Climate change in Mali and Brazil

Towards an evaluation method of climate change and land use policies

René Verburg
Le Chen
Youssouf Cissé (Institut d'Economie Rurale, Mali)
Saulo Rodrigues Filho (Fundação Universidade de Brasilia, Brazil)
Bamoye Keita (Institut d'Economie Rurale, Mali)
Diego Lindoso (Fundação Universidade de Brasilia, Brazil)
Mamadou Demba Traore (Institut d'Economie Rurale, Mali)
Catherine Gucciardi (Fundação Universidade de Brasilia, Brazil)
Adama Tiémoko Diarra (Institut d'Economie Rurale, Mali)
Nathan Debortoli (Fundação Universidade de Brasilia, Brazil)

Report 2009-060
August 2009
Project code 21089
LEI Wageningen UR, The Hague

LEI Wageningen UR conducts research in the following areas:

- International policy
- Development issues
- Consumers and supply chains
- Sectors and enterprises
- Environment, nature and landscape
- Rural economy and use of space

This report is part of the research area Environment, nature and landscape.

This research has been carried out within the framework of the Dutch Ministry of Agriculture, Nature and Food Quality's programme Policy-Supporting Research BO-01-004.

Photo: Bert Spiertz/Hollands Hoogte

Climate change in Mali and Brazil; Towards an evaluation method of climate change and land use policies

Verburg, R, L. Chen, Y. Cissé, S.R. Filho, B. Keita, D. Lindoso, M.D. Traore, C. Gucciardi, A.T. Diarra and N. Debortoli

Report 2009-060
ISBN/EAN: 978-90-8615-357-2
Price € 22,50 (including 6% VAT)
108 p., fig., tab., app.

Developing countries are extremely vulnerable to climate change, where droughts have significant impacts on rainfed agriculture and remaining rainforests are under continuous threat caused by a strong and increasing world demand for livestock feed and biofuels. Adaptation strategies that cope with droughts and mitigation strategies that maintain the world's carbon sink in rainforests are needed to reduce current and future vulnerability of climate change. This study analysis sustainable development in two case-study areas - the *Office du Niger* region in Mali that faces recurrent droughts and therefore reduced rice production in the near future and the Mato Grosso (MT) state in Brazil that experience strong deforestation for soy bean production.

Ontwikkelingslanden zijn zeer gevoelig voor klimaatverandering. In deze landen hebben periodes van droogte een grote impact op de regenafhankelijke landbouw en bovendien worden de overgebleven regenwouden voortdurend bedreigd door een sterke en toenemende wereldwijde vraag naar veevoer en biobrandstoffen. Er zijn adaptatiestrategieën nodig om de droogte te bestrijden en mitigatiestrategieën die ervoor zorgen dat de regenwouden als koolstofput voor de wereld blijven dienen om de huidige en toekomstige kwetsbaarheid voor klimaatverandering te verminderen. In deze studie worden duurzame ontwikkelingen in twee casestudiegebieden geanalyseerd: het gebied Office du Niger in Mali, dat steeds opnieuw te maken krijgt met droogte waardoor de rijstproductie in de nabije toekomst zal afnemen, en de staat Mato Grosso in Brazilië, die te maken heeft met sterke ontbossing vanwege de productie van sojabonen.

Orders
+31.70-3358330
publicatie.lei@wur.nl

LEI is ISO 9000 certified.

Contents

Preface

This report describes an evaluation method of adaptation and mitigation policy options towards climate change in developing countries. The method was partly developed in the EU 6th framework project LUPIS, while the climate change dimension of this method was further developed in the project presented in this report. The method was tested in two case studies. In Mali, the Office du Niger region was used to evaluate adaptation options. The researchers from the Institut d'Economie Rurale (IER) provided data and a background report published in part II of the current publication. In Brazil, the Mato Grosso region was used to evaluate mitigation options. The researchers from the Fundação Universidade de Brasilia (FUB) also provided data and a background report published in part II of the current publication.

This research was funded by the Dutch Ministry of Agriculture, Nature and Food Quality (LNV) and carried out in the framework of the Policy-Supporting Research cluster 'Vital rural area' (BO-01-004). We greatly acknowledge Hayo Haanstra of LNV for his support and feedback during this project.

Prof Dr R.B.M. Huirne
Director General LEI Wageningen UR

Summary

The Dutch ministry of Agriculture, Nature and Food Quality (LNV) is responsible for a sound policy contribution of adaptation strategies towards climate change in both national and international context. The relevance of such policies in an international context is found in the fourth IPCC assessment. A key question for the ministry is to develop knowledge by which the possibilities for adaptation in developing countries can be evaluated. Specifically, information is needed on the costs of such adaptation strategies. This report is a first step towards an evaluation of the costs of adaptation towards climate change.

The analysis of sustainable development in developing countries often involves hidden trade-off relations between the different pillars of sustainable development. Policy choices have to be made to maximise development on one side and minimising risk and damage to the other side. Developing countries are extremely vulnerable to climate change. Droughts have significant impacts on the economy of developing countries, since those economies strongly rely on rain fed agriculture. Rainforests in tropical countries are under continuous threat caused by a strong and increasing world demand for livestock feed and biofuels. Rainforest are a strong sink for carbon and the clear-cut of forests will release substantial amounts of CO_2 into the atmosphere. Hence, successful adaptation and mitigation strategies are needed to reduce current and future vulnerability of climate change.

In this study a method was developed to evaluate land-use policies and adaptation and mitigation strategies towards climate change. This method includes an ex ante impact assessment of sustainable development combined with an evaluation and weighting technique in a multi-criteria analysis. The impact assessment is developed in the EU 6th framework project SENSOR and includes Land Use Functions. The weighing of indicators related to these Land Use Functions is an iterative process that can be carried out by local stakeholders and policy makers. Therefore, the method can be applied in case studies and is relevant to stakeholders in developing countries.

The Office du Niger is a major source of rice production in Mali and the area depends substantially on water availability of the Niger River. Predictions on climate change indicate strong negative effects on water availability with lower water levels for rice production. Preliminary results show that among the adaptive strategies of future scenarios the ones with alternative cropping systems score highest in the multi-criteria analysis. The difference between vegetable cropping

and sunflower production is small. The vegetable cropping scenario shows a slightly higher score for land based production in the economic dimension. However, many hidden costs (such as investment in the maintenance of the irrigation system) are not yet taken into account in this study. Further research on investment costs is therefore needed. Recommendations for the Mali case includes a further analysis on the effects of climate change extremes, an evaluation of a likely increase of migration patterns of people from the dry north of the country to the study area and an evaluation of the effects of water use in the study area on international protected wetland systems (RAMSAR) further downstream. Moreover, the suggested adaptation scenarios in this study are in line with the recommendations of the National Action Plan of climate change adaptation (NAPA) to promote less water-demanding crops in agricultural areas.

Due to a road construction in the north of Mato Grosso state in Brazil the rainforests are under threat of local timber activities and expansion of the agricultural frontier by for example the increasing global demand for biofuels. The objectives of this study are to provide a useful method for policy making in the climate change arena. Preliminary results show a clear and strong trade-off relation between the local rural economy and the global targets of mitigation for carbon storage in rainforests. Land use change from forest to soybean production increases local livelihoods but reduces the capacity to mitigate greenhouse gas emissions worldwide. Policy recommendations for Brazil are that effective land-use policies in sustainability for the current situation also need to address environmental effects in the future.

Both case studies show two commonalities: lack of data availability to predict the effects of policy options on the dimensions of sustainable development and the lack of support by stakeholders and (local) policy makers in the evaluation process. The scenarios created with the multi-criteria analysis tool are a strong dialogue bridge towards policies, but it also illustrates clearly the necessity of further analysis in the longer term.

For Mali, the case-study area would highly benefit from a pan-African initiative on the assessments of adaptation strategies to coming droughts. The case study shows that such droughts will have strong impacts on socio-economic issues. The 2009 initiative of the Dutch Ministry of Agriculture in the Policy-Supporting Research cluster 'Vital rural area' brings climate change on the agenda of East African countries. Capacity building of local researchers will help to enrol the sense of urgency to study adaptation options. Consequently, local stakeholders and decision makers should be more involved to meet the institutional dimension in the evaluation.

From the Brazil study case it becomes clear that liberalisation, WTO negotiations and development of an EU Biofuel directive will have strong local effects. The socio-economic dimension will strongly benefit from globalisation but local environmental conditions further deteriorate. On a global scale a trade-off relation can be found between WTO negotiations on trade on one hand and meeting post-Kyoto agreements on the other hand.

Samenvatting

Klimaatverandering in Mali en Brazilië; Naar een evaluatiemethode voor beleid inzake klimaatverandering en landgebruik

Het ministerie van LNV is verantwoordelijk voor een goede beleidsmatige inbreng op zowel nationaal als internationaal niveau in de op te stellen adaptatiestrategie bij klimaatveranderingen. De beleidsrelevantie voor LNV in internationale context ligt bij het IPCC vierde assessment. Relevante vragen voor het ministerie liggen op het vlak van een verkenning van mogelijkheden voor adaptatie in ontwikkelingslanden, het samenbrengen van kennis die hiervoor noodzakelijk is en een overzicht van de mogelijke kosten van adaptatie in ontwikkelingslanden. Dit rapport is een eerste stap in een evaluatie van kosten die gemoeid zijn bij mogelijke adaptatiestrategieën in ontwikkelingslanden.

In een analyse van duurzame ontwikkeling voor ontwikkelingslanden spelen verborgen afruilrelaties tussen de verschillende dimensies van duurzame ontwikkeling een belangrijke rol. Beleidskeuzes zullen gemaakt moeten worden om de ontwikkeling in één dimensie te maximaliseren terwijl tegelijkertijd de schade aan een andere dimensie zo klein mogelijk wordt gehouden. Ontwikkelingslanden zijn zeer gevoelig voor klimaatveranderingen, omdat droogtes een groot effect hebben op de lokale economie. Deze economie is vooral gestoeld op landbouw die sterk afhankelijk is van regenwater. In veel ontwikkelingslanden rond de evenaar worden regenwouden bedreigd door een toename in de vraag naar de productie van veevoeder en bio-energie. De kap van regenwouden heeft echter tot gevolg dat grote hoeveelheden CO_2 in de atmosfeer komen, omdat regenwouden grote hoeveelheden koolstof hebben vastgelegd. De ontwikkeling van succesvolle adaptatie en mitigatiestrategieën zijn nodig om de kwetsbaarheid van ontwikkelingslanden voor klimaatveranderingen te verkleinen.

In dit onderzoek is een methode ontwikkeld om beleid ten aanzien van landgebruik en nieuwe beleidsvormen voor adaptatie en mitigatiemaatregelen voor klimaatveranderingen te kunnen evalueren. De methode bevat twee onderdelen. Het eerste deel is een ex ante analyse van beleidseffecten op duurzame ontwikkeling. Deze analyse is ontwikkeld in het EU 6de kaderprogramma SENSOR en bevat de definitie en het gebruik van indicatoren van zogenaamde landgebruikfuncties. In het tweede deel van de methode worden criteria, zoals beleidsopties en de waarde van landgebruikfuncties ten opzichte van elkaar gewogen, met behulp van een multicriteria-analyse. De aard van deze analyse berust op een iteratie van keuzes door lokale belanghebbenden en beleidsmakers. Daarmee is de hele methode relevant voor gebiedsprocessen en de belanghebbenden in ontwikkelingslanden.

De Office du Niger is een regio in Mali die zeer belangrijk is voor de nationale rijstteelt. Het gebied is sterk afhankelijk van wateraanvoer uit de rivier de Niger. Voorspellingen over klimaatveranderingen laten sterke nadelige gevolgen zien op de wateraanvoer van de rivier en daardoor op de toekomstige rijstproductie. In de Braziliaanse staat Mato Grosso leidt de aanleg en verharding van een belangrijke weg tot een toename in houtkap en het opschuiven van het landbouwareaal richting het regenwoud. Deze ontwikkelingen worden in gang gezet door een toenemende wereldvraag naar bio-energie en veevoedergewassen (soja).

De doelen van deze studie omvatten een methodische ontwikkeling om beleidsopties richting klimaatveranderingen te kunnen analyseren en het inzicht geven van de bruikbaarheid van de methode in twee casussen. Om deze doelen te realiseren zijn alternatieve beleidsopties geformuleerd als mogelijke richtingen voor het opvangen van klimaatveranderingen. De ontwikkelde methode bevat een multicriteria-analyse.

De eerste voorlopige resultaten uit de Mali-casus laten zien dat bij adaptieve maatregelen vooral alternatieve landbouwproductiesystemen kansrijk zijn. Hierbij is gezocht naar alternatieve gewassen voor rijst in het droge seizoen. De verschillen tussen de teelten van groente of zonnebloemen zijn klein, maar het economisch profijt is voor groenteteelt iets hoger. Uit de analyse blijken veel verborgen kosten die niet meegenomen zijn in de multicriteria-analyse. Zo is een investering in het irrigatiesysteem noodzakelijk. Verder onderzoek is nodig om de investeringskosten voor verschillende adaptatiestrategieën in beeld te brengen. Daarnaast is een verdere verkenning nodig om de effecten van klimaatextremen en een toename in mogelijke migratiestromen van de bevolking naar het onderzoeksgebied in kaart te brengen. Een toenemende watervraag in het studiegebied zal mogelijk grote gevolgen hebben voor het internationaal belangrijke RAMSAR-moerasgebied dat verder stroomafwaarts ligt. Ook deze effecten zullen in kaart gebracht moeten worden.

De eerste resultaten uit de Braziliaanse casus laat een duidelijke afruilrelatie zien tussen de versterking van de lokale rurale economie en het wereldwijde doel kooldioxide op te slaan en biodiversiteit te beschermen in tropische regenwouden. Deze afruil wordt veroorzaakt door grote veranderingen in landgebruik van regenwoud naar sojaplantages. Beleidsaanbevelingen voor de casus laten zien dat sturend beleid alleen effectief is wanneer op een lange termijn gekeken wordt naar alle dimensies in duurzame ontwikkeling. Dit betekent dat een sterke groei van de lokale economie op korte termijn afgeremd zal worden maar dat de negatieve effecten op natuur en milieu juist verkleind worden.

Beide casussen laten twee overeenkomsten zien: 1) het gebrek aan relevante data om de analyse van beleidsopties te evalueren en 2) het gebrek aan steun van lokale belanghebbenden en beleidsmakers om het probleem van klimaatveranderingen op de agenda te zetten. De ontwikkelde scenario's in beide casussen kunnen verder uitgebouwd worden en bieden een goede start voor een vervolgonderzoek.

Het pan-Afrikaanse initiatief om adaptatie strategieën bij verwachte droogtes te beoordelen en het onderzoek in het BO cluster VLG en Internationaal van 2009 over klimaatveranderingen in Oost-Afrikaanse landen zijn belangrijke initiatieven om klimaatadaptatie op de agenda te plaatsen van ontwikkelingslanden. De casus uit Mali zou hier voordeel uit kunnen halen, omdat droogtes grote effecten zullen hebben op de sociale economische situatie in het studiegebied. De vergroting van kennis van lokale onderzoekers, in samenwerking met belanghebbenden, zijn hierbij van groot belang omdat klimaatveranderingen een urgent probleem worden. Het Nationaal Actieprogramma van Mali (NAPA) laat daarbij zien dat de eerste prioriteit ligt bij de aanpassingen van gewaskeuzes voor minder droogtegevoelige soorten. Dit betekent dat het belang van het studiegebied voor rijst in de toekomst mogelijk kleiner wordt.

Liberalisatie, WTO-onderhandelingen en de ontwikkeling van de EU Bio-brandstoffenrichtlijn hebben grote lokale gevolgen voor de Braziliaanse casus. De sociaal economische dimensie zal sterk bevoordeeld worden door deze ontwikkelingen, ten koste van de lokale milieucondities. Een mondiale afruil kan daarom gevonden worden tussen liberalisatie enerzijds en realisatie van het Kyoto-protocol anderzijds. WTO-onderhandelingen zouden hiermee rekening moeten houden.

1 General introduction

1.1 Introduction

The Dutch ministry of Agriculture, Nature and Food Quality (LNV) is responsible for a sound policy contribution of adaptation strategies towards climate change in a national and international context. The relevance of such policies in an international context is found in the fourth IPCC assessment. A key question for the ministry is to develop knowledge by which the possibilities for adaptation in developing countries can be evaluated. In specific, information is needed on the costs of such adaptation strategies.

Sustainable development in developing countries is crucial where in many cases poverty levels are high, food security is deteriorating, land conversions are uncontrolled and loss of biodiversity through land use changes is eminent. The urgency to achieve goals towards sustained productivity, reduction of food vulnerability, and poverty alleviation is reflected by the Millennium Development Goals of the UN. The EU 6th framework project LUPIS (Land-use policies and Sustainable Development in Developing Countries, www.lupis.eu) aims at the improvement of systematic knowledge of the impact that different land-use options will have on the sustainable development of developing countries through the use of quantitative methods developed in a European context.

One key issue of sustainable development is inherent, but often hidden, namely trade-off relations. An improvement in the development of one sector may harm the development of another. Policy choices have to be made to maximise development on one side and minimising risk and damage to the other side. Scientific research in the field of sustainable development is characterised by integrative assessments and the contribution of many different fields of science. Such studies can provide many data and alternative scenarios for future development. An overwhelming amount and precision of scientific data may be difficult to handle by policy makers. Scenarios can include different alternative policy options as possible solutions to developmental pathways. Decision and discussion support tools, like multi-criteria analysis, can assist to improve the linkage between science and policy making. Multi-criteria analysis provides insight into the effects of policy choices, given the data input for the calculation of various alternatives. The tool however does not give absolute answers or make a final choice for a particular alternative.

Climate change

Developing countries are extremely vulnerable to climate change. Local economies strongly rely on rain fed agriculture (Ludwig et al., 2007), while agriculture is prone to forthcoming droughts as predicted by different IPCC scenarios on climate change. Therefore, climate change is likely to reduce economic growth and development especially in Asia and Africa. Droughts have significant impacts on the economy of developing countries, which particularly will affect the poorest the most. Moreover, poor countries have hardly any budgets for expensive adaptation options that will cope with strong droughts and flooding events in the coming decades. Hence, adaptation strategies are needed that are relatively cheap and applicable on a regional scale.

In addition, many developing countries in the tropical belt still harbour large areas of tropical rainforest. These forests store large amounts of carbon, which will be released to the atmosphere when forests are clear-cut. In addition, new forests in these areas possess a huge mitigation potential to store CO_2. Unfortunately rainforests are under continuous threat with a strong and increasing world demand for livestock feed and biofuels. Local rural economies might benefit from this demand, but will compete with the global target for carbon mitigation and biodiversity conservation.

Adaptation and mitigation strategies

Development efforts will be seriously hindered if related policies do not consider the effects of climate change. Reduced economic growth due to damages caused by climate change, threatened investments, and low food production due to mal-adaptation to climate change are examples of negative influences of climate on development. Unsustainable development will lead to high emission of greenhouse gases from energy, transport, agriculture, and forestry that will exacerbate climate change (Kok et al., 2006).

Most developing countries are found in places where natural climate variability is high. Both long-term droughts and excessive rainfall often occur in many African, Asian, and other tropical regions. Development policies that take climate change into consideration may reduce the vulnerability to climate change on one side and the reduction of greenhouse gas emissions within the Kyoto agreements on the other side. Traditional climate policies used to focus on mitigation strategies only. Due to forthcoming droughts and floods adaptation strategies are needed as well. Therefore, both adaptation and mitigation strategies are needed for sustainable development. Mitigation is to keep climate change damages manageable while adaptation is to reduce the impacts of climate change (Ludwig et al., 2007). Successful adaptation and mitigation strategies should reduce vulnerability as well as future vulnerability to climate change (Huq et al., 2003).

1.2 The study areas

Mali is an example of a developing country in an arid region with a strong dependence on water supply. The Office du Niger is a major source of rice production in Mali. It supplies almost 40% of its national rice demand and therefore has a strong implication on national food security. As a consequence, this zone has an important economic as well as a political value. The entire zone is dominated by a dam on the Niger River. The dam conveys irrigation water through abandoned river channels to a hierarchic irrigation network. Therefore the zone depends substantially on water availability of the Niger River. Predictions on climate change indicate strong negative effects of lower water levels on rice production. This study aims at the development of adaptation strategies for the agricultural sector in this zone.

Developing countries in the tropical belt that harbour large areas of tropical rainforests are prone to agricultural expansion. In Brazil 66% of the land surface area is still covered with natural forests. Due to a road construction in the north of Mato Grosso state these rainforests are under the threat of local timber activities and expansion of the agricultural frontier by for example the increasing global demand for biofuels. Tropical rainforests also are one of the major global sinks to store carbon. They play a crucial role in mitigating climate-change effects by storage of CO_2. The agricultural frontier in Brazil slowly moves into the forested areas. Converting forest land into agricultural land for biofuel 'plantations' serves an economic goal at the local level that conflicts with the global aim to mitigate greenhouse gas emissions by increasing carbon storage. A balance between the local and the global goals may be found when the ecological services provided by the rainforests are acknowledged. In this study, the Brazil case serves as an example of how global and local objectives can be analysed and compared.

1.3 Objective of the study

The objectives of this study are twofold. First, the study should provide a useful method for policy making in the climate-change arena of developing countries. This is carried out by the development of a methodology to include both scientific knowledge and policy making in a multi-criteria environment. Second, the study should give insights into how such a methodology can be performed by using two case studies. In these case studies we develop and assess adaptation and mitigation strategies towards climate change: the Office du Niger in Mali and the state of Mato Grosso in Brazil. In both cases climate-change policies (i.e. adaptation strategies in Mali and mitigation policies in Brazil) are evaluated for three dimensions of sustainable development; economy, social and environment. These performances of the strategies are evaluated with climate change taken into effect in 2025 that includes a no new policy scenario. Such a scenario can be considered as the *cost of inaction*. The evaluation of the different policies is carried out with multi-criteria analyses.

1.4 Outline of the report

This report consists of two parts. Part I provides a brief introduction and results of an analysis of the case studies. Part II provides detailed information on each case-study area and the methodological framework of the study.

In Part I, Chapter 2 presents the current situation, the adaptation strategies, and the results of the MCA of the Mali case study. Chapter 3 presents the current situation, the adaptation strategies, and the results of the MCA of the Brazil case study. Discussion and conclusions are presented in Chapter 4.

In Part II, Chapter 5 introduces the stepwise methodological framework of this study. Chapter 6 and Chapter 7 describe the drivers that cause the problem, the current situation, impacts of climate change, and the alternative strategies of the Mali and Brazil case study respectively.

Part I Main results

2 The Mali case study

2.1 Current situation and summarised case-study description

Situated in the western part of the Niger River central delta the Office du Niger is one of the largest and oldest irrigated perimeters of West Africa (see Figure 2.1). The potential of irrigable lands is 1,907m. ha. At present, about 87,000ha have been developed for irrigation of water from the river Niger. The irrigation system was established in 1932.

