lake Basins. Beijing: Science Press.

Zhang, W., S. Wang, H. Ji, and H. Kolbe, (2004). Estimation of agricultural non-point source pollution in China and the alleviating strategies I. Estimation of agricultural non-point source pollution in China in early 21 century, *Scientia Agricultura Sinica* **37** (7): 1008-1017.