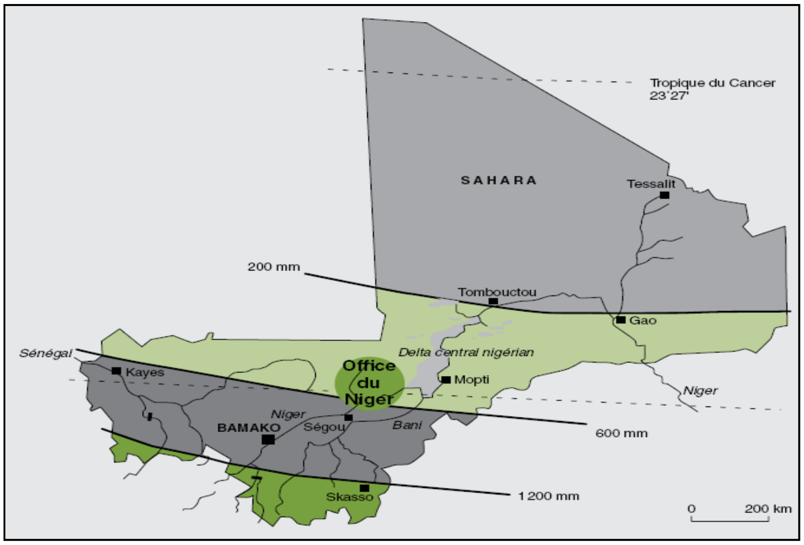
The Office du Niger has a semi-arid climate. The yearly rainfall varies from 300 to 600mm and is concentrated from July to September. This climate type leads to three distinct seasons in the area: a rainy season, a cold dry season, and hot dry season (also called off-season).

Rice production is the dominant agricultural activity in the rainy season while market garden production is dominant in the cold dry season. During the cold dry season, agricultural production focuses on rice cultivation. Rice production occupies nearly the total amount of improved (irrigated) lands. During the hot dry season (off-season), about 15% of the irrigated lands are under rice cultivation. In this period it is the most difficult to have access to water resources.

The Office du Niger has an agro-pastoral livestock production system. In this system, animal production is associated with dryland cropping, with some cultivation and the exchange of manure for stubble grazing. Cattle, goats, and sheep are the main species raised. About 75% of the by-products of rice production (i.e. rice straw, and bran flour) are used as animal feed. During the rainy season, animal feed is provided by the natural pastures. There is also a potential availability of fodder in the Office du Niger when water availability is present. The inputs of oxen-drawn plough and manure are important factors contributing to the increase in rice yields.

Water management in this area builds on a network of canals to guide water to the farmers, and then allow it to flow downstream into the drainage network. Most of the water that this large system diverts from the river is never replaced, such as the 2,812.5m. m^3 per year for rice and vegetable crop production. A full description of the case study can be found in Chapter 6.

Figure 2.1	Location of the Office du Niger study area in Mali



The Office du Niger in Mali is facing the danger of decreasing water availability of the Niger River that threatens livelihood of the local population. Such threats call for effective adaptation strategies.

2.2 Current policies, climate change and adaptation strategies

2.2.1 Current policies

Malian government and several international donors initiated and invested in the rehabilitation of the infrastructure in the Office du Niger in the early 1980s World Bank, 1996). As a result, rice production in the area tripled in 1983-94, which had contributed significantly to poverty alleviation and food security of the country. This achievement makes the Office du Niger not only economically attractive but also politically important. Immigrants are attracted every year, which leads to fast expansion of the irrigated area. In addition, the government also encourages rice production during the hot dry season (from February to June) to further ensure food security (15% of the land is engaged in rice production in the dry season).

Policies related to agricultural intensification should also stimulate farmers to choose sustainable expansion paths. For example, the incentives of investing in improving the efficiency of water management come from the security of land tenure. However, because customary rule excludes vulnerable groups and statutory law centrally controls land ownership, farmers are not encouraged to invest in irrigation systems. Moreover, according to Vandersypen et al. (2006), current levels of water consumption are unsustainable given the rapid expansion of the irrigated area of the Office du Niger.

2.2.2 Climate change

Projections for the future climate are surrounded by significant uncertainties. Most climate change scenarios predict a decline in precipitation in the range of 0.5-40% with an average of 10-20% by 2025. Many of these scenarios describe a generally more pronounced downtrend in flow regimes and the replenishment of groundwater. As a result, extreme climate events are expected in some parts of West Africa. However, considering the many possible future scenarios, what matters is the ability to manage or adapt to the uncertainty.

For the Office du Niger, current water availability is ensured for only 8 months per year, which will decrease in the near future. In addition, the area of irrigated land is still expanding which will put an even higher demand on surface water. Therefore, the efficiency of the irrigation system has to be improved. The increasing probability of extreme climate conditions (e.g. drought and/or flood) has negative impacts on the agricultural production (rice and livestock) as well as health conditions of both human and livestock.

The recurrent droughts, resulting from climate change and increasing variability of precipitation accelerates desertification, which in turn contributes to the persistence of drought. This cycle is likely to play a part in increased desert encroachment.

The degradation of water quality is a significant problem for the Niger River. The development of wastewater collection and treatment plants (both for domestic or industrial wastewater) could not keep up with the growth of large cities along the river's banks. Fertiliser use also has an impact on water quality. The drop in water availability or the degradation of its quality often resulted in exacerbated competition for access to water.

The possible impacts of climate change for the Office du Niger are: (1) higher risk of seasonal drought reduces rice production; (2) increasing feed variability induced by greater seasonal drought decreases livestock production; (3) limited access to water resources decreases both rice and livestock productions; (4) intensive storm increases runoff; (5) high temperatures reduce cold dry season productions; (6) increasing climate variability decreases the health condition of the livestock.

2.2.3 Adaptation strategies

The definition of adaptation strategies taken here refers to the adjustment in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts (Huq et al., 2003). In other words, it means that individuals, groups, and natural systems adjust their processes, practices, or structures to moderate or offset potential damages or to take advantage of opportunities associated with changes in climate (Huq et al., 2003). Various types of adaptation strategies can be distinguished. There are anticipatory and reactive adaptation strategies, private and public adaptation strategies, and autonomous and planned adaptation strategies. In the case of Mali, adaptation strategies indicate 1) farmers adjust their activities related to water availability (such as agricultural production), and 2) government adjust its policies related to resource management (such as water management and reforestation).

Based on the current situation, the following adaptation strategies are proposed that should minimise the negative effects of climate change on agricultural production. There are many problems defined in the study area, such as those related to crop production, to livestock production and so on. In this study, we focus on problems related to crop production, i.e. less water availability in the dry season in Office du Niger. Due to climate change, a negative impact on rice production during the dry season can be expected.

The adaptive strategies are designed to reduce the negative impact of less water availability on rice production in the dry season. We are aware that there are other adaptive strategies that might also reduce the negative impact. Due to the short time span of the project and the scope of our study, we decided to focus on adaptation strategies where rice production during the rainy season is followed by fallow land, vegetable production, or sunflower production in the dry season.

In the Mali case study, we designed one baseline scenario - the current policies, where in the rainy season all irrigated land is engaged in rice production while in the dry season only 15% is, plus less water availability (50% less) in the dry season due to climate change. Combining the baseline scenarios with three alternative strategies, we have four scenarios in the Mali case study (see Table 2.1).

Table 2.1	Scenarios in the Mali case study			
Scenario	**Year**	**Rainy season**	**Dry season**	**Climate change effects**
Current situation	2008	Rice	Rice (15% of land)	-
Baseline	2025	Rice	Rice (15% of land)	50% reduction in water availability in dry season
Alternative 1	2025	Rice	Fallow	50% reduction in water availability in dry season
Alternative 2	2025	Rice	Vegetable (30% of land)	50% reduction in water availability in dry season
Alternative 3	2025	Rice	Sunflower (30% of land)	50% reduction in water availability in dry season

Figure 2.2 provides an overview of relations between components in the Mali case study. The centre of the case study is less water availability from the Niger River, which has a negative impact on rice production in the dry season in the Office du Niger. Less water availability is caused by climate change such as less rainfall. Water from the Niger River produces electricity, provides drinking water for both humans and livestock, and provides irrigation for crop production.

2.3 Results

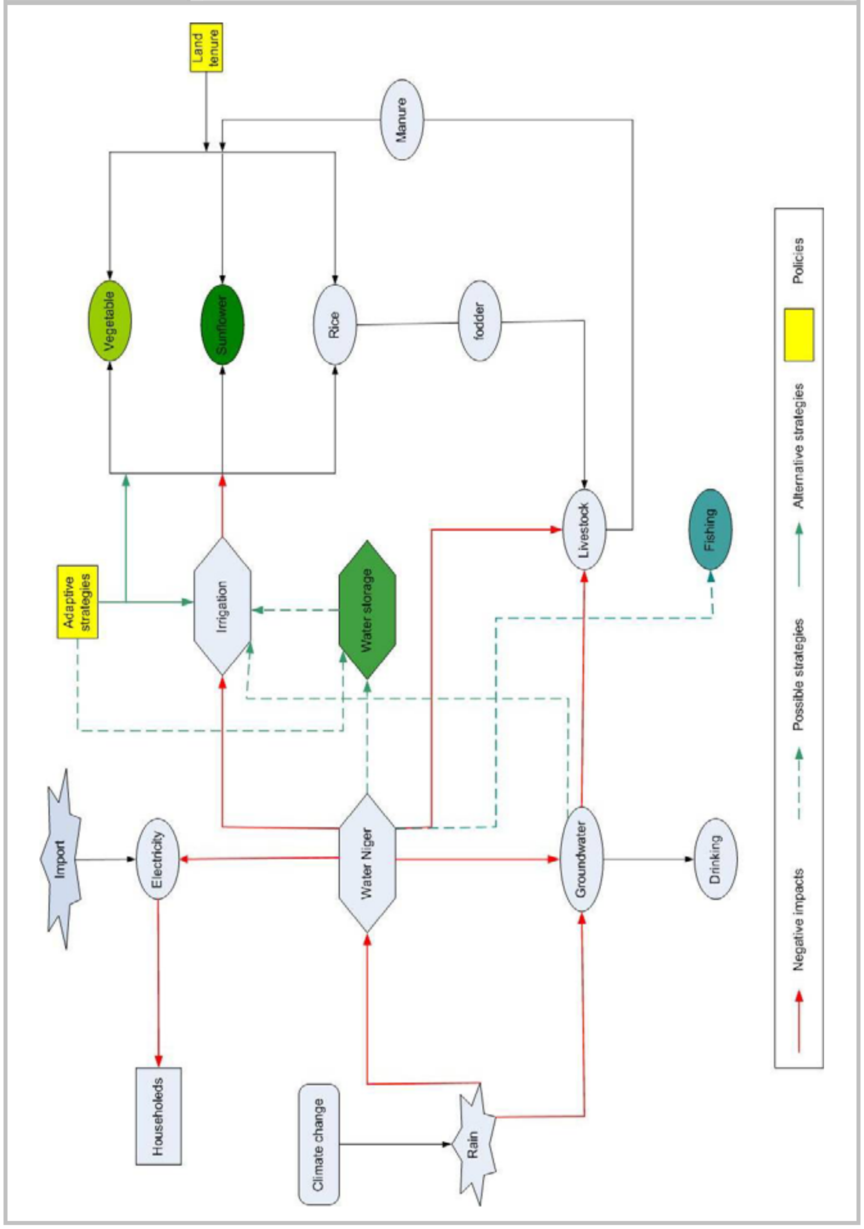
2.3.1 Data input and limitations

For each Land Use Function (see Section 5.2.1) a number of indicators were defined. Based on the criteria listed in Section 5.2.3, a list of indicators was selected. Variables to measure the indicators are defined and listed in Table 6.2. Due to data limitations, responses of indicator values were derived by educational guesses. In Table 2.2, the indicators, Land Use Functions and dimensions of sustainable development are depicted that were used in the Multi-criteria analysis. Given all the values of all the variables, MCA is performed in this step in order to assess alternative strategies.

2.3.2 Multi-criteria analysis

Figure 2.3 depicts the results of the MCA analysis for the Mali case study. The figure comprises three types of information that will be discussed below.

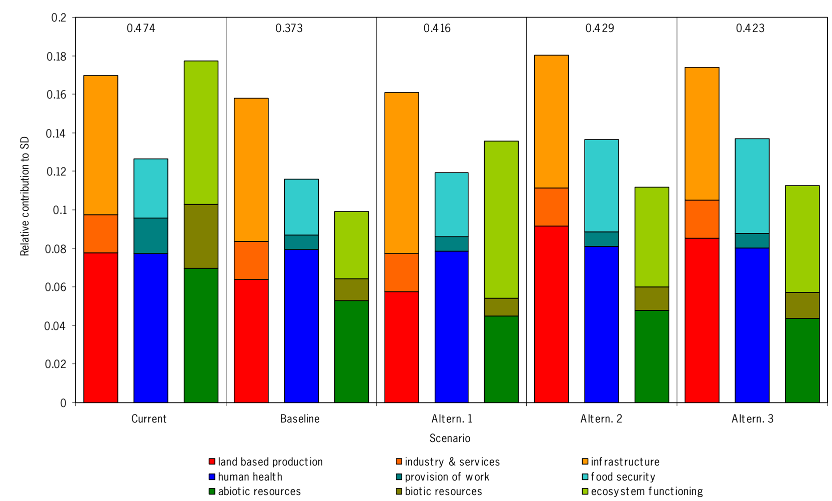
Figure 2.2	Schematic representation of processes in the Office du Niger case study in Mali



Overall performance of scenarios

In Figure 2.3 the numbers above the different coloured columns refer to the total contribution to sustainable development for each studied scenario. The current status scores highest (0.474). Given the equal relative weights of the three dimensions of sustainable development and those of the land use functions (see Section 5.2.1) this result indicates that the current situation offers the relatively best contribution to sustainable development. This does not mean, however, that the current situation can be considered sustainable. The baseline scenario can be considered a 'no policy' action scenario. In the baseline no climate-change policies are adopted and this scenario has the lowest overall score (0.373). All alternative scenarios (alternatives 1-3) have higher overall scores than the baseline. Therefore, the different policies assumptions have a better contribution to the overall sustainable development score. Among the different alternatives, alternative 2 (rice + off season vegetable production) scores highest. However, all alternatives have lower overall scores than the current situation.

Figure 2.3 **MCA results of the Mali case a)**



a) Red tones indicate the contribution of the economic dimension, the blue tones the contribution of the social dimension, and the green tones the contribution of the environmental dimension to the final result. Each bar comprises the three Land Use Functions per dimension of sustainable development.

Table 2.2	The used indicators of the nine Land Use Functions for the three dimensions of sustainable development in the Mali case study	
Dimension	**Land Use Function**	**Indicator**
Economic	Land-based production	Agricultural income
		Value crop production
		Value livestock production
		Expenditure fertiliser use
	Industry & services	Nr of small business
	Infrastructure	Share of water used for irrigation
		Total length of canals
		Management irrigation system
		Water fee
Social	Human health	Life expectancy
	Provision of work	Immigration rate
	Food security	Regional staple food consumption
		Months of household food provisions
Environmental	Abiotic resources	Soil nitrogen & phosphorus
		Fertiliser use
		Precipitation
		Water flow Niger
		Share clean water per household
		Water use agriculture
	Biotic resources	Share of forest land
		Share land under production
		Agricultural yield
		Gap between potential & actual yield
	Ecosystem functioning	Nr of (keystone) species
		Water use ecosystems

Performance of the dimensions of sustainable development

Each stacked column in Figure 2.3 depicts the relative contribution of each dimension to the overall sustainable development goal in the MCA analysis. Climate change (50% water reduction) has the strongest negative effect on the environmental dimension. In all future scenarios (the baseline and the three alternative policy options) the overall score of this dimension is reduced the most. In the baseline scenario the MCA scores of all dimensions are reduced. Amongst the different alternatives, alternative 1 scores highest for the environmental dimension, but has lower scores in the social and economic dimension. Alternative 2 has the highest score in the economic dimension.

Performance of Land Use Functions

In general terms, the Land Use Functions (LUF) (abiotic resources, ecosystem functioning (both the environmental dimension), land based production, infrastructure (both the economic dimension), and human health (social dimension)) contribute the most to the sustainable development overall score, since their relative scores are the highest among the different LUFs. This is partly caused by the relative high number of available indicators in these LUFs. In the economic dimension the LUF land base production varies the most and has the highest relative score in alternative 2 and 3. In the social dimension only food security shows variation. This function is highest in alternatives 2 and 4. In all future scenarios (baseline and the three alternatives) a reduction of the LUFs abiotic and biotic resources in the environmental dimension can be found. An improvement of the environmental dimension in the alternative scenario 1, and to a lesser extent in alternatives 2 and 3, is caused by a higher score of the LUF ecosystem functioning.

Sensitivity of the MCA results

The multi-criteria software package used in this study provides a tool to study the effects of changing weights of the criteria, like dimensions and LUFs, on the overall score. If large changes in the relative weights of criteria will not change the outcome of the MCA score, then the weighing is very robust. When small changes in preferences change the outcome drastically, then the MCA results should be critically evaluated. The highest sensitivity to the final MCA score is variation in the environmental dimension. The weights implemented for all dimensions were 33%. Reducing the weight of the environmental dimension to 26% will alter the preferred scenario. The next high sensitivity was found for the social dimension, and an adjustment weight to 45% will alter the outcome. The third highest sensitivity was found in the LUF food security. In all these cases the next best scenario was alternative 2. Hence, the current status and alternative 2 are scenarios with close MCA scores. For almost all studied MCA objectives alternatives 2 and 3 were very close and mostly showed parallel responses to changes in weights of objectives, with somewhat lower scores for alternative 3.

2.3.3 Conclusions

The Office du Niger in Mali is facing a reduction in future water availability with climate change (less precipitation and less water flow in the Niger River). The proposed policies all include adjustments in agricultural production, with a decreasing focus on rice. With no adjustments implemented in the baseline scenario, the development in the Office du Niger becomes less sustainable. Consequently, the cost of taking no adaptive measures (i.e. the cost of inaction) is a reduction among all dimensions of sustainable development. The environmental dimension is reduced most strongly when no actions are taken. Among the adaptive strategies of future scenarios the ones with alternative cropping systems scores best. The difference between vegetable cropping and sunflower production is small with a slightly higher score for land-based production in the economic dimension for the vegetable cropping alternative.

The unavailability of current and future indicator data and the high uncertainty of predictions of future water availability make the evaluation of different adaptive strategies difficult. Investment in data structure of the region is needed to evaluate future policies more precisely.

3 The Brazil case study

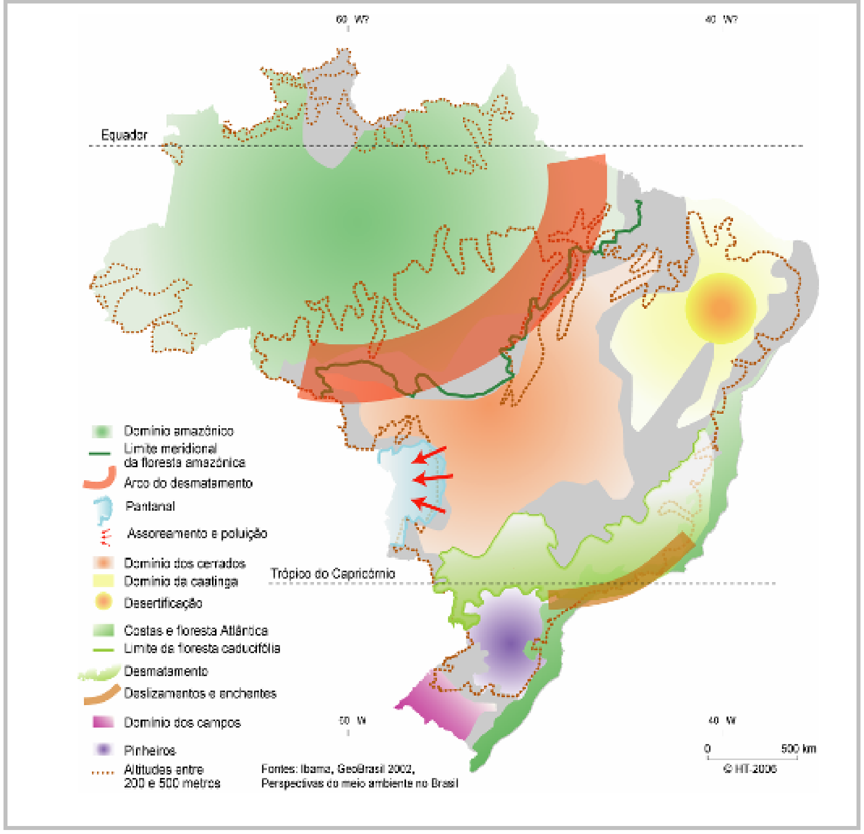
3.1 Current situation and summarised case study description

The state of Mato Grosso in Brazil is facing the conflict between agricultural expansion (largely due to an increase in biofuel demand) and conservation of the Amazon rainforests that are important for carbon storage. Since 1970 more of the Brazilian Amazonian forest (Legal Amazon)[1] has been destroyed than in the previous 450 years since European colonisation. By 2005, deforestation had exceeded 690,000km^2, which accounts for 14% of the Amazonian forest and is an area larger than France and Portugal. This has generated 200m. t of carbon emissions per year or even more. Brazil is the world's fourth largest emitter of greenhouse gases (Volpi, 2007).

Development of infrastructure, especially paved highways, accelerates migration to remote areas and increases the clearing of forest. According to Ferreira et al. (2005), deforestation intensifies in areas that are close to highways and decreases exponentially with increasing distance to highways. The majority of deforestation is concentrated along a so-called 'Arc of deforestation', which includes the states of southeast Maranhão, north of Tocantins, south of Parana, north of Mato Grosso, Rondonia, south of Amazônas and the southeast of Acre (Figure 3.1).

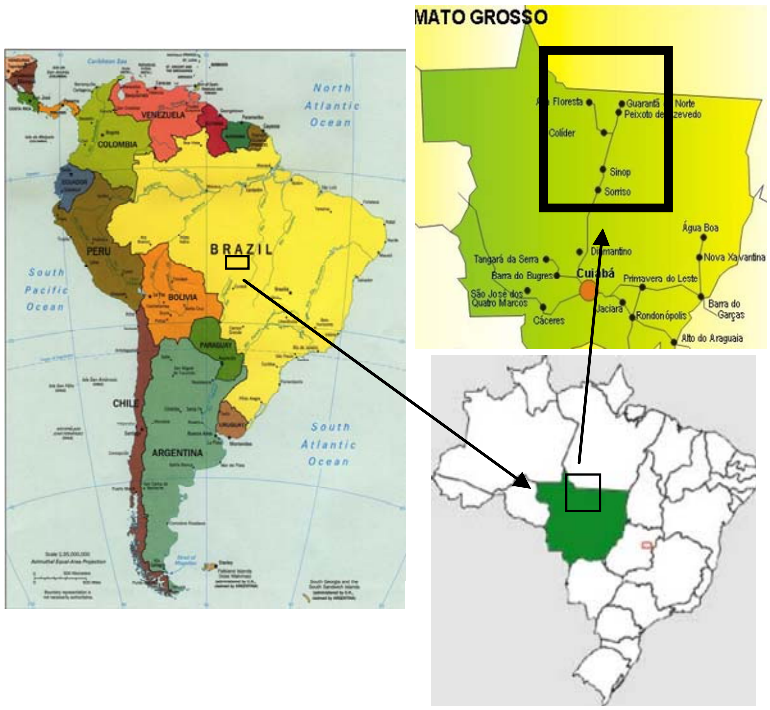
[1] The Legal Amazon is composed of the following states: Acre, Amapá, Amazonas, Pará, Rondônia, Roraima, Tocantins, Mato Grosso and the majority of Maranhão.

Figure 3.1 **Arc of deforestation in 2005**



In Mato Grosso and Pará (PA), deforestation is concentrated along highway BR-163 (Figure 3.2). This highway is partially paved as an effort made by the Mato Grosso state government to provide market accesses for local soybean farmers. Increasing trade in soybeans under the influence of globalisation has made it attractive for the government to pave the unpaved part of the highway BR-163. However, this greatly increases its impact on deforestation in the surrounding area. Hence, the effectiveness of environmental policies that protect Legal Amazon is crucial. Therefore, we focus on the north of Mato Grosso and the south of Pará in the Brazilian case study.

Figure 3.2	Location of the case study a)



a) Brazil (left); State of Mato Grosso in green (lower right corner), north of Mato Grosso delimited by the black rectangle with the BR-163 highway.

3.2 Current policies, climate change and mitigation strategies

3.2.1 Current policies

Historically, extensive cattle ranching has been encouraged by generous governmental subsidies, land-tenure rules, and fiscal policies (Fearnside, 1993). Low-productivity cattle ranching continues to expand due to land-tenure rules and land speculation (Volpi, 2007). Moreover, the tax system stimulates deforestation, since uncleared forest land is considered unused which results in higher taxes. In addition, the government-sponsored colonisation programmes with subsidies for food allowances, money for housing and credit at reduced interest rates also stimulates deforestation (Volpi, 2007).

While policies mentioned above lead to further deforestation, there are also policies aimed at conserving Amazon rainforest. A mosaic of indigenous territories and Conservation Units that target integral protection and sustainable land use are located by the government in the north of Mato Grosso. The federal programme endures for 10 years and intends to create at least 50 m. ha of protected area in Amazon Biome by 2013. Moreover, the federal government reinforces its monitoring system that has slowed down the deforestation speed.

The inefficient presence of the state and failing communication between the land registry system - INCRA (Instituto Nacional de Colonização e Reforma Agrária - National Institute of Colonisation and Land Reform) and the legal registry system (Registry offices) is facilitating the actions of the land grabbers, favouring the illegal occupation of public lands. Corruption occurs on several institutional levels, including inspection institutions and positions of state bureaucracy, which has contributed to the escalation of the situation (Rodrigues Filho et al., 2008).

The reduction of pasture in the central-south of Brazil pushes cattle ranching further into the Amazon. Lands that are left behind are replaced by intensive agriculture. The demand for soybeans from Europe and China further drives deforestation. Soy imports by Europe from Brazil have grown by 15% between 1999 and 2003. Currently, one half of EU soy imports and 30% of soy imports of China are from Brazil (Volpi, 2007).

Infrastructure development such as paved highways also contributes to deforestation. Along highway BR-163, the expansion of deforestation is mainly led by small farmers and timber producers.

3.2.2 Climate change and climate policies

The various existing climate models indicate a larger possibility for the reduction of precipitation in the Amazon. The average of the regional models of INPE, considering the A2 and B2 IPCC-SRES scenarios, foresee a drier and warmer climate in the case study (see Chapter 7 for details) in the period 2071-2100. Forest and soils drive the global carbon cycle by sequestering carbon dioxide through photosynthesis and releasing it back into the atmosphere through respiration and decomposition of organic matter (Volpi, 2007). One of the consequences of deforestation is carbon emission, which causes climate change. In 2000, Brazil was the world's fourth largest emitter of climate-changing greenhouse gases (Volpi, 2007). Deforestation is responsible for 75% of the total GHGs emissions and about 60% of the carbon emission comes from Amazon deforestation (Volpi, 2007). About 25% of the carbon emission in Brazil comes from combustion of fossil fuels.

The participation of biofuels in the National Energy Matrix (MEN) is increasing. The government, through public policies, seeks to promote the production of primary material for ethanol and biodiesel, as well as incorporate these fuels into the national energy dynamics. The expansion of 'total flex' technology (motors that can function either on gasoline or on alcohol) beginning in 2003, associated with the prospects of enlarging the international biofuel markets, has stimulated an increase in the national production of ethanol. In the case of biodiesel, similar goals have been set, making a 2% and 5% mixture of biodiesel with conventional diesel mandatory beginning in 2008 and 2013, respectively (IICA 2007). Incentives, such as the reduction of tariffs and even fiscal exemptions for biodiesel producers that purchase a certain percentage of primary material from family farmers, aim to promote social inclusion and the participation of family agriculture in the productive chain of biofuels.

Brazil has committed itself to the global effort to stabilise the atmospheric levels of greenhouse gases. It recognizes the shared responsibility, but differentiated between member countries and the historic responsibility as a determining factor in balancing the goals of reducing greenhouse gas emissions that each country must achieve individually. The act was incorporated into Brazilian legal order and it was promulgated in 1998 by Decree 2652. With this aim in the last ten years, government and civil society are looking for synergies in the construction of an institutional context that catalyses the incorporation of the climate issue in public policy.

3.2.3 Mitigation strategies and alternative scenarios

Drivers that lead to deforestation in the study area form a complex story. Facing a bundle of policies involved in the Brazil case, many mitigation strategies can be recommended. However, in this study, we want to point out that above all policy recommendations, the most obstacle of combating deforestation in Brazil is its institutional inconsistency. Policies announced by different states or by different ministries and government agencies have conflicting objectives that give land grabbers and illegal activities opportunities to devastate the Amazon rainforest.

In spite of institutional inconsistency, Brazilian government should:

1. Improve law enforcement and surveillance. The government should strengthen supervision, control and enforcement of environmental legislation;

2. Ensure more effective actions such as to form more consistent land tenure policies that concedes property rights. To reach such objectives, strategies that require institutional cooperation are fundamental;
3. Expand Conservation Units and protected areas. Protected areas such as parks, extractive reserves and indigenous lands slow down the speed of deforestation;
4. Reconsider policies on taxes, subsidies, and credits, and land reform programmes. Existing tax incentives, credit systems and subsidies for cattle ranching and agricultural expansion have negative impact on the rainforest;
5. Reconsider infrastructure projects such as paving BR-163 highway. Plans for new roads and road paving should be evaluated considering the impacts on environment;
6. Consider economic instrument such as taxation on deforestation to oblige agents to internalise the environmental costs. The alternative to this strategy would be to compensate agents for not deforesting.

To design a baseline and alternative scenarios, we focus on two aspects: (1) the effectiveness of alternative policies that combat deforestation; and (2) the development of global economy. In the baseline scenario, we assume that by 2025 there are no changes in policies and the global economy keeps on expanding (e.g. 50% increase in soybean import of EU). Besides the baseline scenario, three alternative scenarios have been developed for the Brazil case study:

1. In alternative scenario 1, we assume that the global economy keeps on expanding (e.g. 50% increase in soybean import of EU) and policies implemented by the government are more effective (e.g. deforestation area under 11,000km^2) by 2025;
2. In alternative scenario 2, we assume less expansion of the global economy (e.g. 20% increase in soybean import of EU) and policies implemented by the government are more effective (e.g. deforestation area under 11,000km^2) by 2025;
3. In alternative scenario 3, we assume less expansion of the global economy (e.g. 20% increase in soybean import of EU) and there are no changes in policies implemented by the government (e.g. deforestation area under 39,000km^2) by 2025.

Table 3.1 lists the current situation, the baseline scenario, and all alternative scenarios of the Brazil case study.

Table 3.1	Scenarios in the Brazil case study		
Scenario	**Year**	**Global economy**	**Policy effectiveness**
Current situation	2008	-	-
Baseline scenario	2025	50% increase in soybean import of EU	Less effective (39,000km^2 of deforestation area)
Alternative scenario 1	2025	50% increase in soybean import of EU	More effective (11,000km^2 of deforestation area)
Alternative scenario 2	2025	20% increase in soybean import of EU	More effective (11,000km^2 of deforestation area)
Alternative scenario 3	2025	20% increase in soybean import of EU	Less effective (39,000km^2 of deforestation area)

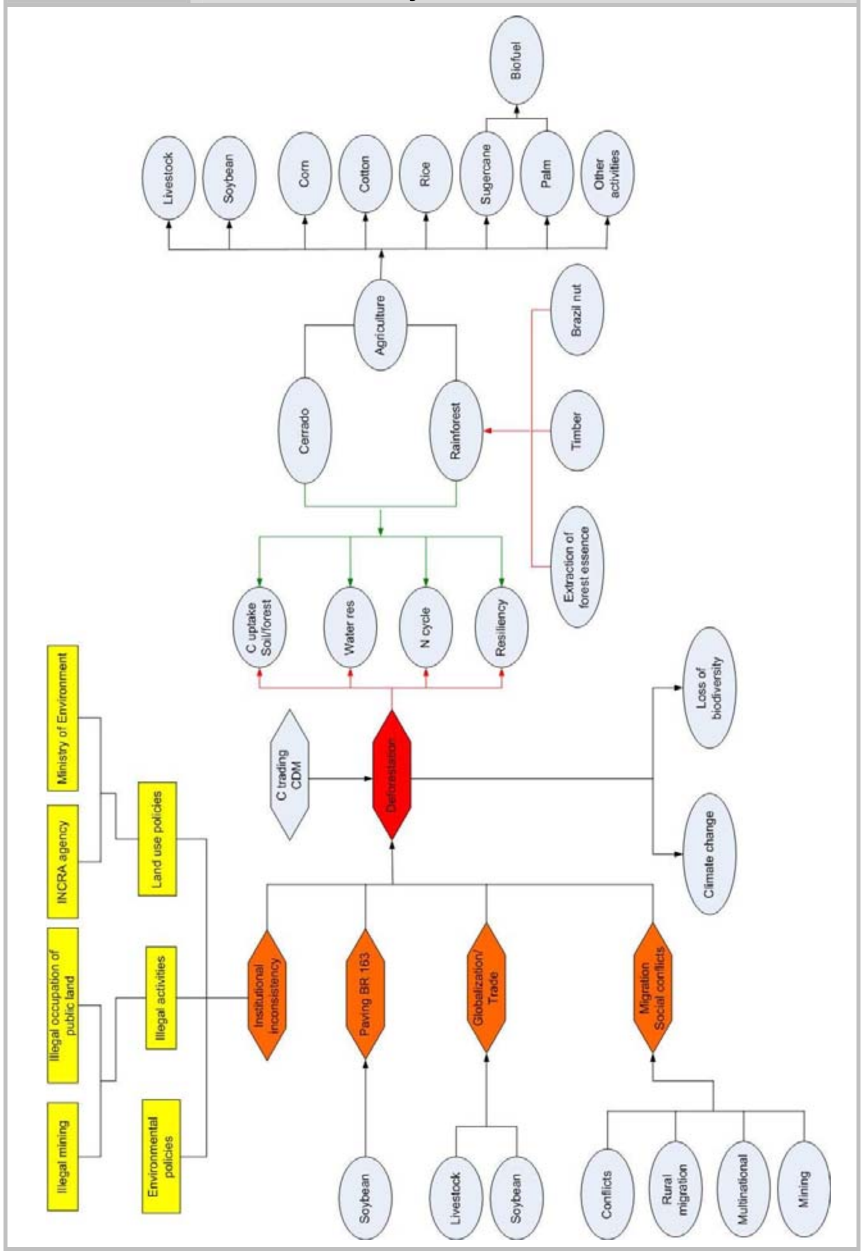
Figure 3.3 provides an overview of relations between components in the Brazil case study. The centre of the case study is the deforestation of the Legal Amazon. Drivers that cause deforestation are grouped into 4 blocks (in orange). Negative impacts of deforestation are also listed in the figure.

3.3 Results

3.3.1 Data input and limitations

For each Land Use Function (see Section 5.2.1) a number of indicators were defined. Based on the criteria listed in Section 5.2.3, a list of indicators was selected. Due to data limitation, some responses of indicator values were derived by educational guesses. The values of all the variables under different scenarios are shown in Table 7.11. In Table 3.2 the indicators, Land Use Functions and dimensions of sustainable development are depicted that were used in the multi-criteria analysis. Given all the values of all the variables, MCA is performed in this step in order to assess alternative strategies.

Figure 3.3 **Schematic representation of the processes in the Mato Grosso study area in Brazil**



3.3.2 Multi-criteria analysis

Figure 3.4 depicts the results of the MCA analysis for the Brazil case study. The figure comprises three types of information that will be discussed below.

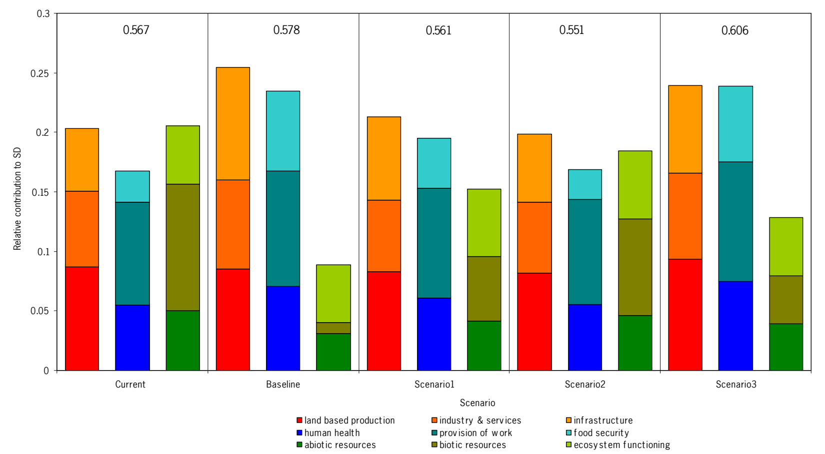
Overall performance of scenarios

In Figure 3.4 the numbers above the different coloured columns refer to the total contribution to sustainable development for each studied scenario. Scenario 3 (20% increase in soybean import with less effective policies) scores highest (0.606). Given the equal relative weights of the three dimensions of sustainable development and those of the Land Use Functions (see Section 5.2.1) the overall performance of scenarios also indicates that scenario 2 (20% increase of soybean import with effective policies) scores lowest, also lower than the current situation in the case study. The scenarios that include effective policies (scenario 1 and 2) score low on the overall MCA value. Consequently, effective policies do not seem to contribute to the overall MCA value. Increasing import does not necessary leads to an increase in overall score. With less effective policies a lower import of soybean scores better, but with effective policies a larger import of soybean contributes more to sustainable development. With effective policies in place, sustainable development does not seem to improve. The clarification for this contra-intuitive result can be found in the different responses of the three dimensions of sustainable development to the scenarios.

Performance of the dimensions of sustainable development

In the current situation and scenario 2 (20% increase soybean import of EU and effective policies) the MCA scores of the three dimensions are more or less equally distributed. However, in these scenarios the overall MCA score is lower than in scenarios with an uneven distribution (baseline and scenario 3). These latter two scenarios show a strong increase in the economic and social dimension at the expense of the environmental dimension. Hence a clear trade-off can be found between the development in economic dimension (and less in social dimension) against the environmental dimension.

Figure 3.4 **MCA results of the Brazil case a)**



a) Red tones indicate the contribution of the economic dimension, the blue tones the contribution of the social dimension, and the green tones the contribution of the environmental dimension to the final result. Each bar comprises the three Land Use Functions per dimension of sustainable development.

Performance of Land Use Functions

The biotic resources (LUF) in the environmental dimension are mostly strongly reduced with ineffective policies or increasing EU demand on soybean. The strongest driver of this reduction is the increasing deforestation rate with these scenarios and hence a smaller amount of forest land with subsequently lower carbon storage and other reduced values of the indicators involved in this Land Use Function. Industry and infrastructure (LUFs in economic dimension) and provision of work and food security (LUFs in social dimension) are improved in scenario 3 (ineffective policies) and the baseline (ineffective policies and 50% increase in soybean export to EU). Hence, the local rural economy and livelihood strongly benefits from increasing open markets and ineffective environmental policies. The global aim to mitigate greenhouse gasses by carbon storage can best be achieved with effective environmental policies and a smaller fraction of open markets, but at the expense of a smaller growth rate for the local economy compared to the current situation.

Table 3.2	**Used indicators for the nine Land Use Functions for the three dimensions of sustainable development in the Brazil case study**	
Dimension	**Land Use Function**	**Indicator**
Economic	Industry & services	Non land-based business
		Diversification econ. activities
	Land based production	Agricultural income
		Total land under production
		Timber production
		Livestock production
		Rice production
		Cotton production
		Corn production
		Soybean production
		Sugar cane production
	Infrastructure	Total pavement BR-163
		Access to remote forest
Social	Provision of work	Employment rate
		Children to school
		HDI
		Gini
	Human health	Life expectancy
		Residential standards
	Food security	Staple food consumption
		Poverty index
Environmental	Ecosystem functioning	Deforestation rate
		Size of nature reserves
		Disturbance C cycle
	Biotic resources	Forest land
		Carbon storage
	Abiotic resources	Fertiliser use N
		Carbon emission
		Fertiliser use P
		Pesticide use
		Fertiliser use K

Sensitivity of the MCA results

The overall multi-criteria outcome and ranking of scenarios is mostly sensitive to the weighing of the environmental dimension. When the current weighing (33%) of the environmental dimension is changed to 42%, the scenario that describes the current situation will have the highest score. This is mostly achieved by increasing the weight of the Land Use Function biotic resources. In the current evaluation the weight has been set on 33% (equal weight of all Land Use Functions). Increasing the weight within the environmental dimension to 54% will also lead to the current situation as the scenario with the highest score. The multi-criteria analysis is also sensitive to the weighing of the social dimension. Reducing this weight from 33% in the current evaluation to 22% will lead to the current situation as the scenario with the highest overall score. The MCA outcome is less sensitive to changes in the economic dimension. Increasing the weight to 68% will lead to a different preferred scenario (baseline). Therefore, the results on the economic dimension are rather robust in the evaluation of mitigation policies in the Brazil case study.

3.3.3 Conclusions

The results of the MCA evaluation of the Brazil case study show a clear and strong trade-off relation between the local rural economy, depicted by the economic and social dimension and the environmental dimension which contributes to the global targets of mitigation of carbon storage. The deforestation rate is the dominant driver of change, which is caused by the agricultural frontier. Land-use change from forest land to soybean plantations increase local livelihoods but reduce the capacity to mitigate greenhouse gas emissions worldwide. The EU demand for soybean has a strong effect on the deforestation rate.

4 Discussion and conclusions

This report focuses on two issues: first, the development of a method to evaluate climate-change policy options in developing countries and, second, the evaluation of climate change adaptive strategies in a case study in Mali and climate change mitigation strategies in a case study in Brazil. This chapter evaluates the main results of the methodology and the proposed strategies in the two case studies. Policy options and recommendations for follow up studies are defined in the last section of this chapter.

4.1 Potential and limitation of multi-criteria analysis for evaluation

The analysis of climate-change policies for adaptation and mitigation strategies in the two case studies revealed four crucial elements to be met for a constructive evaluation. These four criteria included 1) the cooperation of relevant policy makers in the process, 2) a sense of urgency of the climate change problem and the future policy options to be evaluated by policy makers, 3) a multidisciplinary team of researchers available in the process, and 4) the availability of relevant data. The research in the case studies showed that the lack of one or more of these criteria will make a justified evaluation of policy options very difficult.

The advancement of a methodology to evaluate policy options on land based issues of sustainable development is one of the main goals in this report. Land based development processes are described as Land Use Functions, and these functions are distributed among the three pillars of sustainable development; the economic, the social and the environmental dimension. The proposed multi-criteria analysis structures the various issues in a strict hierarchical order; from the main goal of the multi-criteria scheme to achieve sustainability to the dimensions of sustainable development, to nine Land Use Functions, distributed equally among the dimensions, and finally to a number of indicators of which each of them represent and measure responses of a Land Use Function to a variety of policy options. The objective of such a multi-criteria analysis is to weight and compare different alternative policy options to a common goal, given the weights put on the different hierarchical criteria described above.

The key issue of such a multi-criteria analysis is the weighing procedure. In general, the multi-criteria analysis includes two types of weighing input; the one carried out by policy makers and the one obtained by scientists. The weighing of the dimensions of sustainable development and the Land Use Functions are the domain of policy makers. Here the emphasis on various policy objectives (not alternatives) can be placed. Governmental objectives may include a balanced weighing of dimensions, or giving more emphasis to the development of one set of criteria and less to another set of criteria. This focus can be included in a multi-criteria analysis by giving different weights to the criteria (dimensions and Land Use Functions). In both case studies, however, the weighing of both dimensions and Land Use Functions was carried out by the research team. All dimensions and Land Use Functions were given equal weights, giving their representativeness to sustainable development. The weighing of indicators on the other hand, can be seen as the scientific domain. The weights are no more than the response values of indicators, as absolute or percentage values, calculated under different policy alternatives. In integrative assessments these responses can be obtained from different models, like the modelling phase procedure to be carried out in the LUPIS project. In the case studies, however, we obtained response values by using simple response functions and educational guesses. For a balanced evaluation of policy options weighing of criteria should be carried out by involvement of stakeholders and policy makers. An important aspect is that stakeholders and policy makers may have different emphasis on different dimensions and Land Use Functions, which can alter the choice of a preferred policy option.

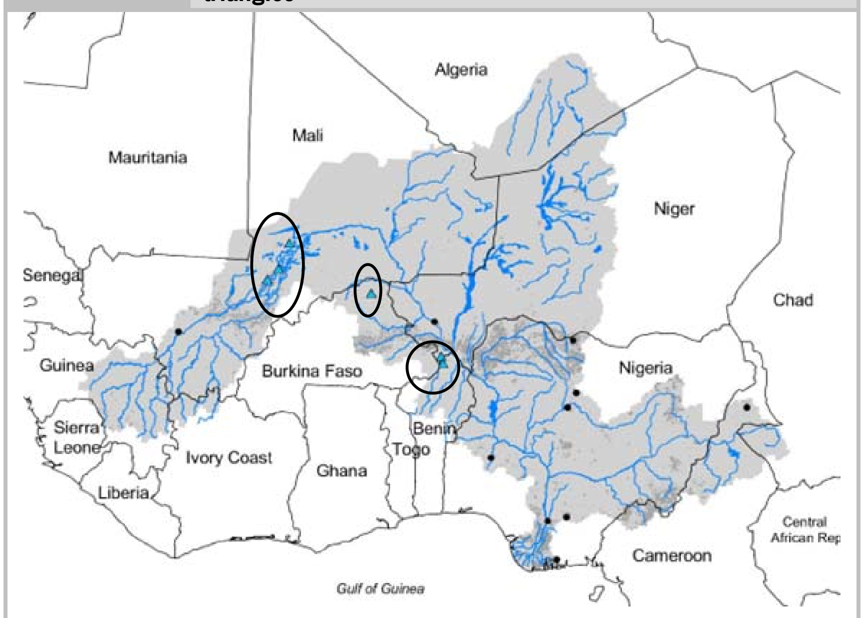
Data limitation is always a constraint to doing research in developing countries. This study faces the same problem. Due to data limitation, most of the indicator values used for the multi-criteria analysis were derived from educational guesses based on experienced local researchers. A more robust and scientific approach could be using quantitative models to estimate indicator values for different scenarios.

Important to mention is that the results the multi-criteria approach are a starting point of a discussion, not an end point. The relative weights of alternatives in the main goal (SD) provide only directions; the multi-criteria analysis cannot be considered a model but only a tool to structure decisions and discussion. A critical question to be asked by both policy makers and scientists is the result of the ranking of alternative options. The robustness of this ranking can be evaluated with sensitivity analysis as has been carried out in both case studies. If small deviations in the weights of criteria lead to a new ranking of options, then these policy options may be much alike in their performance. Hence, the decision outcome is not robust. The weights (values) of indicators play a less crucial role in the overall outcome. In addition to the weighing method, more alternative policy options could be developed that are also in the range of sustainable development. As a rule of thumb, between 4 to 8 policy options will give meaningful results for a decision discussion.

4.2 Recommendations on adaptation strategies in Mali

For the Mali case study, a 50% shortage of surface water from the Niger River is assumed due to climate change in the dry season for all alternative future scenarios, while all other driving forces are assumed to be equal to the current situation. However, it is likely that with forthcoming droughts people will migrate from the dry North (Sahel) to the relative humid South and the Office du Niger. Hence, we can also assume an increase in migration of people due to climate change. Research questions related to this issue would be what the expected effects are on smaller farms or smaller parcels per farm with increasing population density.

Figure 4.1 **The location of wetlands of International Importance (Ramsar sites) along the Niger River, indicated with triangles**



Source: World Resources Institute.

The present study only focused on the Office du Niger and its future water demand. A stronger withdrawal of river water from the Niger in the future may have strong negative effects on international important wetlands downstream. In Mali, the Ramsar site *Delta Intérieur du Niger* constitutes over 4,119,500ha of wetland and is, amongst other criteria, important for its outstanding variety of flora and fauna species (Wetlands International website). Further downstream Ramsar wetland sites along the Niger river are also found in Burkina Faso (Figure 4.1). Therefore, policy choices for water management in the Office du Niger may have strong side effects on international biodiversity hotspots downstream. Further steps towards climate change adaptation options should therefore also include the environmental effects outside the study area.

Climate change extremes are not evaluated in the present study. Extreme droughts during the dry period may result in a complete stop of the river flow of the Niger. This situation has already occurred in the past (see section 6.5) and can be expected to occur more frequently in the near future. Crop production will in such cases solely depend on rain and groundwater. Also other sectors like generating hydropower and income form fresh water fisheries will be suppressed. Moreover, demand for groundwater (livestock and human) will increase due to the assumed immigration of people. Emphasis on the investment and maintenance of the irrigation system should be given priority, given the fact that the current irrigation system is hardly maintained. Investments are also needed for seasonal water storage and the side effects to the other sectors mentioned above. In a multi-criteria analysis costs of investments associated with policy options can easily be included. Hence, an evaluation of policy options than include the benefits in terms of performance of Land Use Functions and dimensions of sustainable development by their original indicator values and monetary costs of different investment strategies. In the current study such an analysis was not carried out due to the lack of data, information, and policy choices towards investment strategies.

The National Adaptation Programme of Action (NAPA) of Mali (PANA, 2005) evaluates the most urgent adaptation strategies that are needed given the likely climate change scenarios. Also, this NAPA concludes that highest priority should be given to the investment in crop diversity and breeding of drought sensitive crops.

Given the policies that are evaluated in the present study, there are presumably many hidden costs of investments that are not taken into account yet. Further research that includes such hidden costs is needed.

4.3 Recommendations on mitigation strategies in Brazil

The case study of Brazil showed that a complex trade-off relation among the three pillars of sustainable development can be found. Scenario 3 with less effective environmental policies depicts the highest score for sustainable development but trade-offs with major losses in the environmental dimension. Some capabilities of the environment (to the extended of biotic and abiotic resources) to cope and keep its resilience with the exponential production of grains are being lost in such case. These losses in environmental conditions could reduce soil capabilities of production affecting also economic and social dimensions. Global Economy especially in the Brazilian case, is not only deeply adhered and merged with sustainable development issues, but also plays a role in the fast economic growth evidenced in the country in the last years. The imports of soybeans and other rising value crops by the EU in the Amazon are already a concern for Brazilians and the international community - pressure for forest conservation and food supply. This paradox has recently forced the Brazilian government to rush into policy alternatives such as biodiesel, agroforestry, carbon credits, etc. to find sustainable solutions for both environmental and economic issue. This, however, has not yet led to a fruitful outcome.

Scenario 2 with effective policies in place shows a lower growth rate in the economic and social dimensions but rather keeps a more equitable balance among dimensions. It would be suitable to project these scenarios in a longer time horizon. A reduction in the imports of single major cultures could be profitable in a trade-off with a more assorted and environmental friendly rural development in the region. This management might appear risky in the short-term because it deteriorates social and economic dimensions at first gazes, provoking a break in the prominent paradigm in the region. But on the other hand, in the long term, it helps stabilise the three dimensions since it diversifies the economy, raises new technologies, and creates new job opportunities that might not be as exclusive and externalised as soybean production.

The scenarios created with the MCA tool are a strong dialogue bridge towards policies, but it also illustrates clearly the necessity of further analysis in the longer term. With this tool, policy makers and stakeholders can identify if a break of paradigm in the trade of commodities towards an implementation of a more diversified importation of products could benefit the three dimensions for future sustainable development. Effective policies in sustainability need to address problems in the future. If a strong inclination towards the other direction might be necessary until a point of rupture, then decision makers will have to agree regionally and maybe internationally what seems to be the best ending of such predictions for future generations.

4.4 Conclusions and recommendations for policy

The evaluation of adaptation and mitigation policies towards climate change in both case studies shows two commonalities - lack of data availability to project the effects of policy options on the dimensions of sustainable development and the lack of support by stakeholders and (local) policy makers in the evaluation process. In terms of policy recommendations the case study issues should be addressed differently.

Mali

For Mali, and especially in the Office du Niger, the case-study area would highly benefit from a pan-African initiative on the assessments of adaptation strategies to coming droughts. The case study shows that such droughts will have strong impacts on socio-economic issues since local economies strongly rely on agriculture. The 2009 initiative of the Dutch Ministry of Agriculture in the BO cluster VLG brings climate change on the agenda of East African countries. Capacity building of local researchers will help to enrol the sense of urgency to study adaptation options. However, local stakeholders and decision makers should be involved to meet the institutional dimension in the evaluation.

Brazil

From the Brazil study case it becomes clear that liberalisation, WTO negotiations and development of an EU Biofuel directive will have strong local effects. The socio-economic dimension will strongly benefit from globalisation but local environmental conditions will further deteriorate. On a global scale a trade-off relation can be found between WTO negotiations on trade on the one hand and meeting post Kyoto agreements on the other hand.

Part II Background information

5 Methodological framework

5.1 Methodology of the study

In this study, the methodological framework consists of five steps. In this framework, the Land Use Function (LUF) approach is used, which has been developed in the EU 6th framework project SENSOR (www.sensor-ip.org). The Land Use Function approach aims at assessing ex ante policy impacts affecting sustainable development related to land use. It is based on indicators reflecting those goods and services provided by different land-use types that relate to the most relevant economic, environmental and societal issues of a region (Nesheim et al., 2008). Indicators are measures that are used for monitoring and benchmarking of systems or for ex ante analysis (Nesheim et al., 2008). The four steps of the methodological framework are: (1) description of the current situation and definition of problems and drivers; (2) definition of alternative strategies that contribute to sustainable development; (3) definition of indicators that are related with current situation and alternative strategies; (4) evaluation of indicators in the current situation and alternative strategies; (5) application of the multi-criteria analysis (MCA) of alternative strategies. The MCA approach operationalises and consolidates the policy making process. It consists of weighing of criteria and weighing of indicators within the dimensions of sustainable development. Results of MCA indicate to what extent different alternative strategies contributes to sustainable development.

In the LUPIS project sustainable development is defined as the elimination of poverty of present and future generations through management of land and natural resources which avoids the risk of radical ecosystem change (Verburg et al., 2008). The context of sustainable development includes four dimensions: environmental, social, economic, and institutional dimension. The first three dimensions are regulated by the fourth dimension - the institutions. Economic dimension refers to economic growth and equity, while the social dimension refers to cohesion and participation. Environmental dimension refers to natural resources, biodiversity, atmospheric stability, and other ecosystem functions. Institutional dimension refers to policies, regulations, and effectiveness of institutions. In terms of these four dimensions, sustainable development can be interpreted as the development of the social, economic and institutional systems taking into account the negative effects it has on the environment.

The concept defined above links sustainable development with land-use policies and climate change. Land use and climate change are closely interrelated, since climate change has strong effects on land use. However the effects of land use on climate change should not be ignored. Therefore, land-use policies should be adapted in such way that sustainable development can be achieved.

Land-use policies

Three characteristics of land-use policies are observed in developing countries (Bonin et al., 2008). First, land is considered as part of natural resources. Practices on land resources (e.g. agricultural and industrial land uses) require adequate policies that take sustainable development into consideration. Second, developing countries face difficulties in land administration. The inadequate land administration (e.g. incomplete registration system, uncertainty of legal titles, etc.) leads to high transaction costs that distort development. This explains why in many developing countries land policies focus more on administrative reforms than environmental projects. Third, in many developing countries, land use is more than a geographical space. It has a strong cultural feature. For example, different types of property rights are often overlapping and inconsistent in developing countries that originate from different indigenous cultures.

Land-use policies and concomitant institutional arrangements play a crucial role for sustainable development in both developed and developing regions. Lack of institutional power has shown to be a crucial factor in sustainable development of developing countries. With current land-use policies under way to achieve sustainability, projected climates change effects will call for alternative policy options that take climate change into account.

Land use and climate change

Land use influences climate and weather at local and global scales. Key links between changes in land use and climate include the change of greenhouse gases between the land surface and the atmosphere, the radiation balance of the land surface, the exchange of sensible heat between the land surface and the atmosphere, and the roughness of the land surface and its uptake of momentum from the atmosphere (CCSP & SGCR, 2003). Due to these strong links, changes in land use can be an important contributor to climate change and therefore affect ecosystems and many important goods and services that they provide to society (CCSP & SGCR, 2003). While land use change is often a driver of climate changes, a changing climate can in turn affect land use. Climate change alters land-use practices differently in different parts of the world. Examples can be the threat of a rise in sea level to the coastal zones, the damage of serious flooding or drought to agricultural production, etc.

5.2 Step-wise approach

5.2.1 Current situation, problems, and drivers

In the first step, each case study describes the current situation of the case-study area. Problems related with climate change of the case-study area are defined and drivers that cause the problems are specified. In this step, we elaborate on the LUF approach. LUFs aim at pointing out regional differentiations of land use-relevant goods and services on human society within rural areas that are primarily affected by land use changes (Pérez-Soba et al., 2008). In this study, the target of sustainable development implies that the development of environmental, social, and economic dimensions is equally important. Nine LUFs are developed for all dimensions of sustainable development (see Figure 5.1).

Figure 5.1 The Land Use Function approach

Source: König et al. (2008).

The LUFs are defined as follows by Reidsma et al. (2008):

- *Social functions*
    1. Provision of work: the employment provision for all, according to activities in relation with natural resources; quality of jobs, lack of job security, localisation of jobs (constraints/commuting);
    2. Human health & Recreation (spiritual & physical): access to health and recreational services and factors that influence services quality;
    3. Food security: food self sufficiency.
- *Economic functions*
    4. Residential and non-land industry and services: the space where residential, social and productive human activity takes place in a concentrated mode. The utilisation of the space is mainly irreversible due to the high concentrations of the buildings;
    5. Land based production: human productive activities that determine changes which are mainly reversible (agric, for, natural energy sources, land based industry -mining);
    6. Infrastructure: the space used for infrastructures that determine changes which are irreversible.
- *Environmental functions*
    7. Provision of abiotic resources: the capacity of the land to provide sufficient quantity and quality of air, water and soil;
    8. Support & Provision of biotic resources: factors affecting the capacity of the land to provide biodiversity, from the genetic diversity of organisms to a diversity of habitat in the landscape that are in suitable ecological condition;
    9. Maintenance of ecosystem processes: the capacity and factors affecting to vital processes such as water purification, nutrient cycling, etc.).

5.2.2 Current policies and alternative strategies (policies)

Following the specification of problems (related to climate change) and drivers, this step further specifies land-use policies that are closely related with the problems and the drivers. Based on the current problem and the current policies, alternative strategies are designed as such that they are assumed to improve the sustainable development in the case-study area. However, the effects of alternative strategies on LUFs can be manifold. A strategy may have positive effects on some LUFs while having negative effects on other LUFs. Therefore, each alternative strategy should be fully described taking climate-change effects into account. For each strategy both benefits (positive effects of the alternative the strategy on the indicators) and associated costs (negative effects of the alternative strategy on the indicators and also investment) should be included.

In this study the current status, a climate-change baseline scenario and a number of alternatives (strategies) are worked out. The current situation involves the status of today, with current policies in place. The baseline scenario involves the climate-change effects (temperature, water, etc.) but no new policies are included. Hence, this scenario can be considered a no-action policy (i.e., the results of this strategy is called *costs of inaction*). All the alternative strategies are called alternative scenarios, in which alternative policies are designed to minimise the negative effects of climate-change. It is important to point out that the alternative scenarios should be evaluated against the baseline scenario, since those scenarios include the climate-change effects. All the alternative scenarios can be summarised in a table. In such a table, the current situation (baseline scenario) and alternative scenarios are listed, taking climate-change effects into account.

5.2.3 Definition of indicators and variables

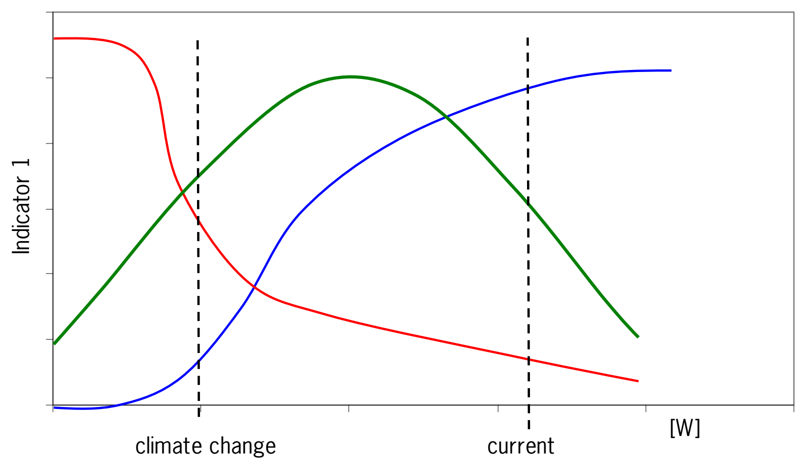
The first step links sustainable development with LUFs. A LUF can be considered as a processed illustration of aggregations of single indicators that are tailored to identify goods and services on land-use issues (Pérez-Soba et al., 2008). A balanced set of indicators can be linked to the nine LUFs. In this step, a list of indicators is selected based on four criteria: (1) facility of analysis, i.e. their relevance with respect to the problems and the drivers; (2) facility for decision making, i.e. the balance between different stakeholders such as policy makers, researchers, and farmers; (3) the ability to reflect the transformations of the environment, and (4) the effect of practices, validity at several scales of analysis (Reidsma et al., 2008).

After the selection of indicators, variables need to be defined in order to measure indicators. For example, one indicator - water quality - may have several variables, such as temperature of the water, dissolved oxygen in the water, acidity of the water, and turbidity of the water. A table can be made to collect all the indicators that are grouped under different LUFs. Such a table can be extended to include all the variables that measures the indicators, giving explanations on how to calculate the variables, the unit of the variable and at which level the data is calculated (i.e. at field level, farm level, regional level, or national level).

5.2.4 Evaluation of indicators and variables

After selecting indicators and defining variables in the last step, specific values of different scenarios are attached to the variables in this step. When the values of the variables under the current situation are established, the current status is known and can be used as a reference for comparison. To evaluate variables under alternative strategies, a response function needs to be identified in order to describe quantitative or qualitative relationships between variables and certain alternative situations. For example, such a response function describes how a variable (i.e. the rice yield) changes given the influence of climate change (i.e. less water available for irrigation). Figure 5.2 shows a hypothetical response function between an indicator (or a variable) and water availability.

Figure 5.2 **A hypothetical response function between indicator 1 and water availability [W] a)**



a) The function can have different forms, as shown by the different coloured lines.

In Figure 5.2 different indicator response functions to water availability ([W]), depicted by different coloured lines, are shown. The figure shows two vertical dashed lines, indicating the current status or the climate-change status. For the current status the indicator will have a particular value, given the response function. With climate change the water availability [W] is expected to reduce to the level of the vertical dashed line with climate change. Given the response function, a new indicator value can be calculated. Such a relation as a response function can be obtained by examining water availability in different years and the corresponding values of a particular indicator. Having a number of observations (e.g. on water supply and the corresponding indicator) a response function can be obtained. For the first round of calculations we assume the most simple response function for each indicator, like a linear or log function.

Some indicators are only indirectly affected by climate change. For example, manure from livestock is not directly dependent on climate change but will change with the number of livestock. If this number is dependent on water availability for example, we can calculate indirectly the response of manure by water availability by using the response of livestock number on water availability. For this manure is calculated as a function of livestock. Any change in livestock, by for example water availability, will therefore affect manure indirectly.

5.3 Multi-criteria analysis

To carry out a multi-criteria analysis (MCA) a full list of alternative options has to be defined. For each alternative the effects on indicator values have to be assessed. This can be done by using different models, or as described in the previous sections, by using response functions. In an MCA all indicator values are assessed in their original units. Therefore, an MCA does not provide a full cost-benefit analysis. The benefits are calculated in terms of MCA performances of the different alternatives. For alternatives where no adaptive measures are taken, the costs of inaction can be measured. These costs are defined as the MCA performance of the alternative which does not include any adaptive strategies. One can expect a low overall MCA performance of different Land Use Functions and associated indicator values. Hence these lower values are costs of inaction. Benefits can include economic benefits, but also benefits in terms of indictors from the environmental and social dimension. In this study, we work with the original units for all indicators. Consequently, we do not have the full benefit in terms of monetary units.

Once values of variables under all scenarios are specified, MCA is conducted as the last step. The MCA approach operationalises and consolidates the policy making process. It consists of weighing of criteria and weighing of indicators and variables within the dimensions of sustainable development. Results of an MCA indicate to what extent different alternative strategies contribute to sustainable development.

5.3.1 Weights of LUFs, indicators, and variables

In the LUF approach of SENSOR and the adopted approach in LUPIS each LUF is built up by a number of indicators. As described in Pérez-Soba et al. (2008), each LUF is determined by the relative contribution of each indicator to the LUF. The following example shows this contribution:

$LUF1 = aI_1 + bI_2 + cI_3 + \ldots + nI_n$

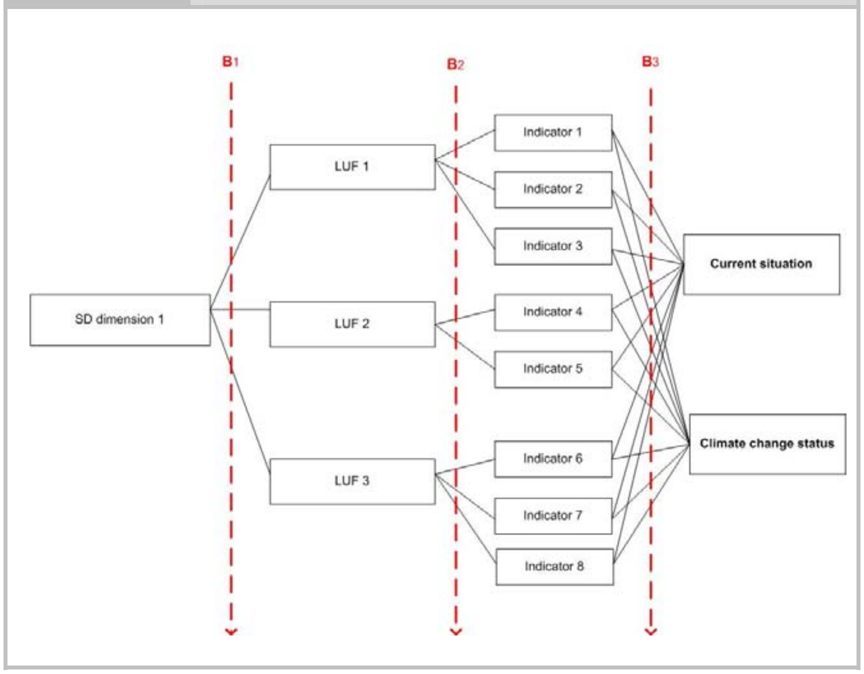
Where I_n = indicator n
a-n = relative contribution to the LUF

The relative contribution in Pérez-Soba et al. (2008) is defined as the relative score of an indicator to the LUF. Consequently, a small change in the value of an indicator strongly or moderately change the value of a LUF. In Pérez-Soba et al. (2008) the relative contribution of an indicator varies between -2 and +2. Consequently, the values of a-n vary between -2 and +2.

In this report we deviate from this structure, since there is a lot of subjective interpretation in assigning the relative contribution of indicators. In this study we simply assume that each indicator in an LUF contributes equally to that LUF. Consequently, when a LUF has 4 indicators, each indicator contributes ¼ to the final value of the LUF. Note that the LUF value itself is meaningless. However, the values allow us to compare among different LUFs. To compare the effects of climate change on the relative performance of the LUFs and eventually on the performance of the three dimensions of SD, all data will be put in an MCA. As an example, the scheme of one dimension is depicted in Figure 5.3.

In Figure 5.3 three branches, B1, B2, and B3 are depicted (the red dotted lines). For branch B1 the relative importance of each LUF in each dimension is established. Since there are three LUFs and we assume equal weights among all LUFs, the weight of each LUF is 1/3. In other words, the relative contribution of each LUF with respect to the SD dimension is set to 33% at a 0-100% scale in MCA. The second branch, B2, denotes the relative strength of each indicator in each dimension. Therefore in branch B2, indicators 1, 2 and 3 each contribute one third to LUF1, indicators 4 and 5 each contribute one half to LUF2, indicators 6, 7, and 8 each contribute one third to LUF3. Note that in Figure 5.3, indicators 1-3 only contribute to LUF1, indicators 4 and 5 to LUF2 and so on. This indicates that the same indicator cannot contributes to two different LUFs. This is vital to an MCA, since the technique is sensitive to duplication or ruminant decisions. The relative contribution of an indicator declines when the total number of indicators in each LUF increases. Therefore, it is important to make sure that each LUF contains more or less the same amount of indicators. Small differences in the total number, however, are not very sensitive in MCA. In branch B3, values of all the indicators will be filled in, one value for the current status and the calculated value for the climate change situation. One of the merits of MCA is that it does not require the homogeneity of the values of all indicators. In other words, values of all indicators that have different units can be directly fed into MCA without any adjustments. The weighing of variables follows the same procedure as the weighing of indicators.

Figure 5.3 **A partial representation of the MCA tree. Note that LUFs and indicators are depicted for only one dimension. The full MCA comprises three dimensions of SD and therefore 9 LUFs in total.**



5.3.2 Final results

Once the LUFs, indicators, and variables are weighted, this information can be fed into an MCA. A multi-criteria analysis routine will calculate an arbitrary value for each LUF for all the scenarios. For each LUF the relative values can be derived from the MCA where they range between 0-1 since we have constraint these values between 0-1 already. The benefits of each strategy are thus the relative performance of each LUF. Which strategy to choose from depends on the costs that are associated with each strategy and the preferences a policy maker will have for one or more LUFs. For example a LUF associated with social dimension might be preferred to the performance of a LUF associated with environmental dimension. Therefore different solutions may emerge. There are solutions that improve one of the three dimensions of SD and solutions that are able to improve performances of all the dimensions. MCA also provides results that depict an overview of contributions of different alternative strategies to sustainable development. Conclusions can be drawn based on such results by saying the alternative strategy that scores the highest also contributes the most to the sustainable development goal.

For the MCA analysis the software package Criterium DecisionPlus version 3.0 was used (InfoHarvest, 2008). For the weighting routine for alternatives the Simple Multi-attribute Rating Technique (SMART) was used (Edwards, 1977; Von Winterfelt and Edwards, 1986).

6 Climate change in the Office du Niger

By Youssouf Cissé, Bamoye Keita, Mamadou Demba Traore and Adama Tiémoko Diarra

Edited by Le Chen and René Verburg

Preface
This chapter provides a description and in-depth analysis of drivers of change and land-use change in the case-study area. The description of the state of affairs is provided by the research team of IER in Mali. The contribution of IER, delivered in a research document, was edited by the LEI team and is reflected in this chapter. The chapter highlights the relevant information of this deliverable. Relevant information and data necessary for the multi-criteria analysis are provided in Chapter 2.

6.1 Introduction

The Office du Niger is continuously expanding. The objective of the Malian government is to reach 200,000ha of improved lands in Office du Niger by 2020. However, the water resource of the Office du Niger is the Niger River - which is facing the threat of less rainfall due to climate change. This raises the question of water availability from the Niger River for all the improved lands. To tackle such a question calls for adaptive strategies to minimise the negative impacts of climate change on the livelihood of the local population.

6.2 The Niger River

The Niger River is the third longest river in Africa. With a total surface of 2.2m. km^2, its basin is the ninth largest in the world. It stretches some 4,200km from its source. The Niger River crosses four climatic fields:

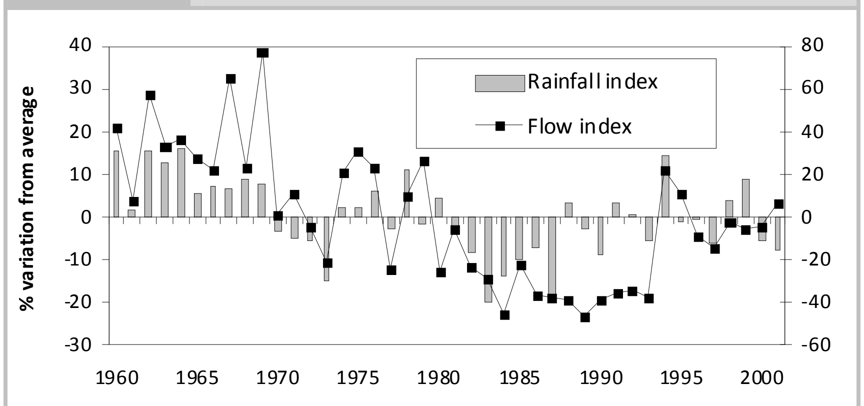
1. the Guinean field, which is the head of the basin that has more than 1,500mm rainfalls;
2. the South-Sudanian field that has rainfalls ranging from 1,000 to 1,500mm;
3. the Sahelian field that has rainfalls ranging from 400 to 700mm;
4. the semi-arid field that has rainfalls ranging from 150 to 700mm.

The upper and middle reaches of the Niger River cover 1,700km and cross Mali. It passes the Sahelian and semi-arid climatic fields. The rainy season (from June to October with approximately 700mm rainfall) and the dry season divide the year into two parts. The river basin is vital to the economy of Sudano-Sahelian region in Mali, particularly the Office du Niger.

Since the beginning of the century, the Niger River has encountered several dry periods. The first two dry periods were in 1913 and the beginning of 1940s (Cisse et al., 2008). Figure 6.1 shows the rainfall and flow indices of the river from 1960 to 2001. From Figure 6.1, we can see that declines in average rainfall continued after 1970. This situation resulted in a 200km southward shift in isohyets. The same figure also shows considerable variation in the river flow. An average decline in the range of 40-60% in river flow was observed since 1970. Hence, Figure 6.1 shows a positive correlation between rainfall and river flows. Andersen et al. (2005) confirmed such correlation between decreased rainfall and low river flow in their study on the Niger River Basin.

The long-term relationship between rainfall and rive flow is largely influenced by groundwater base flow. Cumulative dry periods contribute to a reduction in base flow. The aquifer has to be replenished before the sustained river flow returns. Therefore, decreased rainfall from previous years contributes to the exhaustion of aquifers of the catchment area, especially during a series of dry years.

Figure 6.1 **Average rain and flow indices of the Niger River Basin in 1960-2000**



Source: Diarra and Cisse (2004).

In 1999, an absolute minimum that is marked by a complete stop of the river flow was observed despite a rather heavy rainfall in the same year. The delayed hydrological response of the Niger River indicates that it takes more than a good rainy year to return the river to its previous flow (Andersen et al., 2005). This is due to the depletion of groundwater reserves in the upper catchment areas.

6.3 The Office du Niger

6.3.1 The Segou region

The Office du Niger is located in the Segou region, which is right in the heart of Sahel - the centre of Mali. The Segou region is an area of transition between the dry Saharan region in the North and the tropical region in the South. The Sahel is characterised by the alternation of two seasons annually - a short rainy season (from June to October) and a long and rigorous dry season (from November to May). The dry season itself is characterised by (a) a cold season (from November to February) with a minimum temperature of 15°C and (b) a hot season (from March to May) with a maximum temperature of 45°C. The average temperature in the dry season is around 30°C. The rainfall of the region is concentrated in a 3 to 4-month period (between June and October). Randomly distributed through time and space, it varies annually from 200 to 600mm.

6.3.2 The Office du Niger Dam

The Office du Niger is one of the largest and oldest irrigated perimeters of West Africa. The potential of irrigated land is 1,907m. ha. At present, about 82,000ha have been developed for irrigated land based on a dam constructed for the irrigation system in the zone.

The Office du Niger Dam is also known as the 'Sansanding dam', or the 'Markala dam'. It is a major hydro-agricultural development object in Office du Niger. It is situated on the Niger River at about 35km downstream of Segou and 275km from Bamako. Its construction began in 1934 and ended in 1945. It became operational in 1947. It provides water for irrigation not only for the Office Du Niger zone but also for the Office Riz Ségou.

The Office du Niger is located in outside of the Niger River annual flooding area. Therefore, the livelihood of the local population depends substantially on the water provided by the dam.

6.3.3 The irrigation system

The Office du Niger Dam provides irrigation water through abandoned river channels to a hierarchic irrigation network composed of primary, secondary and tertiary canals. A set of hydraulic infrastructure that contains five canals forms the primary network of the irrigation system. It was designed to dominate the eight hydraulic systems of Office du Niger, covering a total surface 1,907m. ha. Secondary canals are divided into several independent hydraulic units through control structures. The tertiary canals serve tertiary blocks. In a tertiary block, field canals bring the water to the field and evacuate it to a drainage network.

After having been in use for more than 70 years, the irrigation network carries stigmas of its age. The canals, particularly at the level of the primary network, are silted up and have been invaded by all kinds of water plants. Several schemes are in an advanced state of degradation. This has led to low yields of crop production and the decline of productivity.

6.4 Agricultural production system at the Office du Niger

Before the hydro-agricultural development, the Office du Niger was an area subjected to the cultivation of rainfed millet in rotation with long fallow periods and a transhumant livestock husbandry. Today, rainfed crops have been pushed back to dry zones bordering the developed perimeters.

6.4.1 Crop production

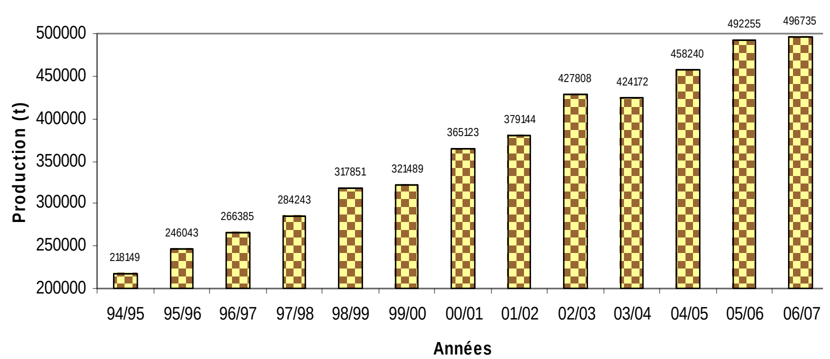
Since the construction of the dam in 1948, irrigated agriculture remained the main production system. The average areas allocated by farmers for rice cultivation vary from 3 to 15ha. There were abundant labour for rice cultivation (e.g. about 10 persons per farm) and oxen were used for ploughing. The yield was rather low - about 1 to 2 tons per hectare.

Later, rice production was intensified under the rehabilitation programmes. These projects disseminated improved agricultural practices for rice cultivation. The achievements of such disseminations were: (1) decreases of the areas allocated for rice production per farm; (2) the adoption of new and improved varieties having resistance to viral infection and appreciated by consumers; (3) the adoption of motorised equipment besides the oxen ploughs; (4) bedding out instead of sowing by broadcasting; (5) the use of chemical and organic fertiliser; (6) the use of small Votex threshing machines. As a result, the amount of seeds used per hectare was reduced, some technical practices were improved, costs of production were reduced, and rice productivity increased from 4 to 6 tons per hectare.

In Office du Niger, almost all the improved lands are used for rice production during the rainy season. Rice production during the off-season (hot dry season) has been underway for many years. Recently, market gardening, vegetables (e.g. tomatoes, shallots, etc.) and/or other crops (such as maize, potato, sweet potato, groundnut, etc.) are allowed to be grown by farmers off-season.

The production of rice and other crops has been increasing since 1994. In 2006-07 the average yield of rice has reached 5,845 tons per hectare. Figure 6.2 shows the production of paddy per cropping season in the Office du Niger.

Figure 6.2 **Paddy production per cropping season in the Office du Niger**



Vegetables and other crops (e.g. wheat, potato, lettuces) were produced in a total area of 8,556ha for a total production of 203,815 tons, among which vegetables occupied 7,278ha with an output of 171,652 tons.

The increase in crop production can be explained through the expansion of lands but not through the intensification of the system. In this way, more hectares of land are put to use that require more water for irrigation. This situation is expected to last because of the increasing demand for rice in Mali and in the sub-region of West Africa.

6.4.2 Livestock production

An extensive type of breeding is practiced traditionally by the ethnic group known as the 'Fulani' who are the professional herdsmen. Today, livestock is totally integrated into the system of agricultural production and constitutes a means of saving for almost all the farmers. Livestock, mostly cattle, contributes to the farming system by supplying energy through the traction of plough and cart and also by providing animal manure to the farm. In 2002, the number of cattle was about 300,000 heads, including 43,000 draft oxen and 16,000 donkeys.

After the harvest period, the transhumant herds migrate to rice-growing fields as sedentary herds. Farmers are in favour of the latter, especially when the animals belong to themselves. Animals are fed by rice straws and supply manure as fertiliser to rice production as substitutes of chemical fertiliser due to its high price. During all the period (eight months) of the presence of cattle in the Office du Niger plots and the surroundings they produce an important amount of manure, estimated at about 38,000 tons in the Office du Niger production zones (Niono, Molodo, N'débougou and Kouroumar), yielding about 1,063 tons of urea. This represents about 18% urea needs of the farmers, and a value of CFA 267m.[1] (410,000 euros).

The major inconvenience of the extensive livestock raising system in the Office du Niger is the degradation of the forests and the rice irrigation networks. The degraded forests are used as grazing lands and the irrigation networks are used as pathways due to the lack of these types of infrastructure.

6.5 Impacts of climate change

6.5.1 The variability of water resources

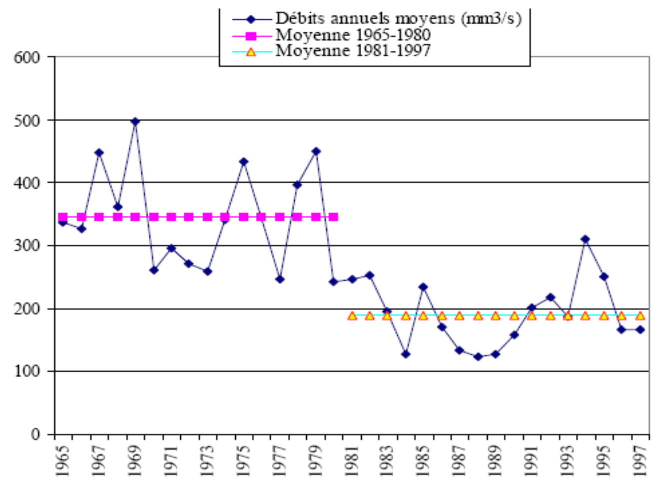
The irrigation service in the Office du Niger depends mainly on the Niger River. Figure 6.3 shows the average annual rate of water flow measured at the Selingue hydrological station. It is clear that the water flow has significantly decreased since the 1980s.

The water availability of the Office du Niger dam depends also on the management of the upstream 'Selingue dam' that has been built on the Sankarani, the main tributary of the Niger River. This is due to the fact that the priority of

[1] Communauté financière africaine.

Selingue dam is to produce electricity that requires massive amounts of water. In 1999, the supply of electricity by the Selingue dam had led to shortage of irrigation water in the Office du Niger.

Figure 6.3 **Average annual rate of flow at the Selingue hydrological station in Mali**



The water availability of the Niger River however depends on the level of rainfall, which is very unpredictable in terms of quantity and distribution. It is known that about 2,000-4,000m^3 per second is transferred by the Niger River in rainy season while only 200m^3 per second is taken by the Office du Niger dam. Therefore, it can be deduced that there is enough water during the rainy season.

However, water supplied by the Niger River only covers 8 months a year. There is not enough water supply during the off-season (i.e. from February to June) so less than 15% of the developed lands (about 12,000ha) are used for rice production. Figures 6.4 and 6.5 show gaps between demand for water and water availabilities per wet and dry decennial year. From both figures, it is clear that there is a water shortage during the off-season and a water surplus during the rainy season.

Figure 6.4	Gaps between demand for water and water availabilities per wet decennial year

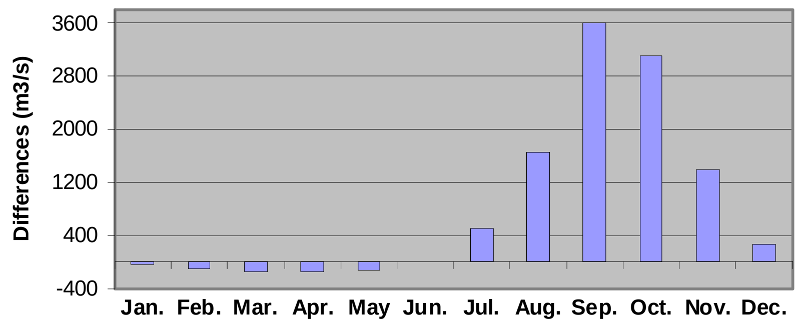
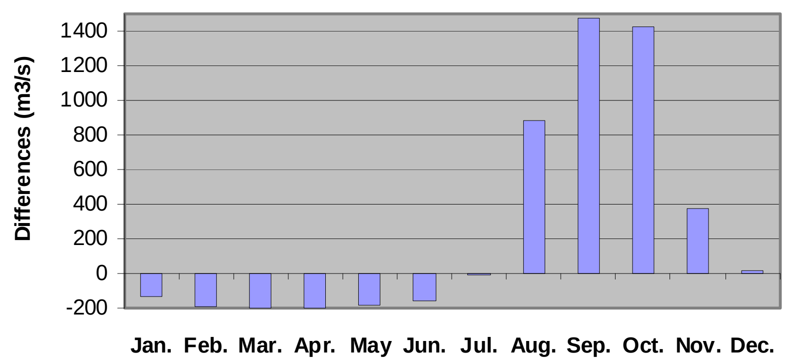
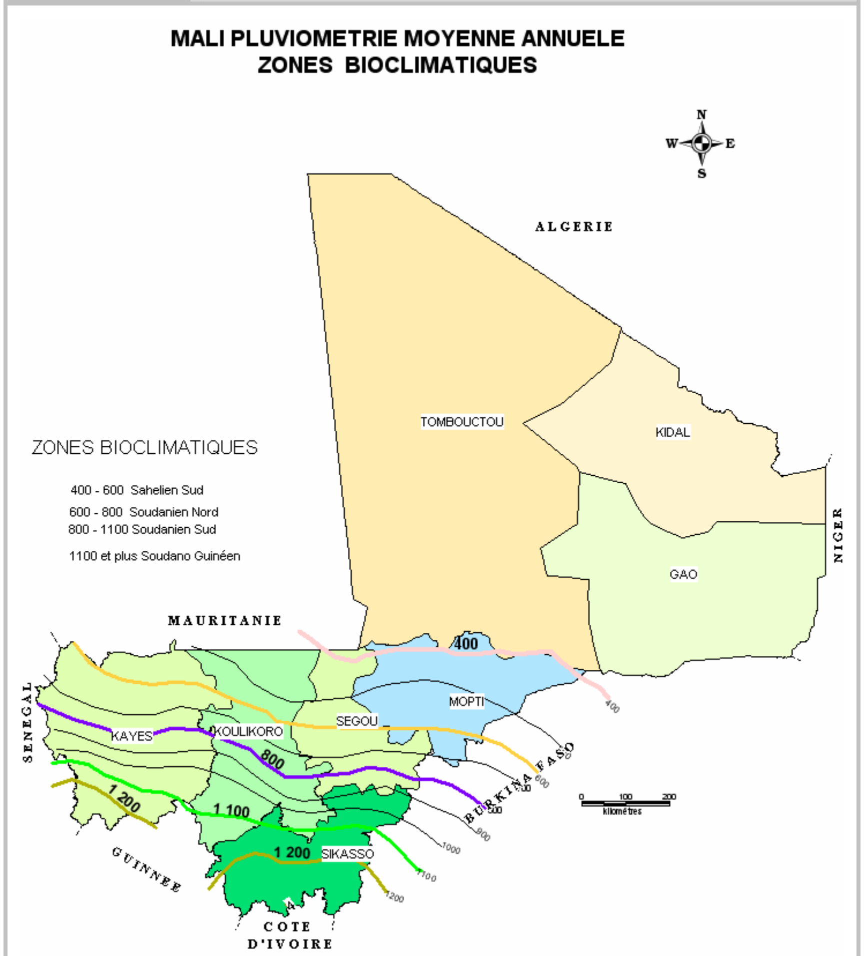


Figure 6.5	Gaps between demand for water and water availabilities per dry decennial year



Due to the increasing variation of water availability, statistics presented in the PANA report (2005) show that the isohyets have drastically changed. It has been moving between 500mm and 1,500mm in the 1950s, barely reached 1,300mm in the last 15 to 20 years. Figure 6.6 presents the average annual rainfall levels and the climatic zones.

Figure 6.6 **Average annual rainfall levels and climatic zones**



Source: PANA report (2005).

Traore et. al. (2003) carried out further analyses on climate change in Mali using rainfall data from the available database at the National headquarter of the metrological services. Several scenarios including the socio-economic aspect, the growth of the population, the spatial distribution of the population and the growth of the economy were simulated in their study. Two maps have been produced based on their projections (see Figures 6.7 and 6.8). The first map (Figure 6.7) shows the average annual variation of the temperature as a percentage of the temperature in Mali in 2050. The second map (Figure 6.8) displays the average annual variation of the rainfall level as a percentage of rainfall in Mali in 2050.

The main conclusions drawn from their analysis are that (1) there will be a decrease in the level of rainfall from the east to the west of the country in 2050, 2075 and 2100; (2) During the dry season, there will be an increase in temperature from the south to the north of the country.

Climate changes have significant negative impacts on the water flow of the Niger River, which leads to less water available for irrigation. The increase in temperature has considerable impacts on livestock production since livestock need to drink more water to cope with higher temperatures.

Figure 6.7 **Average annual variation of rainfall (%) in Mali in 2050**

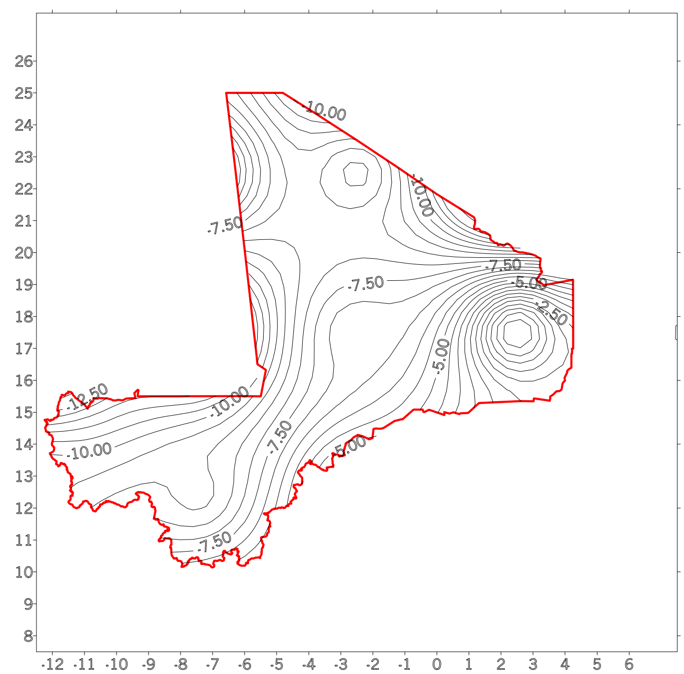
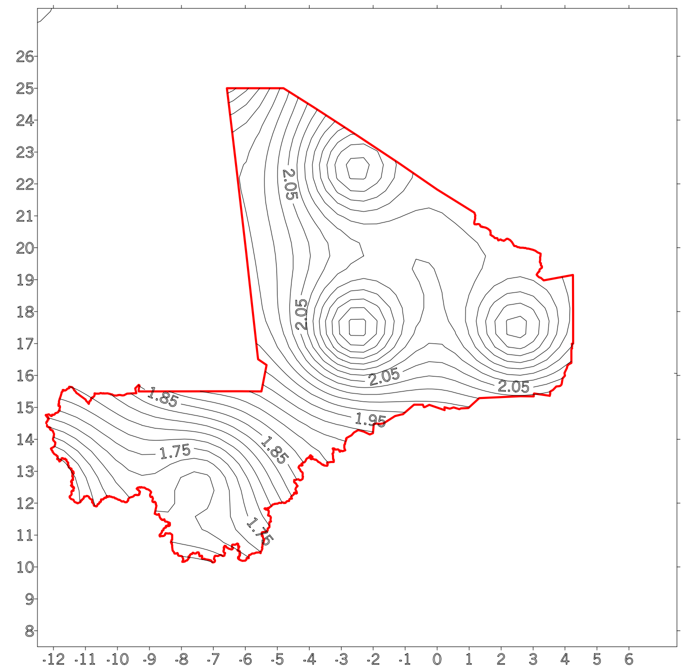


Figure 6.8	Average annual variation of temperature (°C) in Mali in 2050



6.5.2 Impacts of water availability on crop and livestock production

Variation of water availability influences rice production in many ways. Insufficient amounts of water lead to hydric stress[1] and excessive amounts of water lead to the drowning of crops which ultimately leads to poor yields.

The situation of insufficient water is frequently observed off-season but it can also occur in the rainy season, as it happened in Ké-Macina in 2007-08. The situation of excessive amount of water arises especially during the rainy season when some drainages are in such a poor state that they are not able to deal with floods.

In the Office du Niger, irrigated land is for rice, sugar cane and vegetables. Part of the non-irrigated land is for rainfed crops such as millet and sorghum. The remaining part of the non-irrigated land has alluvial deposits that are less

[1] Hydric stress: water deficiency can cause increased susceptibility of the host plant to attack by numerous pathogens (especially wound parasites).

suitable for farming but very valuable for pasture. These lands form a security valve for livestock in the surrounding of the Office du Niger.

When this natural pasture is degraded by droughts, livestock settle in the harvested rice fields for a long period (from December to July). This not only causes conflicts between farmers but also damages to the irrigation drainages.

Higher temperature (around 48°C) may lead to several cattle diseases such as eczemas and vitamin A and E deficiencies. As a consequence, fertility rates decrease. Other diseases such as streptotrichosis, dermatophylosis and nodular dermatosis may appear frequently. These diseases have negative impacts on livestock production such as the skin quality and the mortality rate.

6.6 Adaptive strategies

6.6.1 Rice production

Given the negative impacts of climate change on crop and livestock production, adaptive strategies need to be implemented to minimise the losses caused by the climate change.

To characterise these strategies, it is important to describe the current situation. The current situation is that all irrigated land is used for rice production both in the rainy season and off-season, and that rice is produced on small plots of irrigated land that are rarely larger than 0.25ha.

Based on the current situation, three adaptive strategies have been developed for the Office du Niger. In all the adaptive strategies, it is assumed that rice is the only crop that is allowed to be produced by farmers during the rainy season due to the objective of food security of the Malian government. During the off-season, we assume farmers let the irrigated land fallow, or they grow different crops such as vegetables or sunflowers (Table 6.1).

Table 6.1 summarised all the adaptive strategies developed for the Office du Niger. Possible impacts of each strategy are also given in the table. These impacts can be either positive, bringing profits, or negative, bringing losses.

Table 6.1	Adaptive strategies for the Office du Niger		
Adaptive strategies	**Rainy season**	**Off season**	**Impacts**
Current situation	Rice	Rice (15% of irrigated land)	- Farmer income doubles when water is available. - Rice supply slightly increases. - The irrigation of 15% of the irrigated lands requires the irrigation of the total irrigated land, which wastes water. - In the long run, monoculture of rice leads to land degradation.
Strategy 1	Rice	None	- Land recover from fallow in off season. - Allows for the maintenance of the primary canals by the Office du Niger authorities.
Strategy 2	Rice	Vegetables	- Vegetables require less water for irrigation. - Reduce land degradation via polyculture. - Higher income for farmers. - However, demands for vegetables are low. - Farmers face constraints of vegetable preservation and storage.
Strategy 3	Rice	Sunflower	- Sunflower is tolerant to hydric stress. - The value-added is high for sunflower. - Sunflower requires high technology such as sowing and harvesting. - Sunflower production is more labour intensive. - Sunflower brings less profit than vegetables due to low demand.

6.6.2 Data for the MCA

Table 6.2 listed data that is used for MCA. Due to data limitation, values of variables under baseline and alternative scenarios are derived from educated guesses. Some variables have absolute value and some variables are represented in the relevant values such as changes in percentages or changes in rates.

Table 6.2 **Values of the variables under different scenarios in Mali**

Variables	Current situation	Baseline	Scen. 1 (rice + fallow)	Scen. 2 (rice + vegetable)	Scen. 3 (rice + sunflower)
No. of small businesses (number)	18	18	18	18	18
Agricultural income (CFA)	11,448	10,303	9,730	13,165	12,593
Value of crop production (CFA)	3,885	3,691	3,652	4,079	4,040
Value of livestock production (CFA)	5,724	5,724	5,724	5,838	5,781
Expenditure fertilises use (rate)	1	0.9	0.85	0.9	0.87
Share of water used for irrigation (%)	27	27	27	27	27
Total length of canals (rate)	1	1.1	1.1	1.1	1.1
Management irrigation system (rate)	1	1	1.5	0.7	0.7
Water fee (%)	100	100	100	100	100
Immigration rate (rate)	1	1.3	1.3	1.3	1.3
Migration rate (rate)	0	0	0	0	0
Life expectancy (age)	69.5	71.6	70.9	73	72.3
Regional staple food consumption (CFA)	1,950	1,911	1,891	2,145	2,126
Months of household food provisions	6	7	9	3	4
% Crop losses during storage (%)	0	0	0	0	0
No. of (keystone) species (rate)	1	0.8	1.3	1.2	1.2
Water use ecosystems (rate)	1	0.15	0.9	0.2	0.3
Share of forest land (rate)	1.5	0.5	0.5	0.5	0.5
Share land under production (rate)	4.5	14.5	14.5	14.5	14.5

Table 6.2 Values of the variables under different scenarios in Mali (continued)

Variables	Current situation	Baseline	Scen. 1 (rice + fallow)	Scen. 2 (rice + vegetable)	Scen. 3 (rice + sunflower)
Agricultural yield (kg/hectare)	5,800	3,000	2,800	3,200	3,400
Gap between potential & actual yield (rate)	17.14	19.14	18.14	15.14	14.14
Soil nitrogen & phosporus (rate)	1	1.2	1.25	0.9	0.8
Fertiliser use (rate)	1	0.9	0.85	0.9	0.87
Precipitation (mm/year)	400	200	200	200	200
Water flow Niger (m^3/year)	56.1	28.05	28.05	28.05	28.05
Share of clean water per household (%)	100	98	98	98	98
Water use agriculture (%)	100	50	0	40	20
Amount of waste water (%)	0	0	0	0	0

Notes: CFA is Malian currency. 1 CFA = 0.002078 US Dollar.

7 Land-use policies in Mato Grosso (Brazil)

By Saulo Rodrigues Filho, Diego Lindoso, Catherine Gucciardi and Nathan Debortoli.

Edited by René Verburg and Le Chen

Preface
This chapter provides a description and in-depth analysis of drivers of change and land-use change in the case-study area. The description of state of affairs is provided by the research team of FUB in Brazil. The contribution of FUB, delivered in a research document, was edited by the LEI team and is reflected in this chapter. The chapter highlights the relevant information of this deliverable. Relevant information and data necessary for the multi-criteria analysis are provided in chapter 4.

7.1 Introduction

The growth of agriculture and livestock towards areas of native vegetation in the second half of the twentieth century in Mato Grosso put the state in the leadership of forest depletion, which is shown by the rates of deforestation during the last 20 years. The paving of BR-163 highway catalyses the process, bringing a medley of actors, in precarious living conditions. The paving of the last 1,000km is viewed with caution by environmentalists and as a solution by the economic actors, especially the owners of large farms.

More than half of Brazilian greenhouse gas emissions are related to the conversion of forests and savannas into pasture and agricultural crops, while conservation strategies are aimed at mitigating the Brazilian contribution to climate change. Therefore, in the present case study, deforestation will be the focus of analysis, seeking to identify drivers that determine the deforestation process and possible alternatives from the political arena to control them.

Initially, deforestation in Mato Grosso will be contextualised in relation to the Amazon. Second, drivers will be presented, such as institutional inconsistency, global market of commodities, the paving of BR-163 highway and social conflicts, as well as a discussion of the dynamics of deforestation applied to our case study.

The climate issue will be presented both with respect to the impacts of deforestation in the provision of basic environmental services, as well as its insertion in the political arena of Brazil.

7.2 Deforestation in the study area

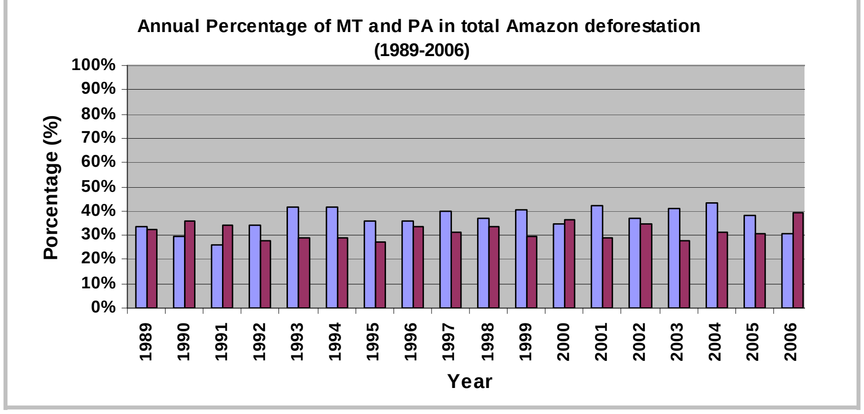
Originally, there were 527,000km² of forest in the State of Mato Grosso, of which 37% (195,000km²) have already been deforested by 2005. Among the remaining 63% (332,000km²), 70% (234,000km²) are not protected, while only 98,000km² are in some way protected though conservation policies (Conservation Units and indigenous lands).

The rates of deforestation have been monitored by INPE (*Instituto Nacional de Pesquisas Espaciais* - National Institute for Space Research) since 1988, in assisting government actions for the reduction of illegal deforestation. There are currently two systems monitoring the entire area of the Legal Amazon. The first system is PRODES (*Programa de Cálculo do Desflorestamento da Amazônia* - Program for Calculating the Deforestation of the Amazon), which uses high resolution satellite images (20m) to produce annual deforestation estimates. The second system is DETER (*Detecção de Desmatamento em Tempo Real* - Real Time Detection of Deforestation), which, despite being of inferior resolution (200m), supplies monthly information regarding the evolution of deforestation in the area, allowing an almost simultaneous monitoring, locating points of deforestation and guiding the inspection of the pertinent organs (Rodrigues Filho et al., 2008).

Figure 7.1 shows the evolution of deforestation in the Legal Amazon, highlighting the years 1995, 2002, 2003 and 2004, in which the deforested area is over 21,000 km². Mato Grosso is at the top of deforestation ranking among the states of this territory, presenting the largest rates of deforestation in 14 of the 18 years registered (Figure 4.4), followed by the state of Pará (Rodrigues Filho et al., 2008).

From August to December 2007, DETER detected a significant increase in the relative rate of deforestation in comparison to the tendency in previous years, where a reduction in the rate of deforestation was observed. Deforestation during this period totalled up to 3,235km². The State of Mato Grosso alone accounted for 53.5% of the total (1,786km²), followed by Pará, with 17.8% (591km²) and Rondônia with 16% (533km²). Due to the limitations of DETER, these values only represent a part of what was deforested in that period. Taking into account historical data, the real area is considered to be 7,000km² (IBAMA: www.ibama.gov.br). In January 2008, the Ministry of the Environment (MMA) prepared a list of 36 municipalities with the highest rates of deforestation in 2007, promising more inspections. Mato Grosso has 19 municipalities on the list, with majority located in the North of the state. More recent data published by DETER in June 2008 shows that in March 2008 deforestation totalled up to 1,123km² in April, among which 71% (794.1km²) occurred in the state of Mato Grosso (DETER/INPE: www.obt.inpe.br/deter). It is important to emphasise that this data does not reflect the real deforestation, since the resolution of DETER only detects areas of deforestation larger than 25ha and has limited gauging because of clouds that covered 14% of the State in April (Rodrigues Filho et al., 2008).

Figure 7.2	**Participation of the State of Mato Grosso (blue) and Pará (purple) in the deforested area of the Legal Amazon in 1998-2006**



7.2.1 Drivers

To find out the causes of deforestation in Legal Amazon, many studies have pointed out its complexity (Margulis, 2003; UNEP, 2006; Volpi, 2007). In this study, we focus on four major drivers that cause deforestation: (1) institutional inconsistency such as land-use policies that encourage occupation of land in Legal Amazon by subsidising agricultural activities such as cattle ranching and environmental policies that try to protect forest land from agricultural activities; (2) the development of infrastructure such as the paving of the BR-163 highway;

(3) the effects of globalisation (especially trade in soybeans), which pushes agricultural frontier further into Legal Amazon; (4) Social conflicts such as land-use conflicts caused by inconsistent policies and the conflicts with indigenous people.

7.2.2 Institutional inconsistency

Historically extensive cattle ranching has been encouraged by generous governmental subsidies, land-tenure rules, and fiscal policies (Fearnside, 1993). In the 70s and 80s, various federal subsidy schemes promoted deforestation (Volpi, 2007). According to Margulis (2003), until the 1980s, cattle ranching guaranteed land ownership and received official credit and subsidies from the government. Low-productivity cattle ranching continues to expand due to land-tenure rules and land speculation (Volpi, 2007). Moreover, the tax system stimulates deforestation. Uncleared forest land is considered unused, resulting in higher taxes. The taxes would fall however if the land is cleared (Binswanger, 1991). Therefore, fiscal incentives played a decisive role in the expansion of cattle ranching in Amazonia.

In addition, the government-sponsored colonisation programme has been distributing tracts of primary forest to poor farmers between 1994-2002. Subsidies such as food allowances, money for housing and credit at reduced interest rates are provided by the federal government to agrarian reform settlers (Volpi, 2007). This has encouraged many families to seek new settlement, leading to more deforestation.

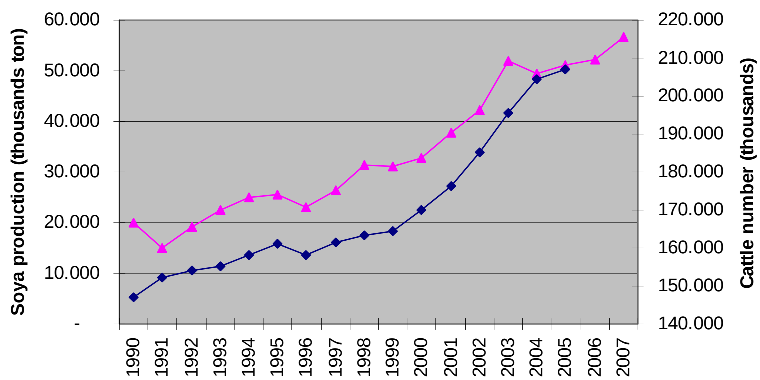
While policies mentioned above lead to further deforestation, there are also policies aimed at conserving Amazon rainforest. At the moment, a mosaic of indigenous territories and Conservation Units that target integral protection and sustainable land use are located by the government in the North of Mato Grosso. These Conservation Units are the National park of Juruena (Parque nacional de Juruena), the National native park of Xingu (Parque nacional indigena do Xingu), and the ecological station Iquê (Estação Ecológica Iquê). Besides, the federal programme - Protected Areas of the Amazon (Arpa - Áreas protegidas da Amazônia) - has a duration of 10 years and intends to create at least 50 m. ha of protected area in Amazon Biome by 2013. Moreover, the federal government reinforces its monitoring system that has slowed down the deforestation speed.

The inefficient presence of the state and failing communication between the land-registry system - INCRA (Instituto Nacional de Colonização e Reforma Agrária - National Institute of Colonisation and Land Reform) and the legal registry system (Registry offices) is facilitating the actions of the land grabbers, favouring the illegal occupation of public lands, the creation of clandestine highways and deforestation. Corruption occurs at several institutional levels, including inspection institutions and positions of state bureaucracy, which has contributed to the escalation of the situation (Rodrigues Filho et al., 2008).

7.3 Global market and deforestation

As for the drivers of deforestation in the Amazon during the last two decades, one can see the growth of world demand for commodities as the main driving force behind the expansion of livestock farming and agriculture towards native forest areas.

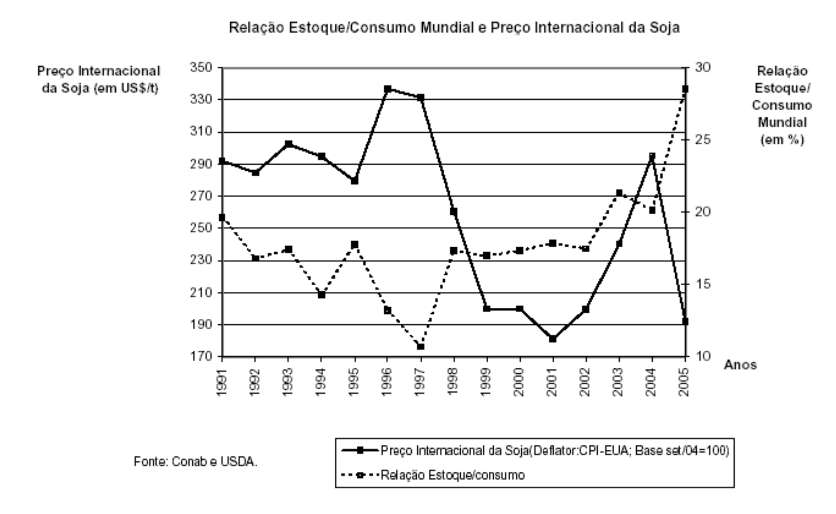
Figure 7.3 **Evolution of Brazilian soybean production between 1990 and 2007 (pink line) and the national cattle herd between 1990 and 2005 (blue line)**



Source: IBGE.

Soybean is a prominent case to illustrate this assumption. The international price of the commodity is regulated by the stock/consumption ratio worldwide. Figure 7.3 shows such relationships from 1991 to 2005. It is observed that in 1996 and 1997, years in which the stock/consumption ratio was low, the price of soybeans peaked, while opposite ratios are related to the most pronounced drop in prices. The period between the years 2000 and 2004 is relevant for Brazil, especially for MT. Successive cracks of U.S. crop due to climate problems in 2002 and 2003, related to the devaluation of Brazilian currency in previous years, and fuelled the expansion of crop area and the national production of soybean (Brandão et al., 2006). During this period Mato Grosso assumed a leader position of national soybean producer. This trend matches with the increase of deforestation in the Legal Amazon observed since 2000, which peaked in 2004, followed by a significant reduction in 2005, simultaneous with a price lowering on the world market. It is important to emphasise that the forest usually is not immediately replaced by agriculture, but mainly by livestock, which is moved to the pioneer front.

Figure 7.4 **Relationship between stock and consumption (%, dashed line, right axis) and international price of soybeans (U.S. $/ton, continuous line, left axis) between 1991 and 2005**



Source: Brandão, 2006.

A similar analysis can be done to livestock. The currency devaluation in 1999 resulted in the increase of domestic beef prices, stimulating accelerated growth of cattle herd. In the Amazon, it jumped from 47m. in 2000 to 74m. in 2005, accounting for 73% of the Brazilian growth (MAY and SMERALDI, 2008); already in the previous quadrennial (1996-1999), Amazon had a less pronounced increase in cattle herd, adding some 10m. animals, although it represented almost 100% of national growth. Figure 7.3 shows that this increase was, together with soybean, followed by a steady rise in the rates of deforestation. Currently, an estimated 53m. ha are intended for extensive livestock in the biome, representing 74% of all deforested areas until 2007. Therefore, the voracity of the international market of commodities directly determines the shrinkage or expansion of Brazilian agricultural production and hence the rate of deforestation not only in the Amazon, but also of other important ecosystems such as the Cerrado.

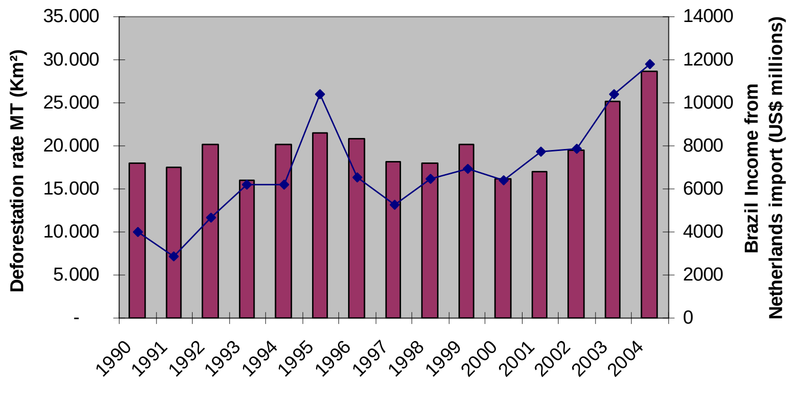
The effectiveness of public policies related to the deforestation control could have only a partial effect. The devastation of the forest is reduced, but illegal deforestation remains powerless in the face of substantial legal area that still will be overturned. This is currently depleted relatively slow ahead of the availability of new areas arising from illegal public land speculation, in agricultural frontier.

It also highlights the participation of the Netherlands in the context presented here, since it is among the seven largest importers of Brazilian agricultural genres as well as being a major consumer of beef in the country and was the second largest importer of the commodity in 2007 (Table 7.1).

In Figure 7.5 we can see that there is a strong correlation between deforestation rates in Mato Grosso and the evolution of imports of Brazilian agricultural products by the Netherlands, explaining the period between 2000 and 2004, in which the rise in imports accompanied the rise in rates of deforestation stimulated by the high price of commodities on the international market, as has been reported previously. It is suggested, therefore, that the Netherlands comprises a major slice of the global consumer market that guides the dynamic Brazilian agriculture.

As for Brazilian exports of beef, we see that the Netherlands is a major consumer market in 2007. Despite occupying the sixth place with regard to the volume imported, it was the second in terms of value produced. Consequently, we find that the Netherlands is key to the agricultural component of the Brazilian trade balance (Table 7.1) and, as such, has an indirect impact on processes and trends of land use in Amazonia and, consequently, in Mato Grosso. That gives it not only responsibility but also provides an opportunity to contribute to efforts to contain the devastation of forests and savannas - through the demand for information proving the merits of the Brazilian products it imports. Obviously, such a commitment demands the existence of an institutional infrastructure and certification that has not yet consolidated in Brazil, but that could be done more quickly if certification is enhanced by the international market.

Figure 7.5	Evolution of imports (in USD) of Brazilian agricultural products by the Netherlands in the period 1990-2004 (in wine bars) and observed deforestation in Mato Grosso



Source: IBGE and MAP.

The negative environmental externality that came from the current production model devised by the logic of the international market for commodities and the policy explained this inconsistency and in many other works. Therefore we cannot overlook the importance for the socioeconomic stability that agriculture currently offers Brazil. In 2004, the agribusiness was responsible for 33% of Brazilian GDP, 42% of national exports and 37% of jobs created (MAPA, 2004). In addition, the frequent fluctuations in international prices of commodities makes the Brazilian economy vulnerable to fluctuations in the world market and global climate change projected over the 20th century. The policy on long-term planning must incorporate these concerns into their consistent strategies and not elect the natural abundance as an opportunity for Brazilian economic growth associated with expanding agriculture.

Table 7.1	Volume (tons) and value (in USD1,000) of beef imported by 8 major consumer markets in 2007. Highlight for the Netherlands as the second largest importer	
Country	**Cattle meat (ton)**	**Income (USD1,000)**
Russian	428,877	907,484
Netherlands	59,846	331,826
Egypt	176,571	331,234
USA	62,353	306,054
Italy	59,414	275,391
United Kingdom	80,496	261,963
China	86,846	171,964
Germany	22,472	135,387
Source: MAY and SMERALDI (2008).		

Table 7.2	Evolution of Mato Grosso participation in Brazil trade balance	
Balance trade	**Brazil**	**Mato Grosso**
2003	72,928,327	1,107,219
2007	160,172,843	3,153,555
Evolution 2003/2007	219,63%	284,82%

7.3.1 Institutional inconsistency

The planned paving of highway BR163 has caused intense migration into the area, impelling land grabbing and land speculation, intensifying social conflicts.

Several municipal, state, and federal Conservation Units (UC), designed for sustainable use as well as for complete protection, related to indigenous areas, were created as a way to contain deforestation and preserve the biodiversity of Amazon Biome. However, the effectiveness of the conservation is challenged by insufficient inspections and the impunity of those who disrespect the environmental legislation. A study accomplished in partnership with IBAMA (Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis - Brazilian Institute for the Environment and Renewable Natural Resources) and WWF points out that such inefficiency is not mainly due to the incompetence of the administrators, but to the lack of infrastructure and a deficiency in the quantity of both human and financial resources.

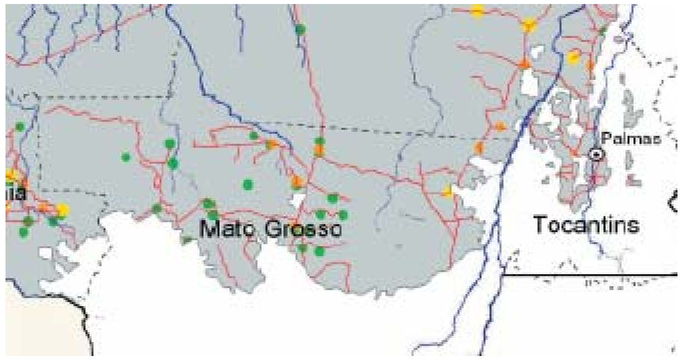
7.3.2 Economic activity

Timber activities have always been present during the colonisation of the region, especially in areas where agriculture was not initially strengthened. Some cities, like Sinop, Alta Floresta and Juína, emerged with their economic base in this activity, diversifying their economy later on. Currently, a complex dynamic of activities and stakeholders that have evolved over time can be observed.

Wood extraction is a nomadic activity, contributing to the expansion of the agricultural frontier. By using satellite images and GPS, land grabbers identify areas of the forest with potential for exploration, increasing the efficiency of illegal deforestation. Wood that is of economic interest is removed and sold, while the remaining wood is burned, clearing the land for the introduction of pasture (Margulis, 2003). Land grabbers divide the deforested areas into lots, which are sold to investors from different areas of the country. Along the highway BR163, the expansion of the frontier is mainly led by small farmers and timber producers, whom, once installed in the area, establish an attractive centre for diverse stakeholders, then, after finishing their activities, confiscate the land, speculating upon the future expansion of the frontier (Margulis, 2003). From this perspective, an important issue to be emphasised is the expansion of the cultivation of sugarcane in the states in the Central Region of Brazil - an administrative region composed of three states. Although the cultivation of sugarcane is limited by the climate of the Amazon, the competition with other cultures in the Central Region may indirectly influence land use along the front of the expanding frontier, dislocating livestock and crops such as soybean, cotton and corn to the North region of the country (WWF 2008).

Livestock usually succeeds timber activities because it demands small investment and yields financial returns over a short period, leading to clear growth in the last decades. According to the report of the World Resources Institute (2005), the number of heads of cattle in the Amazon rose from 27m. in 1990 to 64m. in 2003, and the states of Mato Grosso, Tocantins and Rondônia were responsible for 86% of this growth. In MT in 2006, 26m. heads of cattle were encountered (Table 7.3), of which 10.5m. (40%) were in the North of the state, stimulating the installation of refrigeration and milk centres (Figure 7.6). Some studies affirm that livestock is the main cause of deforestation in the Amazon, such that its expansion is founded by the financial viability of medium and large cattle ranches.

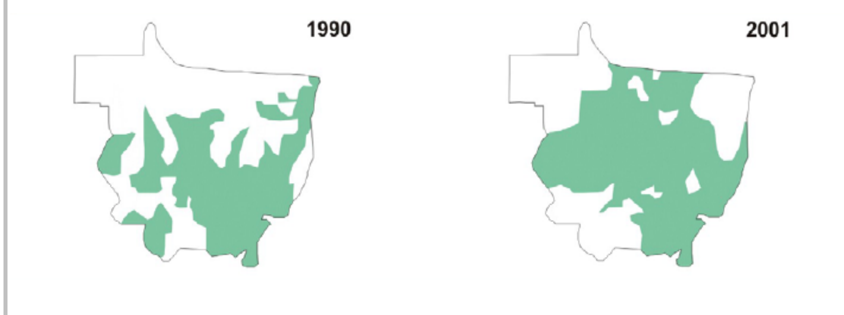
Figure 7.6 **Indication of timber centres (green dots), refrigeration (orange dots) and dairy products (yellow dots) located in the North of Mato Grosso (dotted state line)**



Source: Lentini et al. (2003).

The intermediate stakeholders, anticipating cattle ranching, are directly responsible for the deforestation, having their opportunity costs partially compensated by the guarantee of the future sale of the land for cattle ranching (Margulis, 2003). By using the method of contingent valuation, this author estimated that the environmental costs of livestock in the Amazon are USD100/year/ha, surpassing the economic return estimated by the World Bank of USD75/year/ha. Poultry production and the breeding of pigs are also relevant animal products that occur in the region, the latter being of more importance in the North of Mato Grosso (MT) presenting 58% of the pig breeding in the state, generating a complete support structure for this activity, from the production of pig ration and veterinary products.

Figure 7.7	Expansion of soybean in the state of MT between 1990 and 2001



Source: adapted Anderson (2005).

Agriculture assumes a fundamental role in understanding the problems of land use in this region. The economic development of the municipalities in the North of MT is largely due to agricultural expansion, especially soybean production, corn and rice. Within a global food market that was in sharply increasing before the economic crisis of late 2008, and the respective increases of commodities prices in the international market, the perspective of increasing Brazilian agricultural exports was pushing crops towards the forest. The national harvest for 2007/2008 presented record production, with a growth of 7.8% in relation to the previous period, with prominence for soybean, whose harvest totalled 59.5m. tonnes. In 2005, Mato Grosso accounted for more than 17 million tonnes of soybean, a significant proportion of the Brazilian production, where almost 70% originated in the North of the state. Other goods, such as rice and corn, are also relevant, corresponding to more than half of the state production (Table 7.4).

The economic viability of export agriculture can be encountered in the establishment of a delivery and storage infrastructure for the production. Figure 7.7 represents the dynamics of soybean production in Brazil for the 15 years between 1990 and 2001.

Table 7.3	Animal production in heads: the North of the state of Mato		
Production	**North region of the state**	**Mato Grosso**	**Participation %**
Poultry	4,922,749	21,115,447	23.31
Pigs	796,928	1,359,824	58.6
Cattle	10,712,771	26,651,500	40.2
Total	16,432,448	49,126,771	40.7

Table 7.4	Commodity production (2005): the North of the state of Mato Grosso, the state of Mato Grosso, participation of the North in the state production		
Production (Tonnes)	**MT North region**	**Mato Grosso**	**Participation %**
Rice	1,690,640	2,262,863	74.71
Cotton	657,861	1,682,839	39.09
Corn	2,452,656	3,483,266	70.41
Soybean	12,124,773	17,761,444	68.26
Bean	47,017	66,122	71.10
Sunflower	15,693	22,207	70.66
Total	16,988,640	23,595,902	72.00
Source: IBGE - pesquisa pecuária municipal (2006).			

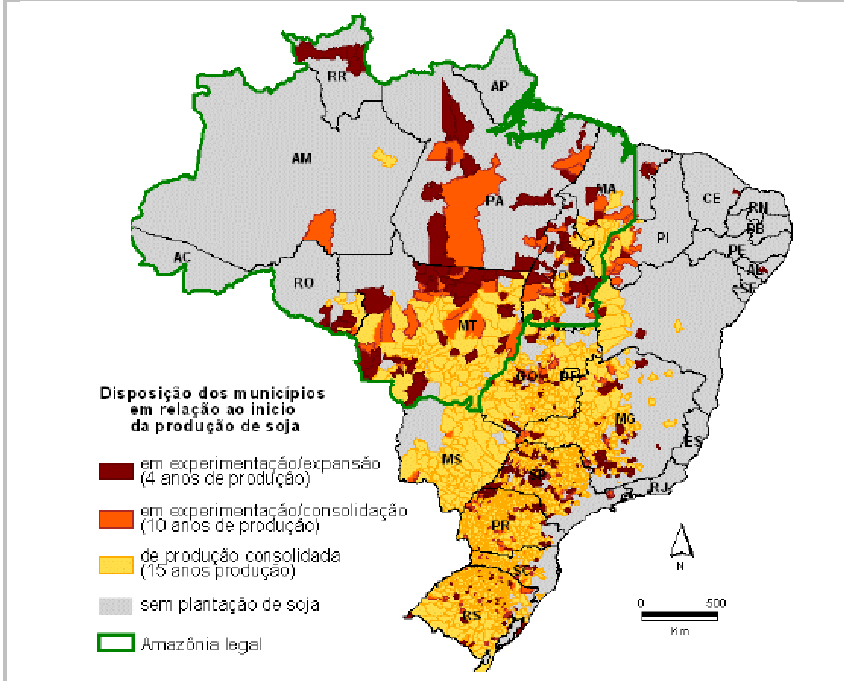
Table 7.5	Economic diversification, highlighting the importance of Mato Grosso's agriculture in agriculture GDP of Centro-Oeste in 2005 (a Brazilian sub-region compounded by three agriculture States: Mato Grosso, Goiás and Mato Grosso do Sul)	
Economic Diversification	**Centro-Oeste**	**Mato Grosso**
Agriculture GDP	19,743,640	10,743,851
Industry GDP	26,354,254	6,299,481
Services GDP	121,699,535	16,418,854
Source: IBGE estados (2005).		

In the case of MT, storage was fundamental in the competitiveness of soybean cultivation, because it maintained low humidity of the stored grain. During the 1990s, BNDES (National Bank for Economic and Social Development - Banco Nacional de Desenvolvimento Econômico e Social) backed private investments in storage infrastructure along the BR163 highway, in close proximity to the areas of production. Traditional forms of commercialisation were substituted for new ones, such as the premature acquisition of agricultural inputs in exchange for part of the future production, establishing a dependence of rural producers on the large exporters of agricultural goods. Within this context, two companies gained prominence: Bunge Brasil and Cargill Brasil. The first, of Dutch origin, acquired various national agricultural companies during the 1990s. It built silos and industrial facilities in the main agricultural delivery corridors of the country, focusing their operations on the purchase of grains and sale of fertilisers to rural producers, deepening the dependence of these producers on the large companies of the agricultural sector and influencing Brazilian territorial arrangements (Becker, 2006).

The logistics for the transport and delivery of agricultural production adopted by the company is based on transportation outsourcing, mainly by rail, involving significant investments in the construction of port terminals and acquisition of rail cars. In comparison, Cargill is a diversified company, from the United States, and has activities in the productive sector, going beyond the food industry, to that of the finance market and export of agricultural goods. It possesses an extensive network of production delivery for the international market in Brazil's main ports, with prominence in Santarém (Pará, PA). This will be directly benefited with the paving of the BR163 highway, concentrating the agricultural production delivery via waterways of Mato Grosso, reducing freight costs considerably.

The resources generated by farming and cattle raising in the North of MT correspond to 75% of the agricultural GDP of the state in 2003. Besides the direct gains, the emergence of the region as agricultural centre has attracted undertakings related to the agricultural industry, mainly companies that market agrochemicals, agricultural machines and agribusinesses, invigorating the local economy. However, the mechanisation of the industry, inherent to the production in large scales, has been demanding higher qualifications and less manual labour, resulting, on one hand, in an increase of investments, and on the other hand, to an increase in unemployment.

Figure 7.8	Arrangements of municipalities in relation to soybean production



a) Production in experimentation/expansion 4 years of production (brown). In experimentation/consolidation 10 years of production (orange). Consolidated production 15 years (yellow). The blue rectangle indicates the area of the North of Mato Grosso under the influence of BR-163. The pattern of occupation in the north of MT is more recent in the extremities and more consolidated in southern direction.
Source: Gama et al. (2006).

7.4 Most crucial policies to prevent deforestation

Once identified deforestation as the main environmental problem in Mato Grosso, we determine in our projections a set of public policies that would mitigate emissions of greenhouse gases from the clear-cut of forests, as well as to encourage the increase and maintenance of stocks of carbon in the form of plant biomass.

The land question is a major holdup for effective control of deforestation. Facing this concern, the System of Environmental Licensing of Rural Properties, the SLAPR, currently being implemented in Mato Grosso, was selected for two reasons: high capillarity and tendency to become a comprehensive system in the long term. The system alone has minor effect on it, but if combined with other management tools it may become a powerful tool to reduce deforestation in rural properties.

Other political strategies complementary to land settlement refer to the creation of Conservation Units and effectiveness of surveillance, demanding the development of technologies for more accurate monitoring and strengthening of enforcement agencies. A brief description of each policy to be considered in the scenarios and the impact of each on the projections is presented below.

7.4.1 Land Tenure policy - SLAPR

Since 2000, the State of Mato Grosso has owned the most sophisticated system of monitoring and control of deforestation in rural properties in the country: the SLAPR (Environmental Licensing System in Rural Properties). Under the responsibility of the State Department of Environment, the system allows the monitoring of deforestation in the properties in return for environmental licencing. This implies the regularisation of land by the responsible environmental agency, requiring the owner to acquire satellite images of its land, detailing the areas of Legal Reserve, Permanent Preservation Areas (APP) and production. Hence, regular monitoring of land use by means of remote sensing will allow the government to establish priority areas for surveillance.

The Instituto Socio Ambiental (ISA, 2005), evaluating the operation of the instrument for the period 2003-2004, found that deforestation of properties registered in SLAPR was higher than that observed in properties not linked to the system, both in the legal reserve and in the area licensed for logging, suggesting that the instrument failed in order to reduce the deforestation of the properties registered. However, the SLAPR, combined with the increase in infrastructure and logistics of enforcement agencies, as well as economic incentives for rehabilitation and maintenance of legal reserves and APP, could contribute to control deforestation in rural properties.

It is worth emphasising that there are several issues to be discussed before legitimating the payment for the conservation of areas already required by the Forest Code within private properties. Nonetheless, it is acknowledge the potential of economic instruments as part of incentives for recovery of deforested areas, reducing the significant environmental liabilities generated by the depletion of legal reserves. Currently, some lines of credit are posing as precondition for release the registration in SLAPR, showing the first efforts to encourage adherence to the system.

In Mato Grosso, deforestation of private properties accounts for 95% of the entire deforestation accumulated in the state. In areas of forest, it is estimated that there are 74,000km² of forest liability, since 39% of the total area of properties located in the biome have been deforested, 19% above the 20% set by law (MICOL et al., 2008). In areas of Cerrado a different situation is observed. The remnants of savannah in the region represent six million hectares available for deforestation within the limits set by the Forest Code. It is expected that a more rigorous monitoring in legal reserves in the Amazon forest will move the expansion of rural activities to the savannah regions, promoting the degradation of this important biome.

Efforts to contain the deforestation should incorporate in their planning strategies to control leakage to other biomes, as the Cerrado. The SLAPR has properties in both biomes registered in Mato Grosso, but the monitoring of the Cerrado has technical and political limitations.

Between 2001-2004, 6116 properties were registered in SLAPR, totalizing an area of about 15m. ha. This corresponds to 17% of the territory of Mato Grosso. However, other 54.8m. ha are in properties not registered. So if we consider that the average rate of registration was 3.8m. ha annually in the period (2001-2004), it is reasonable to expect that an effective land tenure policy would maintain this trend by the year 2025. This would be enough to cover all rural properties of MT. It is worth emphasising again the need to create mechanisms to encourage landowners to register their properties in SLAPR.

In our projections, participation of SLAPR in reduction of deforestation will be incorporated as a factor for increasing efficiency of surveillance (50%). Consequently, the efficiency of the land tenure policy is represented here by SLAPR as previous condition to increase control over deforestation.

As already mentioned, there are 74,000km² of forest liabilities in the region. The SLAPR allows better control of the completion of the Forest Code, forcing the owners to recover its legal reserves and APP. It would be reasonable to consider that 30% of this liability would be recovered by means of reforestation, as defined by the Forest Code. This represents 22,000km², increasing the stock of carbon and reducing the rate of net deforestation. That means an average recovery of 1,168km² per year.

Furthermore, farms located in the Amazon forest of Mato Grosso are allowed to clear 20% of the property, contributing to deforestation regardless of the strengthening of surveillance or land regularisation. The area under this condition represents some 40 thousand km² of forest. According to Souza et al. 2007 (apud MICOL et al., 2008), the legal deforestation accounts for 10 to 20%

of deforestation accumulated until 2007. Therefore, it is expected that effective policies will lead to intensification of legal deforestation.

In this context, it is reasonable to expect that the rates of legal deforestation double in the scenario of effective environmental policies, which leads us to values of 20-40% of total deforestation. In order to incorporate this increase in our scenario, a value of 30% is considered as contribution from legal deforestation.

7.4.2 Conservation and Surveillance Policies

- *Monitoring*
  It was not possible to evaluate the impact of enhancement of remote sensing tools, but INPE expects that, in 2011, it will be able to achieve images every two days, no doubt contributing to increasing the efficiency of surveillance.
- *Surveillance*
  According to data from the MMA, the tougher action in the 36 municipalities listed as 'champions of deforestation' at the beginning of 2008, allowed operations of more intensive surveillance, and resulted in the fall down of the municipalities participation in the total deforestation of the Legal Amazon. In 2006-2007, they accounted for 54% of total deforestation (Table 7.6). In 2008, that share fell to 42%.

Table 7.6 **Evolution of Deforestation in Legal Amazon and in the 36 municipalities ranked as the deforestation champs in January 2008**

Region	2007	2008	2007-2008
Legal Amazonia	11,532 km²	11,968 km²	(+)3,7%
36 municipalities	6,227 km²	5,026 km²	(-)19,0%

Source: INPE (2008).

Data suggest that measures undertaken by the national government in some way reflected in a decrease of 19% of deforestation in these municipalities, against an increase of 3.7% in the deforestation of the whole Amazon in 2008.

Assuming that such policies are still in the process of consolidation and that the infrastructure of enforcement agencies is still unsatisfactory (according to the MICOL et al., 2008, the effective of SEMA is three times smaller than is necessary) one could consider that an effective policy of surveillance would generate a fall of 50% of deforestation compared to its absence.

- *Creation of Conservation Units*
  Mato Grosso's Conservation Units totalized, in 2007, 31,576 km² (4% of the state territory) and their deforested area, by 2005, was 1591 km².

According to IUCN, a minimum of 15% of biomes is needed for conservation purposes. In the territory of Mato Grosso it would be about 135,000km². Once the remnants of Cerrado and Forest totalize 65% of the state territory, or 585,000km², 15% of it as Conservation Units (CU) would be a feasible target. However, as most of those remaining area are in private properties, reaching that number by 2025 would be rather difficult. So we assumed that 10% of the forest territory as CU would be reasonable as an effective conservation policy, which makes 58,500km² of protected forests as a target for 2025. In other words, there would be additional 26,924km² of Mato Grosso's territory protected from unsustainable exploration, which is mainly associated with the expansion of large scale agriculture to meet demands of the global market.

Despite suffering from pressures from outside of their borders, a different dynamic of deforestation is consolidated within the CU, less harmful in depletion of remaining areas of forest. This point that rates of deforestation in CU are substantially lower than in private areas. From this perspective, avoided deforestation can be estimated by evaluating the effectiveness of conservation, with regard to the absence of traditional exploration within the area. Consequently:

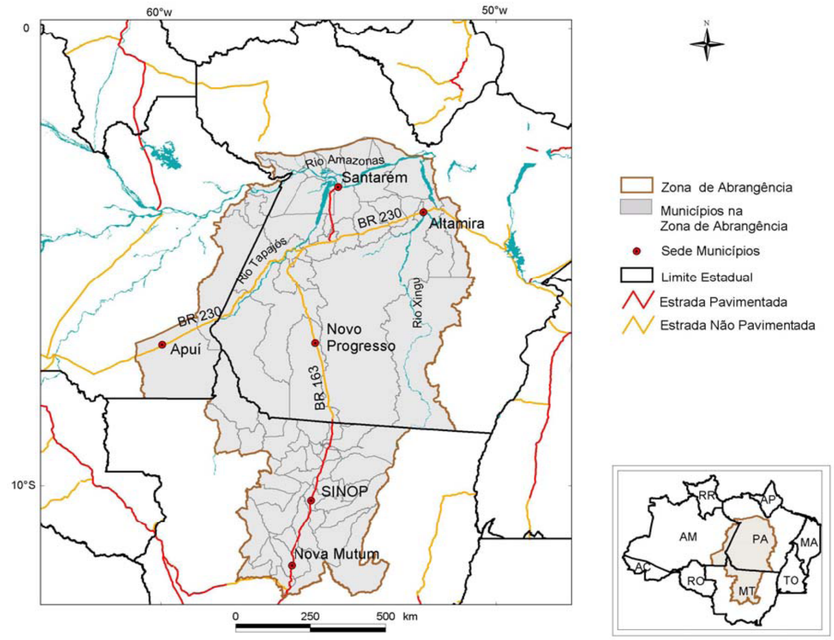
1. Traditional exploration: in 2025, these 26,924km² would have 42% of the area deforested; resulting in 11,000km² removed over 16 years (average contribution 690km² per year*). Deforestation rate = 690km² per year*;
2. Conservation: In 2025, these 26,924km² would have 5% of the area deforested, or 1,346km², contributing with 84km² annually to deforestation. *Deforestation rate = 84km² per year*.

7.5 Paving highway BR-163 and estimation of deforestation

With budgets foreseen in the Programme for the Acceleration of Growth (Programa de Aceleração do Crescimento, PAC), the DNIT (Departamento Nacional de Infraestrutura de Transporte - National Department for Transportation Infrastructure) foresees the completion of the paving of the BR-163 highway (Figure 7) to occur in 2010. The previous environmental license was emitted in 2005, allowing for paving to begin with the section between the North of Mato Grosso and Santarém, in Pará. The work is subdivided into 18 sections, of which eight will receive intervention still this year and the other ten in 2009. The objective is to integrate the highway with the waterway, allowing for a faster system of delivering agricultural production and communication between the Free Zone (Zona Franca) of Manaus and the Centre-South of Brazil. These goals are in agreement with the premises of PAC, which are meant to address the acceleration of economic and productive growth and overcome regional and social inequalities with investments in infrastructure. The paving of several highways that cut the Amazon biome, besides BR-163, is part of a project to integrate the Brazilian road system with that of other countries in South America, such as Chile and Peru, allowing Brazilian products to have access to ports on the Pacific.

According to Soares-Filho (2005) the paving of highways causes an increase in the rates of deforestation and opens new fronts for occupation. In order to estimate the possible consequences of paving Amazonian highways, the authors simulated and evaluated the relation between paving and the evolution of the rates of deforestation. The projections point to the East and the Southeast of the Amazon as potential areas to be most affected. In a scenario with paving and low levels of governance, it is expected that forests located outside the limits of Conservation Units and indigenous reservations will practically disappear by 2050 in the North of Mato Grosso and the South of Pará.

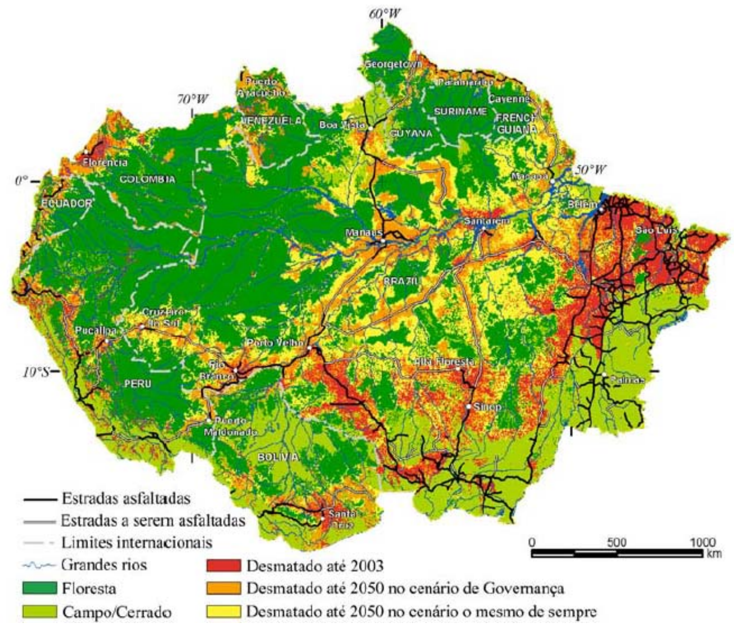
Figure 7.9	Scope of the BR-163 highway. The paved sections (in red) unpaved sections (beige)



Source: Rodrigues Filho et al. (2008).

Considering a scenario with paving and good governance, based on the enlargement of fully protected areas and rigorous and efficient inspections, the projections indicate a reduction of up to 62% of the deforestation foreseen in the pessimistic scenario of business the usual (Figure 7.11).

Figure 7.10 **Projections for the deforestation of the Amazon in 2050 in the scenario with good levels of governance (orange) and the baseline (yellow). In red, deforestation observed by 2003 is shown; forested areas are represented in dark green and areas of pasture or savannah in light green**



Source: Soares-Filho (2005).

Figure 7.11 **Projections (2002-2050) for deforestation in the Amazon considering the following scenarios: Governance without paving (dark green); Governance with paving (light green); business the usual (red); historical tendency (beige)**

Source: Soares-Filho (2005).

7.6 Strategies for adaptation and mitigation

In the face of the whole discussion undertaken so far, the planning of adaptation and mitigation strategies for climate change to the north of Mato Grosso should consider three distinct strands that together form the tripod that will subsidise the effectiveness of public actions in this direction.

The first concerns the development of more elaborate models, which can cover a larger portion of the complex relationships established within the systems that they propose to simulate, including socioeconomic information. The systematic monitoring of climate change and its effects on land uses, provides new data input to the models. It is here that the time scale used in the analysis of climate change involves periods ranging from decades to centuries. The greater the scope of time series of historical climate data used, the greater the amount of information available to more precise understanding of climate trends and their effects. Changes of land use, such as the expansion of agricultural areas and pasture, as well as deforestation and burning must be monitored frequently.

The improvement of technology for remote monitoring especially based on images from geostationary satellites are key tools in developing and monitoring the effectiveness of public policies. This aspect demands investments in science and technology. The formation of multi-institutional research networks must be encouraged in order to seek synergies between public agencies and universities. INPE and EMBRAPA, for example, established a partnership that aims to match up the figures released by first referring to deforestation in the Amazon, and the second, details on the occupation and use of land in the region in order to establish causal relationships since 1980. The improvement of models and methods of monitoring gives a more consistent technical support to political decision-making, leading us to the second pillar of the tripod, which consists of public policies for the use of the land directly, linked to mitigation and adaptation to changes climate.

The projection scenarios of agro-climatic allows the balance between alternative agricultural and grazing management that reduce emissions of greenhouse gases, and allows time for the development of agricultural species more genetically adapted to conditions of temperature and humidity expected. Techniques that prioritize the accumulation of carbon in the production system should also be encouraged. Accordingly, the no-tillage, which incorporates part of plant biomass in the soil, as well as reuse of waste in agricultural production chain are ways that deserve consideration by decision-makers.

The use of waste from swine farming, for example, in biodigestor in the generation of electric energy is a possible destination for a material that would otherwise be contributing to the greenhouse gas atmospheric concentrations, and could be possibly inserted into the CDM projects (Clean Development Mechanism), making their adoption more attractive to investors. Economic mechanisms, such as exclusive lines of credit and reduction of taxation for agricultural activities that adopt unsustainable practices should be addressed in public policy for the region. Moreover, more unsustainable activities should be costly, discouraging its expansion by making them economically unfavorable.

At the international level, discussions concerning land use have always been subject to discussion in the negotiations of CQNUMC. However, projects in agriculture, such as no-tillage, have not yet had their eligibility approved. It calls attention to the necessity of international flexibility at this point, once it could be positive to climate, encouraging the adoption of farming practices that reduce emissions and increase the stock of carbon stored in production systems; agricultural contributions to mitigate the atmospheric concentrations of greenhouse gases. Obviously, there is a risk of encouraging the expansion of crops on areas of forest and savannah. However, if well monitored, the benefit would not only benefit landowners, but also the family farmer, more vulnerable to climate change.

The control of deforestation, based on a more intense surveillance linked to the effectiveness of the judicial enforcement of legislation and creation of areas of permanent preservation and sustainable use, is another aspect that belongs to the political strategies for mitigation and adaptation. The feasibility of legislation should also be considered, because many times their applicability is not adequate support in the context of a given locality, requiring adaptations to particular socioeconomic, political and environmental conditions. That does not mean relaxing the environmental issue in terms of economic and social aspects, but seek ways to achieve less unsustainable scenario more easily and quickly, seeking partnerships and reducing conflicts.

Finally, the tripod has the ultimate upholder policies towards education. Here, comprises both investments that result in the expansion of access to public education of quality, such as the incorporation of content tools for future generations; the knowledge necessary to understand the consequences of various forms of land use on the social, environmental and economic dimensions. A more enlightened population, capable of a more refined critical analysis of reality feels more rightful with the merits of public policy, making the acceptance of these, when there is a prospection of tangible benefits. Obviously, it is a process whose results are long-term, but appears to be thinking the key to sustainability.

This work focusing on the evaluation of public policies to mitigate climate change involving the land use in northern Mato Grosso, aimed at showing that their effectiveness requires a set of policies in other areas such as education, science and technology, emphasising the complexity of the political process in which it is registered.

7.6.1 Control variables of scenarios

Expanding Economy

Observing the 4 years with higher rates of deforestation, it is observed that 3 of them are beyond 2000. This period (2000-2004) is marked by the rise of state of Mato Grosso as the largest national producer of soybean, and the holder of the largest cattle herd thanks for attractive prices of commodities. Those years are to be considered as a historical trend for the Expanding Economy scenario, as follows:

'Regarding the historical average, the average deforestation of 4 years (1995, 2002, 2003, 2004) is 35% higher. Therefore, it is estimated that higher rates of economic growth increase by 35% the rates of deforestation.'

Constricted Economy
As for expanding economy, but choosing the 4 years of lower deforestation rates before the PPCDAM (national plan for deforestation reduction from 2004). By including years of low deforestation after the implementation of the plan would turn it difficult to identify a causal relationship; if it was due to a shrinking market or to a better surveillance. Brandão (2005) presents in his work a substantial increase in the price of commodities in the period 2000-2004, while the global market of the 1990s was under a lower growth.

'Average deforestation of these 4 years (1990,1991,1992,1997) is 36% lower than historical average. Therefore, It is estimated that the economy into recession reduces by 36% the rates of deforestation.'

Table 7.7	**Reference data used to calculate the projection in expanding economy and restricted economy**
Deforestation MT 1990-2008 average	6,061 km²
Expanding economy scenario (average 4 years with the higher rates of deforestation)	8,212 km²
Constricted economy scenario (average of 4 years with lower rates of deforestation)	4,281 km²

Table 7.8	**Calculation of deforestation rates in different scenarios**	
Deforestation rate reference	**Expanding economy**	**Constricted economy**
(legal + Illegal)	8,212 km²	4,281 km²
Historical trends (15% of total)	1,231 km²	642 km²
2025 (30% of total)	2,463 km²	1,284 km²

To avoid double counting, we will consider in the projections for 2025 only the additional contributions to historical trends in each economy scenario:

- Expanding economy: 1,284km² additional to reference data (historical trends);
- Constricted economy: 642km² additional to reference data (historical trends).

The rates of deforestation previously submitted to the scenarios of expanding economy and constricted economy will be the reference on which will enforce the impact of the effectiveness of policies concerning the control of deforestation and land regularisation.

7.6.2 Effective policies

Effective Land Tenure Policy

- 100% of rural properties registered in SLAPR;
- 30% of the liable forest recovered:
  total recovered: 22,000km²
  recovery rate: 1.168km²/year

Effective Deforestation Policy control

- *Strengthening the enforcement agencies (IBAMA and SEMA)*: improving the operational infrastructure and increasing the effectiveness. A 50% reduction of deforestation rate is assumed.
- *Surveillance*: development of more sophisticated remote sensing and intensification of field operations;
- *Creation of Conservation Units*: considering 10% of the region as Conservation Units.

These policy controls will lead to an avoided annual deforestation of 608km² per year.

- Traditional exploration: 690km² per year.
- Conservation (10% of CU): 82km² per year.

The avoided deforestation represents what is left of forest due to the overthrow of legal protection in the form of 10% of Conservation Units. Between 2007 and 2025 this would represent a total of 11,552,000km² of forest that would continue to perform its functions in regulating climate. According to the ICV (2008), the Ecological Economic Zoning (EEZ) in 2004 proposed to the State of Mato Grosso provides for the allocation of over 9,000km² for the Conservation Units. Even the necessary precautions before the effectiveness of the EEZ, it is an indication that new areas could be incorporated into areas of federal and state conservation.

7.6.3 Scenarios and projections

Autonomous Scenario: Non-effective Policies and Expanding Economy. Due to the absence of effective public policies, we consider the market acting as the main driver of deforestation, and therefore, a deforestation volume of 8212km^2 in MT in 2025.

Scenario Non-effective Policies and Constrained Economy. Due to the absence of effective public policies, we consider the market acting as a driver of deforestation, and, therefore, that a constrained economy would result in deforestation rate of 4,281km^2 in MT in 2025. *Deforestation: 4,281 km^2*

Scenario Effective Policies and Expanding Economy

Table 7.9	**Deforestation rate projection for effective policies and Expanding Economy scenario**
Deforestation rate of reference	8,212 km^2
Impact of effective policies	-4,106 km^2
10% avoided deforestation CUs	-608 km^2
Recovery of forest asset	-1.168 km^2
Legal Deforestation	+1,232 km^2
Total	3,562 km^2

Scenario effective policies and constrained economy

Table 7.10	**Deforestation rate projections for Effective policies and Constrained Economy scenario**
Deforestation rate of reference	4,2812 km^2
Impact of effective supervision	-2,140 km^2
10% avoided deforestation CUs	-608 km^2
Recovery of forest asset	-1,168 km^2
Legal Deforestation	+642 km^2
Total	1,007 km^2

7.7 Climate change and deforestation

Forest and soils drive the global carbon cycle by sequestering carbon dioxide through photosynthesis and releasing it back into the atmosphere through respiration and decomposition of organic matter (Volpi, 2007). One of the consequences of deforestation is carbon emission, which causes climate change. In 2000, Brazil was the world's fourth largest emitter of climate-changing greenhouse gases (Volpi, 2007). Deforestation is responsible for 75% of the total GHGs emissions (Figure 4.4) and about 60% of the carbon emission comes from Amazon deforestation (Volpi, 2007Source: Volpi, 2007.

7.7.1 Projections of temperature for the North of Mato Grosso between 2001-2100

Based on information obtained from Tyndell Research Centre, projections for temperatures and precipitation for the North of Mato Grosso between 2001-2100 are conducted. The global model HadCM3 was chosen for the downscaling of their regional models. Figure 7.12 shows that both scenarios (high emission and low emission) predict an increase in average temperature in Brazil in 2001-2100.

When applying Tyndell Research Centre data to those supplied by INPE, an estimated warming tendency in the first half of the 21st century in the North of Mato Grosso was obtained. Although the temperature reached in 2050 is lower than that of scenario A2 (high emissions), the tendency of the B2 scenario (low emissions) is for a more accelerated growth, reaching higher temperatures between 2020 and 2030. Even though B2 is a more optimistic scenario, the speed of warming may bring about complications for adaptation strategies in the short term. The average warming in relation to the average warming in 1961-1990 for the period is 1.1 to 1.4°C for the A2 scenario, with average temperatures varying among 33.6-339°C, resulting in an annual average of 34.8°C in 2025. While in the B2 scenario, an average heating of 0.9 to 1.1°C is expected, with average temperatures varying between 33.4-33.6°C, resulting in an annual average of 34.5°C in 2050.

As for the data regarding precipitation, the extrapolation was made based on the relative information for the historical averages of precipitation in the period of 1961-1990 supplied by INMET for the North of Mato Grosso. As the area has a large historical precipitation range, varying between 1,800mm/year and 3,000mm/year, in this report, only the average value (2,400mm/year) is used to calculate the projections for the first half of the 21st century. The data estimates a behaviour that varies between a reduction of 365mm to an increase in

365mm of the average rainfall between 2070 and 2100. The results for the A2 and B2 scenarios coincide. A variation of rainfall is expected for the period 2001-2050 between +155mm/year and -155mm/year in relation to 1961-1990, representing an annual average of 2,556-2,244mm. The impact of removal of forest on the precipitation are still difficult to estimate. More researches need to be completed before obtaining a solid understanding of the situation.

Figure 7.12	Annual precipitation (mm/day, upper two graphs) and annual temperature (lower two graphs) in the Brazilian Amazon, considering A2 scenario (left) and the B2 scenario (right) for the period of 2071-2100

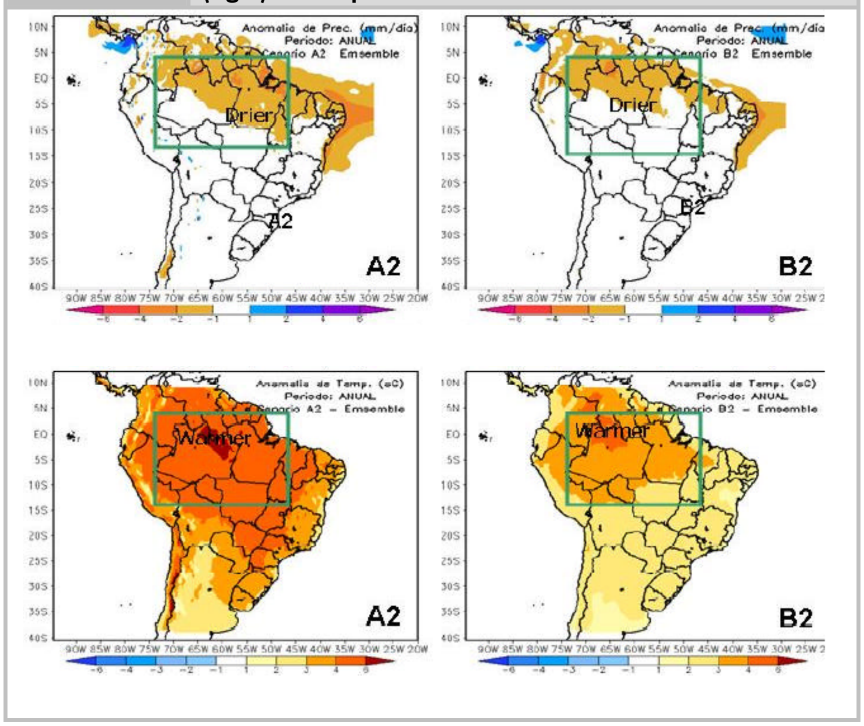


Table 7.11 **Values of the variables under different scenarios in Brazil**

Indicator	Current	baseline	Scenario 1	Scenario 2	Scenario 3	Unit
non landbased business	0.68	0.56	0.74	0.77	0.58	%
diversification econ. activities	0.47	0.79	0.35	0.30	0.72	%
agricultural income	5372	14,903	9592	7495	9524	10^6US$
total land under production	26.4	48	34.68	29.64	38.28	%
timber production	2,109,741	3,835,892	2,771,432	2,368,663	3,059,124	M^3
livestock production	26,064	47,483	30,562	23,881	46,211	1,000 head
rice production	280	671	432	338	496	1,000 ton
cotton production	392	1,127	725	566	695	1,000 ton
corn production	1,079	4,015	2,584	2,019	1,914	1,000 ton
soybean production	5,811	21,659	13,941	10,893	10,304	1,000 ton
sugar cane production	202	5,684	3,658	2,859	358	1,000 ton
total pavement BR-163	742	1,854	1,854	1,854	1,854	km
access to remote forest	23	31	13	4	16	number of roads
employment rate	94.1	96.9	96.05	93.96	95.6	%
children to school	87.8	93.3	93.3	91.1	100.0	%
HDI	0.8	0.85	0.85	0.83	0.95	index
Gini	0.5	0.26	0.41	0.52	0.28	index
life expectancy	73.1	78.38	77.69	76	89.5	years
residential standards	25.2	48.28	31.08	24.28	44.68	
staple food consumption	0.060	0.031	0.049	0.061	0.034	(% nutritional deficit)

Table 7.11 **Values of the variables under different scenarios in Brazil (continued)**

Indicator	Current	baseline	Scenario 1	Scenario 2	Scenario 3	Unit
poverty index	0.2778	0.1449	0.2252	0.2822	0.156	index
deforestation rate	6,061	8212	3562	1007	4,281	km^2
size of nature reserves	31.576	31.576	52.636	52.636	31.576	km^2
disturb. C cycle	6.06	8.21	3.56	1.01	4.28	index
forest land	5,670	-391	3312	4774	2323	km^2
carbon storage	0.48	0.08	0.2	0.33	0.15	ton/ha
fertiliser use N	19.6	34.3	34.3	34.3	34.3	kg/ha
carbon emission	66,671	90,332	35,244	11,077	47,091	tons
fertiliser use P	71.7	80.6	80.6	80.6	80.6	kg/ha
pesticide use	3.6	4.36	4.36	4.36	4.36	kg/ha
fertiliser use K	68.9	101.9	101.9	101.9	101.9	kg/ha

References and websites

Andersen, I., O. Dione, M. Jarosewich-Holder and J.C. Olivry, *The Niger River Basin: A Vision for Sustainable Management.* The World Bank, Washington, DC, 2005.

Binswanger, H., *Brazilian policies that encourage deforestation in the Amazon.* World Development, Volume 19, Issue 17, 1991.

Bonin, M., E. Coudel, J. P. Tonneau and S. Rodrigues, *D3.2: Typology of land-use policies.* LUPIS project, EU 6th Framework Programme, contract no. 36955, www.lupis.eu, pp. 38, 2008.

CCSP (Climate Change Science Program) and SGCR (Subcommittee on Global Change Research), *Strategic Plan for the U.S. Climate Change Science Program*. A report by Climate Change Science Program and Subcommittee on Global Change Research, 2003.

Cisse, Y. et al., *Impact of climate changes on the Niger River water resources and the production systems in Office du Niger in Mali: Cases of rice production and breeding*, 2008.

Diarra A., and Y. Cisse, *Multisectorial Study of the National section of the Niger basin in Mali in the framework of the vision shared by riparian countries for the development of the basin resources.* The Niger Basin Authority (ABN), 2004.

Dijk, H. van, M. de Bruijn and W. van Beek, *Chapter 13: Pathways to mitigate climate variability and climate change in Mali: the districts of Douentza and Koutiala compared.* The impact of climate change on drylands: with a focus on west-Africa, 173-206. A.J. Dietz et al. (eds.). Kluwer Academic Publishers, the Netherlands, 2004.

Djiré, M., *Improving tenure security for the rural poor. Mali - country case study.* Legal Empowerment of the Poor (LEP), working paper #4, 2006.

Djiré, M., *Land registration in Mali - No land ownership for farmers? Observations from peri-urban Bamako.* Issue paper No. 144, International Institute for Environment and Development, 2007.

Edwards, W., *How to use Multiattribute Utility Theory for Social Decision Making,* IEEE Trans. Systems Man, Cybern. 7,326-340, 1977.

Fearnside, P.M., Deforestation in Brazilian Amazonia: 'The effect of population and land tenure.' In: Ambio 22(8): 537-45, 1993.

Ferreira, L.V., Venticinque, E., and Almeida S., *O desmatamento na Amazônia e a importância das áreas protegidas,* Estudos Avançados, São Paulo, vol. 19 n°53, 2005.

Findings, Africa Region, Number 61. The World Bank Group, 1996.

Huq, S., A. Rahman, M. Knoate, Y. Sokona, and H. Reid, *Mainstreaming adaptation to climate change in least developed countries (LDCs).* International Institute for Environment and Development, London, 2003.

InfoHarvest. Criterium DecisionPlus, version 3.0 for windows, 2008.

Kok, M.T.J., B. Metz, A. Verhagen and S.N.M. van Rooijen, *Policy Brief: Integrated Development and Climate Policies: how to realise benefits at national and international level?* The Netherlands Environmental Assessment Agency (MNP), 2006.

Ludwig, F., C. T. van Scheltinga, J. Verhagen, B. Kruijt, E. van Ierland, R. Dellink, K. de Bruin, K. de Bruin and P. Kabat, *Climate change impacts on developing countries - EU accountability.* DG Internal Policies, European Parliament, Brussels, 2007.

Margulis, S., *Causes of Deforestation of the Brazilian Amazon*. Working paper No. 22, the World Bank, 2003.

Nesheim, I., D. McNeill, P. Reidsma, C. Cornu, J. Imbernon, M. Kuiper, M. Bonin, H. König, I. Bezlepkina, R. Verburg, L. Gcahimbi, J. Wamuongo, P. Gicheru, Y. Cissé, M. Sghaier, N. Ounalli, S. Feng, X. Shi, S. N kashyap, S. Purushothaman, W. Widyatmanti , J. Sartohadi and S. Rodrigues, *D2.2: Definition of components of the analytical framework that will be accomplished by the consortium,* LUPIS project, EU 6th Framework Programme, contract no. 36955), www.lupis.eu, 111 pp, 2008.

PANA, *National Action Programme for Adapting to the Climate Changes.* Group Energy. Republic of Mali, 2005.

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, 'Land Use Functions - a multifunctionality approach to assess the impact of land use change on land use sustainability', In: Helming, K., P. Tabbush and M. Pérez-Soba, (eds.), *Sustainability impact assessment of land use changes,* Springer Berlin, Heidelberg, New York, pp. 375-404, 2008.

Reidsma P., H. Koening, S. Sieber, K. Tscherning, K. Helming, I. Bezlepkina and M. van Ittersum, *Deliverable 4.2.1: preliminary indicator framework for assessment of land-use policies in developing countries.* Lupis, 54p, 2008.

Rodrigues Filho, S., D. Lindoso, C. Gucciardi and N. Debortoli, *Land Use and Land-use policies in the North of Mato Grosso (Brazil): A Climate Change Perspective.* Project report, FUB - University of Brasília - Centre for Sustainable Development. 2008.

Traore, F., A. Bayoko and S. Konate, *Past Climate Events and Future Scenarios of Climate Changes in Mali.* (http://amma.mediasfrance.org/france /formation/enseignements/amma2e1/doc/09sept03/FTraore.ppt), 2003.

UNEP, *Brazil: Integrated assessment and planning in the context of the sustainable Amazon Plan: With focus on the BR-163 Highway area of influence and the soybean sector.* Integrated Assessment Planning (IAP) project, UNEP. 2006.

Vandersypen, K., K. Bengaly, A.C.T. Keita, S. Sidibe, D. Raes and J.Y. Jamin, 'Irrigation performance at tertiary level in the rice schemes of the Office du Niger (Mali): Adequate water delivery through over-supply.' In: *Agricultural water management* 83 (2006): 144-152, 2006.

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, *D2.3: Defining sustainable development in the context of LUPIS.* LUPIS project, EU 6th Framework Programme, contract no. 36955, www.lupis.eu, pp. 70. 2008.

Volpi, G., *Climate Mitigation, Deforestation and Human Development in Brazil.* UNDP Human Development Report 2007, 2007.

Von Winterfelt, D. and W. Edwards, *Decision Analysis and Behavioral Research,* Cambridge University Press. 1986.

Wells, T., *Land tenure and the cadastral system of Mali.* Department of spatial information engineering, University of Maine, U.S., 1999.